# RESPONDING TO AN SOS - SAVE OUR SHORES

by
MG E. R. Heiberg III, M, ASCE[1]
L. A. Duscha, E, ASCE[2]
J. H. Lockhart, Jr, M, ASCE[3]

## ABSTRACT

The rising sea level issue affecting U.S. coastal policy is reviewed, and the U. S. Army Corps of Engineers coastal role is summarized. Three case studies are provided to demonstrate the successful application of several structural devices available to solve different coastal problems. The coastal engineer, and other scientists, should contribute significantly to the information upon which society bases its decisions on use of the shoreline.

## INTRODUCTION

The coastal zone represents the most rapidly growing region in the United States in terms of population and wealth. Forty-two percent of the population lives in this zone (U.S. Dept. Comm., 1978). Twelve of the 13 largest cities are located in the 30 coastal states. Increasing pressures of population and development are evident in the competition for use of the shoreline and coastal zone. Pressure is exerted for public access and use of the shore: for development of private residences and high-rise apartments; for construction of facilities for commercial, industrial, and transportation purposes; and for the preservation of aesthetic and natural values of shore and marsh areas (HD No. 93-121, 1973).

Prior to the mid-1800's, the sea usually provided the most convenient and economic means of transportation and communication, and cities grew in the vicinity of the ports. Industrialization and improved inland transportation brought increased population density to the coastal centers. Accommodating the expanding urbanization and the accompanying essential services required additional use of the estuaries and adjacent ocean shores. Harbor entrances and channels were improved and facilities to dispose of industrial and urban waste were constructed. However, very little of the outer coast was developed until the automobile and the airplane, together with a great increase in leisure time, made all coasts accessible and increased the demand for space.

[1]Deputy Chief of Engineers, Headquarters, Department of the Army, Corps of Engineers, Washington, D.C.

[2]Chief, Engineering Division, Headquarters, Department of the Army, Corps of Engineers, Washington, D.C.

[3]Civil Engineer, Hydraulic Design Section, Headquarters, Department of the Army, Corps of Engineers, Washington, D.C.

## PRESSURES TO ABANDON THE SHORELINE

Many U.S. Citizens (individuals and groups) are lobbying publicly for abandonment of the shores and barrier islands of the United States. They reason that rising sea levels, an overly large government support system for protection, utility and transportation subsidies, and the potential devastation of development by coastal storms combine to justify this position. They explain that the barrier islands are transitory and that construction of permanent structures in such environments is futile. They conclude that the obvious solution is abandonment, to be achieved by prohibiting future development and circumscribing rehabilitation of damage. This stance is promoted through the media and through some elements of the scientific community as the only sensible means of saving our shorelines.

What has been overlooked in the debate regarding development in the coastal zone is that the desire for the enjoyment and habitation of the shore seems to be deeply ingrained in the nature of people. Furthermore, the satisfaction of this desire is now within the means of a large segment of the United States populace. The demand for space at the shore will likely be met, eventually, despite temporary obstruction by regulations, policies, or laws. Our objective should be to satisfy this demand without harming those features which make the coast attractive and without so limiting the available sandy shoreline as to make it economically unavailable to lower income families. Laws and policies which prohibit or strongly deter any increase in the shore areas open to development and public use will undoubtedly lead to an increase of land values in the already available coastal areas. Concomitant increases in the price of the facilities and services economically appropriate to those land values will increasingly restrict the number of people who can afford such recreation or who can afford to live there. Overcrowding and unacceptable environmental stress in the areas remaining open and easily accessible to the general public will soon lead to extension of restrictions to these areas. Clearly, some mechanism is required to determine the proper balance between development and preservation.

## RISING SEA LEVELS

A basic rationale used to support the move to abandon the barrier islands and shores of the United States is that of rising sea level. The reasoning is that the sea level has been rising and will continue to do so in the near and long term. With the increasing sea level, the barrier islands are migrating, rolling over themselves like a caterpillar tractor tread, toward shore. All of man's efforts to stem or counter such eventualities are claimed to be futile and a waste of resources. Eustatic changes in sea level are a result of worldwide events which cause changes in either the capacity of the ocean basins or the volume of the ocean waters (Hands, 1977). The direct cause of this change is veiled in the passage of time, and only recently has man developed the technology and data with which to speculate as to the root cause or causes.

