

A Comparison of Beach Replenishment on the U.S. Atlantic, Pacific, and Gulf Coasts

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ABSTRACT

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The record of beach replenishment on the U.S. Atlantic, Gulf, and Pacific coasts has been examined. For the most part, past beach replenishment projects have not been monitored. As a result, limited durability data exist. Fewer durability data exist for the Gulf and Pacific coasts than for the Atlantic coast. Available data suggest, however, that the durabilities experienced by Atlantic and Gulf coast replenished beaches are similar, and that, in general, the Pacific has a better record of artificial beach maintenance than the Atlantic or Gulf coasts. On all three coasts, most fills lasted between one and five years.

The majority of Gulf and Pacific coast replenished beaches are shorter than Atlantic coast replenished beaches. Atlantic coast replenished beaches range in length from 0.5 mile to 10.5 miles; the average length is 3.2 miles. Gulf coast beaches range in length from 1,000 feet to 5 miles; the average length is 1.2 miles. Pacific coast replenished beaches range from 0.2 of a mile to 6 miles; the average length is 1.2 miles.

In general, Pacific coast replenished beaches have the greatest cumulative density (volume per unit length) averaging 6,228,000 cy/mi, followed by the Atlantic coast averaging 1,585,000 cy/mi. Gulf coast beaches tend to have the lowest densities, averaging 547,000 cy/mi.

Storms, as opposed to grain size, length, and density, appear to be the main factor responsible for variation in replenished beach durability for all three coasts.

ADDITIONAL INDEX WORDS: *Density, dredging, durability, funding, offshore disposal.*

INTRODUCTION

In general, our society has three avenues of response to an eroding shoreline: (1) hard stabilization, i.e. seawalls and revetments, (2) soft stabilization, i.e. beach replenishment, and (3) retreat or relocation. At present, the first option, hard stabilization, is recognized as destructive to recreational beaches. Meanwhile, the third option, retreat or relocation, is often politically difficult to implement because many property owners object to relinquishing their land. As a result, beach replenishment is an increasingly popular response to a rising sea level.

This paper addresses beach replenishment on a national scale. Sociopolitical and physical parameters of replenishment operations on the U.S. Atlantic, Gulf, and Pacific coasts are compared and contrasted. Data from all three areas through 1987 are used to determine the

regional scale effects of several beach replenishment parameters on artificial beach durability. The analysis is complex since general beach characteristics and the type of data existing for each area as well as for each design parameter differ. Three beaches, one from each of the three geographical areas, are presented as case studies. These beaches have been replenished according to an engineering design, and monitoring data are available for each.

This study is a synthesis of earlier beach replenishment studies (PILKEY and CLAYTON, 1988; LEONARD, 1988; DIXON and PILKEY, 1989; CLAYTON, 1989). As stated in these studies, limited durability (beach lifetime) data exist due to a lack of project monitoring and published results. Analyses have used data through 1987.

Actual residence times of artificial beaches, measured by volumetric losses or return of shoreline position to pre-project location are

often undocumented. Much of the available beach lifetime data (especially for Pacific coast beaches) are qualitatively rather than quantitatively expressed. That is, in many instances, information about post-placement behavior of the beach is restricted to the terms "lost", "gone", *etc.* Even when all data are used (*i.e.* qualitative and quantitative), numerous gaps remain in the data set. Because of gaps and the unusual mix of both qualitative and quantitative data, only broad and general conclusions may be drawn.

THE U.S. EXPERIENCE

As of 1988, approximately 90 Atlantic coast beaches, 35 Gulf coast beaches, and 30 Pacific coast beaches had been replenished. On most of the beaches, more than one beach replenishment operation has been carried out. Overall, efforts in the United States (as of 1987) have resulted in over 400,000,000 cubic yards of sand emplaced over more than 400 miles of shoreline. The Atlantic coast has the greatest length of replenished shoreline, over 270 miles, followed by the Gulf coast, over 100 miles, and the Pacific coast, over 30 miles.

Funding

Replenished U.S. beaches fall into six broad funding categories: flood control; beach erosion control; navigation; emergency repair; 1962 storm repair (on the Atlantic coast only); and projects designed to mitigate the damages caused by federal navigation projects (referred to as "Section 111"). Beach erosion control projects may be funded by federal, state, local, or private sources, or a combination thereof. The cost of navigation projects is almost always completely federal. The purpose of a federal navigation project is, primarily, channel maintenance. If the dredge material is of beach quality and beach disposal is economically feasible, beaches may be replenished under the federal navigation project category. Although a regular practice on the Pacific coast, beach disposal is less common on the Atlantic and Gulf coasts where many cubic yards of sand are dumped offshore as a result of federal navigation projects. The 1962 storm repair projects were those designed to provide temporary storm protection

after beach losses on Atlantic beaches attributable to the 1962 Ash Wednesday storm.

