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Seawalls Versus Beaches

Orrin H. Pilkey and Howard L. Wright III

Duke University Program for the Study of Developed Shorelines
Department of Geology
Duke University
Durham, NC 27708

ABSTRACT

It is widely assumed that hard shore-parallel structures on the beach are damaging to recreational beaches. Virtually all state coastal management programs assume this to be true. While there is broad agreement that walls are detrimental to adjacent beaches and that walls are passively responsible for narrowing of the beaches in front of them, controversy still remains over the question of whether seawalls play an active role in beach degradation. Coastal management initiatives should not be delayed on account of the technical argument regarding seawall behavior. From the standpoint of the general public, the important question is *whether* seawalls negatively impact beaches, rather than exactly *how* it happens. It is argued in this paper that there are a number of mechanisms by which seawalls can accelerate erosion of the beach in front of them and that, until research proves otherwise, active beach degradation remains a real possibility.

In this investigation, we have also compared the dry beach width on selected stabilized and unstabilized East Coast shorelines and note that dry beach width is consistently and significantly narrower in front of walls. The more dense the hard stabilization, the narrower the beach. Future research on seawall effects must take into account the fact that beach destruction may take place over several decades and study of single events or short-term changes may be of limited value in understanding effects of seawalls.

ADDITIONAL INDEX WORDS: *Seawalls, beach width, shoreline stabilization.*

INTRODUCTION

Our society basically has three alternatives available for the management of eroding shorelines. These alternatives, broadly stated, are: (1) hard stabilization, (2) soft stabilization, and (3) retreat or relocation. *Hard stabilization* refers to the emplacement of any "permanent" and hard structure with a fixed location. Hard structures as generally defined include those built perpendicular to the shoreline (groins) and those built on the beach and parallel to the shoreline (seawalls, revetments, bulkheads). *Soft stabilization* refers primarily to beach replenishment, *i.e.* replacing the beach which has disappeared with a new one. *Relocation* or *retreat,* as the name implies, refers to the practice of moving structures back apace with the shoreline retreat.

The publication of a National Research Council report on the engineering implications of sea level rise (NATIONAL RESEARCH COUNCIL, 1987) lends urgency to the societal debate on shoreline management alternatives. The strong likelihood of the existence of the "greenhouse effect" and the concomitant accelerated sea level rise (and accompanying accelerated shoreline retreat) in coming decades is widely accepted. The model of the Environmental Protection Agency (BARTH and TITUS, 1984) suggests that a 4-7 foot (1.2-2.2 m) sea level rise by the year 2100 is a possibility. 4-7 feet is the so-called "mid-range scenario" of the EPA model, with the extremes ranging from 2 to 12 (0.6-3.7 m) feet above present sea level by the year 2100. Whatever the scenario for the greenhouse effect in the future, there is a strong possibility that shoreline erosion rates will accelerate and that a great deal of shoreline property will be endangered. The problem is of course a world-wide one. CARTER (1987) compares various management strategies of coastal countries facing the problem of eroding shorelines.

The traditional response to shoreline recession has been hard stabilization. This management alternative is generally intended to preserve upland property and structures. The degree of success of seawalls and other structures in this endeavor is highly variable depending upon quality of design, coastal climate, storm history, and other factors. Unquestionably, many buildings along many miles of long-stabilized U.S. shorelines owe their existence to the presence of seawalls. The fact that beaches along these same stretches of stabilized shorelines are frequently narrow and even absent altogether has captured the attention of coastal managers everywhere.

The impact of hard stabilization and particularly seawalls on the quality of recreational beaches fronting seawalls is the main topic of this paper. In this report we briefly review the history of the seawall controversy and discuss the pros and cons of seawall construction as well as the arguments regarding the active role of the seawall in beach destruction. Finally, we present field measurements of beach quality made on barrier island beaches on the U.S. East Coast.

THE GREAT SEA WALL DEBATE

Prior to World War II the most common choice of "shoreline protection" was hard stabilization, usually in the form of seawalls and groins. In this time of low-density island development and of less national affluence, communities without the economic means to construct walls simply fell into the sea, (*e.g.* Hog Island, Virginia and Edingsville Beach, South Carolina), while more affluent communities staked their ground and built their walls. At that time, the sole consideration was the protection of buildings threatened by shoreline recession, and the environmental aspects of coastal engineering were not considered particularly important. However, beginning in the 1950's with the American rush to the shore, large numbers of buildings were constructed adjacent to receding shorelines on all U.S. coasts, and especially on barrier shores. Thus the erosion problem became highly visible to the public, along with the fact that stabilization in any form on an open ocean beach was costly and often resulted in degradation of the beach.

The societal debate was on. Is hard stabilization worth its high price? Is it worth it if the function of stabilization is usually protection and preservation of mostly private property? And at the cost of the recreational beach?

The 1962 Ash Wednesday East Coast storm represented an important watershed in U.S. beach management policy, as the federal government responded by funding at least 25 beach replenishment projects. Soft stabilization, which had been gaining increasing attention, was chosen over hard stabilization. Also in 1962, the Water Resources Act authorized a substantial increase in long-term federal participation in beach nourishment projects, participation which has increased considerably in the 1980's.

In the 1970's, beach preservation continued to become increasingly important. In 1972, the National Park Service announced that National Seashores would be allowed to evolve naturally; if that process included shoreline recession, so be it. The new policy apparently was based on the studies of barrier island migration by Paul Godfrey and Robert Dolan, whose research indicated that shoreline recession on barrier islands was actually part of the larger process of barrier island migration. Among the stated reasons for the new NPS policy were the high cost of shoreline stabilization and the potential for environmental damage.

Since that time, virtually every state coastal management program has installed some regulatory component reflecting the widely held perception that seawalls, while protecting the upland, degrade beaches. This perception has arisen from (1) the simple observation that long-seawalled shorelines which have not been replenished often have highly degraded beaches and (2) the understanding that shoreline retreat is not a threat to the quality of the beach per se. The New Jersey shoreline, particularly its northernmost and southernmost reaches, is frequently held up as the type example of beach degradation. Two states, North Carolina and Maine, anxious to avoid "New Jerseyization" of their own shores, prohibit altogether hard stabilization; the principal purpose of this ban is the preservation of the states' recreational beaches for future generations. Other states, such as Texas, Florida, New Jersey, and Massachusetts still allow seawalls, but view them with an increasingly critical eye. The states with the fewest restrictions on open ocean seawall construction are probably Georgia, South Carolina, and Alabama, but in each of these states there is considerable pressure from environmental groups and other interests to restrict seawall construction.

In line with the national trend of concern for things natural and unaltered, environmental sensitivity has increasingly become the keyword of coastal managers, coastal geologists, and coastal engineers. However, KRAUS'S recent (this volume) literature survey of the environmental impact of seawalls indicates that of a vast literature concerned with seawalls, only a small fraction of it is concerned with impacts upon the beach.

There are three ways in which seawalls are alleged to degrade or destroy recreational beaches. The first is by construction of the wall within the beach recreational zone between the high and low tide lines. Obviously, this practice results in the immediate loss of most of the recreational value of the beach. The most famous example of this type of beach "removal" is Miami Beach, Florida. The second way in which walls impact negatively upon beaches is in a passive mode. If a structure is placed on an eroding shoreline, the natural erosion should be expected to continue unabated (DEAN, 1985). The result is a narrowed beach seaward of the wall (passive erosion). The third way is that seawalls per se are directly responsible for increased rates of beach loss due to intensification of surf zone processes and other factors (active erosion).

There seems to be relatively little controversy over the first two mechanisms of beach degradation by walls. On the other hand, lively disagreement over the *active* role of seawalls in beach alteration still exists and has become the focus of "The Great Seawall Debate."

It should be noted that coastal engineering textbooks and general references such as the *Shore Protection Manual* (U.S. Army Corps of Engineers, Coastal Engineering Research Center, 1984) warn about the occurrence of enhanced erosion rates in front of seawalls, bulkheads, and revetments. Clearly, there is wide acceptance of the concept of active wall participation in beach degradation. As examples, several samples of literature quotations are cited below.