Various measurements indicate that sea level has been fairly stable over the past 2,000 years, probably within a range of about one meter

(O'Brien, 1982). Over the period of 1940 to 1975, tide gage data around the US. coast indicate a eustatic rise in the mean level of 1.15 dynamic mm per year (0.115 meter per century ) (Hicks, 1978). This effect is frequently linked to melting of the polar ice caps, but also includes such factors as plate tectonics, changes in ocean temperatures and densities, climatic changes, underground withdrawal of liquids and gases, compaction, and other phenomena. The magnitude of long term mean sea level change due to various causes, observed at selected locations, is as follows.

Land Subsidence Due to Oil and Gas Production (Hands '77)

| Location | Subsidence Rate (CM/YR) | Period (Yr) | References |
|---|---|---|---|
| Long Beach, CA | 22 | 1926-67 | Allen & Mayuga '69<br>Mayuga & Allen '69 |
| Texas City and Galveston, TX | 13 | 1964-73 | Poland '73 |
| San Jacinto Bay, TX | 12 | 1917-25 | Pratt & Johnson '26 |
| Houston & Baytown, TX | 6 | 1943-64 | Gabrysch '69<br>Small '63 |
| Lake Maracaibo, Venezuela | 0.9 | 1930-75 | Nunez & Escojiido '76 |
| Niigata, Japan | 0.14 | 1900-60 | Comm. for Invest. of Earth Subsidence in Niigata '58 |

Land Subsidence Due to Excessive Ground Water Withdrawal (Hands '77)

| Location | Subsidence Rate (CM/YR) | Period | Reference |
|---|---|---|---|
| Texas City & Galveston, TX | 13 | 1964-73 | Poland '73 |
| Houston & Baytown, TX | 6 | 1943-64 | Gabrysch '69<br>Small '63 |
| South Shore San Francisco Bay, CA | 4 | 1934-67 | Poland '73<br>Poland & Davis '69 |
| Osaka Bay, Japan | 3 | 1885-1928 | Poland & Davis '69 |
| New Orleans, LA | 2 | 1938-64 | Kazmann & Heath '68 |
| Nobi Plain, Japan | 2 | 1888-1973 | Iida, et al '76 |

| | | | |
|---|---|---|---|
| Venice, Italy | 0.2 | 1926-42 | Berghinz '71 |
| | 0.3 | 1942-52 | |
| | 0.5 | 1953-61 | |

Land Subsidence Due to Glacioisostatic Causes (Hands '77)

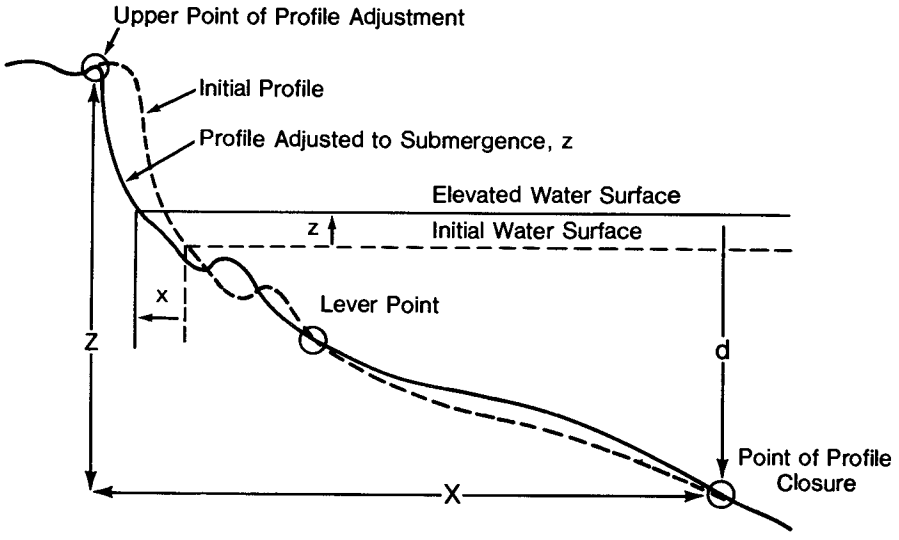
| Location | Subsidence Rate (CM/YR) | Period | Reference |
|---|---|---|---|
| Netherlands | 3-4 | 1880-1930's | Edelman '57 |
| Great Lakes, US. | 0.3 | 1878-1977 | Hands '77 |

Subsidence can occure quite rapidly, as was the case at the Cook Inlet, Kodiak Island, Kenai Peninsula, Alaska, where the March 1964 earthquake lowered about 100,000 square kilometers about 1 meter (Stanley '68). On the Great Lakes, long term climatic cycles (10-30 yrs) can effect a relative subsidence of the land beneath the water (Hands '77). These areas of relatively rapid change require special attention for coastal activities.