On the Atlantic coast, 76% of the replenishment operations for which cost data are available were federally funded. Specifically, 26% were federally funded beach erosion control projects, 23% were 1962 storm repair (mostly in New Jersey), 10% were navigation projects, 9% were emergency repair, 7% were flood control, and two of 163 projects (1%) were Section 111 projects. Twenty-one percent of the replenishments were funded through state and local agencies, and 3% through private sources (PILKEY and CLAYTON, 1988).

On the Gulf of Mexico coast, the 80 federally funded (in part or full) pumpings fall into three broad categories: erosion control/storm protection; navigation; and emergency repair. Thirty-five percent of the replenishments were in the federally funded navigation category. On the Gulf coast, the cost of these projects is completely federal. Twenty-four percent of the projects were in the federally funded erosion control/storm protection, and 11% were in the emergency repair categories. The thirty projects (15%) fully funded by state and local monies are considered beach erosion control/storm protection. Five percent of the replenishment operations received their funding from private sources.

Most Pacific coast beaches have received sand in conjunction with harbor dredging and maintenance (58%). Sixteen percent of the replenishments are beach erosion control/federal, and beach erosion control/state and local, each. Ten percent fell into the privately funded category.

Durability

As mentioned, lack of project monitoring, especially for those projects constructed in conjunction with navigation projects, has resulted in limited available durability data. Where volumetric losses or linear recession rates have been reported, fill response has been quantified in terms of "beach lifetime" categories as a general expression of beach longevity. Beach lifetime categories are defined as the amount of time between fill emplacement and the loss of at least 50% of the original fill volume. Such is a conservative estimate of durability, as most artificial beaches had actually experienced a greater than 50% loss of fill material by the

time assigned as the beach "half-life". The beach lifetime categories used for this study are less than one year, one to five years, and greater than five years. Another measure of beach lifespan is the percent of fill remaining one year after emplacement.

The percentage of replenished beaches in each of the three longevity categories is similar for the Atlantic and Gulf coasts. On the Atlantic coast, 26% of the replenished beaches fell into the less than one year beach lifetime category. Sixty-two percent fell into the one to five year category, and 12% fell into the greater than five year category. On the Gulf coast, the percentages are: 15% less than one year beaches; 75% one to five year beaches; and 10% greater than five year beaches (Figure 1).

Characterizing Pacific coast replenished beaches in terms of fill longevity (beach lifetime categories), 18% of the beaches fall into the less than one year category, 55% in the one to five

year category, and 27% in the greater than five year category (Figure 1).

One might expect a replenished beach constructed to engineering design specifications (*i.e.* beach erosion control project) to exhibit greater longevity than a beach which has served as the disposal site for dredged material. Although most Pacific coast beaches are replenished in conjunction with dredging operations, the Pacific coast exhibits a percentage of beaches in the less than one year category similar to the percentages determined for the Atlantic and Gulf coasts, and a lower percentage of replenished beaches in the one to five year category than on the Atlantic or Gulf coasts (Figure 1). In the greater than five year category, however, the greater longevity of Pacific coast replenished beaches relative to Atlantic and Gulf coast beaches is overwhelming. Twenty-seven percent of the Pacific coast beaches fall into the greater than five year cat-

