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Floating Tire Breakwaters

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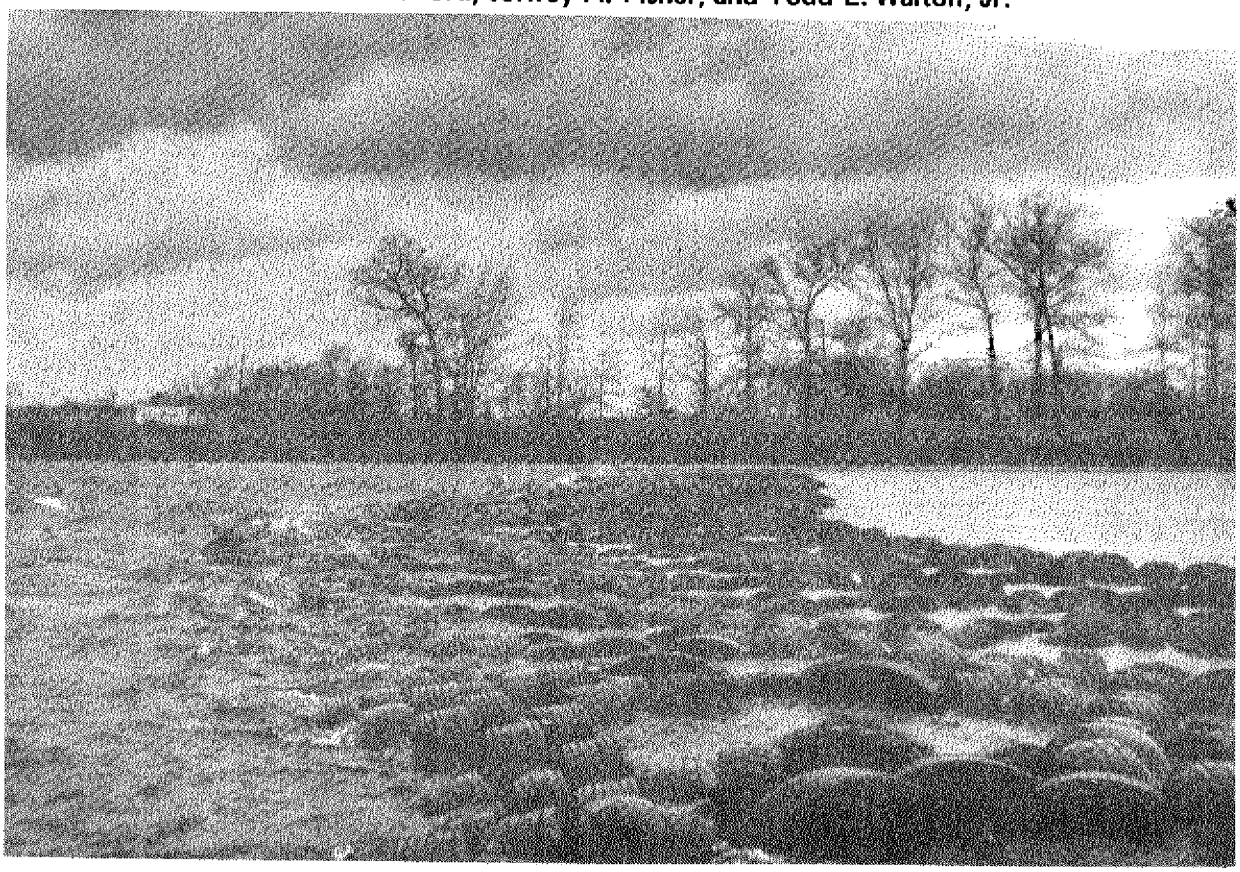

DISCLAIMER

The use of the floating tire breakwater as described in this paper shall be at the sole risk and responsibility of the user with no liability of any nature whatsoever on the part of the Marine Advisory Program-Sea Grant, or the Florida State University System.

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FLOATING TIRE BREAKWATERS - A CASE STUDY OF A POTENTIAL LOW COST SHORE PROTECTION STRUCTURE FOR FLORIDA'S PROTECTED MARINE WATERS

by

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INTRODUCTION

Since the beginning of man's development of the coastal zone, the problem of shoreline erosion has plagued those who build along the coast. The high cost of most structures which have been effective in mitigating shoreline erosion (such as rock revetments) has discouraged the typical coastal landowner from protecting his property. More recently, increasing awareness of the complexity of shoreline processes, the futility or frequent harmfulness when interfering with nature, and the prohibitive cost of correcting mistakes, has led to increased state and federal reluctance to permit widespread use of conventional bulkheads, groins and jetties.

It is important to note that shoreline erosion or recession is not only a problem along the open coast, but also in more sheltered waters. In many Florida lagoons, bays, and marine waterways erosion is a significant problem, with some areas having long term recession rates in excess of six (6) feet per year. Where high ground borders large expanses of open water (i.e. Pensacola Bay, Choctawhatchee Bay) bluff recession can also be a very severe problem.