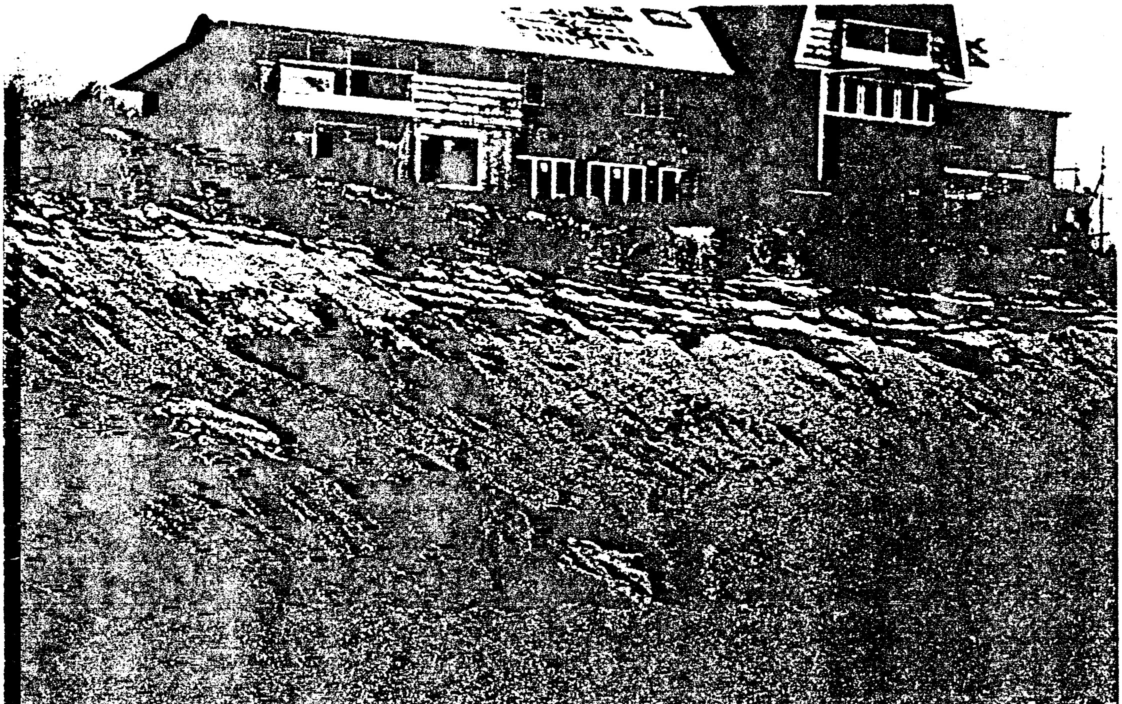


Figure 1. Stabilization on the shoreline of Easthampton, New York.

The U.S. Army Corps of Engineers *Shore Protection Manual* (both the 1973 and 1984 editions) states: "When [seawalls, bulkheads, and revetments are] built on a receding shoreline, the recession will continue and may be accelerated on adjacent shores. Any tendency towards loss of beach material in front of such a structure may well be intensified."

According to SILVESTER (1974, P. 143): "Walls of vertical or sloping character (revetments) have been used for many decades as a purported protection in an erosive situation. It is unfortunate that they have, in the main, promoted further erosion."... "Tests have indicated that beaches in front of walls will recede to the point of being non-existent due to the action of standing waves resulting from reflection."... "The sea-bed profile in front of the wall will steepen and deepen until subsidence of one section will occur during a particularly bad storm..." HORIKAWA (1978, p. 329) states that "On one occasion, for example, a narrow sandy beach disappeared very quickly as a result of the construction of a certain coastal dike."... "We have seen such unhappy accidents at many locations."

Three other important and basic points must be considered in any discussion of the impact of seawalls:

(1). A qualitative review of seawall experience on the U.S. East Coast indicates that seawall impact on beaches is often a long-term phenomenon (on the order of decades). Thus, short-term or single-event observations and studies may have limited meaning.

(2). Response of beaches to seawalls on different types of coasts or in different oceanographic settings is highly variable. Thus the experience gained from a Southern California shoreline structure does not necessarily apply directly to a South Carolina wall and vice versa.

(3). There will be exceptions. The fact that a few beaches remain and flourish in front of walls does not mean that active beach degradation by walls is not a real phenomenon. Much of the "LBJ" seawall built in the 1960's on the Georgia coast was immediately covered by dune sand as natural storm recovery took place. Now, however, twenty years later, most of the buried portions of the wall have been uncovered and in some areas there is substantial narrowing of the beach.

THE PUBLIC VIEW

The public perception of seawalls is an important element of the societal debate over our response to eroding shorelines. Since our deliberations regarding the impact of seawalls are very much in the public realm, it is important for scientists and engineers to be aware of this viewpoint.

There are two populations of "public" who are concerned with seawalls. The first and the most vocal and influential are beachfront property owners. Their objective is protection of their property. Understandably, they favor any kind of shoreline stabilization, including seawalls if need be, to protect their property. Property owners are also the ones who hire consultants to make recommendations, legal testimonials, and public pronouncements. Hence it is the needs and the viewpoints of the beachfront owners which receive the lion's share of professional attention and support.

The second and far more populous group of individuals is made up of those who use the beach without purchase of property adjacent to it. This group is concerned more with beach preservation than with property preservation, but they rarely hire consultants to reinforce their views. Furthermore, they are mobile, and if a beach is narrowed to the point that it is no longer usable, this group simply moves to the "next beach." For example, decades have passed since the huge crowds of swimmers came to the beaches of Sea Bright, Long Branch, and Asbury Park, New Jersey.

In a very real sense, the argument which is the centerpoint of this paper and, for that matter, this volume is probably of little consequence to the general public. That is, we are arguing whether or not seawalls *actively* degrade beaches while in fact the public only wishes to know whether or not beaches are degraded in front of seawalls. The distinction is an important one.

Of the list below of the "sociological properties" of seawalls, property owners obviously consider #1 to be the most important, as a rule. Clearly, each of the items on the list does not apply to all seawalls. The list is based on opinions expressed to us in conversations with individuals in beach communities as well as from media and literature sources (as well as our own observations).

(1). Seawalls protect property and community infrastructure. Hundreds, if not thousands, of buildings along North American open ocean shorelines owe their continued existence to walls.

(2). Seawalls reduce access to the beach (Figure 2).

(3). Seawalls are unsightly.

(4). Seawalls often produce rubble, making swimming dangerous (*e.g.* Sea Island, Georgia and portions of the New Jersey shore).

(5). Emplacement of one wall leads to a proliferation of other walls in "self-defense" from flanking and downstream effects.

(6). Seawalls create a false sense of security and promote increased high-density development in dangerous areas.

(7). Seawalls primarily benefit property owners, who are small in number relative to the number of individuals using beaches.

(8). Seawalls degrade recreational beaches.

(9). DOLAN and HAYDEN (1985) note the following seawall effect: "... although the engineering works have succeeded in stabilizing the shorelines system [in New Jersey], when extreme storms do occur damage is often greater within stabilized areas. Thus the hazard of systematic erosion damage is decreased, but the risk of episodic damage is increased."

A FIELD STUDY OF STABILIZATION ON EAST COAST BEACHES

In response to the question of whether sandy beaches are, in general, degraded in front of seawalls, the Geraldine R. Dodge Foundation funded, during 1987, a field survey of the entire developed open ocean coast of South Carolina, North Carolina and New Jersey (Figure 3). The aim of the survey was to determine the extent

Figure 2. A view of the low tide beach at Sea Island, Georgia, demonstrating how this type of stabilization is unsightly, produces rubble making swimming dangerous, and reduces access to the beach. Clearly no high tide exists in front of this wall.

