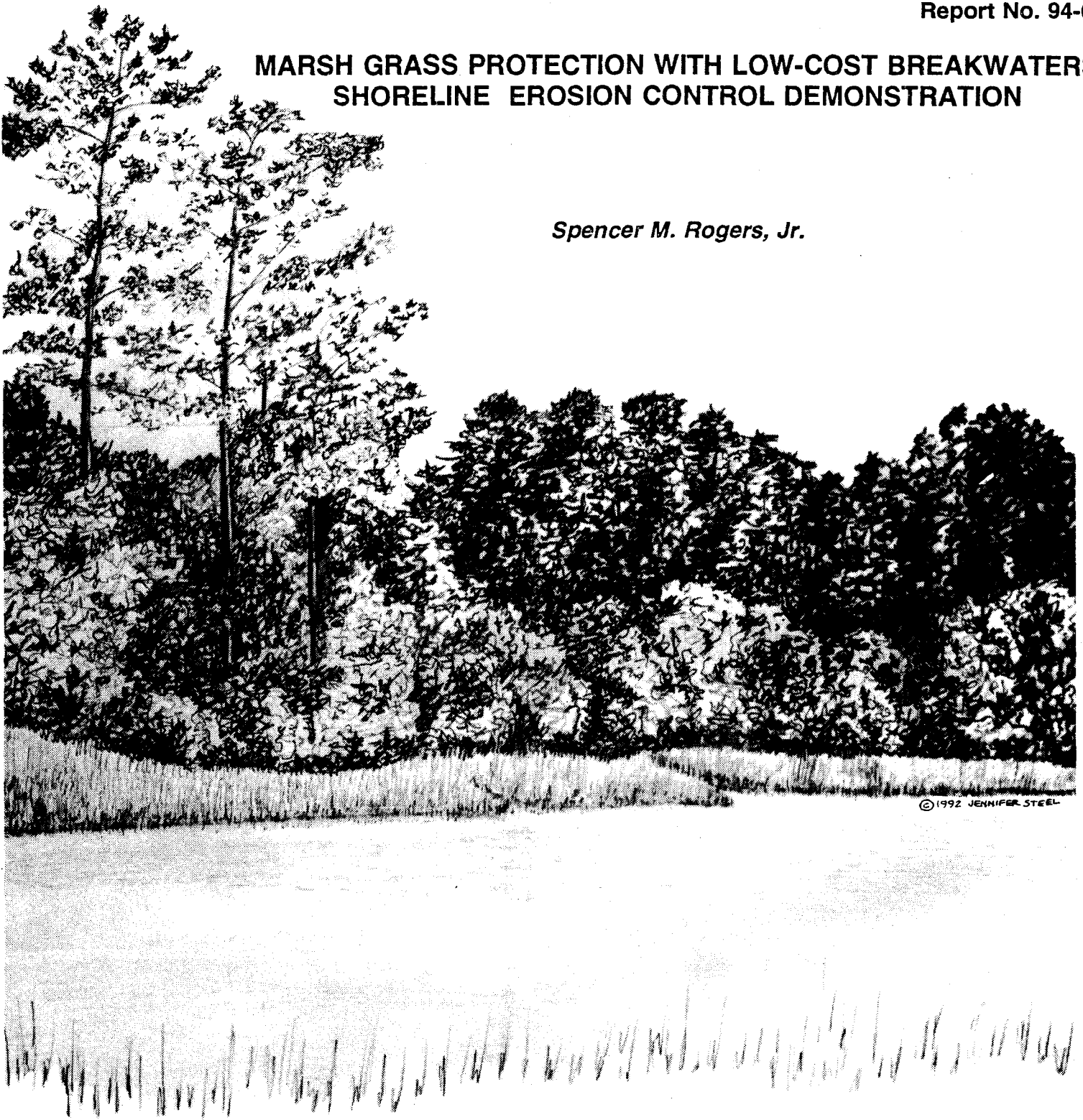


**MARSH GRASS PROTECTION WITH LOW-COST BREAKWATERS
SHORELINE EROSION CONTROL DEMONSTRATION**

Spencer M. Rogers, Jr.



**ALBEMARLE-PAMLICO
ESTUARINE STUDY**

NC Department of
Environment, Health,
and Natural Resources



Environmental
Protection Agency
National Estuary Program



Marsh Grass Protection with Low-Cost Breakwaters
Shoreline Erosion Control Demonstration

Final Project Report
for
Albemarle-Pamlico Estuarine Study

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INTRODUCTION

Previous research with the use of marsh grasses for the control of shoreline erosion has produced excellent short-term (one to five years) results. Unfortunately, use of the method on moderately exposed shorelines in our estuaries has shown limited long-term (20 to 30 years) success. This report describes the design and construction of erosion control demonstration projects using a combination of planted marsh grasses and low-cost wooden breakwaters. The breakwaters can extend the effective lifetime of planted marshes to that of bulkheads and other common erosion-control methods. Since it entails to creating a marsh where none previously existed, significant environmental advantages are apparent over most other erosion-control methods. The method can be attractive to property owners because the marsh/breakwater is significantly less costly than other alternatives offering the same level of protection and useful lifetime.

MARSH GRASSES FOR EROSION CONTROL

Marsh grasses are most effective for erosion prevention during higher water levels when waves are dissipated as they move through the many stems (Knutson et al., 1982; Gleason et al., 1979). The turbulence created by a single stem has little effect on the wave, but when thousands of stems in a fringing marsh are combined, the wave damping effect is substantial (figure 1). In addition, the grasses develop a

tough root mat after only a few growing seasons, creating a shallow, erosion-resistant platform that causes the largest storm waves to break before reaching higher land areas. Water depth always controls the maximum height of a wave. A wave moving into decreasing depths is forced to break when the wave height is roughly equal to the water depth. After breaking, only a re-formed, smaller wave continues forward. Even when flooded during a storm, the shallow water over the marsh's tough root mat breaks the largest waves without harming the marsh.

Therefore, the marsh protects the shoreline by causing the largest waves to break on the seaward edge of the root mat and by dissipating part of the remaining waves through the stems. When only smaller waves reach the higher land, the upland



Figure 1. Waves dissipated by the marsh.

erosion is reduced. In many cases, 20 to 30 ft. of fringing marsh grasses are sufficient to prevent erosion in most storm conditions. It is common throughout the North Carolina coast to see naturally occurring marsh headlands with no evidence of upland erosion, while adjacent eroding banks are fronted by narrow, sand beaches. Numerous successful applications have been reported, including Seneca et al. (1976), Woodhouse (1979), Knutson et al. (1981), Allen and Webb (1983) and Hardaway et al. (1985).

EROSION-CONTROL LIMITATIONS OF MARSHES

In a study of shoreline erosion rates in the North Carolina sounds, Riggs et al. (1978) reported that exposed marshes had higher erosion rates than any other type of shoreline, averaging more than 3 feet per year. If natural marshes are experiencing such high rates, why should planted marshes prove any better? The use of marsh grasses for controlling erosion has two significant weaknesses. When plantings are exposed to larger waves, they can be difficult to initially establish. Even if successfully established, the useful lifetime of the marsh is limited by undermining and loss of the seaward edge of the root mat.

Larger waves on a shoreline cause greater and more rapid movements of sediment. It is often difficult to get marsh seedlings rooted on the beach before they are washed out by a mild storm. Little wave height data is available for most

shorelines. However, a shoreline's open water exposure, or fetch, is usually a good indicator of the relative size of storm waves. Several researchers reported consistent successes with planting when open water fetches are less than 1 mile (Knutson and Woodhouse, 1983; Webb and Dodd, 1978; Hardaway et al., 1985). Planting success has proven unlikely for fetches greater than 3 miles.

Each species of marsh grass is limited in the range of regular water depths in which it will flourish. When planted on an eroding beach it will spread to its seaward growth limit but can form the root mat no deeper. With time, the root mat accumulates in elevation and is typically less than 1 foot thick. The marsh erosion is caused by a general deepening of the nearshore bottom farther offshore, below the growth limits of the marsh (figure 2). Although the root mat and stems protect the upper beach, erosion can be expected to continue in deeper water. Continued

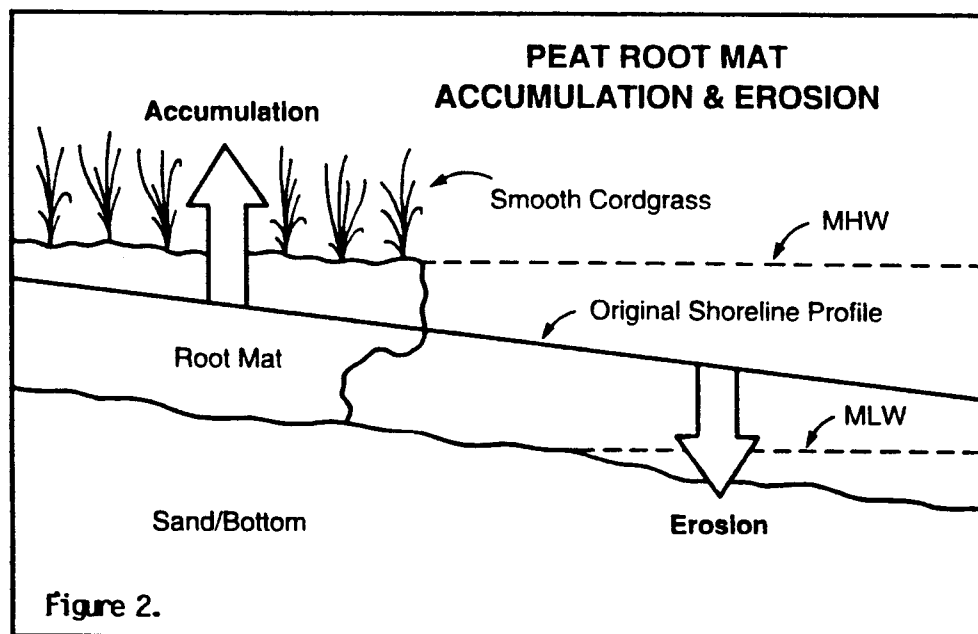


Figure 2.

erosion undermines the outer edge of the mat, removing the unconsolidated soils below (figure 3). Undermining occurs during normal, non-storm conditions when waves break directly on sediments seaward of the marsh or on the vertical scarp of the root mat, causing localized scour. Once undermined, clumps of the mat are torn away during storms by breaking waves. The marsh width is narrowed until its erosion-resistant properties are lost. New grasses cannot re-establish seaward of the root mat because the water is too deep. The marsh is eventually destroyed by natural processes, leaving a sand beach.

Replanting may occur on the new beach formed after the loss of the marsh but must be located farther landward for the proper planting depths of the grasses.



Figure 3. Root mat undermined by erosion.

Therefore, on moderately exposed shorelines, planted marshes can slow the erosion if it can be successfully started. But the need to replant every few years and a gradual retreat of the shoreline can be expected.

MARSH AND BREAKWATERS

A variety of accidental and experimental installations have shown that low-elevation offshore breakwaters offer significant advantages when used with planted marshes. In the Chesapeake Bay and some other areas, the breakwaters are called offshore sills. Initially the breakwater provides a sheltered shoreline on which to plant the grasses, reducing the time and effort necessary to get the plants rooted. Hay bales have been used on sheltered shorelines for protection in the first growing season. Webb and Dodd (1983) describes rows of car tires as a temporary breakwater. A variety of surface covers and temporary breakwater materials were tested by Allen et al. (1984), including tires and various lightweight, surface stabilizing covers. Seidensticker and Nailon (1988) reported on the use of temporary breakwaters constructed with Christmas trees, parachute material and plastic snow fencing.

However, for long-term success with larger fetches, the wave barriers must remain indefinitely to protect the gradually developing root mat from undermining. Allen and Webb (1983) described tests on anchored rows of tires, floating tire and

fixed open-plank breakwaters. Hardaway et al. (1985) reported on rubble-mound sills in the Chesapeake Bay. In North Carolina the successes of a variety of both accidental and planned wooden breakwaters are described by Rogers (1989) that provided the basis for site selection and design of this demonstration (figure 4a-c).

Breakwaters intended to protect marshes have generally been only partial wave barriers. To keep costs to a minimum, the top elevations have been kept low relative to normal high water levels. Storm-induced erosion is usually associated with higher water levels or storm surge. Low-elevation breakwaters are easily overtopped during moderately severe storms. However, the partially flooded marsh then provides



Figure 4a. Two years after "accidental" breakwater construction at Camp Leach.



Figure 4b. Camp Leach after 5 years.



Figure 4c. Six months after removal of breakwater.

protection to the upland property. Individually, neither the marsh nor low breakwater is able to control the erosion on moderately exposed shorelines; but the combination has been found to be very effective. Deterioration of the materials in the breakwater should be the only limit on the effective lifetime for successful shoreline protection.

The necessary design strength and cost of a breakwater is dictated by the size of wave it must withstand. The cost of construction can be kept low along shorelines where the water depths 50 to 100 feet offshore are 3 feet or shallower at normal high tide. The shallow water limits the size of the waves at normal water elevations by forcing the largest waves to break before reaching the breakwater. By keeping the top of the breakwater very low, typically only 6 inches higher than the normal high tide elevation, larger waves occurring simultaneously with higher storm tides will pass over the top of the breakwater without causing damage. During these storm conditions, the marsh offers its best shoreline protection when the transmitted waves reaching the marsh are dissipated by the stems and root mat as previously described.

The breakwaters are located between 10 feet and 50 feet offshore, depending on the water depths available for marsh planting. The ends of the breakwater are left open. Most of the tested breakwaters have been relatively porous, sacrificing better wave-breaking capacity for other advantages. Wave forces on low-cost and lightweight breakwaters can be reduced if more of the wave is allowed to be transmitted through the barrier rather than resisting the full forces. Greater breakwater

porosity transmits more wave activity to the planting area but can reduce the cost of the barrier.

Longer installations of impervious wooden breakwaters have been observed to cause increases bottom scour near larger openings (Rogers, 1989). When storm waves overtop the low structures, the water level behind the breakwater rises above the adjacent body of water. If the return flow is limited to isolated openings or around the ends of several hundred feet of breakwater, bottom scour 1 to 3 feet deeper than would otherwise occur has been observed. Excessive scour can undermine or structurally weaken the breakwater leading to collapse. It is therefore desirable to make the breakwater as porous as possible while still providing a sufficient wave barrier to protect the marsh. It is desirable to distribute the return flow along the full length of the structure rather than concentrated at each larger opening.

It is important to maintain good water quality and circulation behind the breakwater for the health of the marsh, for general environmental reasons and usually for aesthetic requirements of the property owner. As long as the waves are sufficiently reduced and the marsh adequately protected, more openings and higher porosity are desirable both to the environment and the owner.

COST EFFECTIVENESS

As a general rule, the most important factors governing a property owner's erosion-control decisions are cost and expected lifetime. In North Carolina, wooden bulkheads are by far the most commonly used erosion-control method. The number of bulkheads constructed each year is unknown, but a survey of permits in 1986 and 1987 found that 31 miles of shoreline was hardened in the two-year period. As an alternative, rock revetments can offer longer lifetimes if properly constructed but are hindered by the lack of quarries near the coast and high transportation costs. Any new erosion-control method in North Carolina must expect to be compared to a wooden bulkhead in cost and lifetime. For the demonstration, wood was selected as the material for breakwater construction because of its lower cost, well-established useful life throughout the estuaries and the familiarity of installation by the marine construction industry.

The cost for a typical estuarine bulkhead ranges between \$50 and \$75 per foot. In addition to the shoreline length, return walls are needed at each end to prevent flanking and the loss of backfill during storms. If the combination of breakwater and marsh is to be competitive with bulkheads, property owners must be convinced that it has a comparable lifetime to a bulkhead and/or is less expensive to construct and maintain.

ENVIRONMENTAL IMPACT

Any erosion-control method will have an impact on the environment. The biological impacts of installing bulkheads or rock revetments have not been well-documented. Hardening the eroding estuarine beaches usually results in the eventual disappearance of the beach and any flora and fauna that might have been living in the fluctuating sands. The typically permitted construction practices can bury parts of the beach and submerged bottom habitats with backfill or rock. In general, the continual movement of the sand by waves already limits the biological importance of these types of shorelines compared to higher ground elevations or deeper submerged bottoms. Rock revetments, and to a lesser extent bulkheads, are known to provide additional hard substrate that is rapidly colonized below the high water line by many species that could not otherwise exist on the beach. Although our understanding of the impacts are incomplete, any environmental benefits of typical erosion-control structures are thought to be minimal.

Bulkheads on eroding beaches are now authorized by state and federal general permits because they have been judged to present no harm or at least acceptably low levels of harm to the environment. In contrast, the use of the marsh/breakwater requires that the property owner establish a fringing marsh along what would otherwise be an eroding sand beach. As in natural marshes, the planted grasses offer significant environmental advantages by comparison.