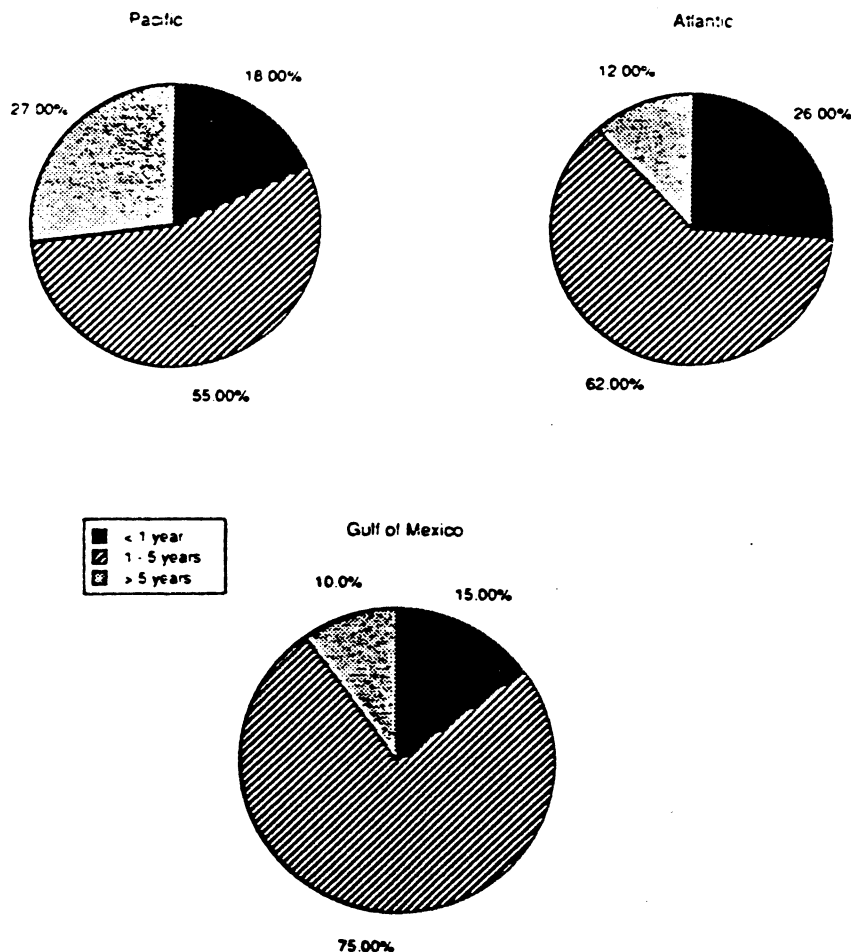


Figure 1. Durability of replenished beaches on the U.S. Atlantic, Gulf of Mexico, and Pacific coasts.

egory, as compared to 12% for the Atlantic coast and 10% for the Gulf coast.

REPLENISHMENT DESIGN PARAMETERS

Length

The length of replenished beaches has been considered an important control on artificial beach durability (DEAN, 1983, 1988). Longer beaches are assumed to experience greater longevities than shorter beaches. Atlantic coast replenished beaches range in length from one half mile (Figure Eight Island, NC) to 10.5 miles (Miami Beach, FL); the average length is three and two-tenths miles. Gulf coast beaches range in length from 1,000 feet (Redington Shores, FL) to five miles (Grand Isle, LA); the average length is one and two-tenths miles. Pacific coast replenished beaches range from two tenths of a mile (East Beach, CA) to six miles (Long Beach, CA); the average length is one and two-tenths miles.

In general, the shorter lengths of many Pacific coast beaches have not hindered the overall success (Figure 2). Initial analysis suggests no relationship between replenished beach longevity and replenished beach length on the Pacific coast. These findings concur with data from the Atlantic coast (Figure 2). Length may exert modest control over replenished beach durability on the Gulf coast (Figure 2). Although the reasons for these relationships are unclear, one possibility is that a lower degree of offshore movement of fill occurs along Gulf coast beaches than along Atlantic or Pacific coast replenished beaches.

Density

Fill density refers to the volume of sand per unit length of shoreline emplaced during the replenishment operation. Initial fill densities for the Atlantic coast range from 142,000 cy/mi (Myrtle Beach, SC) to 1,893,000 cy/mi (Carolina Beach, NC). The range on the Gulf coast is 15,000 cy/mi (Madeira Beach, FL) to 821,000 (Grand Isle, LA). On the Pacific coast, initial fill densities range from 20,000 cy/mi (Silver Strand, CA) to 2,128,000 cy/mi (Surfside-Sunset Beach, CA).

Cumulative density refers to the total volume

of sand per unit length of the shoreline emplaced through replenishment, including the initial replenishment and all subsequent nourishment projects. Pacific coast replenished beaches have the greatest cumulative fill densities, ranging from 250,000 cy/mi (Seal Beach, CA) to 26,221,000 cy/mi (Port Hueneme, CA); the mean Pacific coast density is approximately 1,632,000 cy/mi (Table 1). The Atlantic coast (Table 2) follows with cumulative densities ranging from 135,000 cy/mi (Ludlam Beach Island, NJ) to 5,325,000 cy/mi (Carolina Beach, NC); the mean Atlantic coast cumulative density is approximately 1,525,000 cy/mi. Gulf coast replenished beaches (Table 3) generally exhibit lower densities, ranging from 15,000 cy/mi (Galveston Island, TX) to 2,340,000 cy/mi (Perdido Key, FL). The mean cumulative density for Gulf coast replenished beaches is approximately 547,000 cy/mi.

Fill density is widely assumed to be directly related to replenished beach longevity. Empirical evidence indicates that greater fill densities may yield greater replenished beach longevities (STAUBLE and HOEL, 1986; LEONARD, 1988). On a regional scale, density of individual projects does not exert control over replenished beach longevity as measured by beach lifetime categories on either the Gulf coast (Figure 3) or the Pacific coast (Figure 3). On the Atlantic coast, however, density appears to influence replenished beach durability (Figure 3), particularly when durability is measured as the percent of fill remaining after the first year of project life (LEONARD *et al.*, 1990). On the Gulf coast, this measure supports the conclusion that density does not exert control over durability (DIXON and PILKEY, 1989). Unfortunately, measures of percent of fill remaining after one year could not be obtained for the Pacific coast.