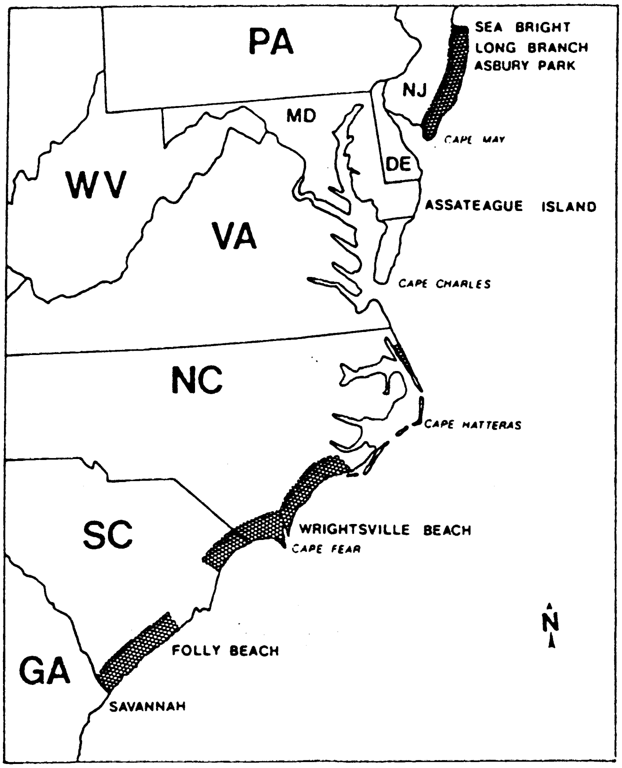


Figure 3. Index map of the Middle Atlantic coast with the study areas for the dry beach width investigation shown in grey-tone.

of hard stabilization in each of these states, and to obtain a comparison of beach width on stabilized and unstabilized beaches. Observations were made at roughly 1/4-mile (0.4 km) intervals along the developed shores of each of the three states; the nature of stabilization was noted and dry beach width was measured. Dry beach width was measured because it was always available no matter what tide stage, and because on most beaches it is the most important section of the recreational beach. Width of the dry beach is defined as the distance between the high water line and the onset of stabilization, dunes, or significant vegetation. Field measurements were made after extended periods of fair weather.

Shoreline reaches were then divided into stabilization classes of 0-10% stabilized (essentially no or only scattered hard stabilization), 11-50% stabilized, 51-89% stabilized, and 90-100% stabilized (totally stabilized). Each shoreline reach was also classified with respect to dry beach width (classes of 0-2 m, 3-10 m, 11-20 m and 20 m+) and matrices were constructed.

Not surprisingly, New Jersey is the state with the highest degree of stabilization. As measured by the amount of shoreline in the totally stabilized category (90-100% walled), New Jersey, America's oldest developed shoreline, is 43% hard-stabilized. South Carolina, which has a mostly post-WWII history of shorefront development and few restrictions on seawall construction has a developed shoreline, 18% of which falls into the 90-100% walled category. North Carolina has actively discouraged seawall construction in recent years and only 3% of the states developed shoreline is stabilized with hard structures. The New Jersey stabilization percentages are somewhat conservative, as shoreline stretches where hard structures are buried by artificial dunes or replenished beaches (such as Long Beach) are not included. The above percentages for all three states do not include the mileage of pub-

Table 1. *Comparison of the degree of hard stabilization density in North Carolina, South Carolina, and New Jersey.*

	Distance (Mi.)	0-10% (Non Stabilized)	11-50% (Partially Stabilized)	51-89% (Stabilization Dominated)	90-100% (Totally Stabilized)
N.J.	101.8	51.8	1.2	3.4	43.6
N.C.	117.1	93.0	2.7	1.5	2.8
S.C.	88.8	72.7	4.4	4.8	18.2

Numbers represent percent of open ocean developed shoreline in various stabilization density categories.

licly owned stretches of shoreline such as National Seashores, state parks, military bases, etc.

Looking at the percentage of shoreline in the partially stabilized classes (Table 1), note that the percentage of shoreline in these classes in South Carolina (9.1%) is twice that of New Jersey (4.5%) and North Carolina (4.2%). We believe this difference in percentages in the intermediate stabilization classes reflects the fact seawalls are proliferating more rapidly along the South Carolina shoreline than the other two states in the survey. It is a fair assumption that partially stabilized shorelines are enroute to total stabilization in most cases. For example, the Corps of Engineers in 1979 measured 1.7 miles (2.8 km) of stabilization on 6-mile-long (9.7 km) Folly Beach (U.S. Army Corps of Engineers, 1979). In our 1987 survey of Folly Beach, we measured 3.6 miles (5.8 km) of hard stabilization along Folly Beach. In eight years, Folly Beach went from 28% to 60% stabilized.

Figure 4 compares unstabilized and totally stabilized dry beach widths for ten coastal communities in the three states. These data are from islands or communities where substantial reaches of both totally stabilized and unstabilized shorelines exist and hence comparisons can be made. Not shown are communities which have no stabilization or communities such as Sea Bright, New Jersey which are 100% stabilized. Also not shown are communities where beaches have been recently replenished. These graphs clearly illustrate that the dry beach is consistently wider in unstabilized reaches than in totally stabilized reaches.

Table 2 shows the range of dry beach widths within each of the four recognized groupings of stabilization densities for 34 communities. The range of beach widths for each stabilization class within the reach is expressed as a percentage. The results clearly show that dry beach width is significantly narrower in front of walls and that the higher the degree of stabilization, the narrower the beach width as a rule. This shows a pervasive trend through 32 of 34 reaches of decreased dry beach width with increased stabilization density.

This survey of the shorelines of three states is the first of its kind in that it attempts to quantify the relationship between beach quality (in terms of dry beach width) and the degree of hard stabilization. The results document the expected narrowing of the beach in front of walls and show that the more dense the stabilization the narrower the beach.

An additional view of the beach narrowing phenomenon is furnished by data from the north shore of Puerto Rico in the vicinity of San Juan (Figure 5). The north shore of Puerto Rico is a rocky shoreline typically consisting of rocky headlands between which are broad sandy calcareous pocket beaches bounded by rocky capes. Figure 6 shows the results of a survey of dry beach widths taken on pocket beaches between Punta Uvero and Punta Boca Juana on the Puerto Rico north shore. Shown is a comparison of the average dry beach width measured on unstabilized shorelines with the beach width in front of hard stabilization usually rock revetments. Clearly unstabilized beaches are wider than stabilized beaches (Figure 6). In addition, it is clear whatever is being protected by the Puerto Rican revetments and walls (usually highways) has little remaining beach buffer for storm protection.

Such surveys as ours of the East Coast and Puerto Rico shorelines cannot directly address the question of whether the effect of the walls is active or passive. In fact, this survey cannot distinguish beach narrowing due to wall construction on the beach proper. However, from the public's standpoint, the results offer docu-

Table 2. *Dry Beach Width surveyed in the summer of 1987 in 34 U.S. East Coast beach communities. (See text for explanation.)*

Location and Width Class	Non Stabilized	Partially Stabilized	Stabilization Dominated	Completely Stabilized
Hilton Head				
20m +	26.5	—	—	—
11 - 20m	64.4	—	—	4.0
3 - 10m	9.1	—	—	15.3
0 - 2m	—	—	—	80.7
Harbor I.				
20m +	59.0	—	—	—
11 - 20m	41.0	—	—	—
3 - 10m	—	—	—	—
0 - 2m	—	—	—	—
Edisto Bch.				
20m +	1.6	—	—	—
11 - 20m	45.1	76.6	—	—
3 - 10m	53.3	23.4	—	—
0 - 2m	—	—	—	—
Seabrook I.				
20m +	100.0	—	—	12.6
11 - 20m	—	—	—	2.4
3 - 10m	—	—	—	1.6
0 - 2m	—	—	—	83.5
Kiawah I.				
20m +	71.0	—	—	—
11 - 20m	29.0	—	—	—
3 - 10m	—	—	—	—
0 - 2m	—	—	—	—
Folly Bch.				
20m +	38.9	—	—	0.3
11 - 20m	48.8	—	20.0	9.1
3 - 10m	11.1	—	20.0	38.7
0 - 2m	1.2	—	60.0	51.9
Sullivans I.				
20m +	51.8	—	—	—
11 - 20m	33.2	100.0	80.0	10.3
3 - 10m	13.1	—	20.0	24.1
0 - 2m	1.8	—	—	65.5
Isle of Palms				
20m +	85.2	—	—	—
11 - 20m	10.6	—	—	—
3 - 10m	4.2	—	—	5.9
0 - 2m	—	—	—	94.1
Debidue Bch.				
20m +	29.8	—	—	—
11 - 20m	—	—	—	—
3 - 10m	70.2	—	—	—
0 - 2m	—	—	—	100.0
Pawleys I.				
20m +	44.1	13.9	—	—
11 - 20m	51.8	54.8	—	100.0
3 - 10m	4.2	31.3	—	—
0 - 2m	—	—	—	—
Litchfield				
20m +	28.2	—	—	—
11 - 20m	71.8	—	—	—
3 - 10m	—	—	—	—
0 - 2m	—	—	—	—