Among the advantages, the new marsh provides increased primary nursery area and supports a significant numbers of a variety of important aquatic species. Surface-water runoff from rapidly developing coastal areas degrades the estuarine water quality with high sediment loads and other pollutants. After construction of a marsh/breakwater, surface runoff is filtered by the marsh prior to reaching the estuary. Sediment and other pollutants are trapped, helping to protect the overall water quality.

Natural and planted marshes are more environmentally productive and offer significant buffers to protect the estuary from upland runoff compared to the sand beaches. Unlike other erosion-control alternatives, the marsh/breakwater is an environmental asset because the breakwater allows the fringing marsh to thrive in wave conditions where it could not normally exist.

PROJECT OBJECTIVES

1. To demonstrate an effective, environmentally compatible erosion-control device for North Carolina estuarine shorelines;
2. To reduce erosion rates along estuarine shorelines, which will, in turn, reduce the influx of potentially damaging materials to the estuarine waters and provide an improved buffer to protect shellfish areas and other resources from nonpoint pollution runoff;
3. To increase the acreage of marsh habitat and productivity while simultaneously retarding erosion;
4. To lower the costs of erosion retardation to homeowners along estuarine shorelines; and
5. To demonstrate that erosion control can be environmentally advantageous.

SITE SELECTION

A site selection committee was established to choose appropriate sites. Staff of the North Carolina Division of Coastal Management (DCM), the U.S. Soil Conservation Service (SCS) and the principal investigator made up the committee. Guidelines for selecting the best demonstration sites were established. The selection guidelines are listed in Appendix B. Eroding sand beaches were given priority, but eroding marsh shorelines were also considered. Previously bulkheaded property was considered if sufficient beach width for planting remained farther seaward.

Breakwaters to protect a marsh can be constructed along practically any estuarine shoreline regardless of water depth, fetch or wave exposure. However, the purpose of this project was to demonstrate a low-cost erosion-control method. To keep the cost of the breakwater to a minimum, the shoreline conditions for acceptable sites were limited. Flat and shallow offshore depths were required. Depths less than 2 1/2 feet below the normal high water elevation extending at least 50 feet offshore. An exposed fetch greater than 1 mile was required, since marsh plantings on more protected shorelines have been relatively successful even without breakwater protection. Beach widths capable of planting 10 to 30 feet of marsh were necessary.

In order to ensure a wider distribution of demonstration sites throughout the Albemarle/Pamlico study area, each property owner was limited a maximum of 100

feet of breakwater. It was anticipated that neighboring owners would be interested in participating in the demonstration. A maximum of three separate owners at any site was established. As site selection progressed, it became apparent that most sites would consist of single owners.

Property owners were made aware of the program by a variety of means. Many came from referrals of routine inquiries for permits or technical assistance to the Division of Coastal Management, Sea Grant and the Soil Conservation Service. News releases were distributed to local media in the study area. Public service announcements were distributed to local radio stations, building officials and others in local government were contacted in selected areas. Marine contractors were also notified.

Property owners with suitable shorelines were offered reimbursement for 50 percent of the construction and planting costs. Spencer Rogers, the author designed each breakwater for the unique conditions at the site and prepared and submitted all federal and state permit applications on behalf of the property owners. In return, each owner committed to allow regular monitoring of the project and viewing of the demonstration by other interested property owners. The owner agreed to conduct reasonable maintenance for five years. Good access was required; however several remote sites were accepted in areas where future development is planned. Widely separated sites with variable shoreline conditions and wave exposures were preferred.

Approximately 75 property owners expressed an interest in the program, and their shorelines were inspected. Of those, 26 requested to participate in the demonstration. Twenty-four property owners at 18 separate sites were selected for cost-sharing by the committee. Thirteen sites were single owners with breakwater lengths of 85 to 100 feet. Two sites included two owners. One site included three. Four other sites were determined to be marginally suitable and given a low priority. One owner after being notified of his selection, delayed submitting the necessary permit information until it was too late to apply for a permit. Because few neighboring owners cooperated, the time and effort to inspect, select, design, construct and plant was much greater than anticipated in the proposal. However, the additional sites offer a wider variety of shoreline conditions are scattered through many areas so more people have a site close to them.

PERMITS

The state and federal agencies expected to review the proposed work were contacted prior to submitting any application. Technical reports on previous accidental and planned marsh/breakwater installations were provided. Pre-application meeting with the agencies provided a slide program describing existing installations. Designs and specifications were prepared for the conditions at each location then reviewed by the owner. A permit application was submitted to DCM for simultaneous processing with the federal review.

Although many bulkhead permits can be authorized in a day under DCM's Coastal Area Management Act (CAMA) "general permit" or "exemptions," the location of the breakwater entirely seaward of the mean high-water line dictated that a more time-consuming "CAMA major permit" would be necessary for construction. CAMA major permits have built-in delays for public notices and multi-agency review. A minimum processing time is approximately 60 days for the simplest, uncontested major permits. DCM is allowed 75 days to review the permit after the application is complete. An additional 75 days of review may be required for more complicated projects. Application fees for a bulkhead are free if located above the mean high-water line or \$50 if partially seaward. The fee is \$250 for the CAMA major permit necessary for marsh/breakwater construction.

DCM decided that the best way to process the applications was a single permit with multiple sites. The first group of three sites was submitted in May 1991 and processed under N.C. permit number 137-91. The remaining sites were submitted in three groups of three to six sites as modifications to the original permit.

During the permit review, the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service expressed concerns about the impact of the breakwaters on submerged aquatic vegetation (SAV) and the potential for excessive sand trapping. Each site had already been planned to avoid SAV's. Permit conditions were added to clarify that they would be avoided and where necessary

DCM would inspect and stake the breakwater alignment immediately prior to starting construction. NMFS's concerns over excess sand trapping and request for extensive shoreline monitoring surveys were discussed at length. NMFS was informed that no similar low elevation breakwater already in use had ever trapped too much sand. Sediment transport models for larger breakwaters also predicted minimal sand trapping. It was argued that the shoreline monitoring proposed by NMFS was too extensive for a demonstration of technology already in general use. NMFS's concerns were never resolved. However, the Corps of Engineers, which administers the federal permit, authorized construction as planned under federal general permit No. CESA-W-C080-N-000-0291. Each site has a separate action number. DCM issued the initial state permit in October 1991.

Permit applications were submitted for 22 property owners at 17 sites. Permits were approved for 19 owners at 16 separate sites for 1,705 feet of marsh plantings and breakwaters. One site in Currituck Sound was not approved when extensive SAVs was found to preclude any breakwater location. It was planned to obtain more permits than expected to be funded to ensure construction of as many demonstration sites as possible.

During or after permit processing, four owners withdrew from the demonstration for economic, family or other reasons unrelated to the erosion-control effectiveness. The approved permits were forwarded to those owners should they wish to build at a later date. At one site, two construction barges were blown ashore in a storm just

before construction was scheduled to begin. The barges came to rest over the planned breakwater location and could not be removed in time to start construction before the APES grant expired.

At the conclusion of the demonstration project 14 property owners have participated in the cost-sharing at 12 separate sites in the APES study area. A summary of the sites is shown in figure 5. A cumulative breakwater length of 1,205 feet has been constructed and planted with marsh grasses.

**BREAKWATER/MARSH DEMONSTRATION SITES
ALBEMARLE/PAMLICO ESTUARINE STUDY**

Name	Location	Length (feet)	Cost per foot	Constructed	Planted
1 Burgess	Albemarle Sound, Camden Pt.	100	\$30	June 92	Jul92/Apr93
2 Foreman	Currituck Sound, west shore	100	\$34	Feb. 93	Apr. 93
3 Britt	Currituck Sound, Duck	modified existing breakwater in June 92			
4 Colington Harbour	Albermarle Sound	100	\$37	Feb. 93	May 93
5 Austin	Roanoke Sound, Nags Head	100	\$29	Nov. 92	May 93
6 Adams	Roanoke Sound, Nags Head	85	\$34	Mar. 93	Apr. 93
7 Civic Club/Golden	Stumpy Point	200	\$23	June 92	Jun92/Apr93
8 Browning	Pamlico Sound, Buxton	100	\$25	Nov. 92	May 93
9 McAllister	Pamlico River, south shore	100	\$26	Apr. 92	June 92
10 Hughes	Neuse River, Oriental	100	\$42	Nov. 92	Apr. 93
11 Weyerhauser	Neuse River, Oriental	100	\$33	June 92	Jun92/Apr93
12 Lischke/Longaker	Neuse River, south shore	120	\$32	Dec. 92	Apr 93
Total		1,205	\$31	Average cost per foot	

Figure 5.

Not including permit application fees

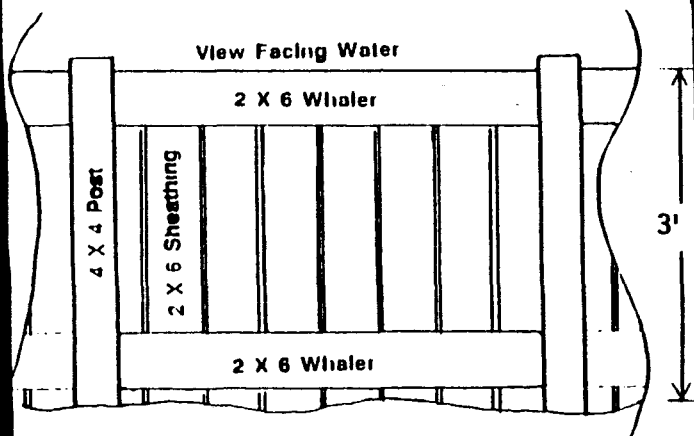
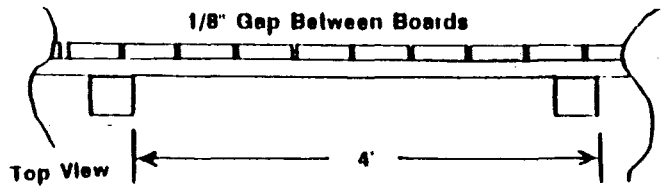
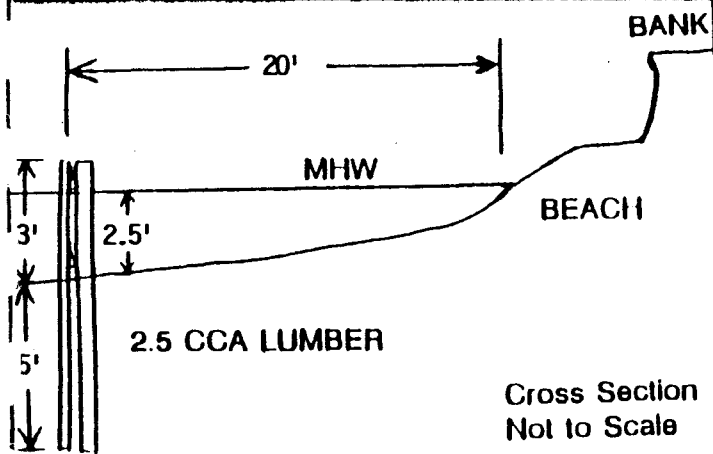
GENERAL DESIGN CONSIDERATIONS

Breakwater designs for all sites were based on materials previously tested in Croatan Sound on Roanoke Island (Rogers, 1989). A typical design is shown in figure 6. The breakwaters resemble a low, free-standing bulkhead but have several important differences. All breakwaters were constructed with treated lumber (marine grade, 2.5 CCA). The posts were 4x4's spaced 4 feet apart. The sheathing and walers were 2x6's. Posts and sheathing were both 8 feet long unless otherwise noted. In some cases 4x6 posts were used when treated 4x4's were difficult to find.

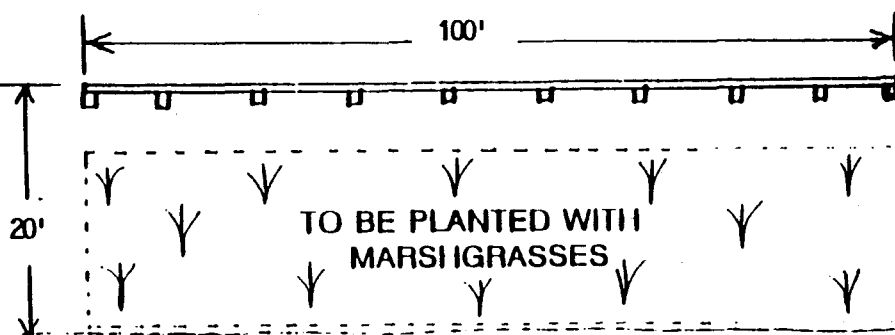
Located in deeper water, a breakwater will experience higher waves than a bulkhead. The materials in the free-standing structure must withstand all of the wave forces, unlike a bulkhead, which transfers most of the force to its backfill. To keep the breakwater cost to a minimum, they were designed to avoid impact by the worst waves. As discussed previously, at normal water levels the shallow water depths cause the largest waves to break farther offshore before reaching the structure. The breakwater must be tall enough to prevent the marsh root mat from undermining. By building the top of the breakwater low, 6 inches above the normal high water elevation, larger waves during elevated storm tides are allowed to pass over the structure, avoiding the worst of the wave forces. The low elevation allows the largest waves to be transmitted to the shoreline but only at higher water levels when the marsh has been found to be best able to handle them. Without a developed marsh,

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

OWNER: _____
 APPLICANT: _____
 DATE: _____
 LOCATION: _____



Plan View Not to Scale



Property of _____

Property of _____

Property of _____

Figure 6.

such low breakwaters have been found to offer little protection to the shoreline.

Also different from bulkhead design is the arrangement of the posts and sheathing. A bulkhead supports the weight of the soil with the sheathing but transfers part of that force to the posts on the seaward side of the sheathing. The forces on the breakwater come from the waves. Therefore the sheathing is placed on the seaward side and the posts on the landward side for better support. The reversed alignment from a bulkhead allows the breakwater to be connected with nails eliminating the need and cost of bolts.

When waves break over the top of the breakwater, water is prevented by the structure from flowing directly back to the estuary. Previous installations have shown that excessive scour could occur if the return flow was concentrated at the ends or at a central opening. To more widely distribute the return flow, a gap of 1/8 inch was left between each sheathing board. The ends of the breakwater are also left open and are not attached to the shoreline. The gaps have the added advantage of ensuring good circulation and water quality behind the breakwater. At one demonstration site the size of the gaps was varied (see Britt). With too big a gap, there will be too much wave activity to plant and maintain a marsh. But as large a gap as possible means better circulation for the environment and lower cost for the property owner.

Smooth cordgrass (Spartina alterniflora) was planted at all sites for its erosion-control properties, its tolerance for a wide range of salinities and its nursery availability. Native stands were found near most sites. Nursery-grown plants were transplanted in peat pots unless otherwise noted. Black needle rush (Juncus roemerianus) was naturally occurring on some of the shorelines. All sites have brackish water with varying salinities. Water levels at all sites are dominated by wind tides, as is the case for most of the Albemarle-Pamlico area. Diurnal tide ranges vary between zero and less than 1 foot.

INDIVIDUAL SITE DESIGN AND CONSTRUCTION

The following section describes the shoreline conditions at each site and the individual design considerations. The owners, locations, construction dates and cost per foot are shown in figure 5. A map of the APES study area which gives the general location of each site, is shown in figure 7. Additional plans and specifications are included in Appendix A.