Grain size

Grain size is also widely assumed to be an important replenishment design parameter and a major factor in determining the durability of a replenished beach. Yet, comparison of grain size versus durability of replenished beaches on the U.S. Atlantic, Gulf, and Pacific coasts reveals no evidence of a relationship. Possibly, this is because the range of grain sizes that has been used for beach replenishment is small.

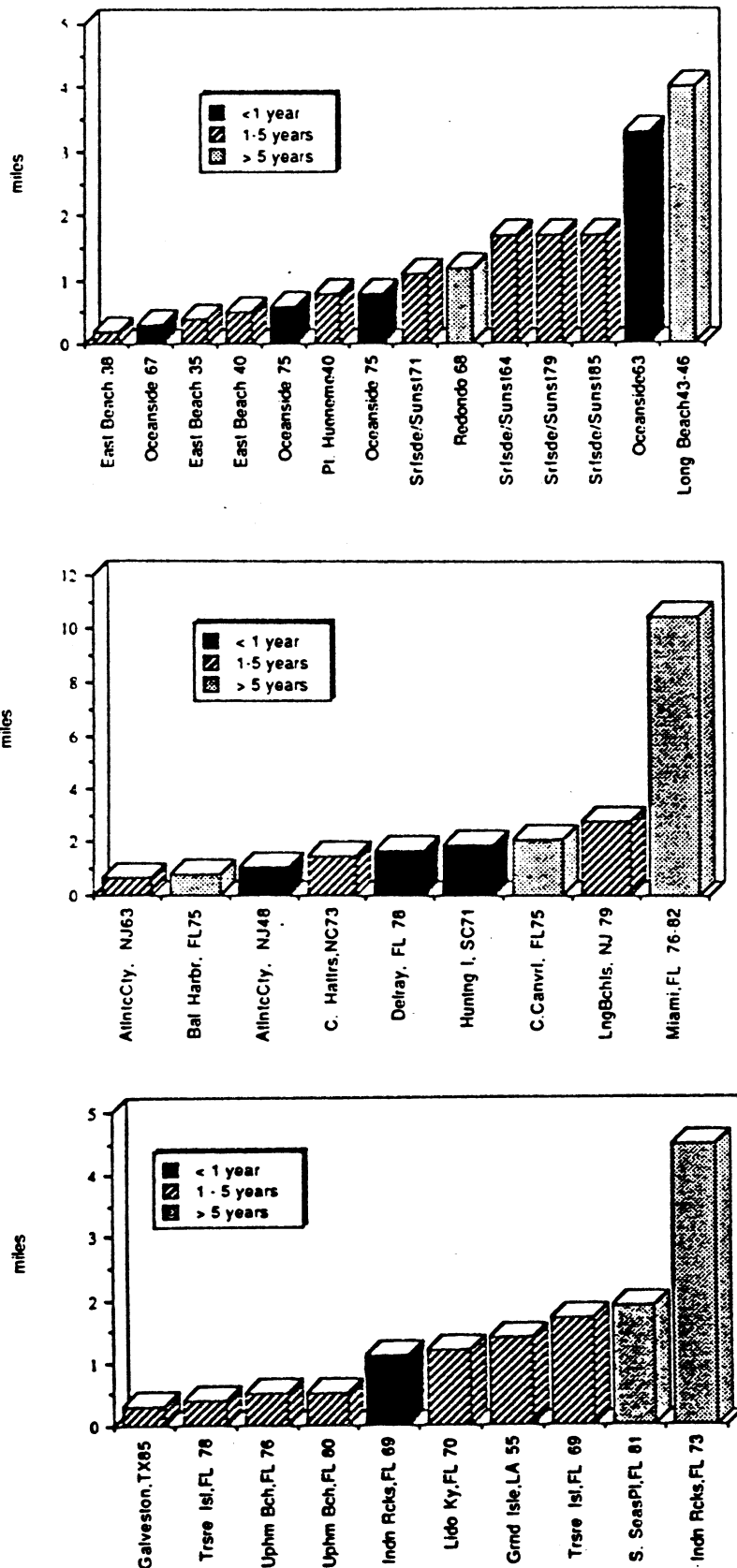


Figure 2. Durability of replenished beaches with respect to length for the U.S. Pacific (top), Atlantic (middle), and Gulf of Mexico (bottom) coasts.

Table 1. Cumulative fill densities and beach lengths for representative U.S. Pacific coast beaches.