A search of recent literature did not reveal that any of the investigations of mean sea level change have ventured a forecast of probable change during the next century (Keehn,1982). Considering the uncertainty associated with past eustatic sea level changes and the scientific uncertainty as to the predominant cause of change, it seems wiser to base public policy on the assumption that mean eustatic sea level will continue to rise during the next century at the same rate experienced over the past century. When more reliable predictive models exist, then public policy can be revisited.

While the physical consequences of mean sea level rise on sandy shores exposed to the open ocean may be significant, storms and their consequences are still the primary concern. Figure 1 illustrates the nature of shore change due to sea level rise and its caption explains the derivation of the formula, known as the Brunn rule (Brunn, 1962). Generally, the landward retreat of the shore (X), is many times the amount of the rise Z. The disproportionality of X to Z will vary from beach to beach, normally ranging hetween 10:1 and 100:1. The concept underlying the Brunn rule seems sound from the standpoint of the processes involved; measurements in the Great Lakes have confirmed this quantitative relationship.

Figure 2, showing profiles of the beach near the U.S. Army Corps of Engineers research pier at Duck, North Carolina during the year 1981, illustrates the difficulty of obtaining a direct measurement of the shore changes attributed to changes in mean sea level. The combined effects of waves and tides during the year were a horizontal movement of the high water line of 39.6 meters and a maximum change of profile elevation of 2.5 meters. Tide gages at Portsmouth, Virginia, north of the pier, and Charleston, South Carolina, south of the pier, had recorded a trend of mean sea level rise of about 3.9 mm per year (Hicks,1978). The Brunn rule indicates an average annual shoreline retreat of 0.15 meters per year. Although this change is unidentifiable in such a short period measurement, the effect, if continued over a




**Use of Bruun Rule (Bruun, 1962). Sketch of Profile Measurements Required to Predict Shore Adjustment to a Change in Water Level Elevation. Providing There Is no Net Gain or Loss Outside the Control Volume, Constancy of Profile Shape Requires That the Ultimate Shore Retreat x Be Equal to zX/Z**

FIGURE NO. 1

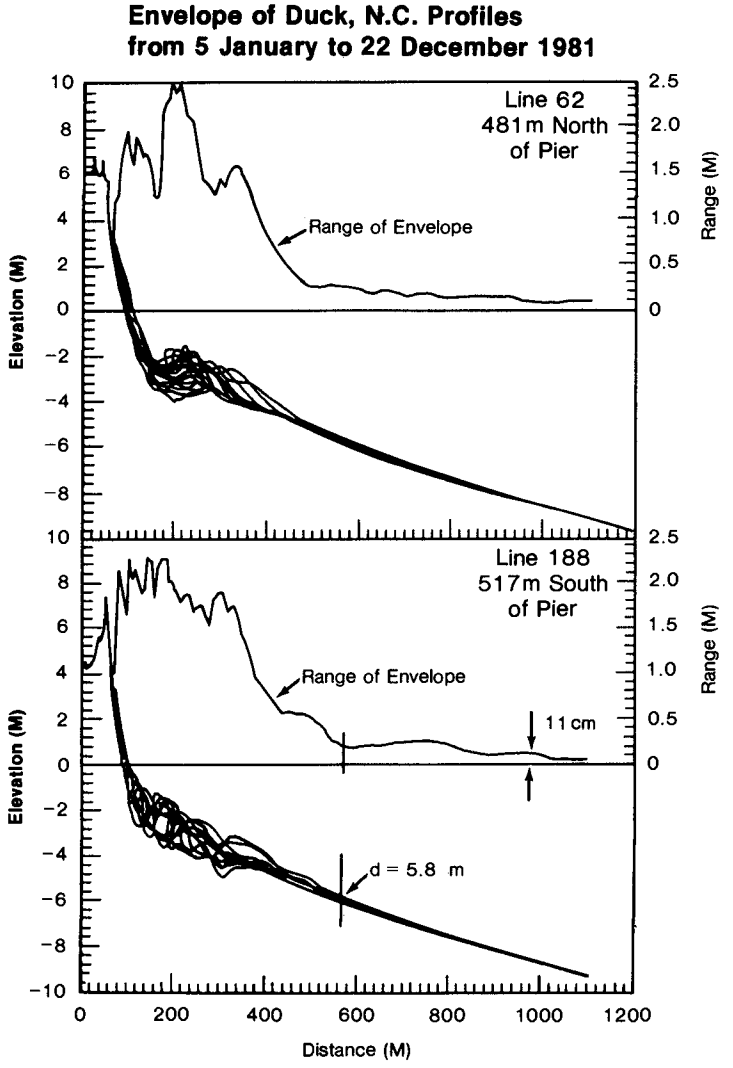



FIGURE NO. 2

(William A. Birkmeier Personal Correspondence, June, 1982)