It is also important to keep in mind that often times coastal structures create as many problems as they mitigate and hence should only be used where proper conditions prevail as determined by an experienced coastal engineer. Existing criteria on which to prejudge possible performance of the scrap tire floating breakwater are not well established. That which we do know concerning the possible effectiveness of this structure in mitigating shoreline damage will be discussed in this paper. That which we still don't know should be kept in mind when evaluating the usefulness of this breakwater for a specific site. When dealing with design and placement of coastal protective structures, one must always realize that the price to pay for poor judgement may be a law suit by adjacent shoreline property owners. A major positive advantage, though, is that if the breakwater does appear to cause damage it can be moved very easily at little cost.

This paper describes the construction and preliminary results of the use of an experimental scrap tire floating breakwater, done as an attempt to control shoreline erosion in a Florida coastal bay at moderate cost and with minimal damaging side effects.

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ABOUT SCRAP TIRE FLOATING BREAKWATERS

The history of the use of many types of floating breakwaters has been summarized by Kowalski (1974), which contains an extensive bibliography, and by Candle, (1975). Principal use has been in semi-protected waters where wave heights were 3-4 feet or less, and where depths, cost or other factors prohibited the use of conventional structures such as rubble mound breakwaters. An additional advantage of floating breakwaters is that they can be re-oriented or removed if they cause more damage than they cure. Comparative disadvantages are lack of durability (compared to massive stone or concrete structures), the need for periodic inspection and maintenance, and the possibility of ground tackle failure letting breakwaters go adrift to strand or become navigation hazards.

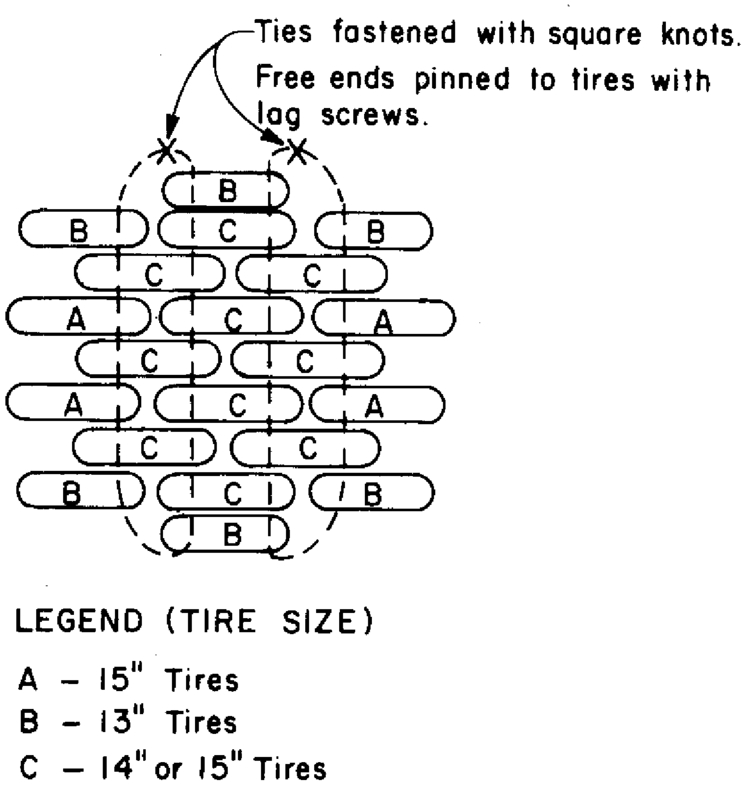


Figure 1. Top view of modified scrap tire module showing tire pattern and fastening ties. After Kowalski and Ross, 1975.

Descriptions of several types of floating breakwaters made of scrap tires are included in Kowalski (1974). Later papers (Sucato, 1975; Kowalski and Ross, 1975; and Candle, 1975) describe the development and testing of a particular design by a University of Rhode Island project jointly funded by the Sea Grant Program and the Goodyear Tire and Rubber Company.

In our configuration, a modification of the Rhode Island prototype (see Figure 1), which was found to be both easy to construct and inexpensive, 20 tires are bound together in a module which floats with the tires vertical in the water, supported by the air trapped in each tire crown. The modules were built on a pier, then tipped over into the water and connected together to form a breakwater unit. This construction method permits building the breakwater wherever it is cheapest or most convenient and towing it to its point of use.

The first such breakwaters built at the University of Rhode Island in September 1974, contained four rows of twelve modules and were about 85' long by 20' wide. Subsequent breakwaters of this type, some of them built up of such units to lengths of several hundred feet, have been installed at many locations along the eastern seaboard and in the Great Lakes. Their principal use has been for harbour or marina protection, where they were permanently anchored in deep water. At the inception of the present project none had been built in Florida and no descriptions of their use in shoreline erosion control had been published.