Location	Length (mi)	Cuml. Density (1000's cy/mi)
Seal Beach, CA	1.0	250
Ocean Beach, CA*	0.3	342
San Buen Aventure Beach, CA	2.0	811
Long Beach, CA	4.0	1751
Redondo Beach, CA	1.2	2022
Imperial Beach, CA	1.0	2100
Santa Monica, CA	6.0	2360
Silver Strand, CA	2.0	2405
Doheny Beach, CA	1.0	2460
Oceanside, CA	3.3	3508
Surfside-Sunset Beach, CA	1.7	6566
Newport Beach, CA	1.6	7246
East Beach, CA*	0.5	7374
Carlsbad, CA	1.0	7857
Port Hueneme, CA*	0.8	26221

*beach length less than one mile

Possibly, also, as pointed out by STAUBLE and HOEL (1986), the standard measures of grain size used for fill material may be inaccurate in

Table 2. Cumulative fill densities and beach lengths for representative U.S. Atlantic coast beaches.

Location	Length (mi)	Cuml. Density (1000's cy/mi)
Ludlam Beach Island, NJ	6.7	135
Myrtle Beach, SC	6.0	142
Key Biscayne, FL	2.4	150
Great South Beach, NY	5.8	172
Southampton, NY	1.0	200
Indialantic-Melbourne, FL	2.0	257
Seabright-Monmouth Beach, NJ	5.0	287
Figure Eight Island, NC*	0.5	296
Jacksonville Beach, FL	7.3	316
Pompano, FL	3.2	336
Long Beach Island, NJ	3.0	355
Ocean City, MD	8.0	408
Sebastian Inlet, FL*	0.6	603
John U. Lloyd, FL	1.5	727
Fort Pierce, FL	1.3	819
Miami Beach, FL	10.5	1143
Jupiter Island, FL	5.0	1163
Cape Hatteras, NC	1.5	1208
Delray Beach, FL	2.5	1263
Canaveral Beach, FL	2.0	1458
Hunting Island, SC	2.0	1762
Bal Harbour, FL*	0.8	2116
Tybee Island, GA	1.5	2200
Sandy Hook, NJ*	0.6	3658
Wrightsville Beach, NC	2.0	3985
Ocean City, NJ	2.0	4268
Rockaway Beach, NY	5.0	4484
Atlantic City, NJ	1.0	4893
Carolina Beach, NC	2.0	5325

*beach length less than one mile

Table 3. Cumulative fill densities and beach lengths for representative U.S. Gulf of Mexico beaches.

Location	Length (mi)	Cuml. Density (1000's cy/mi)
Madeira Beach, FL	2.00	15
St. Petersburg Beach, FL*	0.50	50
Galveston Island, TX*	0.28	53
Venice Beach, FL*	0.17	147
Indian Rocks, FL	4.54	180
Clearwater Beach Island, FL*	0.57	321
Mexico Beach, FL*	0.65	337
Harrison County, MS	26.00	343
Clearwater Beach/Sand Key, FL	1.99	378
Captiva Island, FL	3.00	417
Mullet Key, FL	1.28	574
Lido Key, FL	1.20	792
Panama City Beach, FL*	0.95	935
Grand Isle, LA	1.40	1099
Upham Beach, FL*	0.53	1108
St. Joseph Spit, FL*	0.60	1387
Treasure Island, FL	1.74	2094
Perdido Key, FL	1.04	2340

*beach length less than one mile

characterizing entire fills.

Groins

On the Atlantic coast, groins appear to increase the longevity of replenished beaches. Examples of this include Edisto Beach, SC, where groins have been used in conjunction with replenishment, and Virginia Key, FL, where groins were added in 1977. In both cases, the presence of the groins is believed to have increased the stability of the emplaced fill, so that some of the fill was apparently still in place more than five years after emplacement.

Similarly, the Pacific coast has repeatedly experienced general success at least partly attributable to the presence of groins. Capitola, Cabullo Beach, Redondo Beach, and Newport Beach are examples of beaches where a terminal groin has assisted in stabilizing the beach. An exception to this is Imperial Beach, where a series of groins have not been effective countering erosion (CONVERSE, 1982). Although periodic losses occur (e.g. storm losses), the groins continue to trap littoral drift, thus reforming the beach. In addition, Pacific coast beaches benefit from a "natural" groin system provided by the rocky coastline. The effect of groins on replenished beach longevity could not be conclusively documented on the Gulf coast with available data.