1. Burgess: The site is located in Camden Point Shores on the north shoreline of Albemarle Sound, approximately 15 miles southeast of Elizabeth City, N.C. The residential lot is 100 feet in width and very low in elevation, less than +4.0 feet NGVD. A house recently constructed on the property is well back from the shoreline. The narrow sand beach was actively eroding. Several fallen trees were removed prior to

MARSH/BREAKWATER DEMONSTRATION SITES
ALBEMARLE/PAMLICO ESTUARINE STUDY

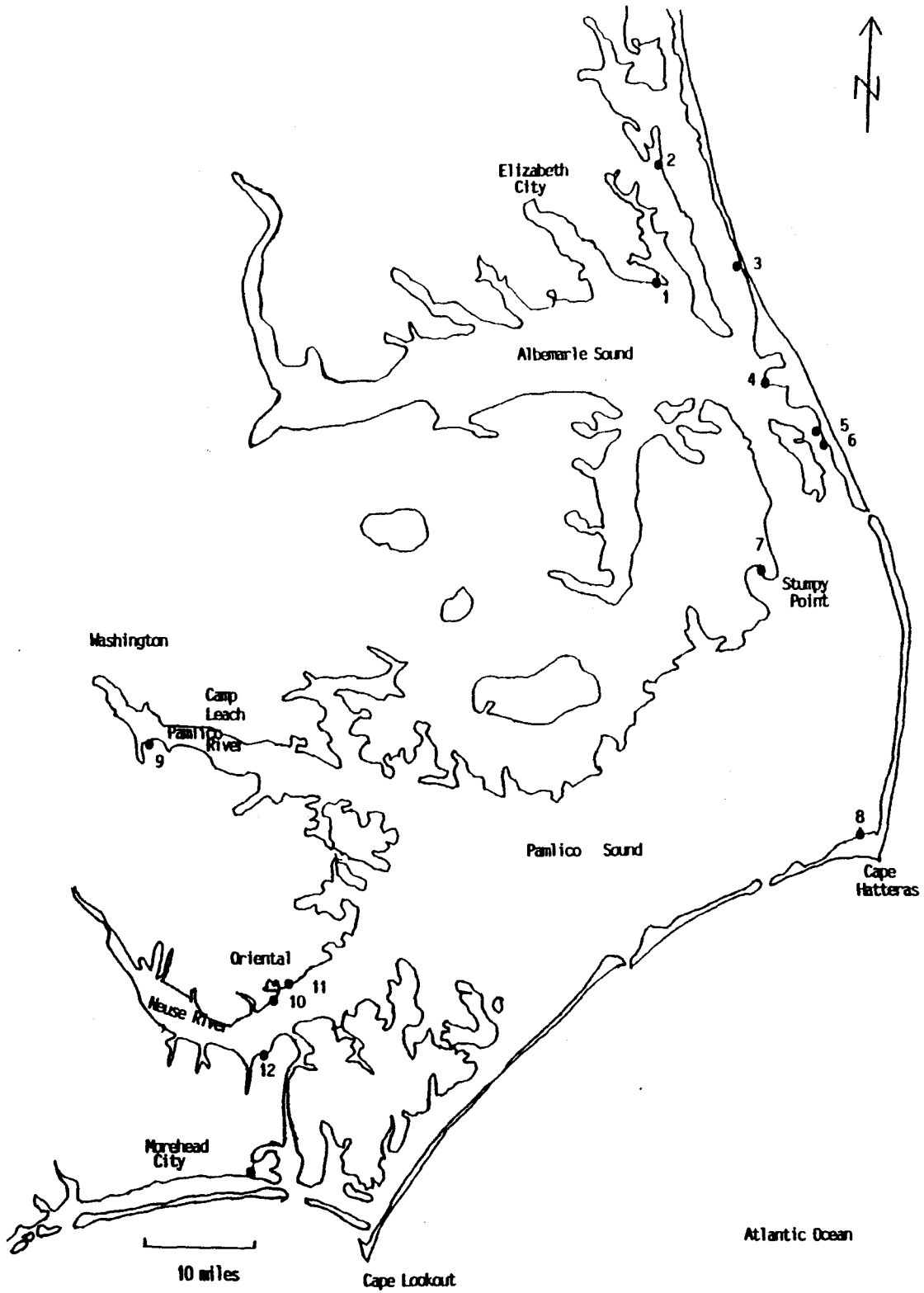


Figure 7.

construction. Many stumps and several cypress trees are located along the shoreline and farther offshore. A narrow overwash ridge has been actively moving landward from the beach during frequent storms. The offshore depths are shallow, approximately 1 1/2 feet below normal water level. The south-facing shoreline has a fetch of 15 miles.

Tall wooden groins had been constructed by the neighbor to the east, including one located on the property line. The groins showed no evidence of trapping any sand in longshore transport and appeared to offer no erosion-control benefits. Because of concerns from the neighbor, only 85 feet of breakwater was constructed, ending 15 feet from the neighbors groin. The breakwater was constructed 20 feet offshore in water 1 1/2 feet deep in June 1992. The shoreline was stabilized enough for an initial planting in July 1992. But problems developed when the vertical groin reflected waves around and behind the east end of the breakwater. Several additional feet of scour occurred in the 15-foot opening between the two structures. Both were threatened by the scour, and many of the plants were lost.

The adjoining property was sold to a new owner who agreed to allow the gap between groin and breakwater to be closed. In March 1993, a storm caused severe erosion along the surrounding shoreline. Because the scour hole was slow to recover after closure, the new section and 15 feet of the original breakwater failed, leaving 65 feet. The neighbor's groins were also destroyed. Prior to the storm, sand had been

trapped at each end of the breakwater. A small amount of fine material deposited behind the center, ideal for marsh establishment. The remaining replanted in March 1992.

2. Foreman: The site is located on the west shore of Currituck Sound near the town of Aydlett, approximately 20 miles north of the Currituck Sound bridge. The property is a farm with several thousand feet of shoreline. The fetch is 5 miles to the east, but 10 miles for the predominate northeast storm direction. The shoreline has a sand/clay bank approximately 10 feet high with a narrow sand beach. Stumps are abundant in shallow water and on what remains of a rapidly eroding headland to the north. The breakwater was constructed 20 feet offshore in 2 1/2 feet of water in February 1993 and planted in April 1993. The shoreline position is unchanged since construction.

3. Britt: More than 800 feet of breakwater had been previously constructed by the property owner in 1989. But the gap size between each sheathing board proved to be too large to adequately protect the repeated plantings. The site was accepted as a demonstration site to show the effect of variations in the size of the gaps.

The site is located on the east shoreline of Currituck Sound, just north of the village of Duck. Upland development includes a small boat rental business, a condominium complex and several single-family residences. Ground elevation is

about +8.0 feet NGVD with higher dunes. The fetch is 4 miles to the west with 15 miles to the southwest through the mouth of Currituck Sound into Albemarle Sound. The shoreline consists of an eroding sand beach and several hundred feet of shallow-water bulkhead. The breakwater was located 40 feet offshore in 1 1/2 feet of water. Smooth cordgrass had been extensively planted for the last few years but had failed to thrive seaward of the bulkhead due to excessive water depths. In a few shallower areas the cordgrass was flourishing.

The original breakwater was constructed with every third sheathing board deleted (2 X 6, nominally a 5 1/2-inch opening) for a porosity of 33 percent. Waves were minimally affected by the barrier even at normal water levels. The sand beach originally fronting the bulkhead had been lost after construction of the breakwater.

The existing breakwater was redesigned to demonstrate 50-foot sections of the following openings:

Remaining openings	Porosity
delete every third board (original design)	33 percent
delete every sixth board	17 percent
delete every ninth board	11 percent
delete every twelfth board	8 percent
reduce to 4-in. opening every third board	24 percent
reduce to 2-in. opening every third board	12 percent
continuous sheathing	0 percent

The breakwater modifications were completed in June 1992. In March 1993 a storm

blew two construction barges ashore, extensively damaging the breakwater and bulkhead. The barges also came to rest where an additional 100 feet of breakwater had been planned and permitted to demonstrate the effect of larger openings between breakwaters (5, 10 and 20 feet). Insufficient time had passed to observe any affect of the porosity modifications. The owner plans to replace the breakwater after the barges are removed. The barges could not be moved in time for construction before this grant expired. Its future construction is up to the property owner.

4. Colington Harbour Association: The site is on Albemarle Sound near the community clubhouse in Colington Harbour on Colington Island, three miles west of Kill Devil Hills, NC. The fetch to the west is over 40 miles, the length of Albemarle Sound. Southwest and northwest fetches are 6 miles. The shoreline is a 30-foot sand bluff fronted by a sand beach on approximately 85 feet of shoreline. The adjacent shorelines are bulkheaded for at least several hundred feet in either direction. Several low groins are located to the north. Higher groins are located several hundred feet to the south. The bluff is steeply sloped to the narrow beach and is the only remaining sand supply for the entire shoreline.

One hundred feet of breakwater was constructed 20 feet seaward of the shoreline in 2 feet of water. The breakwater begins 15 feet south of the neighbor's bulkhead, protecting 70 feet of beach and 30 feet of bulkhead. Construction was completed in February 1993. Planting was planned in April but the storm in March

caused severe erosion of the bluff. So much sand was removed from the bluff that the entire area behind the breakwater as well as seaward of the adjacent bulkheads was buried in sand. As expected, without the marsh the breakwater provided little erosion protection in the storm. The redistributed sand left no intertidal area wet enough to plant the marsh. The new sand is being transported along the beach in both directions by normal wave conditions. Planting areas behind the breakwater are slowly forming. Planting is planned in early summer.

5. Austin: The site is located on the east shoreline of Roanoke Sound in Nags Head, NC. The property is near the south boundary of Jockey's Ridge State Park. The lot is about +7.0 feet NGVD with single-family home, dock and existing breakwater. The shoreline includes an eroding sand beach and eroding cordgrass headland. The fetch is 8 miles to the west and 3 miles to the southwest. Seventy-five feet of existing breakwater had been previously constructed to protect the beach from northwest waves. After construction, it became apparent that southwest waves were a significant contributor to the beach losses and prevented successful planting of more marsh. The southwest waves were also actively undermining the existing marsh headland.

One hundred feet of breakwater was constructed, extending from the existing breakwater across the marsh headland up to 20 feet offshore in depths of 1 1/2 feet. Construction was completed in November 1992. The shoreline position is unchanged.



Figure 8a. Site 6 prior to construction.



Figure 8b. After breakwater construction. Beach width increased due to March storm.

The beach has been planted, and existing grasses are expected to spread now that better wave protection is provided.

6. Adams: The site is located one-half mile south of Austin on the east shoreline of Roanoke Sound in Nags Head, NC (figure 8). The fetch varies from 3 to 8 miles. The shoreline has a sand beach with 5- to 10-foot dunes. A bulkhead has been constructed to protect a single-family house on half the shoreline. Little beach remains seaward of the bulkhead. Fifty feet north of the property another bulkhead extends considerably farther seaward, providing partial shelter from the northwest. Smooth cordgrass has actively colonized an area sheltered by the neighboring bulkhead but hasn't spread farther to the south. The southern half of the property has a wide sand beach.

Eighty-five feet of breakwater was constructed 20 feet seaward of the beach in 2 feet of water. Protection was extended approximately 10 feet along the bulkhead to control flanking of the return wall. Construction was completed in March 1993 and planting one month later.

7. Stumpy Point Civic Club/Golden: The Civic Club building and adjoining private lot face south on Stumpy Point Bay (figure 9). The fetch is 2 miles. The shoreline is a narrow sand beach with a short section of eroding smooth cordgrass. The land elevation is low, below +5.0 feet NGVD.



Figure 9a. Site 7 before construction.



Figure 9b. Two years after construction and planting.

Two hundred feet of breakwater was constructed 20 feet offshore in water 1 foot deep. One-inch sheathing in lengths of 6 feet was used. Construction and initial planting were completed in June 1992. Smooth cordgrass transplanted from local marshes. Sand accreted at each end of the breakwater with little change in the center. The site was replanted with nursery-grown grasses in April 1993.

8. Browning: The site is located on the south end of Pamlico Sound in Buxton on Hatteras Island near Cape Hatteras. A bulkhead with no beach is located between two marsh headlands 60 feet farther offshore. The fetch to the north is over 35 miles. Ground elevations behind the cordgrass marsh is about +5.0 feet NGVD with higher elevation behind the bulkhead.

One hundred feet of breakwater was positioned 70 feet seaward of the bulkhead in 1 foot of water to partially shelter one of the marsh headlands. Construction was completed in November 1992. Sheathing length was shortened to 7 feet. Water depth just seaward of the bulkhead is about one foot, too deep for planting. A higher shoal, 50 feet offshore, was planted soon after construction. Smooth cordgrass in the headland should spread as well.

9. McAllister: The site is located on the south shoreline of the Pamlico River, approximately 6 miles east of Washington, NC (figure 10). A narrow sand ridge and beach separates the river from a cypress swamp. Several clumps of black needlerush

were scattered along the eroding beach. Stumps and fallen trees were abundant. Several cypress trees were on or near the beach. Ground elevation of the ridge is approximately +4.0 feet. The fetch is 1 1/2 miles to the north.

One hundred feet of breakwater was constructed 30 feet offshore in 2 1/2 feet of water in April 1992. Smooth cordgrass was planted in June 1992. The existing black needlerush is expected to spread as well. The shoreline has remained unchanged since construction. The planted grasses are surviving but have shown slow growth in the first season.



Figure 10. Site 9, one year after construction and planting.

10. Hughes: The site is a large parcel of undeveloped land on the north shore of the Neuse River, 1 mile southwest of Oriental, N.C. Fetch to the southwest is 5 miles. The shoreline has a 7-foot eroding clay bluff and narrow beach. A screened camp enclosure is located 50 feet from the bluff.

In November 1992, 100 feet of breakwater was constructed 20 feet offshore in 2 1/2 feet of water. The beach widened following construction in part due to the movement of an offshore bar located farther away from shore. Smooth cordgrass was planted in May 1993.



Figure 11. Site 11, one year after breakwater construction.

11. Weyerhaeuser Corporation: The site is a large tract of land on the north shore of the Neuse River approximately 8 miles northeast of Oriental, NC (figure 11). The land is undeveloped but long range plans expect it to be subdivided for residential development. The fetch is 4 miles. An 5-foot eroding clay bluff is fronted by a narrow beach.

One hundred feet of breakwater was constructed 20 feet offshore in 1 1/2 feet of water and planted in June 1992. Sand was trapped at each end of the breakwater with a sheltered area in the center. Marsh growth has been slow. The area was replanted in April 1993.

12. Lischke/Longaker: The site is a residential subdivision on the south shore of the Neuse River about 14 miles north of Morehead City, NC. The shoreline is partially a 4-foot clay bluff and eroding beach. The western lot is bulkheaded and has no beach at normal water levels. Erosion was flanking the return wall at the end of the bulkhead. Stumps and fallen trees were abundant on the beach and offshore. The fetch is four miles to the north.

In December 1992, 140 feet of breakwater was constructed 20 feet offshore in 2 feet of water. Of that length a 120-foot section was eligible for cost-sharing. One hundred twenty feet protect the beach and bluff. Twenty feet of breakwater extends seaward of the bulkhead to protect the return wall from additional flanking. The beach

widened after construction, partially burying the clay bank. The shoreline was planted with smooth cordgrass in April 1993.

CONSTRUCTION AND COST SUMMARY

Twelve breakwaters were constructed by 14 property owners as part of the demonstration. The sites are widely scattered around Albemarle and Pamlico sounds. More sites participated than originally conceived in the proposal, requiring more time to select, permit and construct the projects. However, the additional sites offer easier access by those wishing to observe the demonstration.

One of the project goals was to allow marine contractors to gain experience with the method. Ten contractors built at least one breakwater. Two contractors built at two separate locations. Once contractors become familiar with the method it is expected they will inform other property owners of the marsh/breakwater as an alternative to bulkheads and other erosion-control methods. One contractor also planted the marsh grasses as part of his contract. Nine owners chose to plant their own marsh. One property owner hired a landscaping firm to do the planting. The contractors and property owners have already started recommending the method to other owners.

Total construction and planting costs varied considerably between sites (figure 7). The least expensive was \$23 per linear foot. The most expensive was \$42 per linear foot. The average cost per foot for all sites was \$31. The costs do not include the permit application fee, which is discussed in the later section. The prices appeared reasonable and near the middle of the predicted \$25 to \$35 range. Wood prices were above normal during the construction period and may drop closer to previous levels in the future. Construction time and labor cost may also be reduced as the contractors become more familiar with the ease of installation.

Each breakwater has been planted with marsh grasses except for Colington Harbour, which will be planted as soon as the excess sand eroded from the bluff redistributes along the shoreline. Since planting the other sites, insufficient time has passed for growth of a thick marsh or development of a root mat. Several sites have required replanting, as is often common with planted marshes. Based on performance to date, all installations are expected to have enough marsh for effective erosion control in one or two growing seasons. The author will continue to work with the property owners to develop a stable, healthy marsh.

Monitoring of the demonstration installations is expected to continue after the expiration of the APES grant. In several years, after the marshes are well established, there is are long range plans to conduct more analytical biological comparisons of shorelines with marsh/breakwaters, bulkheads, eroding beaches and natural marshes.

INSTRUCTION BOOKLET

Another goal of the grant was to develop and publish information for property owners and contractors on the use of the method for erosion control. A booklet entitled Shoreline Erosion Control Using Marsh Vegetation and Low-Cost Structures (UNC-SG-92-12) has been prepared. Planting methods for marsh grasses both with and without breakwaters are described. Guidelines are given to evaluate suitable shoreline conditions. Design guidelines are provided for breakwater materials and locations. Fertilizer application methods to stimulate spreading of the grasses are reported. The environmental benefits of planting a marsh and the functional use of the breakwater are discussed. The report was written by Steve Broome, Department of Soil Science; Ernest D. Seneca, Department of Botany; and Spencer Rogers, UNC Sea Grant and the Department of Civil Engineering, all from N. C. State University.

The booklet has been published by UNC Sea Grant and is available for a small fee to cover printing costs. News releases and publication announcements have been distributed and will continue.