THE PROJECT SITE

The scrap tire floating breakwater described in this report was built by Dr. Charles A. Gifford (co-author of this report), at his home in Pensacola Beach, Florida, on the south shore of Santa Rosa Sound, in August-September 1976. The test site was chosen for a number of reasons. Upland ownership was necessary for obtaining construction permits from the Santa Rosa Island Authority (S.R.I.A., governing body of Pensacola Beach), the Florida Department of Environmental Regulation, the U.S. Army Corps of Engineers, and the U.S. Coast Guard. Easy access by road, space for temporary storage of tires and other materials, and a pier extending to water deep enough to float the completed breakwater were all helpful in on-site construction.

The site also exhibited traits common to many eroding shorelines in Florida's coastal bays. A broad shallow shelf extends about 300 feet from shore before reaching a mean low water (MLW) depth of 3 feet, then drops off quickly into deeper water. The shoreline had receded about 30 feet in the preceding five years, but erosion had been sporadic, with periodic hurricane or extra-tropical storm waves attacking the upper beach and foredune, loosening sand for gradual removal by wave and wind induced currents. Similar erosion has occurred along the nearby shoreline. The exact location of the breakwater is shown on a copy of a hydrographic chart of Santa Rosa Sound (Figure 2).

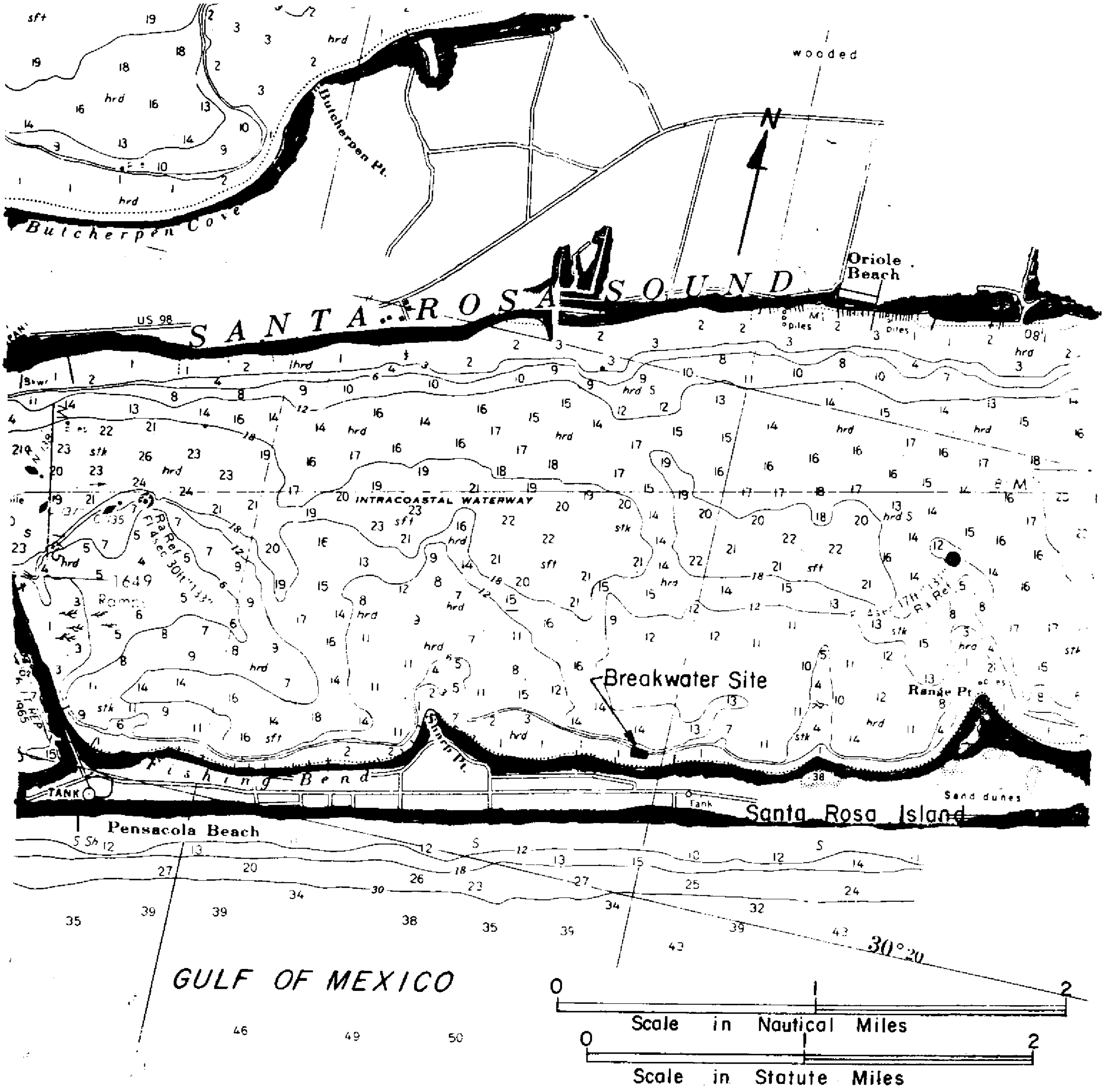


Figure 2. Project Site

BREAKWATER CONSTRUCTION

Preliminary consideration and trials suggested that some modification of the prototype scrap tire floating breakwater developed at the University of Rhode Island would be needed to adapt it to the conditions described above. Effectiveness of an offshore breakwater in shoreline protection depends on a number of factors: its length, its distance from shore and the range of approach angles of incident waves. Since breakwater length was limited to 100 feet (by permit) and exposure to damaging waves ranged from WNW to ENE (about 150°), it was felt necessary to place the breakwater as close to shore as possible, that is, up on the shallow flats.

This use exposes the breakwater to stresses not encountered in dissipating free running waves in deep water. Breaking waves in shallow water exert great horizontal as well as vertical force, necessitating stronger internal ties and heavier ground tackle. Depending on its draft and the depth of the water, the breakwater can either be pounded violently on the bottom or become permanently stranded if the bottoms of the tires become filled with sand.

The following modifications were developed to increase strength of the breakwater and to prevent stranding. One or two 1 1/2" holes were punched in each tire, close to any existing break or puncture. During module assembly these holes were oriented to be on the bottom when the module was tipped into the water, thus facilitating release of trapped sand. It is essential that each tire be inspected, marked and placed so that all holes will be under water. The part of the tire above the waterline must be airtight to insure flotation.