Table 2. *continued.*

Location and Width Class	Non Stabilized	Partially Stabilized	Stabilization Dominated	Completely Stabilized	
Lower Strand					
20m +	42.4	—	—	—	
11 - 20m	14.7	—	—	81.5	
3 - 10m	42.9	100.0	100.0	9.6	
0 - 2m	—	—	—	8.9	
		Upper Strand			
20m +	6.0	—	52.7	4.5	
11 - 20m	40.4	12.7	47.3	10.6	
3 - 10m	46.2	11.1	—	26.0	
0 - 2m	7.4	76.2	—	58.9	SC
					NC
Sunset Bch.					
20m +	55.2	—	—	—	
11 - 20m	24.4	—	—	—	
3 - 10m	20.4	—	—	—	
0 - 2m	—	—	—	—	
		Ocean Isle Bch.			
20m +	11.3	—	—	—	
11 - 20m	77.8	—	—	—	
3 - 10m	10.5	—	—	—	
0 - 2m	0.4	100.0	—	—	
		Holden Bch.			
20m +	30.9	—	—	—	
11 - 20m	55.4	—	—	—	
3 - 10m	13.7	92.0	—	—	
0 - 2m	—	8.0	100.0	—	
		Oak Island			
20m +	27.7	20.3	—	—	
11 - 20m	49.7	79.7	12.5	—	
3 - 10m	21.6	—	87.5	—	
0 - 2m	1.0	—	—	100.0	
		Carolina-Kure Bech.			
20m +	84.2	—	100.0	—	
11 - 20m	11.2	—	—	—	
3 - 10m	4.5	—	—	—	
0.2 - 2m	0.2	—	—	100.0	
		Wrightsville Bch.			
20m +	94.6	—	—	—	
11 - 20m	5.4	100.0	—	—	
3 - 10m	—	—	—	—	
0 - 2m	—	—	—	—	
		Figure Eight I.			
20m +	—	—	—	—	
11 - 20m	29.1	—	—	—	
3 - 10m	48.4	—	—	—	
0 - 2m	22.5	—	—	—	
		Topsail I.			
20m +	18.3	—	—	—	
11 - 20m	41.4	—	—	—	
3 - 10m	30.0	30.6	—	—	
0 - 2m	10.3	69.4	—	—	

Table 2. *continued.*

Location and Width Class	Non Stabilized	Partially Stabilized	Stabilization Dominated	Completely Stabilized	
Bogue Bank					
20m +	60.9	—	—	59.0	
11 - 20m	36.5	—	—	32.0	
3 - 10m	2.1	—	—	9.0	
0 - 2m	0.4	—	—	—	
Outer Banks					
20m +	28.2	—	—	8.3	
11 - 20m	33.4	100.0	—	45.8	
3 - 10m	29.6	—	—	45.8	
0 - 2m	8.9	—	—	—	NC
Cape May					NJ
20m +	14.7	—	—	4.6	
11 - 20m	68.2	—	—	25.4	
3 - 10m	17.1	—	—	6.9	
0 - 2m	—	—	—	63.1	
Wildwoods (5 mi. bch.)					
20 m +	—	100.0	—	97.9	
11 - 20m	—	—	—	0.8	
3 - 10m	—	—	—	1.3	
0 - 2m	—	—	—	—	
7 mi. bch.					
20m +	72.1	—	—	49.8	
11 - 20m	26.4	—	—	34.9	
3 - 10m	1.4	—	—	11.1	
0 - 2m	—	—	—	4.3	
Ludlums I.					
20m +	58.4	—	—	19.2	
11 - 20m	33.0	—	—	31.3	
3 - 10m	7.4	—	—	39.2	
0 - 2m	1.2	—	—	10.3	
Ocean City					
20m +	100.0	47.0	—	73.6	
11 - 20m	—	18.2	—	6.3	
3 - 10m	—	19.7	—	5.8	
0 - 2m	—	15.2	—	14.2	
Absecon Island					
20m +	100.0	100.0	—	84.7	
11 - 20m	—	—	—	9.2	
3 - 10m	—	—	—	5.0	
0 - 2m	—	—	—	1.1	
Brigintine					
20m +	100.0	100.0	—	—	
11 - 20m	—	—	—	—	
3 - 10m	—	—	—	—	
0 - 2m	—	—	—	—	
Long Beach Island					
20m +	59.0	—	—	—	
11 - 20m	39.6	—	—	100.0	
3 - 10m	1.4	—	—	—	
0 - 2m	—	—	—	—	

Table 2. *continued.*

Location and Width Class	Non Stabalized	Partially Stabilized	Stabilization Dominated	Completely Stabilized
Mainland: S. Seaside Park—Manasquan				
20m +	56.6	—	—	71.7
11 - 20m	41.4	—	—	16.3
3 - 10m	2.0	—	—	12.0
0 - 2m	—	—	—	—
Mainland Manasquan—Shark River I.				
20m +	71.3	—	—	79.4
11 - 20m	21.5	—	—	20.6
3 - 10m	5.8	—	—	—
0 - 2m	1.4	—	—	—
Mainland: Shark River I.—Seabright				
20m +	63.0	—	4.4	22.8
11 - 20m	12.3	—	14.3	8.3
3 - 10m	13.6	—	16.9	4.6
0 - 2m	11.1	—	64.2	64.3

Numbers are percentages of beach width in each of four stabilization classes.

mentation of the negative impact of walls on their recreational beach. It is also important to recall that in the absence of a wall, the beach is always present.

THE SEA BRIGHT, NEW JERSEY SAGA

Sea Bright, New Jersey, has achieved some noteriety as a suggested endpoint in hard shoreline stabilization. A brief review of its stabilization history provides a long-term view of the problem and also a view of the future in a time of rising sea level. Sea Bright is the northernmost developed barrier island (spit) in New Jersey. It is a community made up largely of single-family dwellings and has a large (17 ft/5.2 m crest elevation) concrete rubble seawall extending for most of its length (Figure 7). The community is small in areal extent—less than one square mile, and in population—less than 2000 year-round residents. The barrier spit is generally narrow and low in elevation and connects to the north with Sandy Hook. In March of 1984 an intense northeaster, possibly a 30-year storm, struck Sea Bright and caused $82-million in damage. No significant damage occurred to buildings other than some minor flooding. Damage, which was said to be restricted to the seawall and beaches, was of the same order of magnitude as the value of all of the buildings in the town. Clearly the economics of this situation dictate that Sea Bright is not worthy of salvation although politics and other considerations may decide otherwise. The prudent management alternative in this community would be gradual removal or relocation of the buildings.