century, is 15 meters of shoreline retreat. Shoreline change studies on Bodie Island south of the pier for the period 1937-1975 and on Hatteras Island for the period 1852-1946 indicate that actual shoreline retreat rates are 2 to 5 times greater than the 0.15 meter per year which may be attributed to sea level rise.

A trend noted in the comparison of the 1852 and 1946 maps of Hatteras Island was a general decrease in the total subaerial land mass of the barrier island, which indicated erosion on both the ocean and bay sides. In addition, the portion of the island that was marsh increased from approximately 26.6% in 1852 to 35.1% in 1946. This increase in marsh area occurred primarily as a result of seaward propagation of the marsh into low areas that were classified as upland in 1852. Overwash and aeolian processes were evident along the marsh line, but their effects on the island characteristics were minor compared to the ocean and bay shoreline erosion and marsh grass propagation seaward over the barrier island. These changes do not support the generalized theory of barrier island migration, at least within the time frame of several generations. (US Army Corps of Engineers, Wilmington, N.C. 1980)

The question at issue is not whether a rising sea level would cause erosion, hut rather what the prohahle course of sea level change will be over the next century. So far no one has been willing to make such a prediction. The National Academy of Sciences, through its Marine Board, has established a blue ribbon committee, chaired by Professor Rohert G. Dean of the University of Florida, to investigate the sea level change phenomena and to determine the efficacy of forecasting such changes.

## RESOURCES MANAGEMENT

As indicated above, the growing population and growing demands for coastal vacations are providing for increased development pressure along our coastlines. The mechanisms used to balance these demands for coastal resources and to manage the utilization of coastal areas are incorporated within the governmental systems at all levels. As example, at the local level, zoning ordinances are used to regulate the type and density of development; at the state level, highway and bridge construction determines the accessability of coastal areas; and at the national level, significant historical, ecological, and scenic areas are preserved through acquisition and management or by withholding national subsidies. A law prohibiting the Federal Government from funding commercial and residential growth on undeveloped barrier beaches and islands was signed by the President on October 18, 1982. More than 190 pieces of land stretching through 16 states, incompasing 700 miles of coastal property are affected. The law specifies which portions of those islands should no longer receive Federal flood insurance or money for water and sewer systems.

The influence exerted on these barrier systems by changes in sea level will depend on the magnitude and direction (higher or lower) of future projected trends and the confidence in the projections exhibited by the scientific community and conveyed to the government decision makers. The shoreline and water level changes which accompany seasonal storms and variations in the along-shore littoral sand supply, as influenced hy nature and man, are normally much greater than the effects of mean sea

level change. These changes, and the attendant environmental consequences have influenced coastal resources management up to now. It is these changes, with the exception of some local areas such as those listed previously, rather than mean sea level changes, that cause the primary adverse effects with which rescue of the shore areas must deal.

## THE CORPS ROLE

Nearly 100 years ago, the United States government, recognizing the need to maintain navigable waterways, gave the U.S. Army Corps of Engineers the mandate to develop and protect the Nation's waterways. At that time, the interests of navigation were considered paramount. Many of the affected beach areas were then undeveloped, and there had been little systematic study of the littoral processes involved.

The 1930 River and Harbor Act enacted by Congress provided a broader Federal role in shore protection. The Corps of Engineers was empowered to make studies of beach erosion problems at the request of, and in cooperation with, cities, counties, or states. In 1946, Federal contributions to construction costs were permitted when projects protected publicly-owned shores, or if such protection would result in public benefits. The Corps mission was expanded to include hurricane flood protection in 1955. Contained within the 1968 Federal legislation was the mission to prevent or mitigate shore damage attributable to Federal navigation works. An objective evaluation of the cost of Federal shoreline programs administered by the U.S. Army Corps of Engineers will show that a conscientious effort has been made to insure that public benefits substantially outweigh the public cost.