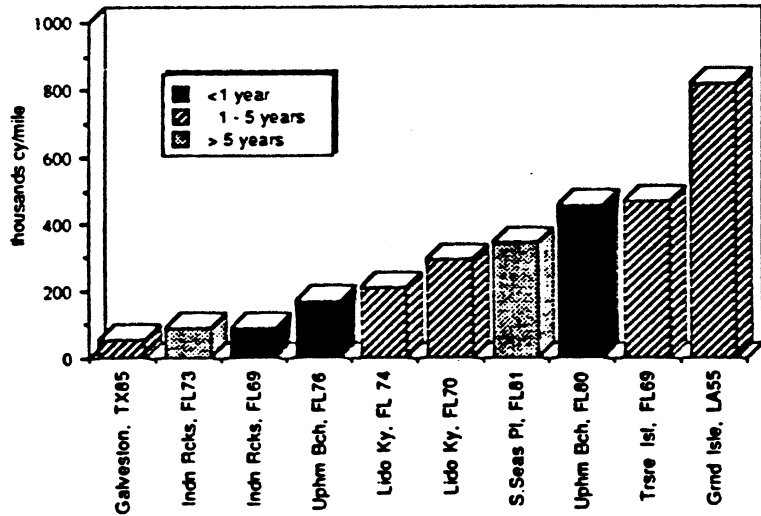
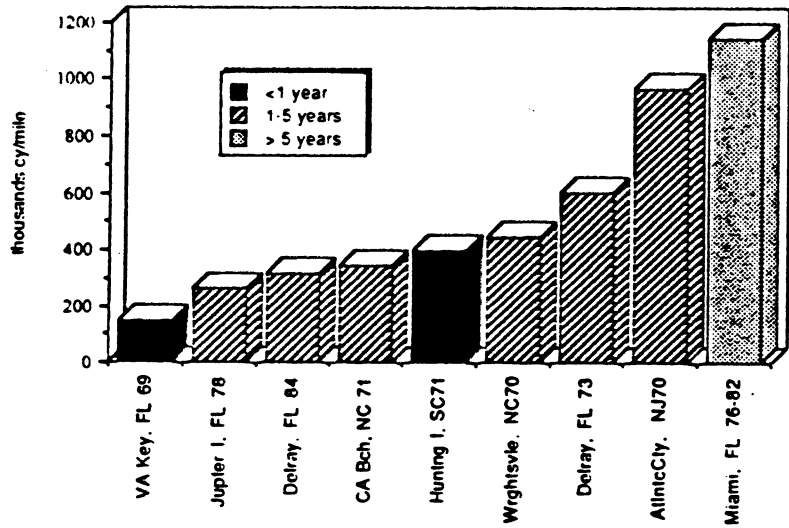
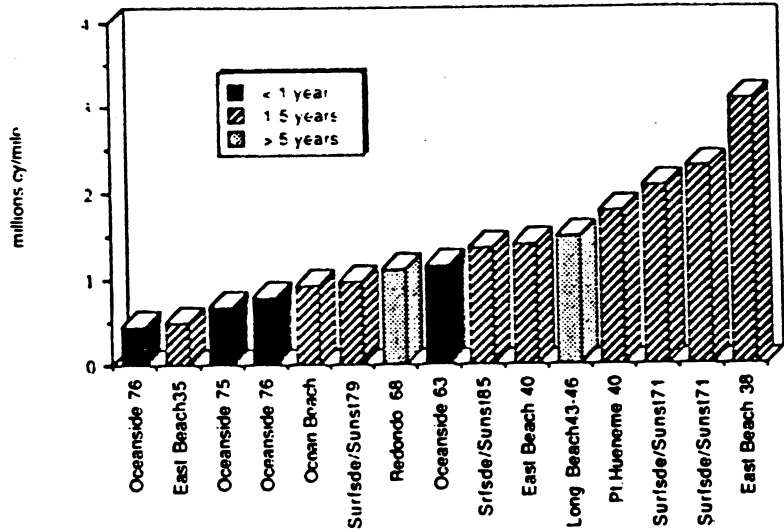


Figure 3. Durabiity of replenished beaches with respect to fill density for the U.S. Pacific (top), Atlantic (middle), and Gulf of Mexico (bottom) coasts.

Storm Activity

The effects of storms on movement of replenished beach sand has been well documented (e.g. ASHLEY *et al.*, 1987; WINTON *et al.*, 1981; LEONARD, 1988). LEONARD (1988) observed that the longevity of Atlantic coast replenished beaches is closely linked to the number of storms in the first year of a beach's existence, as well as the time between fill emplacement and the first storm event. Similarly, a correlation between high erosion rates on Pacific coast artificial beaches and the passage of major storms has been documented (CLAYTON, 1989).

Although no quantitative correlation between replenished beach longevity and storm activity has been documented for the Gulf coast, the Gulf coast beach replenishment literature cites storm activity 20% of the time to explain replenished shoreline changes (DIXON and PILKEY, 1989). In the Atlantic coast literature, unexpected storm activity is cited as the underlying reason for a beach's success or failure almost 47% of the time (LEONARD, 1988).