PERMIT TIME AND APPLICATION FEES

The effectiveness, low cost and environmental advantages of planted marsh grasses and wooden breakwaters are being clearly demonstrated by the project. The

method can be effective on a wide range of shoreline exposures with shallow offshore slopes. Although not suitable for all shorelines, it can be beneficial to many property owners dealing with erosion in North Carolina. However, the contacts with many property owners and the author's preparation of more than 20 permits has revealed that the permitting process will place the marsh/breakwater at a significant disadvantage compared to other erosion-control methods.

Erosion often becomes apparent to the property owner after a moderately severe storm. Although the real problem is a long-term erosion trend, the owner perceives the erosion as an immediate threat that requires immediate action. A permit to build a breakwater and marsh requires two to five months for approval. Most of the delays are due to public notices and review by numerous agencies.

The N.C. Coastal Resources Commission and the Coastal Area Management Act should be commended for establishing simple permit processing for most erosion-control structures. Recognizing that most estuarine bulkhead and revetment permits were always being approved through the full permit review process, the CRC established quicker categories of permits for projects meeting specific conditions that ensure their environmental acceptability. Both the delays for processing applications and the time and cost of DCM staff needed for review have been significantly reduced without increased risk to the environment.

Under most circumstances, estuarine bulkheads and rock revetments near the high-water line are permitted with a general permit, in effect a pre-authorized permit. If the site meets a set of general conditions, a permit is issued at the time of the DCM field inspection. Construction can begin immediately. When an owner believes the erosion problem requires immediate attention, the marsh/breakwater's minimum delay of two months is a severe disadvantage compared to the instant bulkhead permit.

Another deterrent for the use of marsh breakwaters is the difference in application fees. Typical bulkhead permit fees are: 1) no charge for exemptions when the alignment is landward of the mean-highwater line and landward of any wetlands or 2) \$50 for general permits if the alignment is above any wetlands but partially seaward of the mean highwater line. For a marsh/breakwater, a major permit is required along with an application fee of \$250. The fee for a typical major permit, for example construction of a marina, is reasonable compared to the time required to evaluate the project and the potential impact of the work. But to construct 50 feet of marsh and breakwater, \$250 can increase the total construction cost by 20 percent.

The attractiveness of the marsh/breakwater to property owners with shoreline erosion problems would be greatly enhanced if the Coastal Resources Commission allowed construction under a general permit just as is already available for bulkheads, revetments and piers. For example, all four of the owners who withdrew from the demonstration program would have started construction immediately if permits had

been available. Each of those sites will ultimately have a bulkhead or revetment in deep water, without a marsh or beach.

CONCLUSIONS AND RECOMMENDATIONS

The effectiveness of the low-cost combination of planted marsh grasses and small, wooden breakwaters has been demonstrated as planned. Twelve sites are located in easy driving distance of anyone in the Albemarle/Pamlico Study Area. Other property owners are already visiting the sites and have requested more details. 300 copies of Shoreline Erosion Control Using Marsh Vegetation and Low-Cost Structures have already been distributed. Additional orders are arriving daily.

Compared to a bulkhead, the marsh/breakwater offers significantly lower costs to the owner while establishing a marsh where it could not otherwise survive, an environmental asset. The primary disadvantage to wider use of the marsh/breakwater is substantially longer time to obtain a permit. It is recommended that Division of Coastal Management and the Coastal Resources Commission consider establishing an exemption or general permit for marsh/breakwaters. The Division of Coastal Management staff, based on performance to date, has expressed an interest in preparing specific design conditions for use in a general permit. This demonstration as well as other previously constructed projects, both planned and accidental, should

offer sufficient experience to establish a list of design conditions necessary for one of the preauthorized permits.

All general permits must balance the tradeoffs between public and private rights to develop, between riparian and public use of submerged land, and the biological impact. A general permit for a marsh/breakwater should be carefully worded to allow use of the method on appropriate shorelines while still protecting other public and private rights. The availability of a general permit should remove the marsh/breakwater's significant disadvantage of three to six months of additional permit time when property owners compare the method to a bulkhead.

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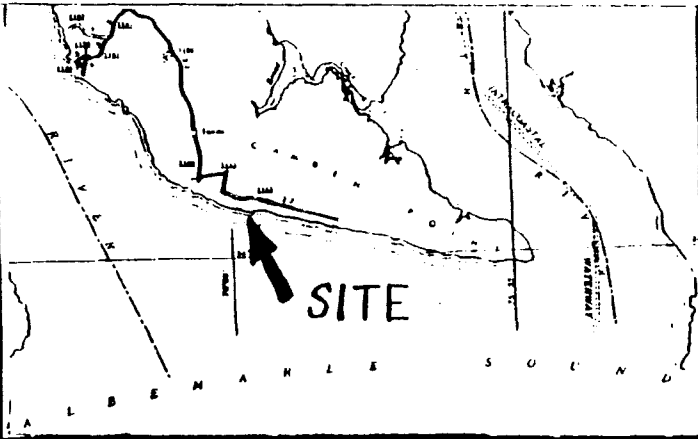
Appendix A

Site Plans

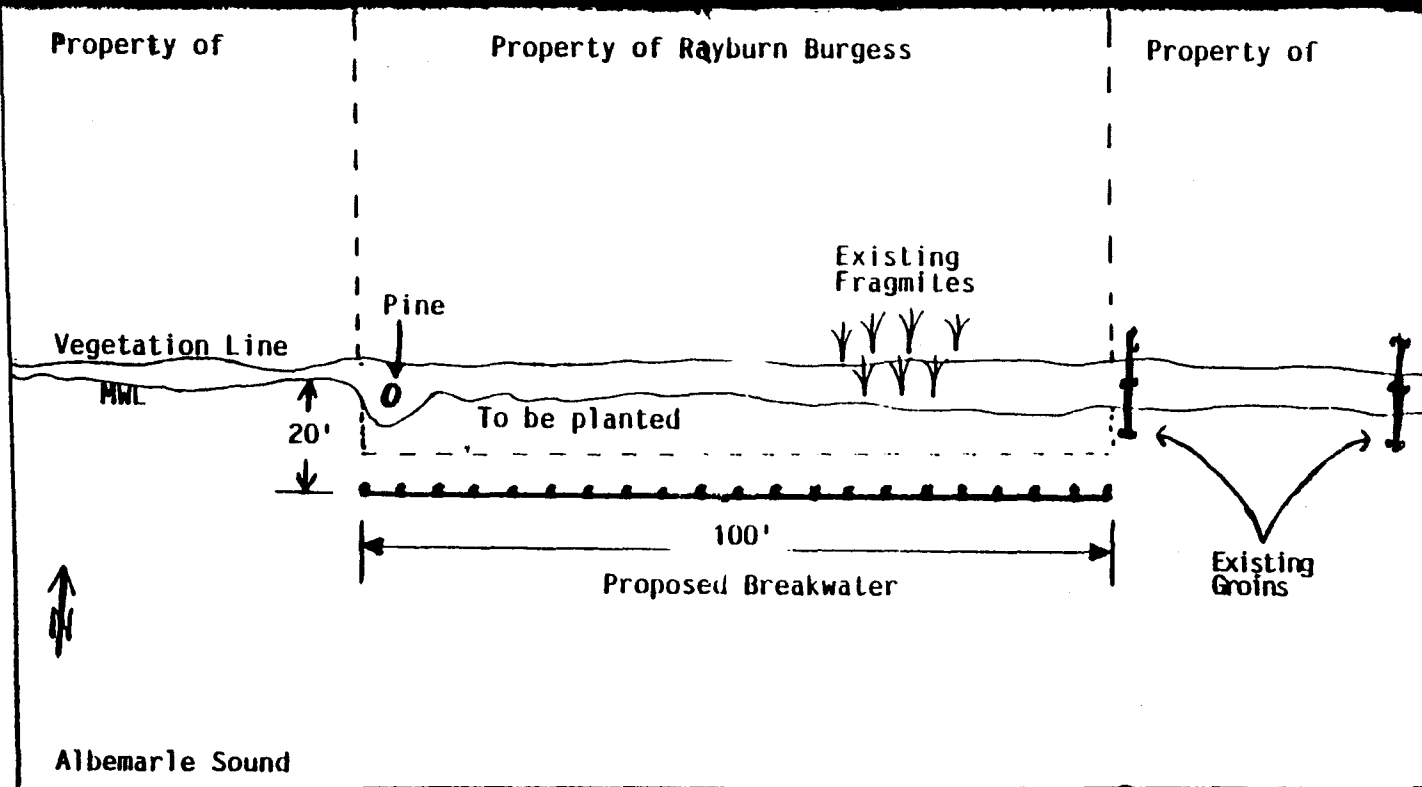
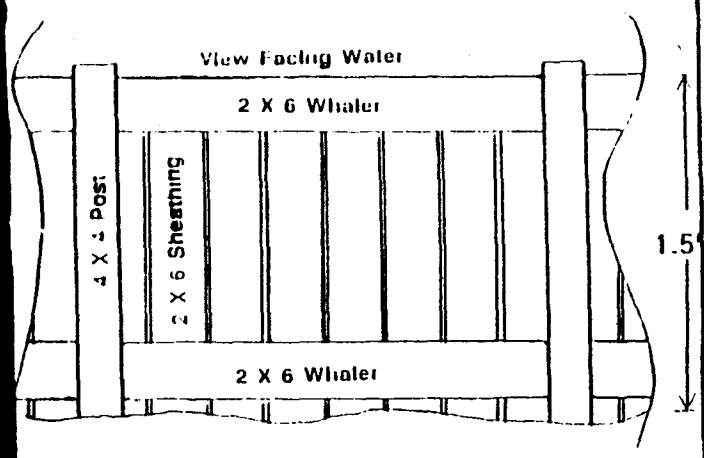
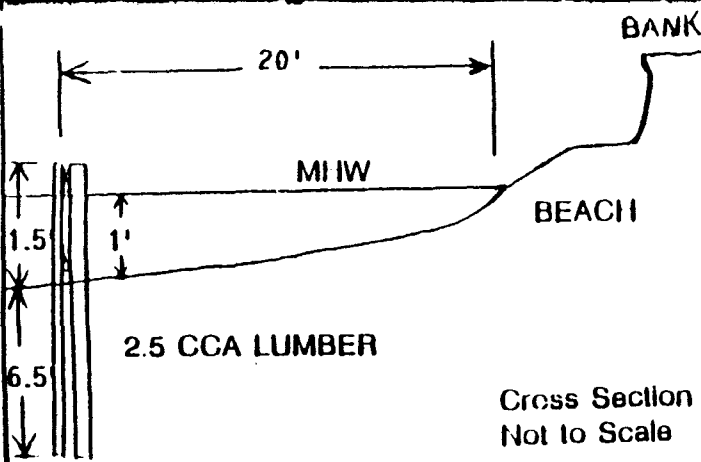
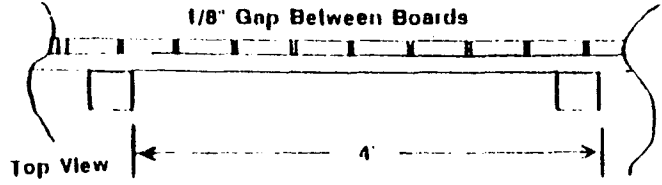
Marsh/Breakwater Demonstration Project

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 1

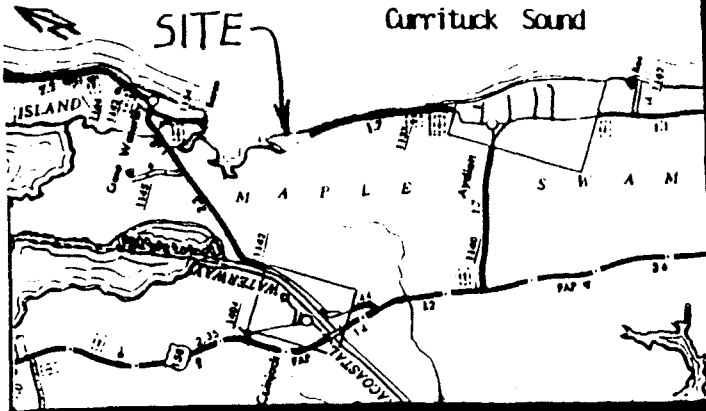


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 APPLICANT: Spencer M. Rogers, Jr.
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 LOCATION: Camden Point

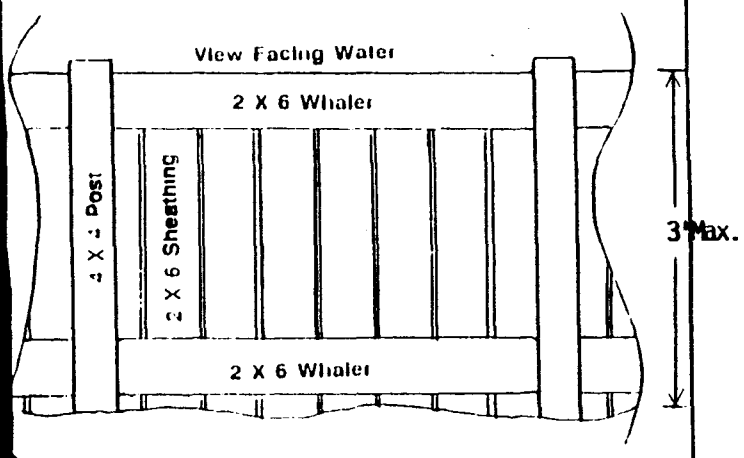
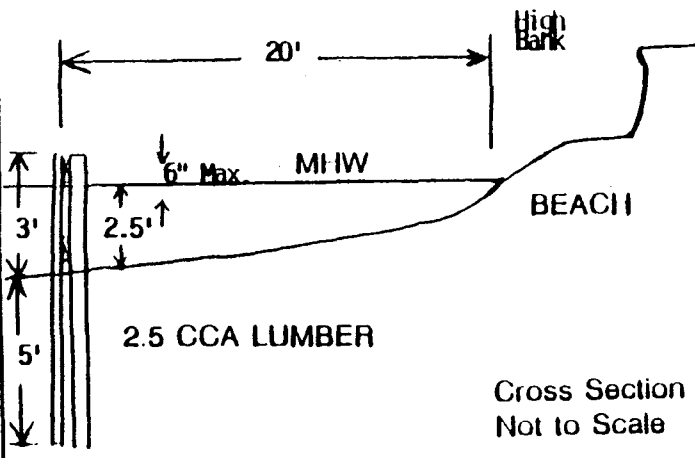
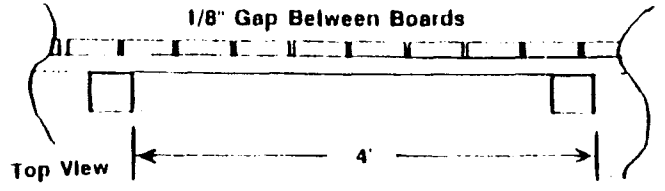


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

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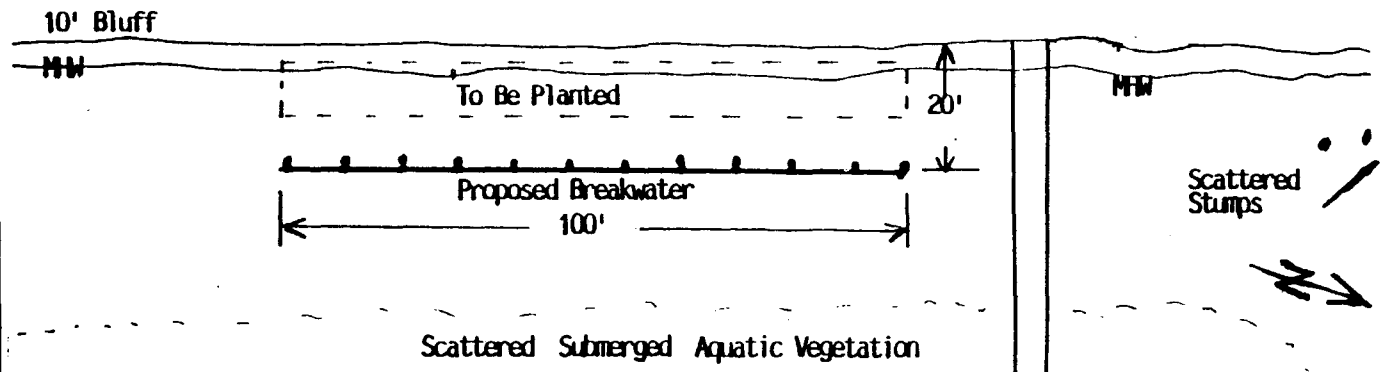


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 APPLICANT: Spencer M. Rogers, Jr.
 DATE: October 12, 1992
 LOCATION: North of Aydlott/Currituck Sound