As suggested by Albert Davis of the University of Rhode Island, Department of Ocean Engineering, the material used to tie the breakwater together was the scrap cut from the edges of heavy industrial conveyor belts in their manufacture. This material comes as strips from 2"-6" wide by 1/4 - 3/4" thick and up to several hundred feet long. Like tire sidewalls, it is a laminate of dacron or nylon cord plies embedded in synthetic rubber. Its breaking strength is about 10,000 lbs./sq. in. It is highly resistant to abrasion and does not stretch, corrode or deteriorate in sea water. It is easy to cut with a hacksaw or sharp knife. At the time of construction it was available for $30/ton, plus freight.

Instead of fastening the ties with nylon bolts, as was done in Rhode Island, the ties were fastened by tying them in square knots. After approximately 10% of the knots worked loose during severe storms the decision was made to pin the ends of the ties beyond the knots to the tires with lag screws. This stopped both knot failure and tire rotation. Module heavy galvanized construction and knot tying are shown in Figure 1.

The connections between modules were modified from the Rhode Island design in the following manner. A large truck tire, ranging in size from 8.00X17 to 8.5X22.5, was used as the main connector, with two smaller tires placed concentrically on either side of it. Where needed, additional small tires were placed at either end of the truck tire, between it and the two modules being connected. All of these tires, plus those projecting from the ends or corners of the modules, were then compressed as much as possible with a spanish windlass. The tie fastening strips were then put in place, tied, and pinned to the tires.

This modification affects two major changes in breakwater structure and function. As the breakwater begins to strand, the large truck tires hit bottom first. This, plus the greatly increased stiffness of the intermodule connnection, prevents the modules themselves from stranding and filling with sand. The sidewalls of the truck tires are high enough to keep sand out. As the water rises, the unencumbered flotation of the modules lifts both them and the truck tires. The increased connector stiffness resulting from this modification also appears to increase the effectiveness of the breakwater in wave energy dissipation. Large truck tires were also tied to the modules forming the outer edges of the breakwater, drawn tight, tied and pinned. The completed breakwater consisted of four rows of 16 modules each, and measured approximately 100 ft. long by 22 ft. wide. The approximate draft was 3 ft. Finally two separate surrounding belt lengths of tying material were passed through the outermost tires of the breakwater, tied and pinned.

The breakwater was built by adding modules to one end. As its length increased the completed section was pushed away from the pier and anchored in deeper water by 25 lb. Danforth-type anchors attached (by 1/2" nylon line) at about 30 ft. intervals along the seaward edge and at about 50 ft. intervals along the shoreward side. After completion the breakwater was brought back into water just deep enough to float it at low tide (about 3 ft.). Anchor lines were initially attached to the large tires projecting from the edges of the breakwater. After several knot failures occurred in the unpinned connector and module ties near the points of anchor line attachment along the seaward edge, the anchor lines were led through the breakwater in sections of flexible plastic pipe to prevent chafing and attached to the surrounding belts along the shoreward edge. This distributed the stress more evenly along the perimeter of the breakwater.