## COASTAL STRUCTURES

Shoreline restoration and stabilization structures built with the assistance of Federal dollars and by the Corps of Engineers are tested by: (1) an economic analysis which indicates the benefit-to-cost ratio is greater than one; (2) an engineering analysis and an environmental assessment based on current technology, which has had the benefit of at least one and often two levels of review, usually including that of the Coastal Engineering Research Center; (3) a cost-sharing policy which reduces the Federal share--normally 50 percent--by the ratio of private to total benefits; and (4) a policy which requires public beach access and public beach use as a condition for Federal aid.

## EFFECTIVENESS OF COASTAL STRUCTURES

The Corps of Engineers has constructed more than 800 jetties, breakwaters, and coastal groins. More than 80 beach fill projects have been constructed. Early coastal structures were mostly breakwaters to protect anchorages from wave action, jetties to stabilize the location of entrance channels, and sea walls to protect exposed port or urban areas. Most of these were built in support of navigation, and many have performed their intended functions for nearly a century. Structures to protect or stabilize sections of the open coast (groins, revetments, seawalls, and beach fills) are generally of more recent origin. Examples of long terms of effective service are understandably more limited. However, the record of coastal structures is generally one of

overall success, rather than of failure. It is, of course, true that coastal processes have become better understood in recent years and design techniques have improved correspondingly.

We have referred above to a large number of projects. If we had a huge number of failures, then we would have a national disaster. To list and comment on even the 100 or so projects constructed prior to 1900 is impractical for this presentation. We will instead focus on only three projects. One was an almost immediate success, one has evolved into a very successful project, and one is a recent project, which promises considerable success. The three projects perform different functions and illustrate a relatively wide variety of coastal structures.

## GALVESTON, TEXAS, SEAWALL

At the turn of the century, Galveston, Texas, had a population of about 38,000. The first floors of residents and businesses were elevated as a safeguard against storm-induced flooding, which the city occasionally suffered. On September 8, 1900, a hurricane struck Galveston with a storm surge of 4.6 meters msl, accompanied by winds of up to 40.7 meters per second. The storm left in its wake 3,600 demolished buildings and about 6,000 people dead. The city rebuilt and protected itself with a seawall (See Figure 3). On August 16-17, 1915, another severe hurricane swept across Galveston. The winds exceeded 26.8 meters per second for over 19 hours and exceeded 31.3 meters per second for over 9 hours. By comparison the September 1900 hurricane winds had exceeded 26.8 meters per second for only about 7 hours, and its surge height was 8.9 centimeters less than the 1915 storm surge. In striking contrast to the less severe hurricane of 1900, there was comparatively small damage and few casualties (12) within the city in 1915. There was considerable scour along the toe of the seawall and the apron was undermined in places. However, the concrete section of the wall suffered no major damage. The seawall undeniably paid for itself during this one storm (Davis, 1961).

## SANTA BARBARA HARBOR, CALIFORNIA

During the 1920's, the beaches of Santa Barbara, California, (Figure 4) and the communities to the east were developed with expensive public improvements and private beach homes. There was a demand for a protected harbor for small boats because severe storms and the open coastline made the Santa Barbara roadstead unusable as a safe moorage. During 1927-29, the city constructed a breakwater offshore to protect a harbor area of about 34 hectares. The breakwater was about 550 meters long and had a short arm at its western end which curved landward. A 183-meter gap to permit an unobstructed flow of sand along the beach was left between this arm of the breakwater and land.

On completion of the offshore section, the breakwater cast a "wave shadow" which caused the littoral transport to be deposited and sand began to shoal the harbor. Complete filling of the harbor was feared, and the breakwater gap was closed. Figure 5 shows the harbor shortly afterwards in 1930. By 1933, the beach had accreted to the bend in the breakwater and a shoal was building into the harbor from the eastern end of the breakwater. At the same time, the beaches to the east of the

FIGURE 3. Galveston Seawall. 1976.