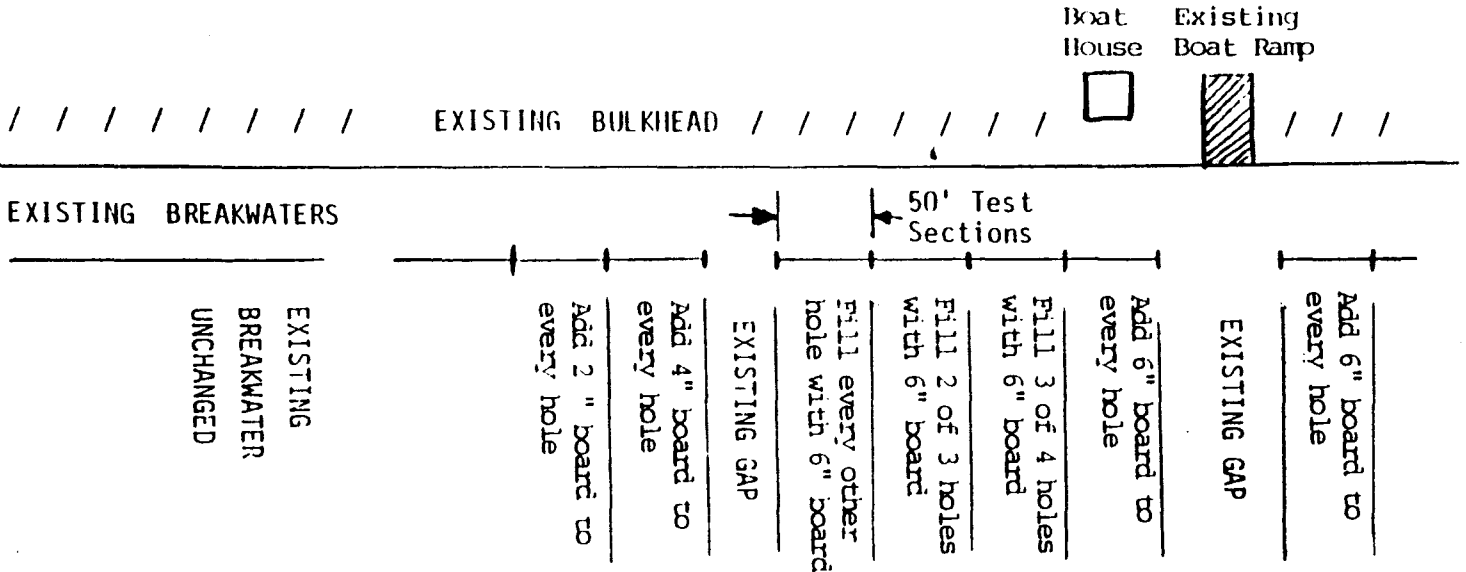


Property of: John W. Foreman

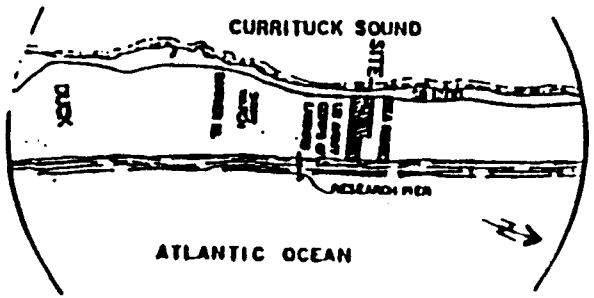
Existing Building



Site 3



LOCATION MAP



PROPOSED PERMIT MODIFICATION

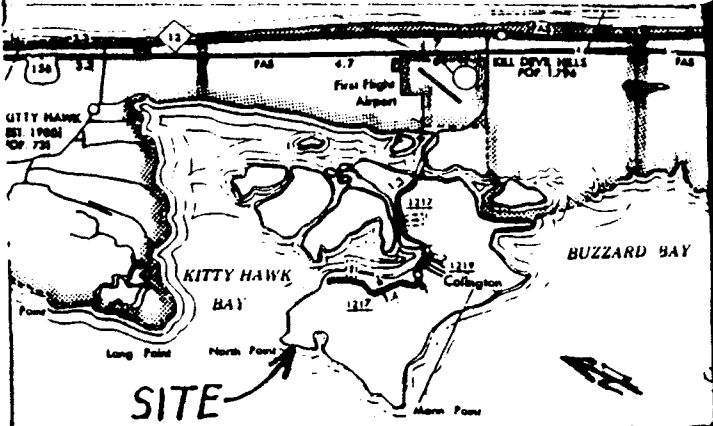
Property of

Joe C. Britt
1308 Duck Road
Currituck Sound

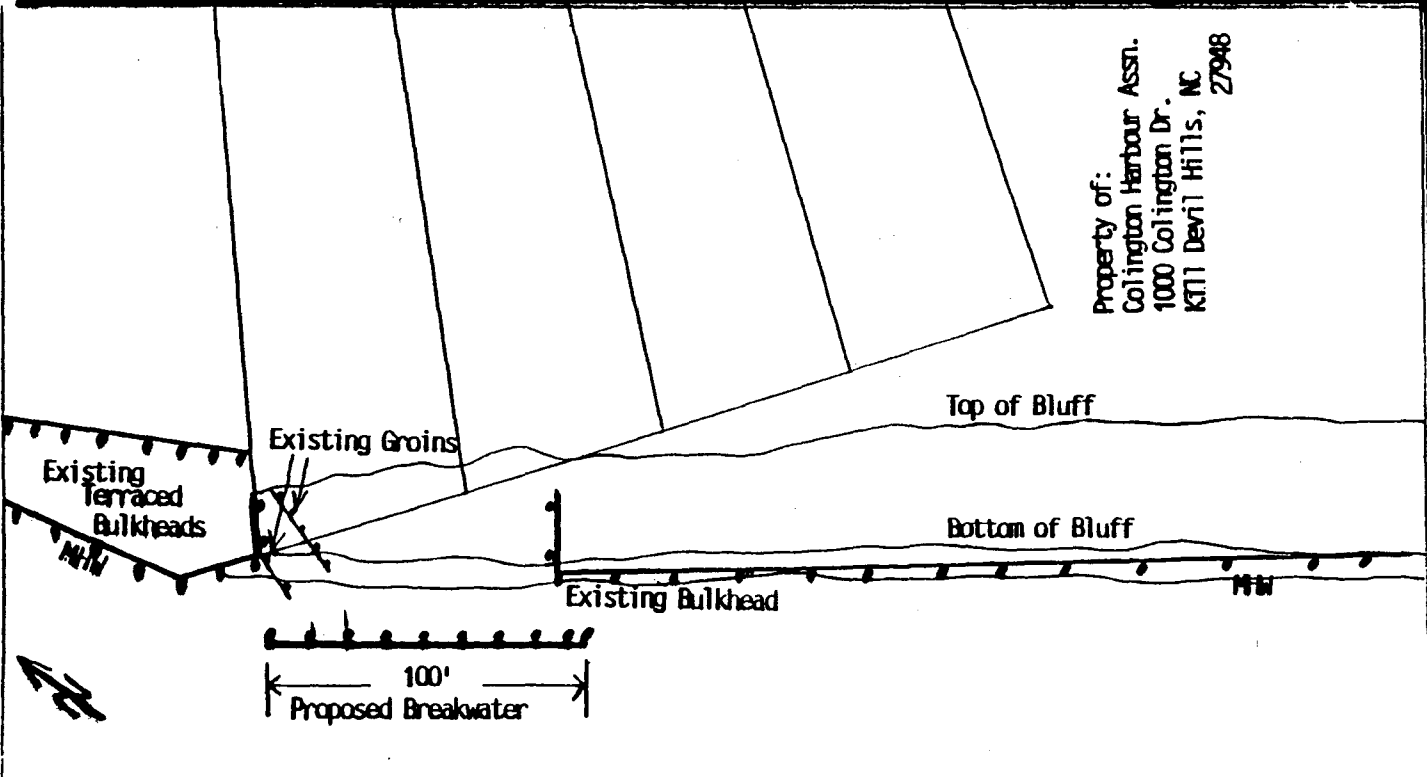
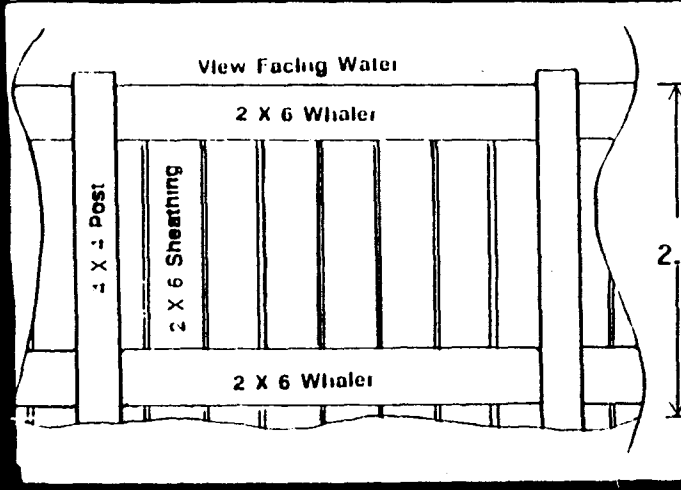
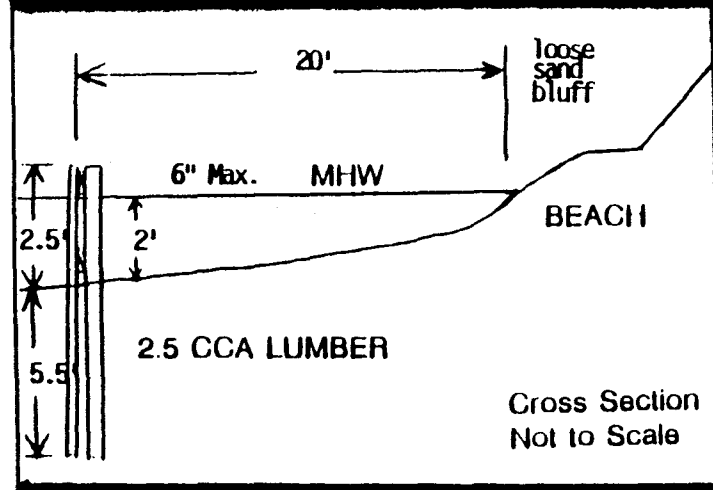
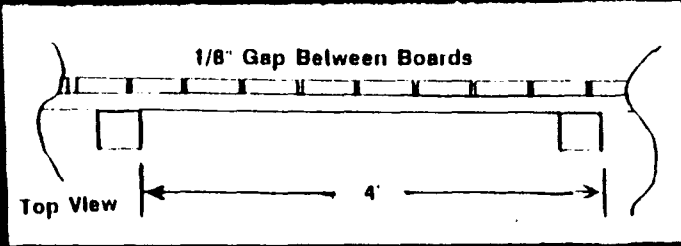
Submitted by: S.M. Rogers, Jr.

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 4



OWNER: Stuart Olmstead
 APPLICANT: Colington Harbor Association, Inc.
 DATE: Spencer M. Rogers, Jr.
 DATE: October 12, 1992
 LOCATION: Dare County

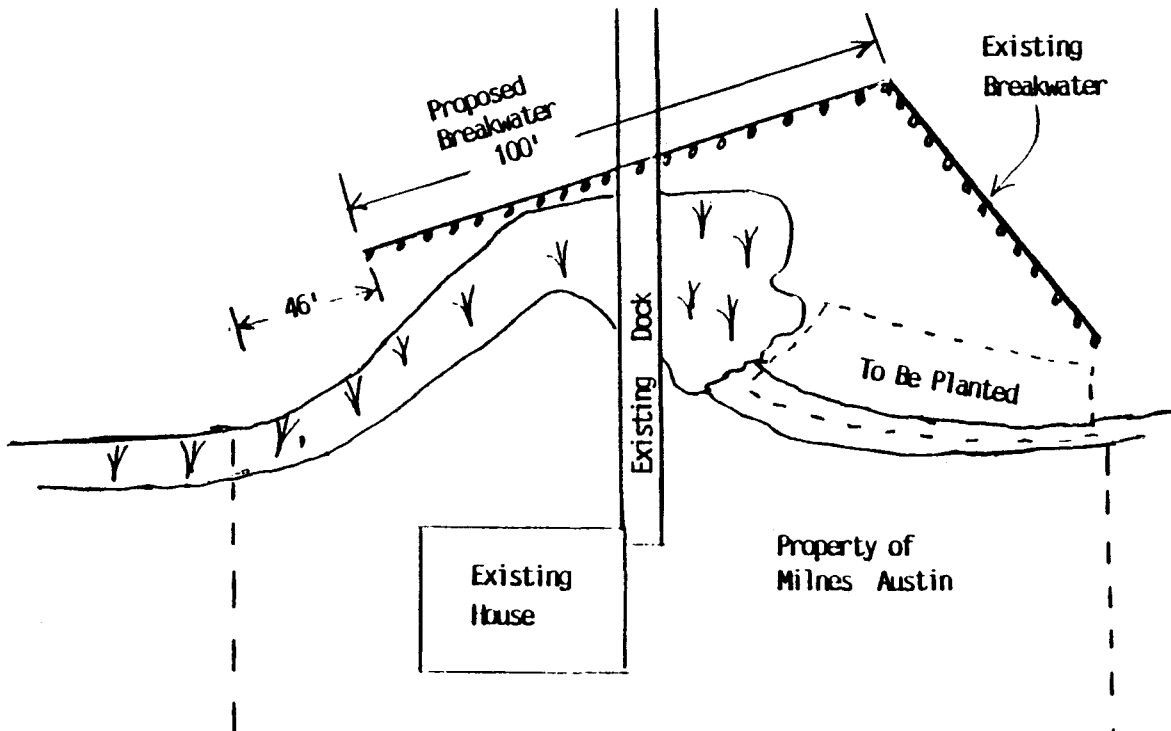
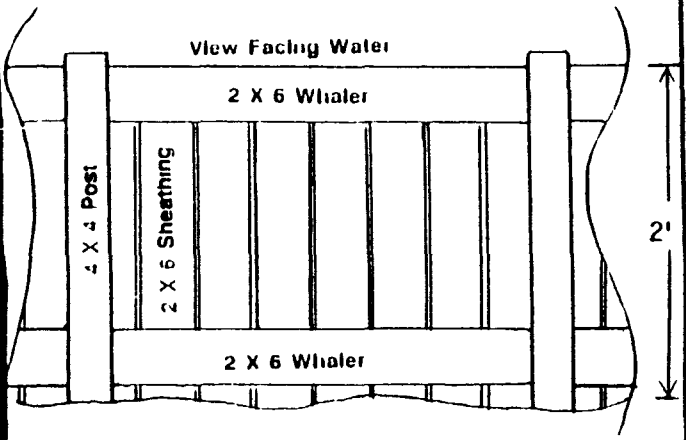
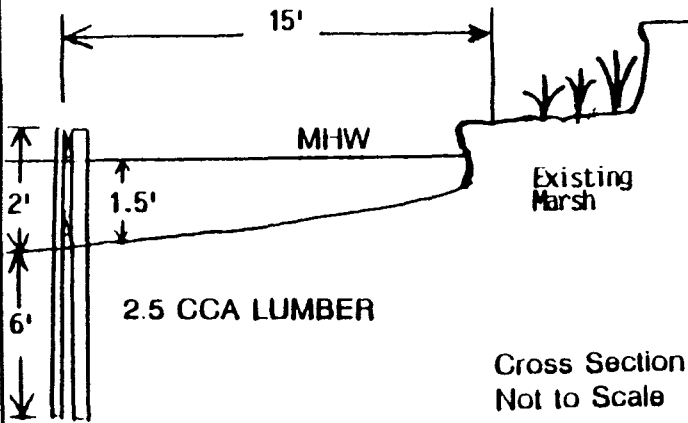
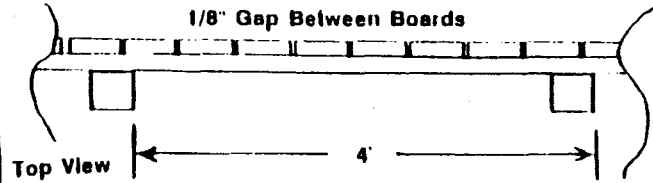
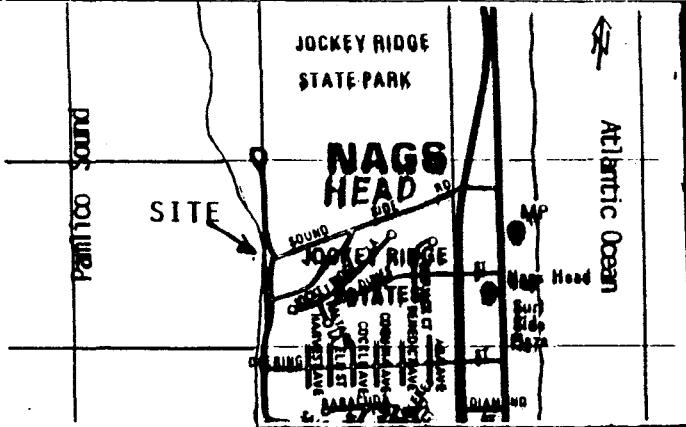