During the first half of the 19th century, Sea Bright remained a narrow, undeveloped spit with probably a few dozen fishermen shacks scattered about. Old drawings and photographs indicate that the natural unstabilized beach was a steep and narrow one (Figure 8). In 1869 the first "permanent" house was built at the north end. Photographs furnished to us by Mr. George Moss, a Sea Bright resident, show that the shoreline in 1877 (Figure 9) was lined with houses with no dune protection and positioned very near the high-tide line. One sketch shows that by 1886 (Figure 10) at least one low wooden bulkhead has been built in front of some houses, and a postcard dated 1903 shows a large rubble wall lining a portion of the north end beach (Figure 11). According to KRAUS *et al.* (1988), the first rubble mound wall in Sea Bright was installed in 1898. In 1931 (Figure

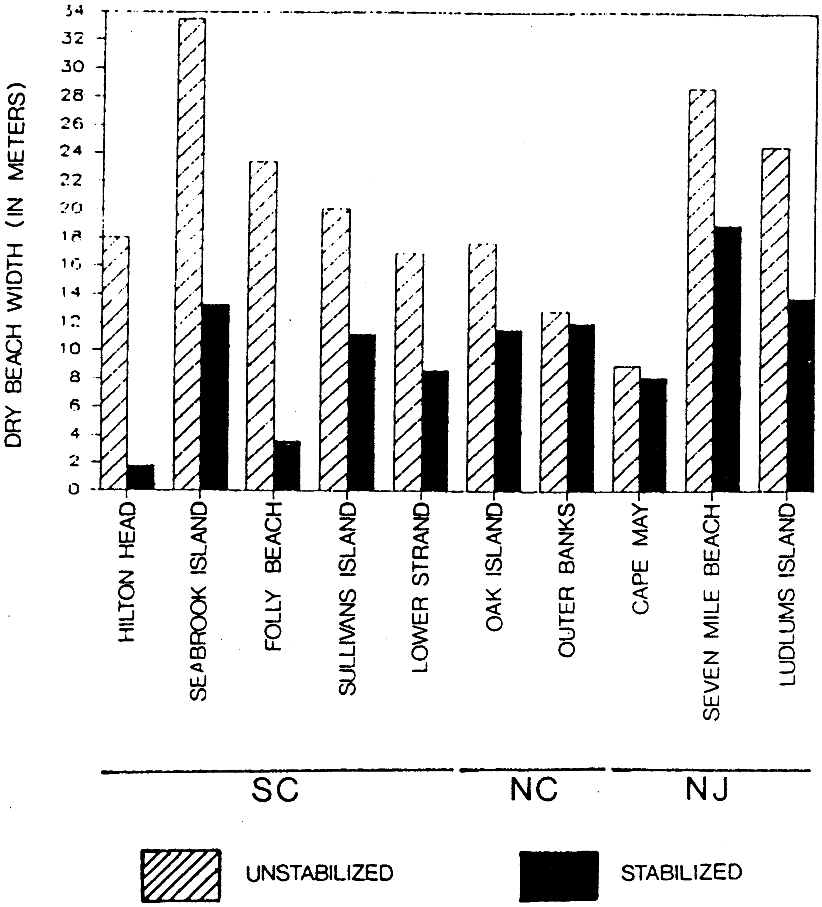


Figure 4. A comparison of dry beach width for totally stabilized and unstabilized stretches of beach within 10 communities. In our study area, only these ten communities had significant stretches of stabilized and unstabilized beaches without large stretches of replenished beaches.

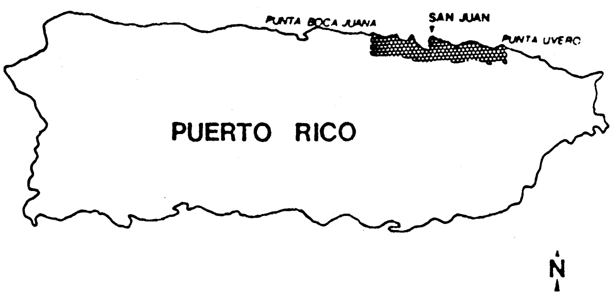


Figure 5. Index map of Puerto Rico with the study area for the dry beach width investigation shown in grey-tone.

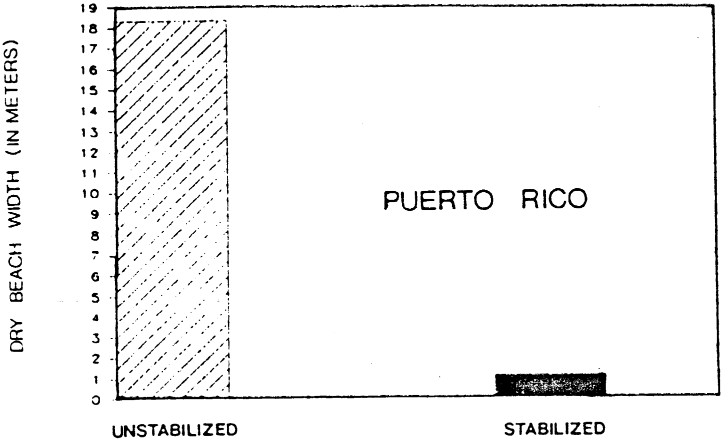
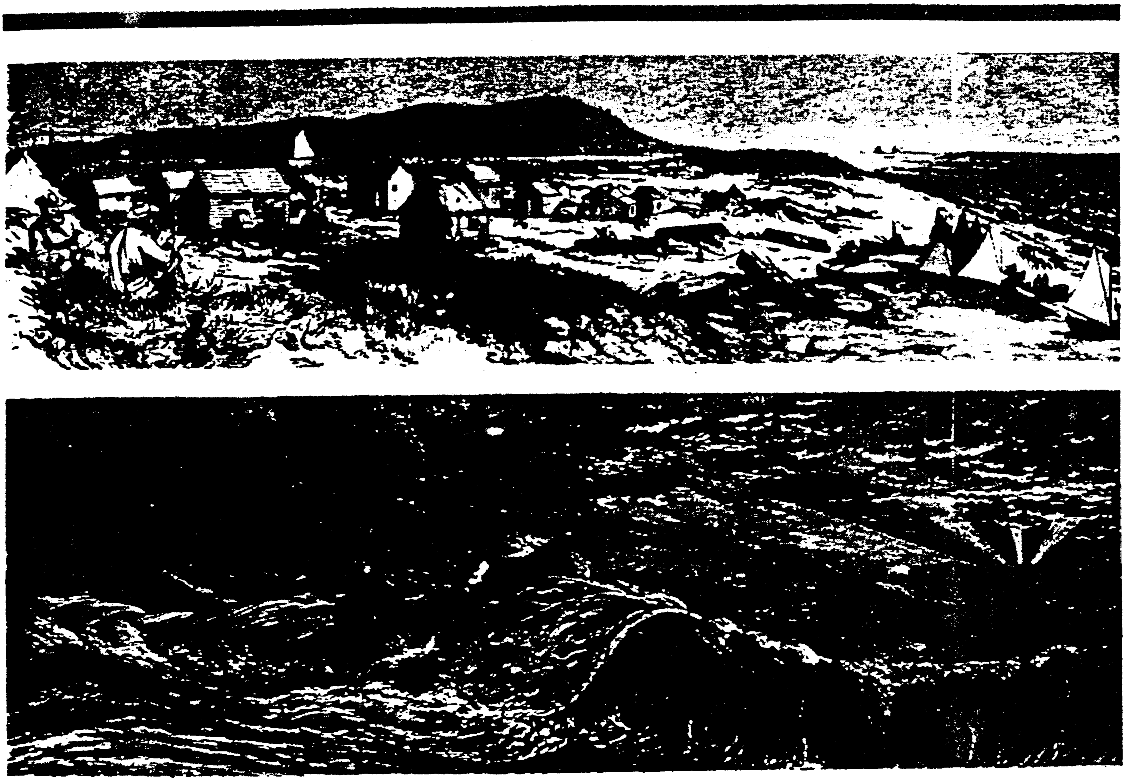


Figure 6. A comparison of dry beach width for totally stabilized and unstabilized stretched within the Puerto Rico study area.

Figure 7. A view of the seawall in 1987 at the N. end of Seabright, New Jersey. The beach is totally absent here except for small pocket beaches adjacent to groins.



(Above) The fishing village of Nauvoo; Rumson and the Highlands of the Navesink in background. Sand dunes (now replaced by sea wall) offered protection for the then new railroad.
(Below) "Toilers of the Sea" launching their boats at daybreak.

Harper's Weekly, August 22, 1868.

Figure 8. Fishing Shacks at Nauvoo (now Seabright), New Jersey, from Harpers Weekly in 1868. [Photo courtesy of George H. Moss (1964) in Nauvoo to the Hook].