WAVE SUPPRESSION

The amount of wave suppression due to a floating tire breakwater is measured by the "transmission coefficient," K_t of the breakwater (see definitions) and is dependent on a variety of factors such as the "wave steepness" H/L, width of breakwater to wavelength ratio w/L, draft of breakwater, water depth, and tire pattern configuration.

Previous prototype tests of a similar floating tire breakwater with a 25 foot beam and a 2 1/2 foot draft in Narragansett Bay, Rhode Island, in 15 foot deep water have documented K_t values on the order of 0.25 - 0.35 for the present type configuration of tires at wave periods approximately equal to 2 seconds (Kowalski 1974). The incident wave steepness of the waves was about H/L = 0.06.

A floating tire breakwater with a somewhat different tire configuration has been tested in wave tank experiments (U.S. Army Waterways Experimental Station, 1968). For the same incident wave conditions as the Rhode Island prototype breakwater experienced, a transmission coefficient of $K_t = 0.4$ would be found. The results of these tests are shown in Figure 3. Figure 3 shows that K_t is dependent on both the width to wavelength ratio w/L, as well as the incident wave steepness H/L.

It is important to note that the total energy dissipation which this type of breakwater would encounter can be estimated by the equation:

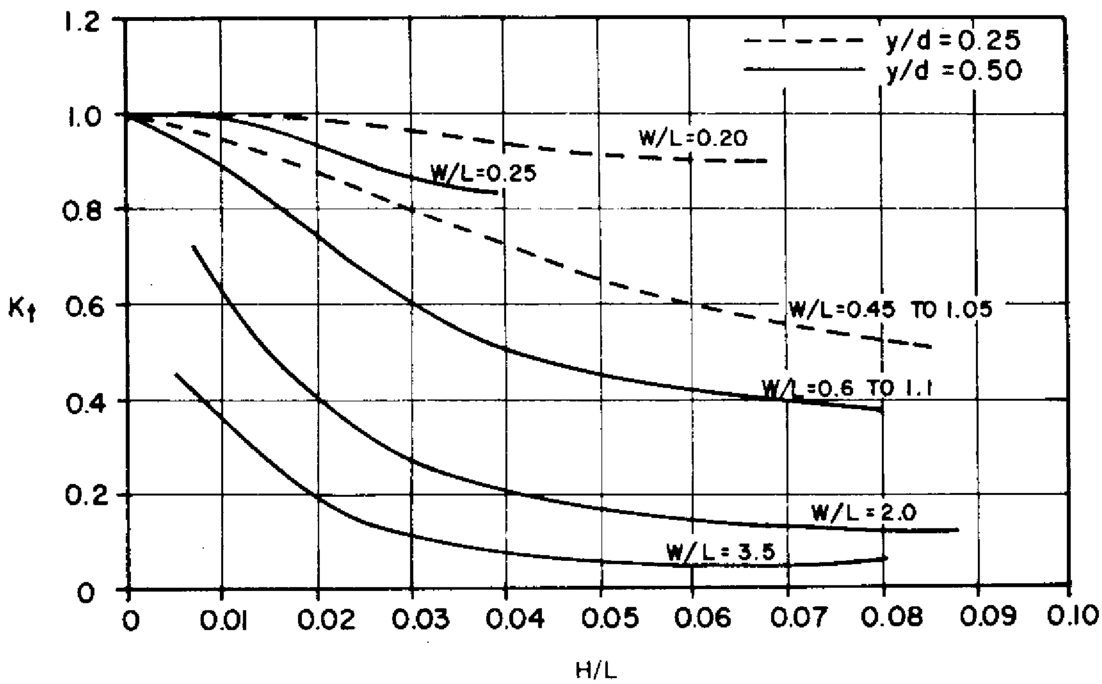
$$\text{energy dissipated} = 1 - K_t^2$$

where it is assumed that only minor wave energy reflection is noted. Thus, based on the Rhode Island and Waterways Experimental Station tests, the wave energy dissipated and/or relected for short period waves (on the order of 2 seconds) ranges from 86 - 94%.

MOORING FORCES

Mooring forces in the Florida tire breakwater were not tested; however, they appeared to be greater than those described in the Rhode Island experiments. The mooring forces in the Rhode Island prototype unit mentioned previously were found to be under 30 lbs. in the two forward lines of the unit during 3 foot wave action with 15 - 20 knot winds (Kowalski and Ross 1975).

The Florida Tire breakwater had 6 mooring lines (one at each corner and one in the middle of each end) which held the unit in place. The mooring lines were of 1/2 inch diameter nylon lines. The anchors were 25 lb. Danforth type. The approximate scope of the lines was 10:1.



W = Width of breakwater

L = Incident wave length

H = Incident wave height

y = breakwater draft

d = depth of water

Figure 3. Wave Transmission Characteristics of "Maze" Type Floating Tire Breakwaters. After WES, 1968.