Property of:
 Colington Harbour Assn.
 1000 Colington Dr.
 Kitty Hawk Hills, NC 27948

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

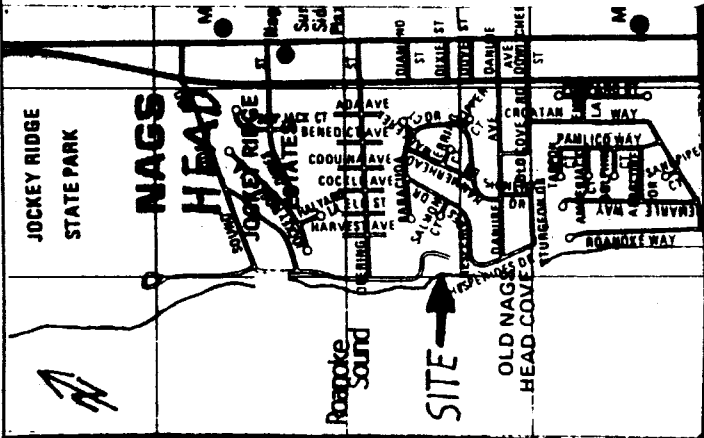
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OWNER: Milnes Austin
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: June 12, 1992
 LOCATION: Nags Head, NC Roanoke Sound

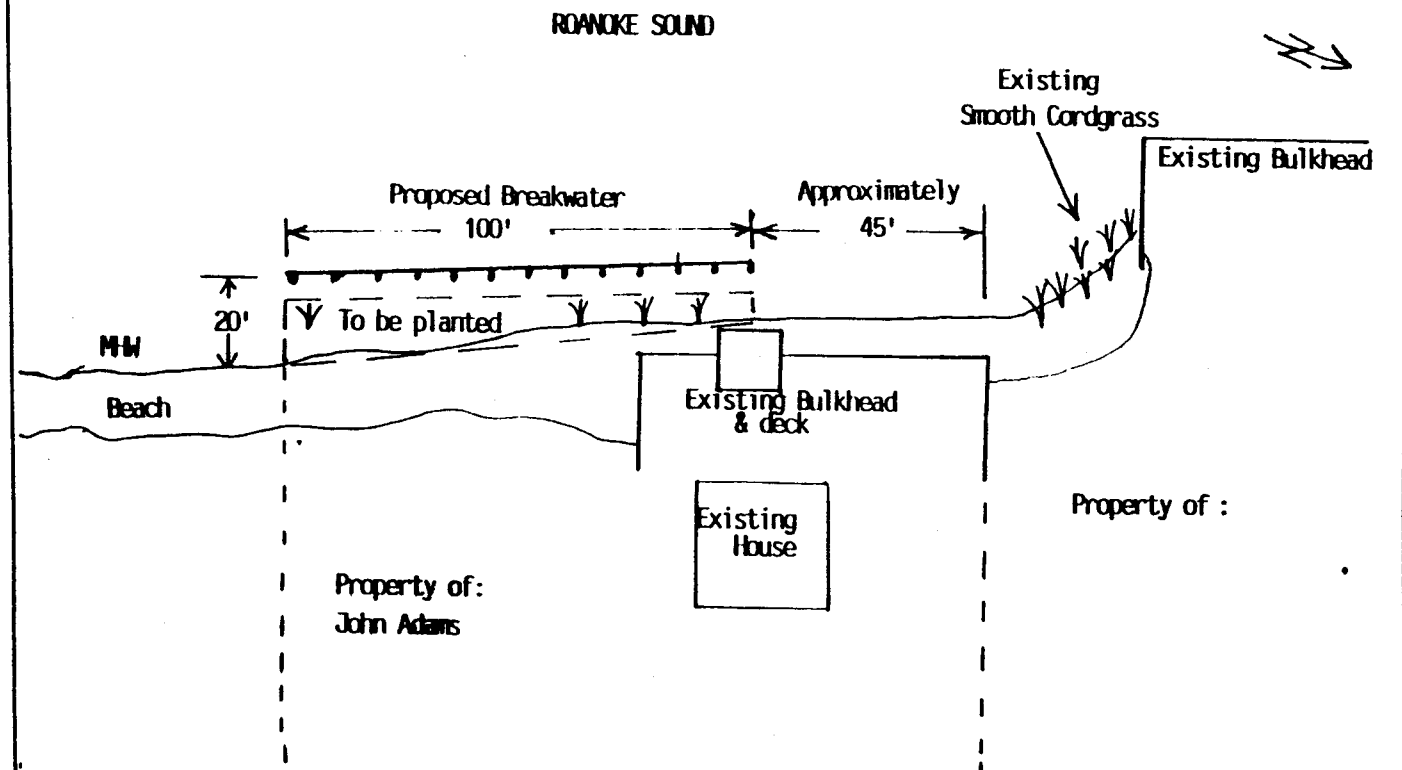
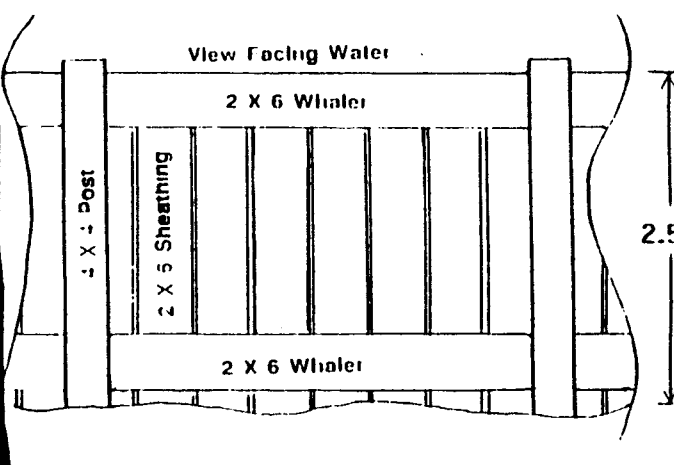
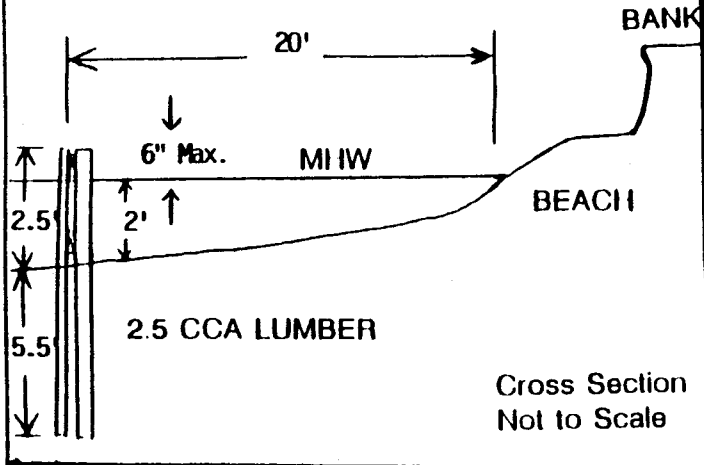
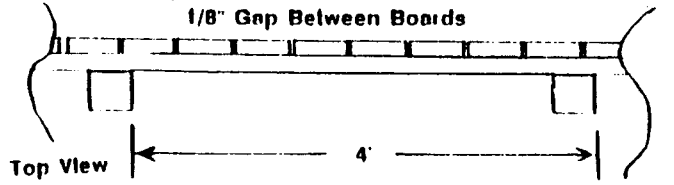


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

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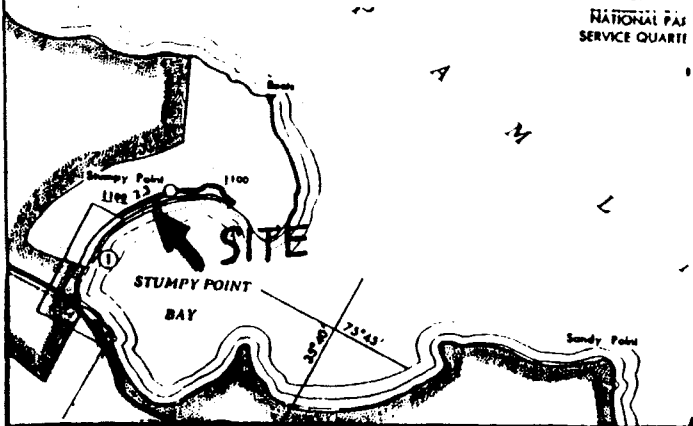


OWNER: John Adams
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: October 12, 1992
 LOCATION: Nags Head/Dare County

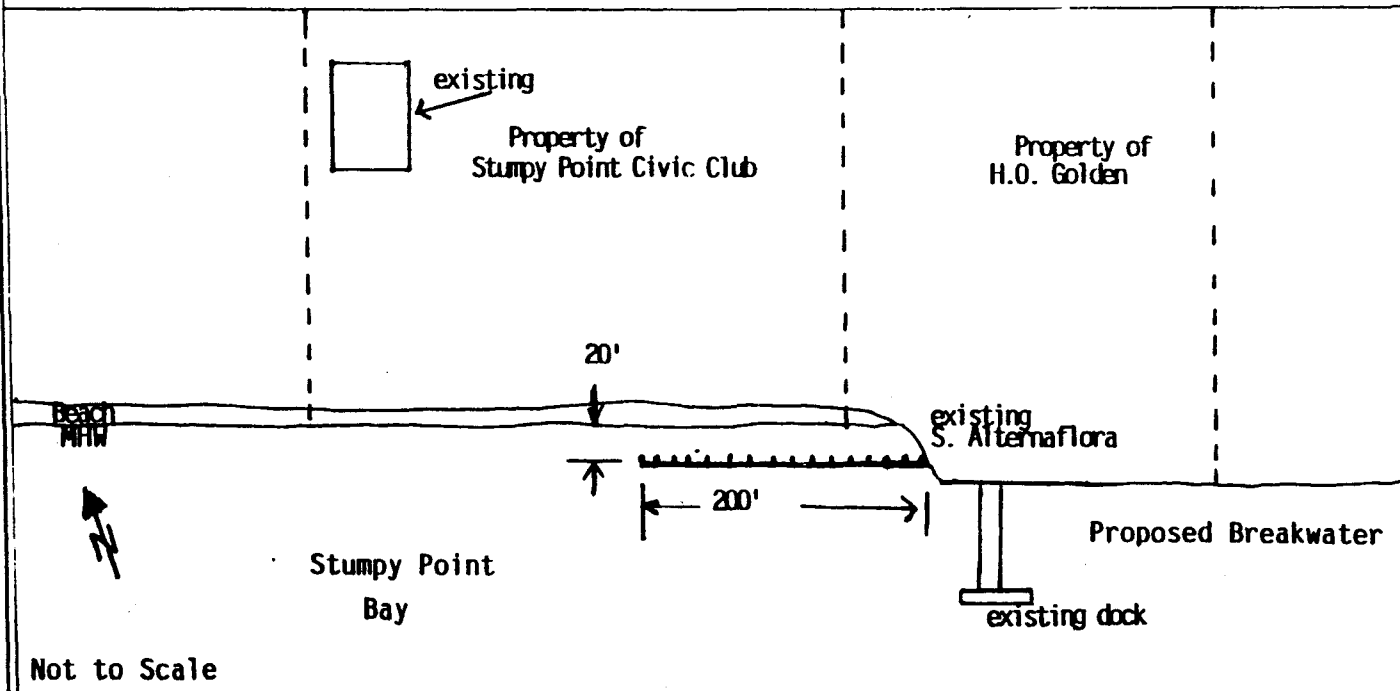
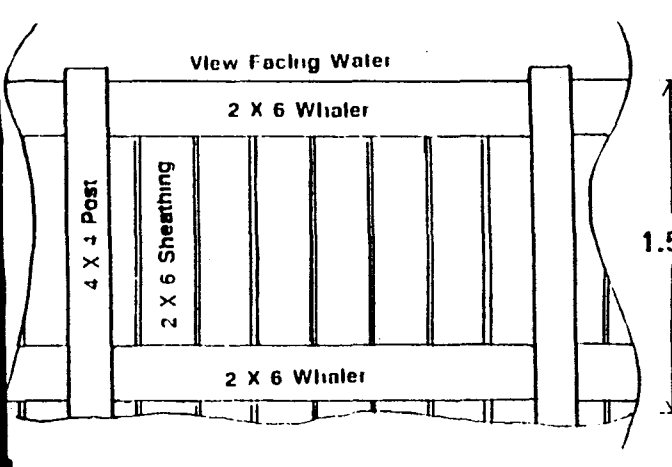
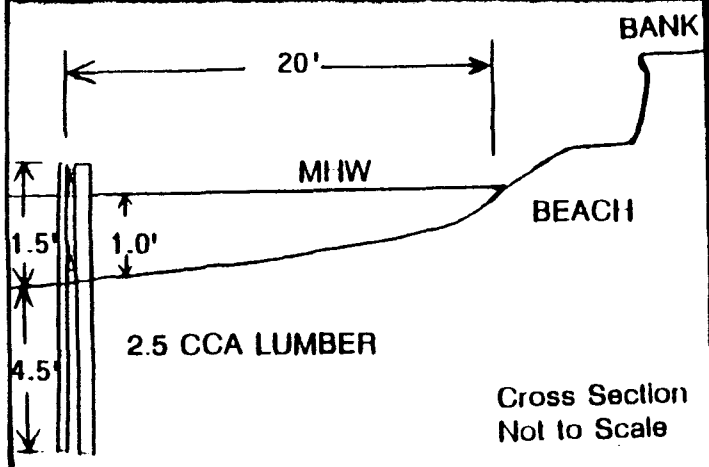
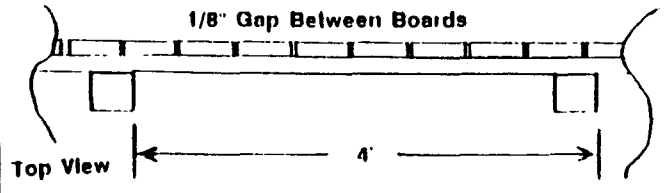


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 7

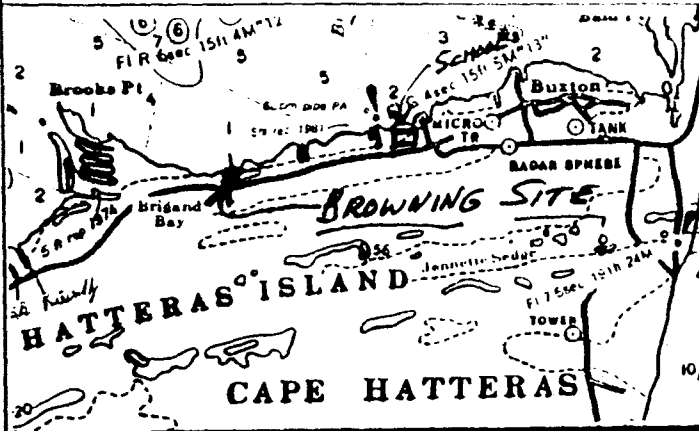


OWNER: Stumpy Point Civic Club & Hildred O. Golden
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: December 5, 1991
 LOCATION: Stumpy Point