CASE STUDIES

Three beaches have been selected as representative nourished beaches in their respective geographical area (*i.e.* Atlantic, Gulf, Pacific). Selection criteria are: project was designed and constructed as part of a beach erosion control project (federal or non-federal), and monitoring data exist for the project. The beaches chosen are: Wrightsville Beach, NC (Atlantic coast); South Seas Plantation, FL (Gulf of Mexico coast); and Carlsbad, CA (Pacific coast) (Table 4).

Wrightsville Beach, North Carolina

Wrightsville Beach in New Hanover County, NC, has been subjected repeatedly to local and federal efforts to stabilize the shoreline (Table 4). The beach is approximately 4.19 mi in length, with an average dune height of 13 feet above mean sea level. Wrightsville Beach is one of the most frequently nourished beaches on the U.S. Atlantic coast, and is an example of a beach where local and federal efforts have more or less continuously kept a beach in place for 25

years. From 1939 to 1987, these efforts cost more than \$7,500,000.

Local attempts to stabilize Wrightsville Beach began as early as 1923 with the construction of five timber groins, and again in 1925 with the emplacement of an additional six concrete reinforced groins. The earliest documented replenishment operation occurred as the result of funding by local interests in 1939 when 700,000 cy of sand were placed on the beach. From 1939 to 1960, Wrightsville Beach experienced extensive shoreline retreat attributed to hurricanes in 1944, 1955, 1958, and 1960 (WINTON *et al.*, 1981). An estimated 500,000 cy of sand were placed on the beach between 1955 and 1960 in an attempt to compensate for the sand losses resulting from the passage of these storms (U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT, 1980).

Federal funding of replenishment at Wrightsville Beach began in 1962 when Congress authorized the construction of a combined beach erosion control/hurricane protection project along the 14,000 feet of Atlantic shoreline extending north from Masonboro Inlet (U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT, 1982). During initial construction, 2,993,000 cy of very coarse shelly sand was dredged from Banks Channel and placed on the beach. Subsequent nourishment operations in May and October 1966 were completed with 318,000 cy and 42,000 cy of sand dredged from Masonboro Inlet and the estuary behind neighboring Shell Island.

The construction of the first of the Masonboro Inlet jetties between 1965 and 1986 was said to adversely affect Wrightsville Beach project longevity. Since the jetty was at the "downstream" end of the beach, the cause of any adverse effect is unclear. The replenished beach experienced unexpectedly high rates of erosion, particularly along the northern 7,000 feet of the project (U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT, 1982). The total volume of sand emplaced during the 1966 fill (approximately 360,000 cy) was lost from the study area in two years (WINTON *et al.*, 1981). As a result, 1,377,000 cy of material were dredged from Banks Channel, and placed over almost three miles of the beach in 1970.

From 1970 to 1980, no additional fill was placed, although the shoreline had receded to

Table 4. List of beach replenishment operations in the three case studies in this paper.

Beach	Year	Volume (cy)	Length (mi)	Cost (\$)
Wrightsville Beach, NC	1939	700,000	2.6	\$98,000
	1955	38,000		
	1956	35,000		
	1957	304,000		
	1959	100,000	1.5	
	1965	2,993,100		\$739,339
	1966a	319,408		\$39,193
	1966b	42,700		\$8,448
	1970	1,436,553	3.2	\$518,775
	1980	540,715	1.3	\$520,456
	1981	1,249,699	1.3	\$4,427,792
	1986	900,000		\$1,209,000
	Captiva Island, FL	1961	110,000	
1962		7,000		
1962-1963		57,000	0.9	
1963		50,000		
1964-1967		80,000		\$100,000
1965		12,000		\$12,000
(South Seas Plantation)	1981	655,500	1.9	\$3,600,000
	1985	3,300	0.9	
	1988-1989	1,400,000	4.5	\$10,000,000
Carlsbad, CA	1954	4,080,000	1.0	\$2,500,000
	1955	111,000		
	1957	232,000		
	1960	371,000		
	1961	225,000		
	1963	308,000		
	1965	223,000		
	1967	160,000		
	1969	97,000		
	1972	200,000		
	1974	341,000		
	1976	392,000		
	1979	419,000		
	1979	430,667		
	1988	333,930	1.3	

the pre-1970 shoreline position by 1974 (WINTON *et al.*, 1981). In 1980, approximately 500,000 cy of medium to coarse sand were added as part of an emergency fill (U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT, 1982).