12), the rubble mound wall had dimensions similar to the present one, but a recreational beach remained. The beach has essentially remained in place for more than a century stabilized by long groins for a 3-4 block stretch in front of "downtown" Sea Bright. To the north and south, virtually no beach remains and the original first row of houses is gone.

Apparently extensive hard stabilization was in place within 30 years of the first development in Sea Bright. The photographic evidence indicates that the barrier spit was very low, with few dunes, and was overall a very unsafe location for construction. Judging from the 1877 photograph, it is likely that extreme exposure to overwash, rather than a rapid rate of shoreline retreat, may have been responsible for the unusually rapid emplacement of the hard structures. Apparently, a significant beach remained in place for 60-70 years (held by numerous groins), although there is some indication that small beach replenishment projects have been periodically carried out.

Historical photography may be the only way to reconstruct the history of shoreline stabilization in a community. This is an essential first step to understand the nature and rates of the environmental impact on long-stabilized shorelines.

KRAUS *et al.* (1988) analyzed profiles of the shoreface off Sea Bright and noted that between 1953 and 1985 very little change in offshore slope occurred. Obviously to determine if shoreface steepening has occurred since stabilization began in the 1870's, more than 30 years of observation is required but accurate profiles to do this are often lacking in most areas.

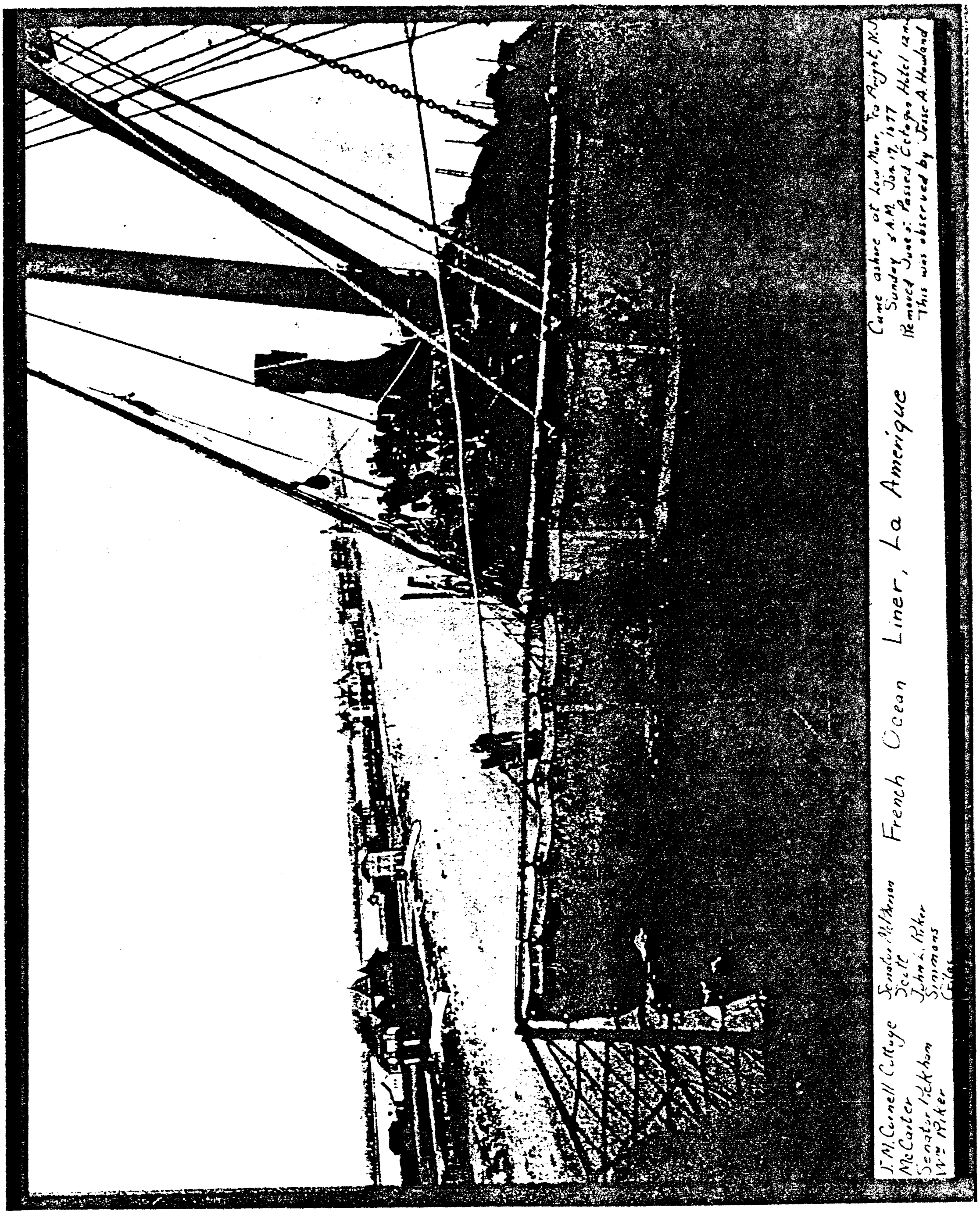
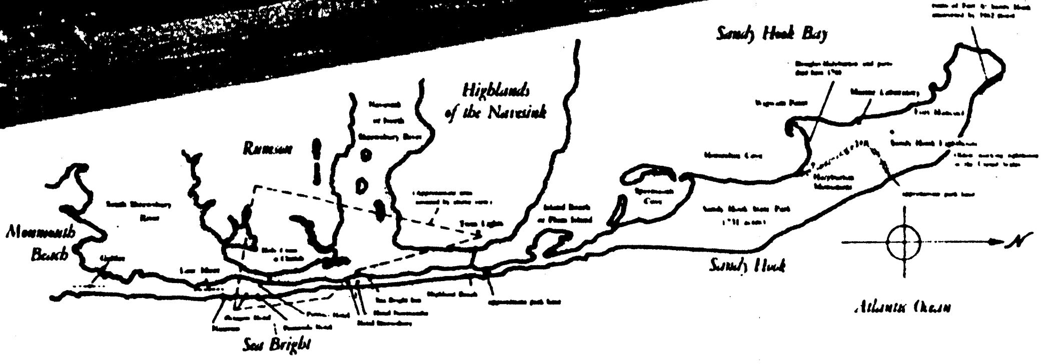


Figure 9. View of the shorefront of Seabright, New Jersey, from the shipwrecked French liner La Amerique in 1877. The photograph shows that these houses, built less than 10 years after the first development at Seabright, are low in elevation, very close to the beach and with zero dune protection. Possibly, stabilization in the form of a single row of boulders is in front of the third or fourth house from the left. (Photo courtesy of George H. Moss Jr.)



(Above) A bird's-eye view of Sea Bright circa 1887.

(Right) The barrier beach today in relation to places referred to in the text

MECHANISMS RESPONSIBLE FOR ACTIVE EROSION BY HARD STRUCTURES

Returning to the question of enhanced erosion by shore-parallel structures on the beach, the following is a list of the presumed effects of seawalls leading to erosion of beaches in front of walls or on adjacent beaches. The list is formulated largely from suggestions in the literature or is based on well-established principles of beach or barrier island evolution. Because of the wide variation in the oceanographic and geologic frameworks of beaches, the relative importance of these various effects and processes will vary widely. Artificial factors, also important in determining the fate of a seawalled beach, include the length and age of a wall and the effects of upstream stabilization. In addition, purely natural processes such as inlet or inlet channel migration may be the most important control of local deposition and erosion on beaches, with or without walls.

(1). Removal of bluffs from the sand supply system. Construction of seawalls at the base of eroding bluffs immediately cuts off this source of beach sand (McCORMICK *et al.*, 1984). Examples where such appears to be happening today include Long Branch, New Jersey, and Easthampton, New York. To the extent that walls prohibit erosion of barrier island dune systems, sand supply will also be reduced in this system. Depending on the local sand budget, blocking off a local bluff sand source can have either local or far field impact. In situations where large segments of eroding bluff sources have been almost entirely removed from the system as in New Jersey, it is difficult to distinguish the effects of local walls from long-distance starvation.