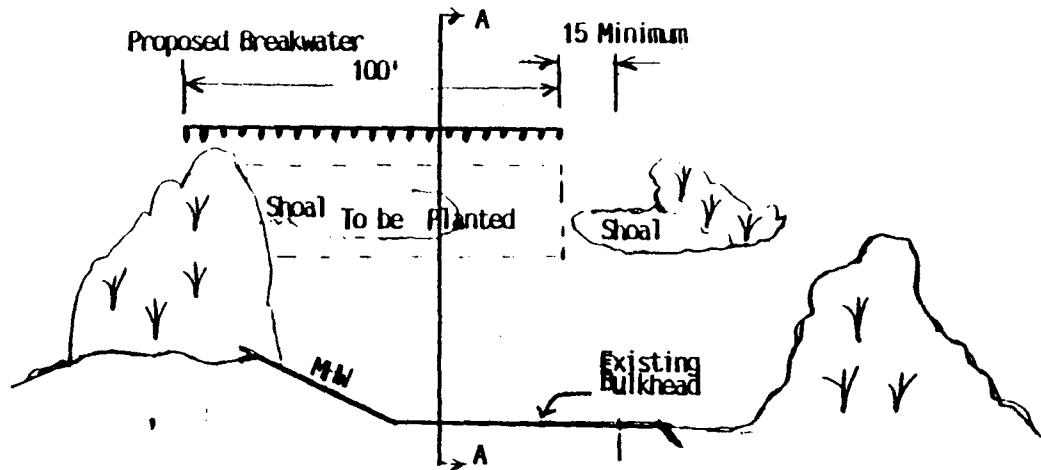
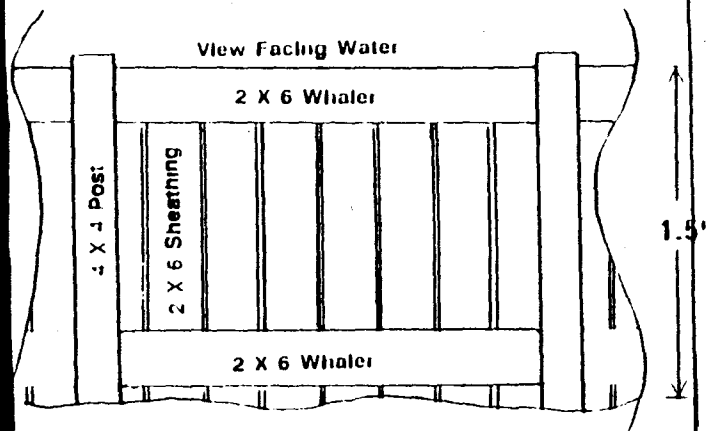
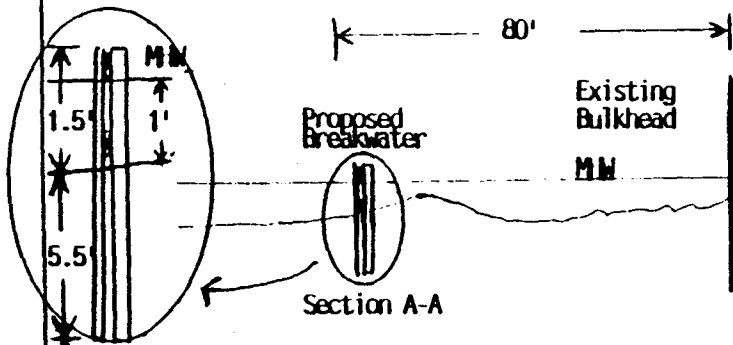
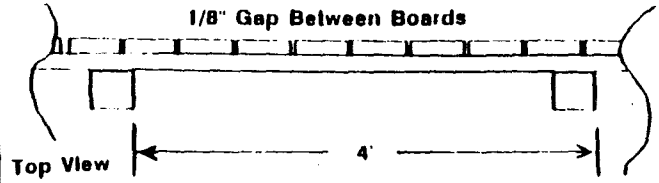


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 8



OWNER: Leonard L. Browning, Jr.
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: June 4, 1992
 LOCATION: Buxton, NC Pamlico Sound

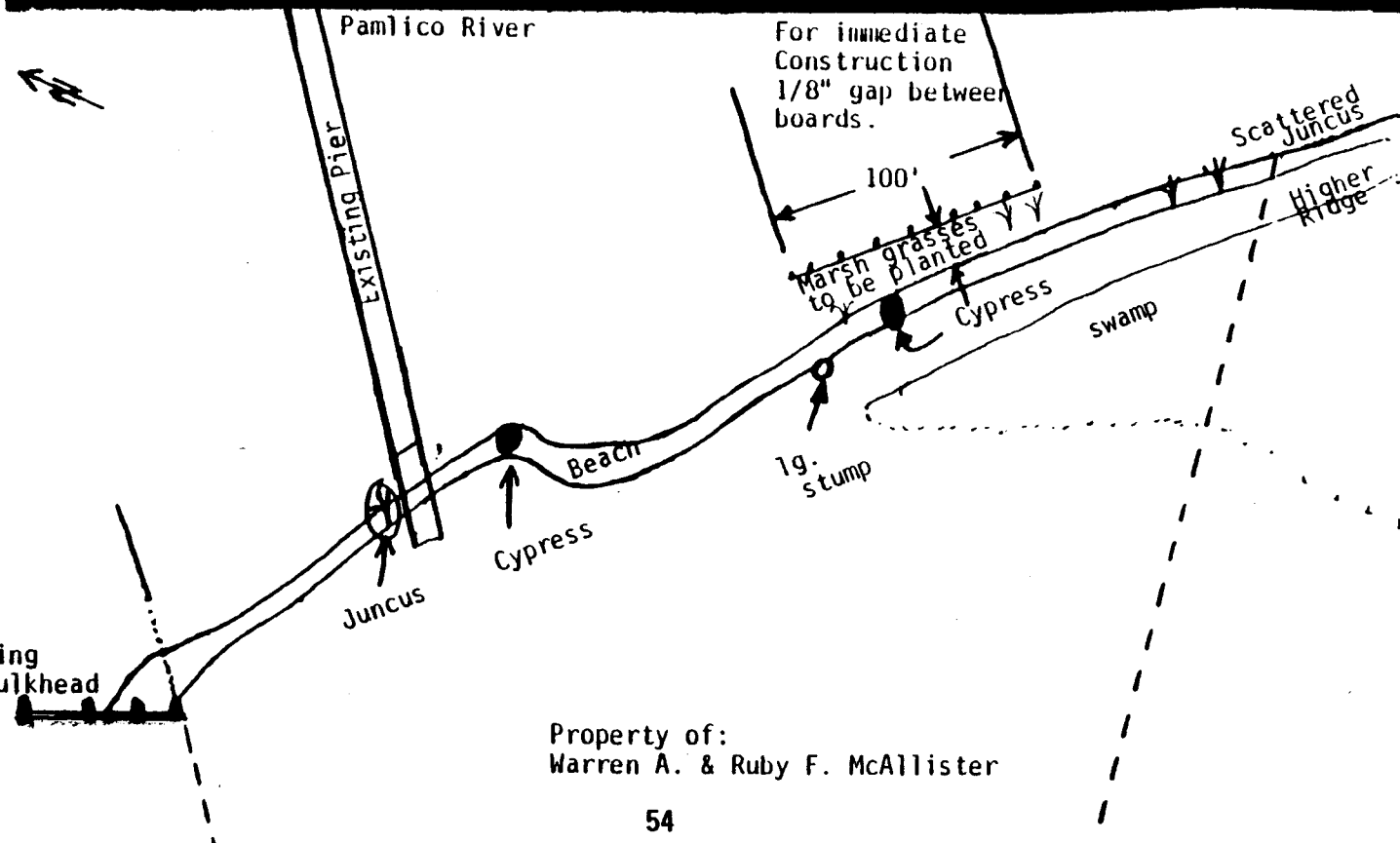
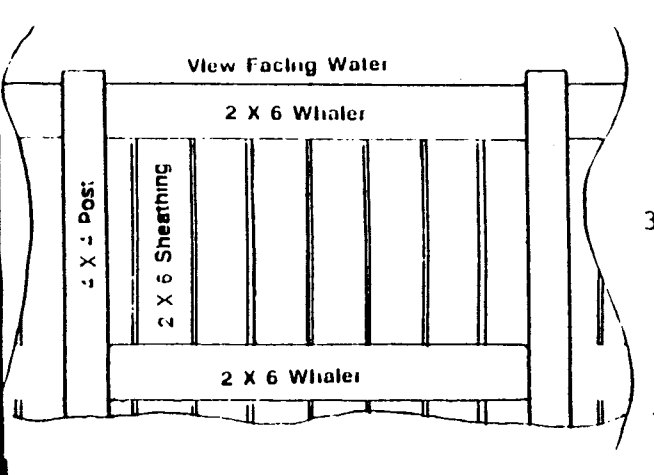
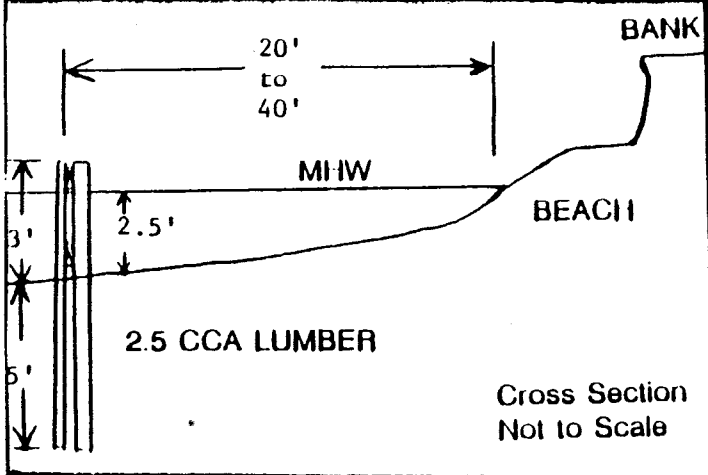
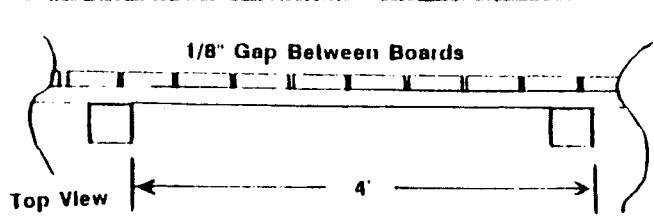
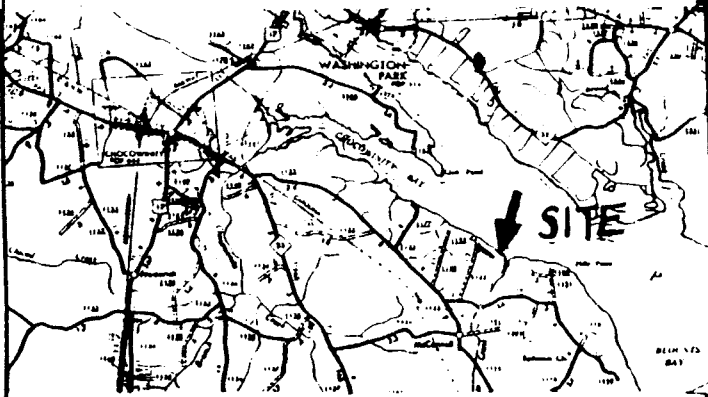


Property of:
 Leonard L. Browning, Jr.

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 9

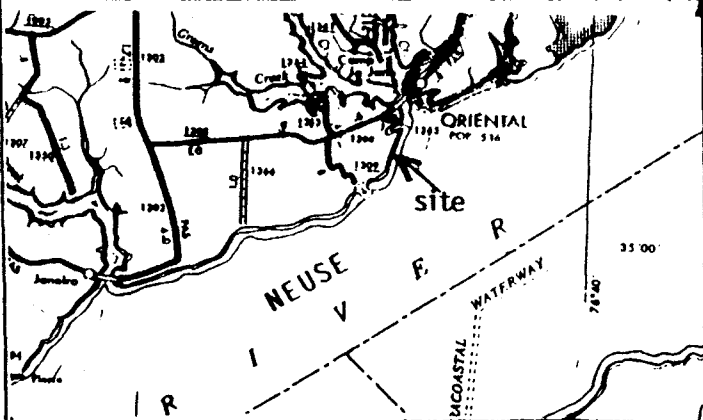
OWNER: Warren A & Ruby F. McAllister
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: April 26, 1991, Revised 8/1/91
 LOCATION: River Hills Subdivision, Pamlico River



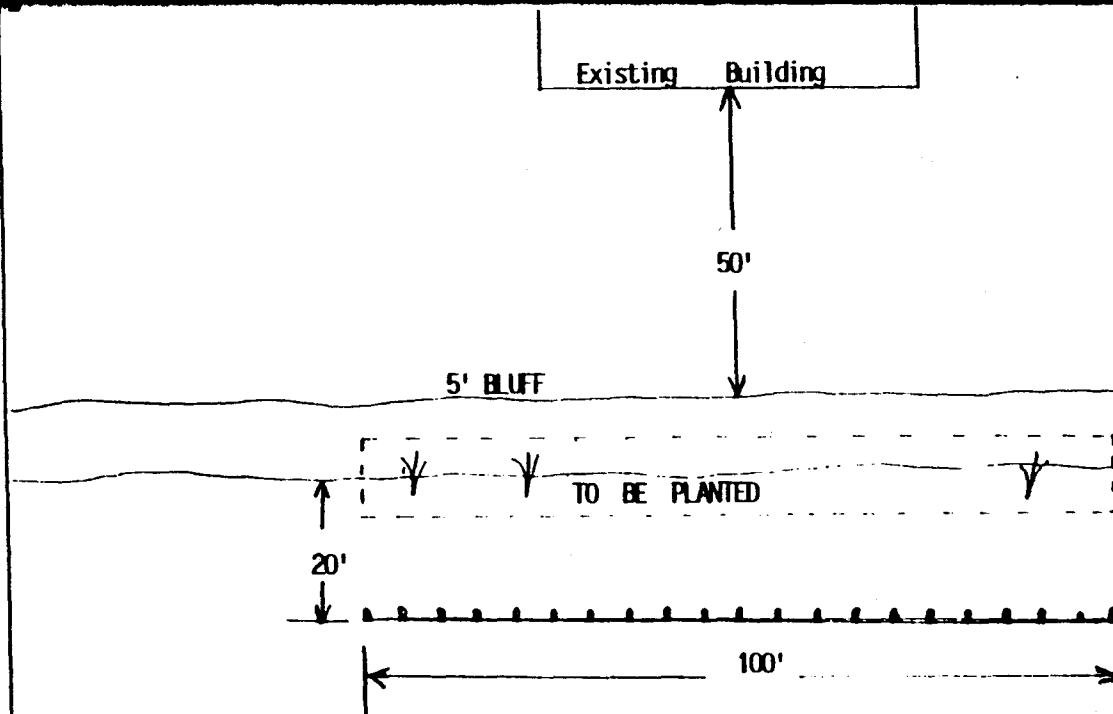
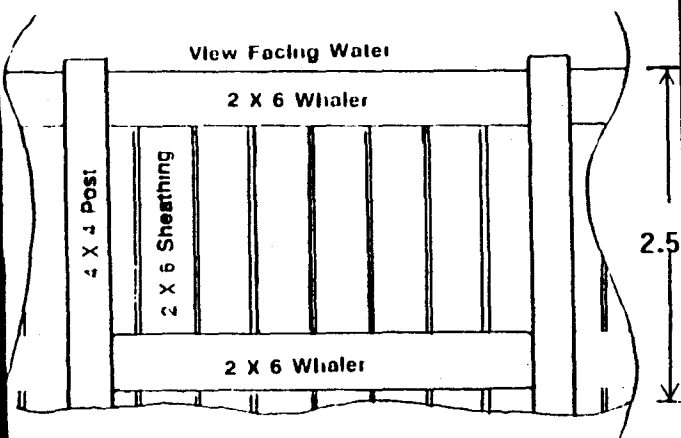
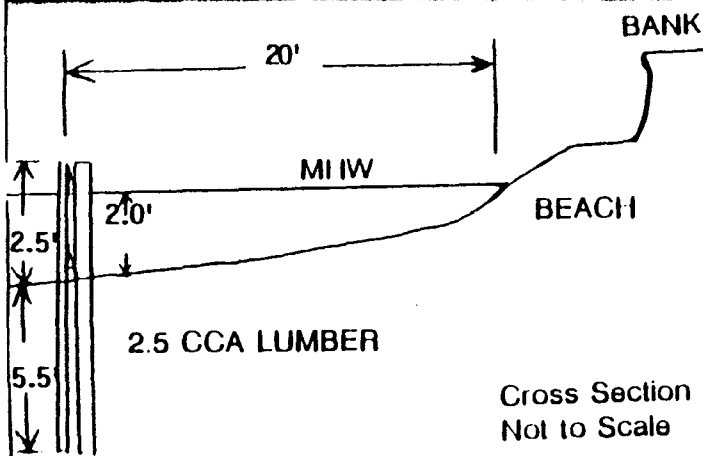
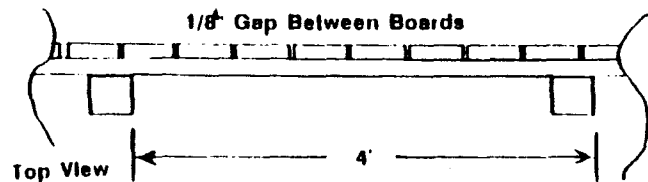
Property of:
 Warren A. & Ruby F. McAllister

APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 10

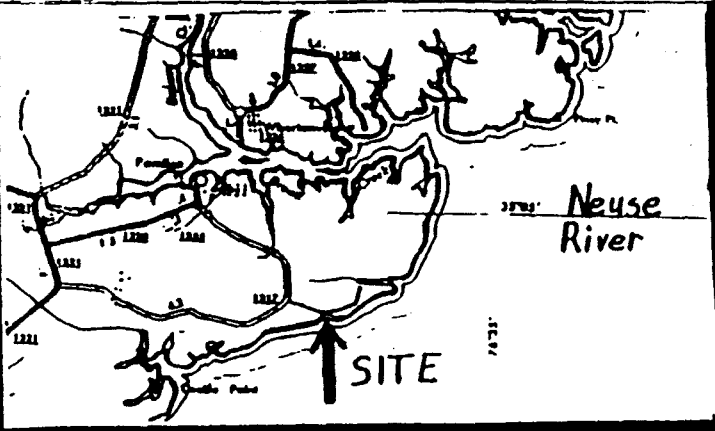


OWNER: Samuel Hughes for the
 Perry Griffin Foundation
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: June 3, 1992
 LOCATION: Neuse River near Oriental, NC