EFFECTS OF THE BREAKWATER

(a) Wave attenuation

The scrap tire floating breakwater appears to effectively attenuate the largest waves (2' - 3' high, 10' - 20' long, periods of 1 - 2 seconds) which commonly occur in Santa Rosa Sound, though the effect is often obscured by oblique incident wave angles, diffraction around the breakwater ends, reflection of waves from nearby shorelines, or wind ripples starting in the lee of the breakwater. Waves striking the leading edge of the breakwater often do not break; they just disappear. In heavy waves the first row of modules moves violently, the second row less so, while the third and fourth rows are nearly motionless. The water surface between the third and fourth rows of modules, and in the lee of the breakwater remains a slick, glassy calm.

(b) Shoreline effects

Prior to discussing the noticed effects which the scrap tire floating breakwater had on the shoreline, it is important to look at the shoreline history of the area and the natural features of the site.

Figure 4 is a summary of historical shoreline changes in the site area from shoreline maps provided via the Mobile District Corps of Engineers. The present sound shoreline in the area of the breakwater is much further soundward than it was in 1871. In more recent years, though the sound shoreline has been eroding in the site area as evidenced by a beach (sound shoreline) nourishment project which was conducted by the Santa Rosa Island Authority in the 1950's. In this project sand was pumped from the sound onto the shoreline. Many 6-10 foot (beneath natural sand bottom) dredge holes still exist from this earlier project just off the shallow 1 - 3 foot depth shelf along the site area.

Figure 5 is a profile perpendicular to the shoreline at the breakwater site.

The shallow inner shelf is seen to have a slope of about 1° at the site while just off the inner shelf the outer shelf is about 9°, much higher than a natural beach. The depth just off of the shelf is in excess of natural depths due to a remnant dredge hole from the nourishment project mentioned earlier. The outer shelf slope would still be exceptionally steep though without this dredge hole. One reason for erosion of the beach in this area may be due to beach sand sloughing off of the inner shelf area during storm wave action to deeper water where it cannot migrate back up the steep outer shelf slope under mild wave action.

The breakwater was placed just shoreward of the steep outer shelf slope. The ratio of the length of the breakwater to the distance offshore is a significant parameter which determines the degree to which an offshore structure will affect the shoreline and was 100 feet/275 feet or 1:2.75.

Various types of transverse bars migrate along the shallow inner shelf of Santa Rosa Island (sound side) in the site area and can cause fluctuations of the shoreline on the order of 30 feet or so in periods of a month or less.

Sand began to accumulate in the wave shadow cast by the breakwater before the breakwater was completed in October 1976, and became more pronounced during an unusually severe series of winter storms. The shoreline in the wave shadow of the breakwater has built out 20 - 40 feet in the six months since the breakwater was completed. As the accretion occurs over approximately a 100 foot length of shoreline, the phenomena does not resemble a natural shoreline rhythm due to migrating transverse bars, but, rather, a "tombolo"