Continued losses required complete restoration of the original (1965) shore protection project. This replenishment was performed between December, 1980 and April, 1981. The return to the original design configuration required the dredging and placement of approximately 1,250,000 cy of sand from Masonboro Inlet over the northern 7,000 feet of the project area (U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT, 1982). The behavior of this fill is undocumented; however, subsequent losses required an additional 900,000 cy

of sand be placed on Wrightsville Beach in May, 1986.

Despite the varying combination of replenishment parameters incorporated in the replenishment design plans at Wrightsville Beach, the longevity of any one pumping operation has not exceeded four years. Analyses of repeated pumpings at Wrightsville Beach (LEONARD *et al.*, 1990) suggest that changes in grain size and length do not affect beach longevity to the extent that changes in fill volume and storm activity do.

South Seas Plantation, Captiva Island, Florida

South Seas Plantation on Captiva Island, Lee County, FL, is considered by many as the

replenishment "success story" or the "Miami Beach" of the Gulf of Mexico coast (Table 4). Redfish Pass, opened during a hurricane in 1926, bounds the northern end of the island. A somewhat ephemeral inlet, Blind Pass is the southern boundary of Captiva Island. South Seas Plantation is a privately owned resort on the northern end of Captiva Island.

The South Seas Plantation project is relatively long, had high unit construction costs, and has been remarkably durable. Because of its durability, South Seas Plantation is something of an anomaly among Gulf coast projects, as Miami Beach is among Atlantic coast projects. South Seas Plantation is the only open ocean Gulf project which falls into the greater than five year beach lifetime category (DIXON and PILKEY, 1989). The fill lost only about 31% of its original volume in five years.

Previous stabilization attempts at Captiva Island include the installation of 134 Budd Wall concrete "dog-bone" groins in 1961 (OLSEN, 1982). Some of these groins fall within the South Seas Plantation project area, and were covered by fill. Most of the efforts at Captiva have been locally and/or privately funded groins, revetments, seawalls, and small fills along various small stretches of shoreline. A federally funded beach erosion control project received Congressional authorization in 1970, but was never implemented due to lack of local cooperation (STEVENS and OLSEN, 1979).

The South Seas Plantation project was constructed to an engineering design, and has been monitored. Construction of the project took place from July to October, 1981. The project is nearly two miles long. Another exceptional fact about this project is that it was funded fully by private resources at a cost of about \$3,600,000 (OLSEN, 1982). The hydraulically emplaced 650,000 cy of fill was taken from the ebb tidal delta of Redfish Pass at the north end of the project area. The southern end of the project is about two miles from Blind Pass. A "terminal groin" was constructed at the north end of the project to retard transport of fill material into Redfish Pass.

The long life of the project is attributed to grain size of the fill material (OLSEN, 1982). The fill material was nearly identical to native, with an excess of coarse shell (STAUBLE and HOEL, 1986). Yet, attributing the longevity of the project to grain size may not tell the whole

story; other factors may contribute to the longevity of the project. The project is long on a Gulf coast scale. Analyses suggest that longer beaches may experience longer lifetimes on the Gulf coast (DIXON and PILKEY, 1989). Fill retention might also be attributed to the presence of shore perpendicular structures beneath and at the northern end of the fill. Monitoring shows relative accretion in the northern section of the fill and erosion in the southern section (STAUBLE and HOEL, 1986). Perhaps the terminal groin at the northern end is trapping sediment.

A beach erosion control project was constructed from August, 1988 through May, 1989 over the length of Captiva Island, including most of South Seas Plantation (HAGERUP, 1989) (Table 4). The project covers four and a half miles, and used 1,400,000 cy of sand borrowed from Redfish Pass. Cost of this most recent Captiva project was about \$10,000,000 from private, local, and state funds.

Carlsbad, California

Carlsbad on the Pacific Ocean in San Diego County, CA, lies to the south of Oceanside Harbor adjacent to the Agua Hedionda Lagoon. The Carlsbad beach has received replenishment material from the Lagoon since 1944 (CLAYTON, 1989) (Table 4). Since 1955, over 4,000,000 cy of material have been emplaced at Carlsbad in conjunction with channel maintenance (CAHILL *et al.*, 1989), but not to a specific design. The fill left the beach disposal site soon after each nourishment. Rapid loss of fill is attributed to fine grain size.

In 1988, the Carlsbad shoreline was replenished to engineering design specifications. Project length is an approximate total of 1.25 miles over three separate reaches. Since construction, the project has been monitored (CAHILL *et al.*, 1989). About 330,000 cy of fill was emplaced from February to April, 1988. The project included three areas, two of which were bounded on their seaward edge by dikes built of native cobbles (three to six inches in diameter). Fill was pumped to the surf zone of the third area as it had been in past operations. Fill disappeared almost immediately from the third area.

The two areas with dikes showed better retention of fill. One of the dikes failed within