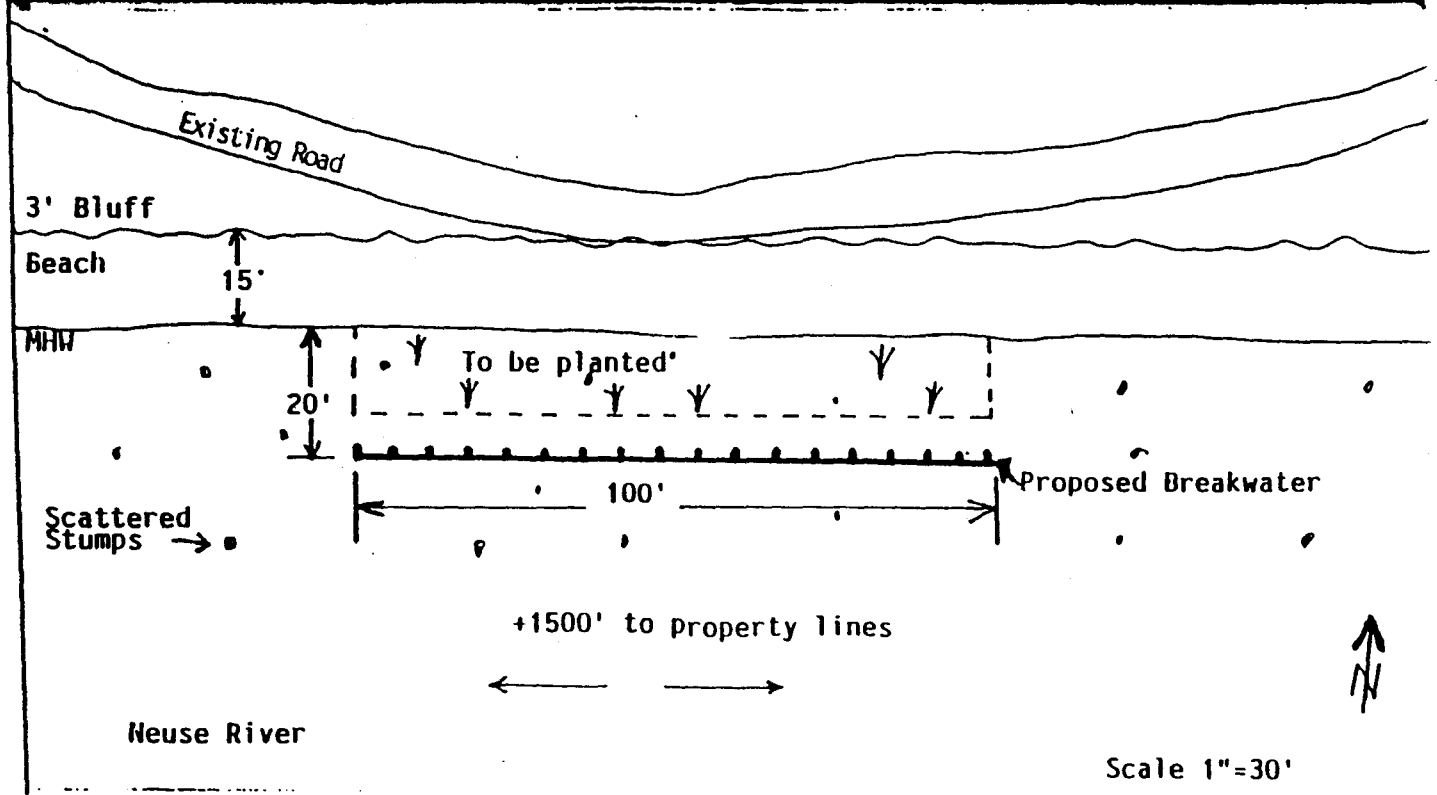
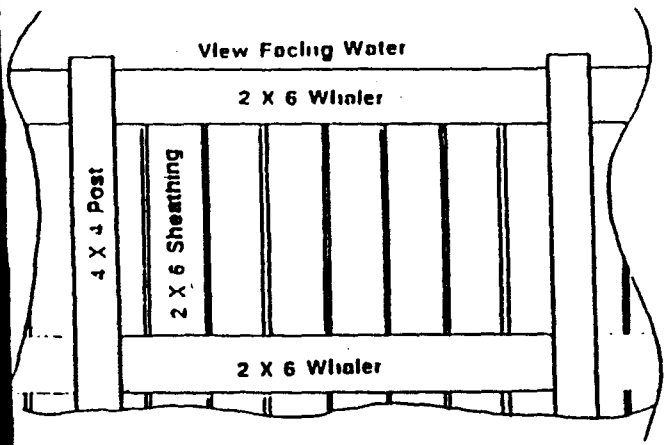
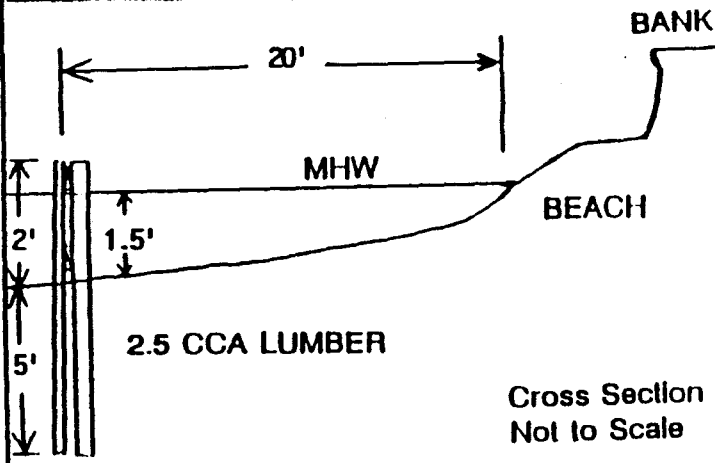
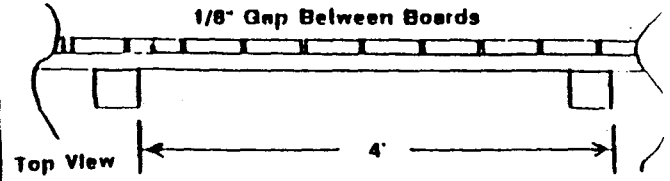


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 11

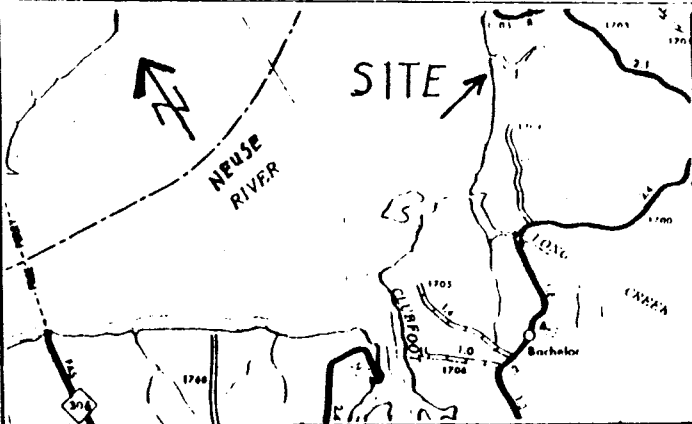


OWNER: John Doughty
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: December 5, 1991
 LOCATION: Neuse River near Broad Creek

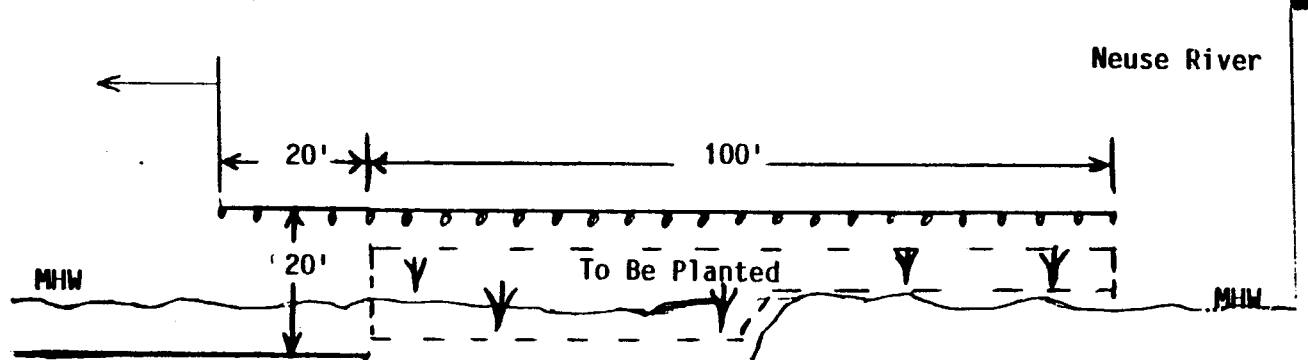
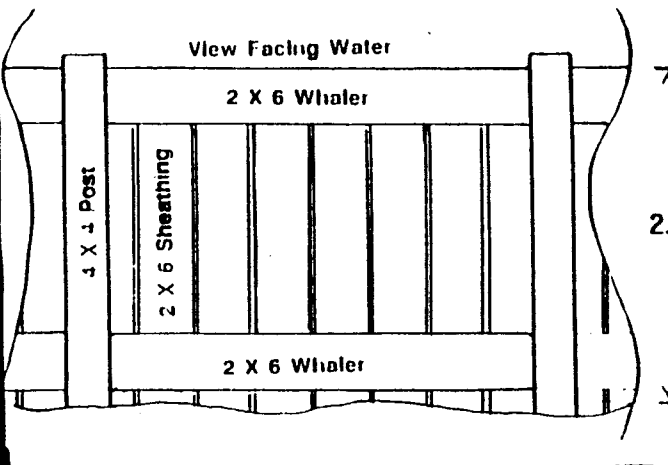
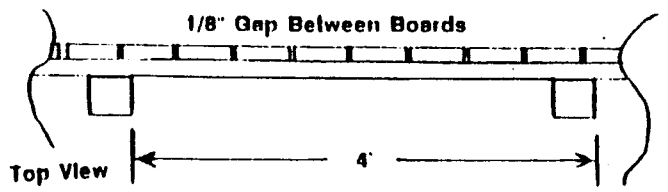
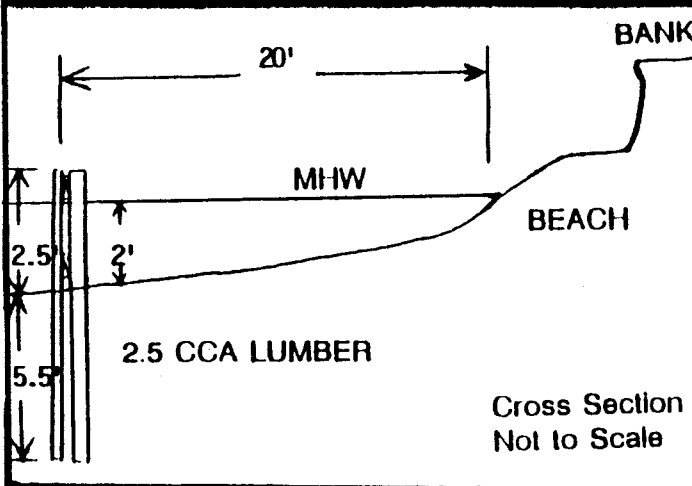


APES BREAKWATER/MARSH GRASS DEMONSTRATION PROJECT

Site 12



OWNER: Erwin J. Lischke & Stephen Longaker
 APPLICANT: Spencer M. Rogers, Jr.
 DATE: July 16, 1992
 LOCATION: Coaches Creek, Craven County



PROPERTY OF:
 Stephen Longaker
 9399 Kingston Crossing
 Cir.
 Alpharetta, GA 30201

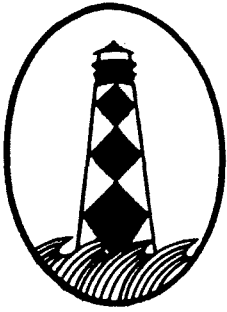
Property of:
 Erwin Lischke



Appendix B

Site Selection and Property Owner Agreements

Marsh/Breakwater Demonstration Project



UNC SEA GRANT COLLEGE PROGRAM
MARINE ADVISORY SERVICE

P.O. Box 130
N.C. Aquarium/Fort Fisher
Kure Beach, N.C. 28449

Marine Agent (919) 458 5498
Coastal Engineer (919) 458 5780

MEMORANDUM

TO: Coastal Property Owners
FROM: Spencer M. Rogers, Jr.
Date: March 7, 1991
Subject: Cost-sharing funds available for shoreline erosion control.

The Albemarle/Pamlico Estuarine Study (APES) and the Environmental Protection Agency have funded a program by the Sea Grant Marine Advisory Service to demonstrate the effectiveness of small offshore breakwaters in combination with planted marsh grasses to control shoreline erosion. The breakwater/marsh can be a low-cost alternative to a bulkhead along certain sound, bay and river shorelines. While controlling shoreline erosion at one-half to one-third of the cost of a bulkhead, the method offers the environmental advantage of creating new marshes along what were originally eroding sand beaches.

Funding is available to assist 10 to 15 property owners which must be geographically distributed throughout the APES study area. Property owners must pay for at least 50 percent of the cost of construction and agree to allow shoreline access to show others the effectiveness of the method. Expected total finished costs are \$25 to \$35 per foot of shoreline protected. The method will only work on shorelines with flat offshore slopes. Water depths 50 feet offshore should be no more than 2.5 feet deep at normal high tide.

The breakwaters are constructed of wood and are similar to a bulkhead in appearance. The structures are located 30 to 50 feet offshore and are not backfilled with soil. They are very low, extending no more than 6 inches above the normal high water level. For more details contact Spencer M. Rogers, Jr. at UNC Sea Grant College Program, P.O. Box 130, Kure Beach, NC 28449. 919/458-5780.

Other conditions of the program are as follows:

Site selection criteria

Favored sites will have the following shoreline conditions:

1. A. Eroding sand beaches.
B. Bulkheaded shorelines with a sand beach.
C. Eroding marsh banks.
2. Flat beach slope capable of growing marsh grasses 20 feet wide.
3. Water depth at normal high tide of less than 2.5 feet at a distance of 50 feet offshore and a flat slope continuing offshore.
4. Exposed fetch of more than 1 mile.
5. Easy public access.

The APES Program will provide the owner:

1. Project design, plans and specifications.
2. Preparation and submission of permit applications.
3. Assistance in selecting contractor.
4. Inspection of finished breakwater.
5. Technical assistance with planting marsh grasses.
6. 50 percent of the cost of:
 - A. Permit application fees.
 - B. Breakwater materials.
 - C. Labor for breakwater construction.
 - D. Marsh grass seedlings.
 - E. Labor to plant marsh grasses.

All expenses for cost-sharing including bids for construction or materials are subject to prior approval by UNC Sea Grant and will be subject to maximum limits. Payment for cost shared expenses will be made to the property owner after completion of construction and marsh planting, and after final inspection, confirming that the project was completed as planned. Labor provided by property owners or family members will not be compensated as cost shared expenses.

The property owner must agree to:

1. Provide clear, written documentation and receipts for all construction costs subject to cost-sharing.
2. Accept ownership of the structure.
3. Perform reasonable maintenance for at least 5 years.
4. Allow periodic inspections to monitor the project.
5. With reasonable notice, allow public inspection of the project by those interested in the erosion control method.
6. Acknowledge that although successful erosion control is anticipated the method is still considered experimental and success cannot be guaranteed. The project is not expected to be immediately effective at controlling shoreline erosion but success is expected after a dense growth of marsh grass is established usually within one or two

- growing seasons. Replanting by the property owner may be necessary if the first planting does not become established.
7. Hold the State, Federal Governments and their employees harmless.

Limits of financial assistance

1. Cost-sharing with any individual property owner is limited to no more than 100 feet of breakwater length.
2. With multiple property owners, cost-sharing is limited to not more than 300 feet of breakwater at any single site.
3. Cost-sharing with any property owner will have a maximum limit depending on local material and construction costs.

Other site selection goals

1. Sites should be spread geographically over the APES study area including Currituck Sound, Albemarle Sound, Pamlico Sound, the Neuse River and Bogue Sound.
2. A variety of shoreline types are desired.
wider experience with the design and construction methods.
3. Different contractors at each site are preferred to provide
wider experience with the design and construction methods.