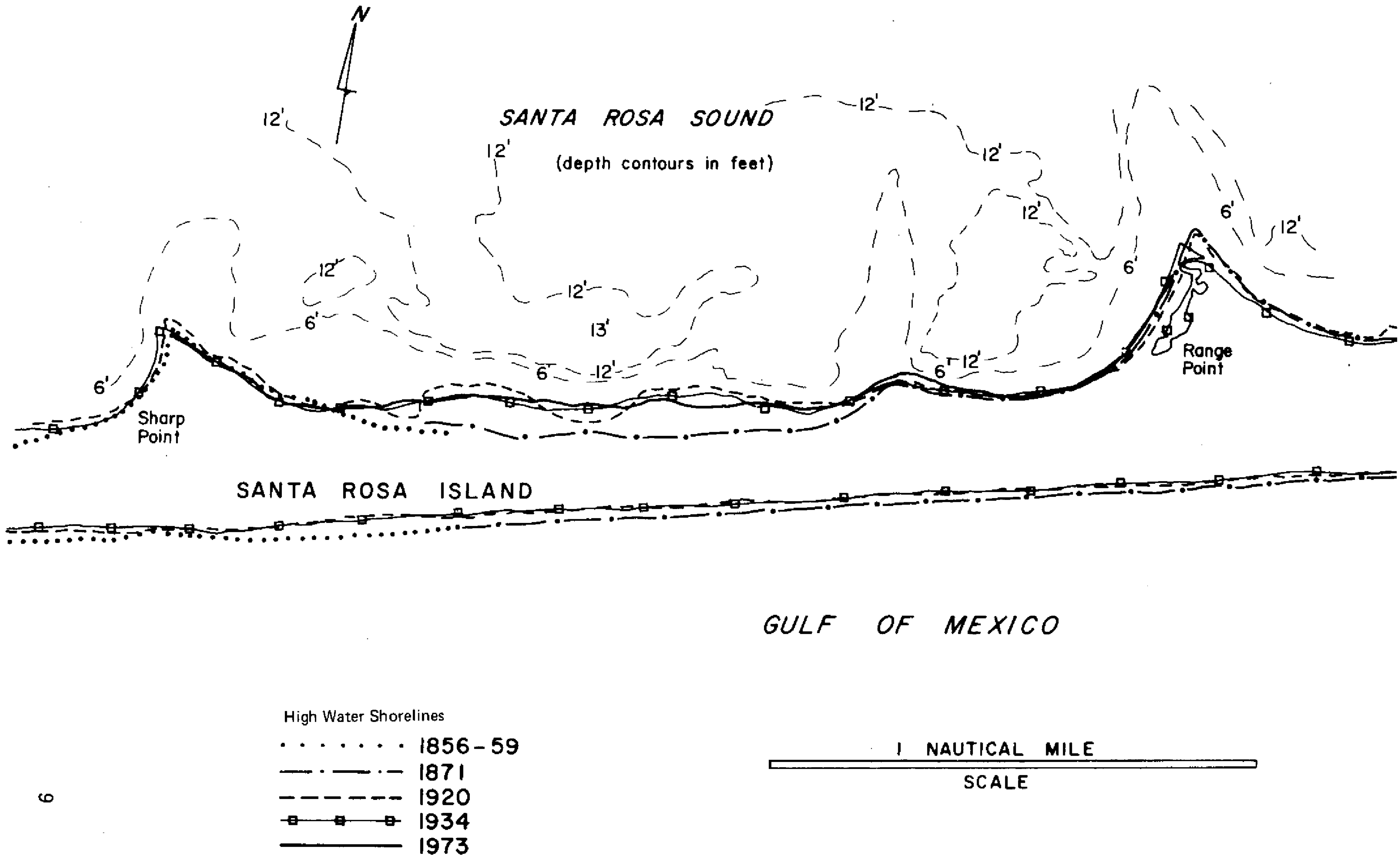


Figure 4. Historical Shoreline Changes in Area of Breakwater Placement

effect which occurs due to sand dropping out of the littoral current caused by wave action in the sheltered area behind the breakwater. When this phenomena is due solely to littoral drift (sand transport parallel to the shoreline), a corresponding erosion occurs further down the shoreline. In the present observations though, no noticeable shoreline erosion appeared to be occurring on either side of the structure. If the sand transport in an area is predominantly in an onshore - offshore direction, rather than a longshore direction (i.e. parallel to shore), sand being "sloughed" off of the inner shelf slope to deeper water during storm wave action might be prevented by a floating tire breakwater and hence outweigh the negative aspects of possible "downdrift" erosion problems caused by shore structures.

As the only evidence of shoreline changes comes from photographic records and visual observation it becomes impossible to define the exact extent of benefits (or damages) done by the floating tire breakwater, but, the authors feel that the potential of this structure for limiting shoreline erosion is high if used under the proper circumstances. The authors feel that field testing of an extensive breakwater at a site similar to the present one and well monitored would be a useful step in future judging of the scrap tire breakwater potential for mitigating shoreline erosion in sheltered waters.