(2). The groin effect. Eventually, an isolated wall built on a retreating shoreline will extend into the longshore transport system (Figure 11). Under these circumstances the wall should act as a groin in reducing downstream sand supply (DEAN, 1985); *The Shore Protection Manual* (1984).

(3). Sand transportation gradient. Both DEAN and MAURMEYER (1983) and WALTON and SENSABAUGH (1979) note that profile sand requirements in front of a wall are such that outside sand is required to maintain them. Both articles speculate that sand is derived from adjacent beaches, thereby causing more erosion on adjacent beaches than if no seawall were present.

Figure 10. A "bird's-eye view" painting of Seabright ca. 1886. Note the boardwalk at the lower left of the figure and the low bulkhead at the right right edge. (from Moss, 1964). (Facing page).

(4). The flanking effect. A well-documented problem is increased erosion rates at one or both ends of an isolated wall (THE SHORE PROTECTION MANUAL, 1984). It is this problem that forces neighboring property owners to stabilize in self-defense and leads to the proliferation of walls.

(5). Inhibition of two-way sand exchange between beach and the upland. Overwash and sand dune formation are two major natural processes which, in effect, remove sand from beaches. These processes are particularly important on barrier islands (OERTEL, 1974; NUMMEDAL, 1983), but are found on other shoreline types as well. Oertel reviews the role of frontal dunes in beach evolution, especially during storms. Perhaps the most important role is that of a sand reservoir for storm response. Oertel states "sand eroded from the dunes nourishes the eroded portions of the beach. Nourishment from this source of sand buffers the effect of erosion and prevents an accelerated lowering of the beach profile."

This sand exchange is a two-way affair. OERTEL (1974) notes that between storms the dune sand reservoir is rebuilt. LEATHERMAN (1976) demonstrated that during a 26-month observation period, more sand was lost from Assateague Island through seaward-blowing winds than was gained from seven overwash events.

To the extent that seawalls prohibit landward transport of wind-blown sand they may actually increase the sand retention on the beach. To the extent that walls prohibit seaward transport of sand by wind, they decrease the beach sand supply. The situation will vary widely from place to place.

(6). Inhibition of storm response. Beaches respond to storms by moving sand about to flatten the surf zone profile or to form offshore bars, or both (DAVIS, 1985); U.S. ARMY CORPS OF ENGINEERS, 1981). The effect of this flattening is the dissipation the wave energy over a broadened zone while the bars have the effect of "tripping" waves in the outer surf zone. To the extent that additional sand is required to

The Bathing Grounds at Sea Bright, N. J.

Made in Germany. Photographed & Published by W. B. Goff, Sea Bright, N. J.

respond to a storm, seawalls will inhibit that response. During large storms some of the sand in the system is obtained from erosion of the upper beach and dunes, and walls cut off this source. The problem of inhibited storm response is intensified with narrowing of the beach in front of walls.

(7). Inhibition of storm recovery. There are many indications that the beaches in front of walls usually recover from storms differently and more slowly than natural systems (SEXTON and MOSLOW, 1981; DAVIS and ANDRONACO, 1987; SAYRE, 1987), but sometimes there is no difference (KRIEBEL, 1987). As with all things on beaches the phenomenon varies from location to location. MORTON (this volume) makes the point that storm recovery involves more than just forebeach recovery, which all of the above papers are concerned with. It is important to consider a larger picture.

(8). Shoreface steepening. This particular effect has not been clearly documented. For one thing, long-term natural profile changes on unstabilized shorelines are not understood and might be difficult to distinguish from human-induced changes. Nonetheless, the very steep shoreface off Sea Bright, New Jersey, is suspected to be a response to long-term stabilization. If steepening occurs, it should have an important effect on wave climate affecting the system and should also change the manner in which the beach responds to storms.

(9). "Telescoping" of the surf zone. During a storm a portion of the surf zone widening is carried out by landward translation of the landward boundary of the surf zone. Emplacement of a seawall prevents this movement and hence causes the surf zone to be narrower during a storm than on natural shoreline stretches (WALTON and SENSABAUGH, 1979; KRIEBEL *et al.*, 1986). As a result, storm energy is expended over a smaller area and surf zone processes can be expected to intensify accordingly. Processes that may be intensified include: (1) longshore currents, (2) wave reflection, (3) storm rip-currents, and (4) pressure gradient related currents. Intensification of longshore currents in this situation is suggested by WALTON and SENSABAUGH, (1979). According to SILVESTER (1977), "reflection of waves from walls obliquely doubly applies energy to a sedimentary bed and hence expedites the transmission of material downcoast." COOK and GORSLINE (1972) and SWIFT (1976) note the importance of offshore transport of sand during storms by rip currents even on coasts where such currents are not developed in fairweather conditions. Presumably, in a telescoped surf zone, rip current intensity would be increased. It is also likely that a long, continuous, and high wall would increase the pressure gradient in the nearshore water column responsible for the geostrophic coastal currents discussed by SWIFT (1976) and NIERDORODA *et al.* (1985).

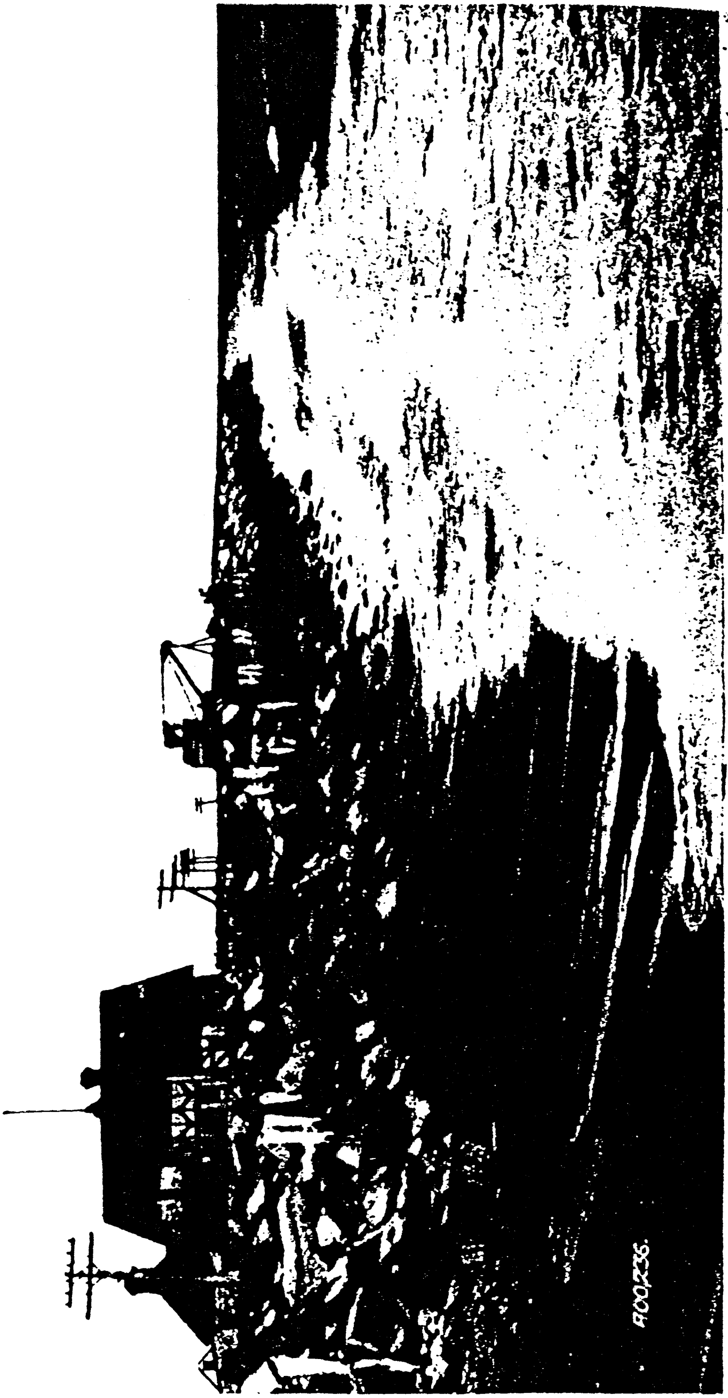
Figure 11. A wide recreational beach in the central part of Sea Bright, New Jersey, from a 1903 post card. (Facing page).