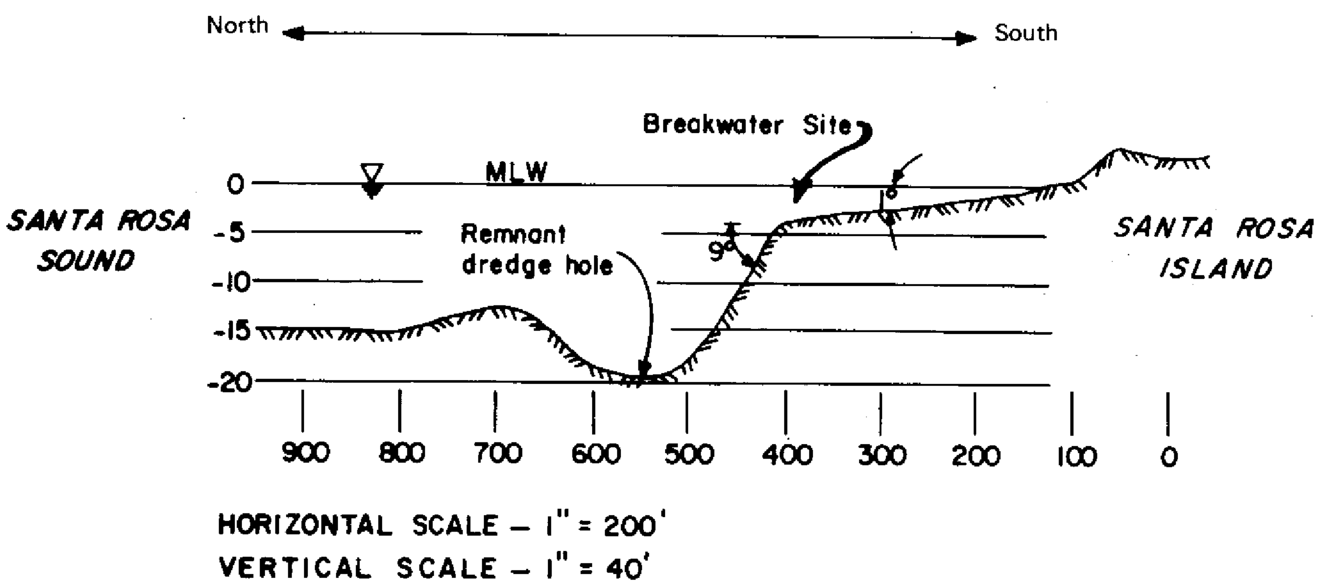


Figure 5. Offshore Bottom Slope at Breakwater Site

(c) Biological effects

A scrap tire floating breakwater can affect biological processes in several ways. It provides an immense, stable inert surface, with a great range of combinations of protection and water movement, for colonization by attached plants and animals. In its wave shadow the bottom becomes stabilized, protected and supplied with a rich supply of settling organic matter. The shoreline behind it is protected from wave action, permitting establishment of emergent vegetation and possibly increased populations of beach dwelling organisms.

Encrustation of the breakwater with oysters, barnacles, serpulid polychaetes (calcareous tube-building worms) and bryozoans, as well as occupation of its free surfaces and protected internal spaces by many kinds of small fish and crustaceans, were noticeable within two weeks of placing the first modules in the water in early August. Growth of and continued recruitment to this biological community was extremely rapid until the onset of cool weather in November. Growth of fouling animals had nearly ceased by late October. No species list has been made. During fall and winter the growth of attached animals was covered by a heavy growth of green, brown and red algae. The composition and growth rate of the fouling community is definitely dependent on the season in which the breakwater is built. Seasonal changes are still being followed.

The bottom in the breakwater wave shadow has become much darker than the nearly white sand of the adjacent shoreline flats. This color change is probably due to the settling of detritus in the protected water and the release of detritus by the breakwater fouling community. A marked increase in density of burrowing worms and mollusks has occurred immediately behind the breakwater.

Transitory appearance of rooted submerged grasses in the wave shadow, in spite of severe cold, suggests the possible use of this type of breakwater in protection and/or re-establishment of submerged grass flats and emergent shoreline plants as a means of providing increased habitat for fish, shrimps and crabs, as well as permanently stabilizing the protected shoreline.

SOME ADVANTAGES AND DISADVANTAGES OF FLOATING TIRE BREAKWATERS

Advantages:
- effective dissipation of waves less than 3 ft. high with short wave lengths
- low construction costs
- easy to build and to repair
- can be moved from one site to another or easily disassembled if found to adversely affect adjacent shore property owners
- minimal damage created should boat collision occur
- creation of a floating biological reef effect
- can be used for boat shelters, i.e. marinas
- design and orientation can easily be modified if sufficient wave damping is not ocurring

Disadvantages:
- hazard to navigation - will need navigation markers in some areas
- can collect debris which must be cleaned out occasionally
- does not damp long period waves or low steepness waves effectively
- can cause adverse shoreline effects if longshore sand transport is a predominant sand motion in the area, i.e., can cause "downdrift" erosion
- not aesthetically appealing

DEFINITIONS

"Significant" wave height - (H) the average of the highest 1/3 of all waves at a site. This is a reasonable design wave height for floating tire breakwaters.

"Significant" wave length - (L) the wavelength corresponding to the period of the waves where the maximum wave energy lies. This is a reasonable design wave length for floating tire breakwaters. To determine significant wave length, first determine the average period (T) of the oncoming waves by measuring the average time in seconds between two successive wave crests passing a given point (such as piling or buoy) during an interval of about five minutes. Then calculate the significant wave length (L) using this formula: $L = 5T^2$. This formula applies to deepwater waves or those where the depth of water is greater than half of the wavelength (L). In shallow water, the calculation is not as simple.

Wave steepness - defined here as the incident significant wave height divided by the incident significant wave length (i.e. H/L).

Length of breakwater - the dimension parallel to the oncoming waves, determined by the size of the area to be protected.

Draft - or immersed depth, is determined by the height of significant waves occurring in the area. As a "rule of thumb": draft should be greater than half of the height of the significant wave.

Beam - (W) or width, is determined by the predominat wave length in the area to be protected. Increasing this dimension increases the suppression of wave height. The beam should be greater than half of the significant wavelength for good wave suppression.

Transmission coefficient - (K_t) defined as the ratio of the transmitted significant wave height = H_t to the incident significant wave height = H (i.e., $K_t = H_t/H$).

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