THE CASE AGAINST SEAWALL-CAUSED EROSION

It is clear from the review by KRAUS (1987) that much remains to be learned about the environmental impact of seawalls. Much of the sparse literature is concerned with single events or single experiments which may not have much bearing on a phenomenon involving decades-long time spans. Thus, the evidence (other than the fact that many seawalls have narrow beaches in front of them) has still to be developed for a quantitative understanding of seawall impact. Much of the literature to date, including this paper, requires a goodly input of "coastal experience" from the authors.

Perhaps the most important paper in opposition to the concept of the active participation of seawalls in beach destruction is that of DEAN (1985), because the paper is already widely quoted in the public arena. For example, it was used in Volusia County, Florida (RUSSELL GRACE, *Pers. Comm.*) and in Texas (ROBERT MORTON, *Pers. Comm.*) to argue in favor of hard stabilization adjacent to recreational beaches. The general tone of the article is that passive erosion does occur, but that active erosion caused by walls is not of significant engineering impact. The following is a thumbnail summary of Dean's article, based on his Table 1. Listed are some "commonly expressed concerns dealing with coastal armoring" and Dean's assessment as to their validity.

(1). Coastal armoring placed on an eroding shoreline causes increased erosion on adjacent beaches. TRUE.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(2). Coastal armoring placed on an eroding shoreline will cause the seaward beaches to diminish [passive erosion]. TRUE.

(3). Coastal armoring causes an acceleration of beach erosion seaward of the armoring. PROBABLY FALSE.

(4). Isolated armoring can accelerate downdrift erosion (Groin Effect). TRUE.

(5). Coastal armoring results in a greatly delayed post-storm recovery. PROBABLY FALSE.

(6). Coastal armoring placed well back from a stable beach is detrimental to the beach and serves no useful purpose. FALSE.

Concerns 3 and 5 are germaine to "The Great Seawall Debate." These points directly address the question of active seawall participation in beach degradation. Dean responds to each of these concerns in his Table 1 by stating "*no known data or physical arguments support this concern.*" On these issues, we strongly disagree. The data are sparse but not unknown. Morton's paper in this issue and the study by OERTEL (1974) of beach bulldozing offer hard data pointing to active participation of walls in beach loss. As to physical arguments, there are a large number of indications that active seawall participation in beach degradation is likely.

The foremost line of data is frequent narrowness and absence of beaches in front of seawalls. Until all the evidence is in, active beach degradation must be considered a possibility in explaining this widespread phenomena.

We would believe that there are a number of physical arguments to support mechanisms by which active seawall participation in beach degradation may occur. These were listed in the previous section. Walls may actively participate in frontal beach destruction by shoreface steepening, inhibition of storm response and recovery and, most importantly, intensification of a variety of surf zone processes by telescoping of the surf zone during storms. The major processes that may be intensified include rip currents, longshore currents, and wave reflection. Whether or not intensification of these processes takes place remains to be proven by future research. These are plausible mechanisms for beach removal suggested by a number of coastal scientists and engineers. MORTON and PAINE (1983) and MORTON (this issue) note that the beaches of Texas follow a four-phase cycle in storm recovery. Forebeach recovery is phase I, but complete recovery of the beach involves aeolian processes, flooding during minor storms and plant colonization. Recovery phases 2, 3 and 4 are prevented by the presence of a seawall or similar structure.

Figure 11B. A non-existant recreational beach also from a 1903 post card, showing a view of the northern tip of Seabright. It appears that the rubble mound seawall was being constructed at the time of the photograph. (Both photos courtesy of George H. Moss Jr.). (Facing page).

The important illustration by Morton is that there is a need to first understand completely how the natural system recovers before it is possible to gauge whether or not storm recovery in front of a wall is complete. Simply observing forebeach recovery is not enough.

FUTURE RESEARCH: A NEW APPROACH IS NEEDED

The previously mentioned literature review by KRAUS (1987) makes it clear that our limited quantitative understanding of seawall/beach interaction is based on single events or single experiments. Yet it seems well-established by qualitative "coastal experience" that beach degradation is often a long-term phenomenon. PILKEY *et al.* (1980) found that seawalls destroy beaches in a time frame that ranges from 2 years to 60 years. Sea Bright, New Jersey, may have retained some beach for as long as 70 years after stabilization, but this beach retention was greatly aided by groins and probably small replenishment projects. Whatever the case, it is clear that beach degradation in front of walls must result from a sum total of many events, both fair weather and storm. These events can be of an infinite variety of durations, intensities, directions, and frequencies. It is doubtful whether short-term research can offer an answer to the question at hand.

The situation is further complicated by the great variation in oceanographic and geologic settings of beaches. For example, according to PILKEY and CLAYTON (1987), adjacent beach nourishment projects behave dramatically differently; for example, Carolina and Wrightsville Beaches, North Carolina and Canaveral and Indialantic Beaches, Florida. Hence, intense study of a single seawall situation may prove fruitless if the "wrong" wall at the "wrong" location is chosen.

As a consequence of the time scale and geo-

graphic variability problems, the ideal seawall research project should involve long term observations at numerous locations. Obviously, such a project would be difficult to undertake. A less desirable but more feasible alternative would be to document the historical beach behavior in front of a wide variety of older walls. The problem with this approach is the data re: beach behavior are very limited, but sequential areal photography available for most coastal areas beginning in the late 1930's should prove useful. Nonetheless, considering the stage of the game of our quantitative knowledge of wall/ beach interaction, this approach could be very fruitful.

In the future, monitoring of storm event effects on walled beaches as well as continued wave tank experiments will undoubtedly help us understand the problem. However, it is important that these results be interpreted in the light of our knowledge that beach degradation in front of walls in a long-term incremental process. In other words, the principal question is, "What will happen in 20, 40, and 60 years?" rather than "What will happen in a single big northeaster?"

Additional field observations such as those we made on the South Carolina, North Carolina, and New Jersey shorelines are also needed. Our approach, measuring dry beach width, is a simple start toward documenting a complex problem. Future studies should include observations of the entire intertidal beach and of course should include other coastal types.

CONCLUSIONS

(1). Care must be taken not to divert coastal management efforts to restrict seawalls, simply because the scientific community is arguing about the mechanisms of beach behavior. The most important question from our society's standpoint is *whether* seawalls negatively impact beaches. *How* seawalls impact beaches is of much less importance

(2). Seawalls can degrade beaches in three ways: (1) passive erosion due to tendencies which existed before the wall was in place, (2) active erosion due to interaction of the wall with local coastal processes, and (3) construction of walls in the intertidal zone. The importance of active seawall erosion remains controversial, but a number of physical arguments do offer support for mechanisms by which active beach degradation by the seawall may occur. Lack of hard data proving the existence of active erosion is no reason to assume that it does not occur.

(3). Dry beach width was measured along the entire developed shorelines of South Carolina, North Carolina, and New Jersey. Comparison of totally stabilized and totally unstabilized reaches of individual barriers indicates that dry beach width is consistently narrower in front of hard stabilization. In addition, there is also a positive correlation between dry beach width and density of stabilizing structures.

This study is essentially the first effort to quantify the effect of hard stabilization along long stretches of U.S. shorelines. It is only a start and much more research effort is needed. This information is very basic to our understanding of the environmental effects of seawalls.

(4). More research is certainly needed, but future studies must take into account the fact that beach degradation in front of walls is usually a decades-long phenomenon and that there is wide variability in the coastal climate affecting seawalls from location to location. Monitoring of beach behavior in front of seawalls in the future is very improtant.

ACKNOWLEDGEMENTS

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Figure 12. Swimming at Highland Beach, the North end of Seabright, in 1931. Note the numerous groins and the rubble mound wall which is nearly the same dimensions of the modern wall. In 1931, sufficient beach remained for use by large numbers of swimmers. (Photo courtesy of George H. Moss Jr.). (Facing page).

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