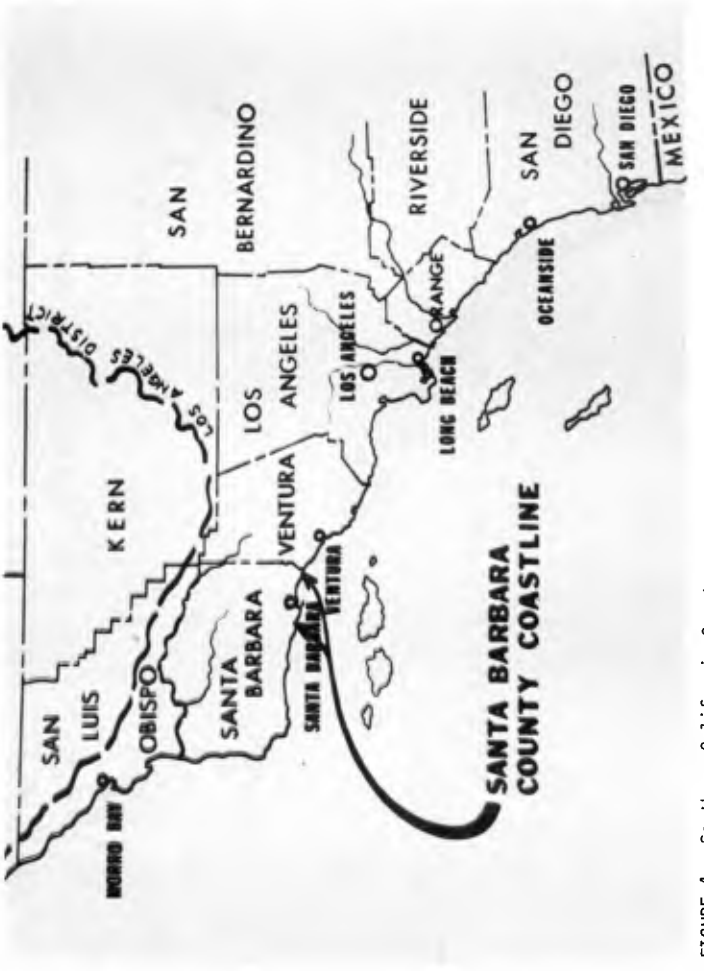



FIGURE 4. Southern California Coast


FIGURE 5. Santa Barbara Harbor, California - 1930.

FIGURE 6. Santa Barbara Harbor, California - 1938

FIGURE 7. Santa Barbara Harbor, California - 1970

harbor began to erode. Riprap walls and groins were constructed to protect the eroding areas. Ultimately, erosion proceeded eastward some 21 kilometers. In 1935, approximately 154,000 cubic meters of material were removed from the shoal by hopper dredge and placed as close to shore as possible. It was hoped that the sand would move shoreward and help replace the beach. The sand was placed in 6.1 meters of water, and very little, if any, reached shore. Years afterwards it was still possible to identify the disposal area when soundings were taken. Figure 6 is a 1938 photograph of the harbor. Initiation of periodic pipeline dredging of the shoal followed shortly thereafter. The material is placed east of the harbor beyond the wave shadow of the breakwater and the eastern beaches have recovered. Besides providing about 700 boat berths in an area of increasing demand (see Figure 7), the project has restored beach property values far in excess of expenditures and is now considered successful (Penfield, 1960).

This project was a first in "sand bypass" engineering. The processes involved were not as clear then as they are today, some 50 years later. The shoreline at Santa Barbara is shielded by the Channel Islands which shelter approximately 40 kilometers of the coast. Normal wave action enters the Santa Barbara Channel from the west and induces an eastward littoral transport through most of the year. However, storms may occasionally reverse the littoral transport for short periods. This situation was not clear when the breakwater was designed. Due to the limited wave exposure behind the Channnel Islands, the littoral drift at Santa Barbara is almost uni-directional and sand bypassing presents a relatively simple challenge. In other situations, where the littoral drift reverses over extended periods, as often is the case, the gross littoral transport quantity may be many times the net littoral transport quantity and the problems of designing a sand bypass system are an order of magnitude more difficult than the problems at Santa Barbara.

DADE COUNTY, FLORIDA

The beach erosion control and hurricane surge protection project for Dade County, Florida, provides a good example of the recent technology in beach fills.

Responding to public concern, the State of Florida, Dade County, and the Corps of Engineers cooperated in constructing the Dade County project, which is designed to withstand a hurricane similar to the 1926 hurricane, the maximum recorded at Miami, Florida. The project provides beach erosion control and hurricane surge protection by the initial placement of 10.7 million cubic meters of sand to form a protective and recreational beach and protective dune for 16.9 kilometers of Miami Beach shore. The project provides for a dune 6.1 meters wide at the crown at an elevation 3.5 meters above mean low water and a level berm 15.2 meters wide at an elevation of 2.7 meters above mean low water with a natural seaward slope (see Figure 8). The beach would be nourished, as needed, to compensate for erosion losses estimated at an annual rate of 161,000 cubic meters. All project fill came from borrow areas 1,800 to 3,700 meters offshore. The fill material was pumped ashore through a submerged discharge line hy a floating hydraulic dredge (US Army Corps of Engineers, Jacksonville, 1980).

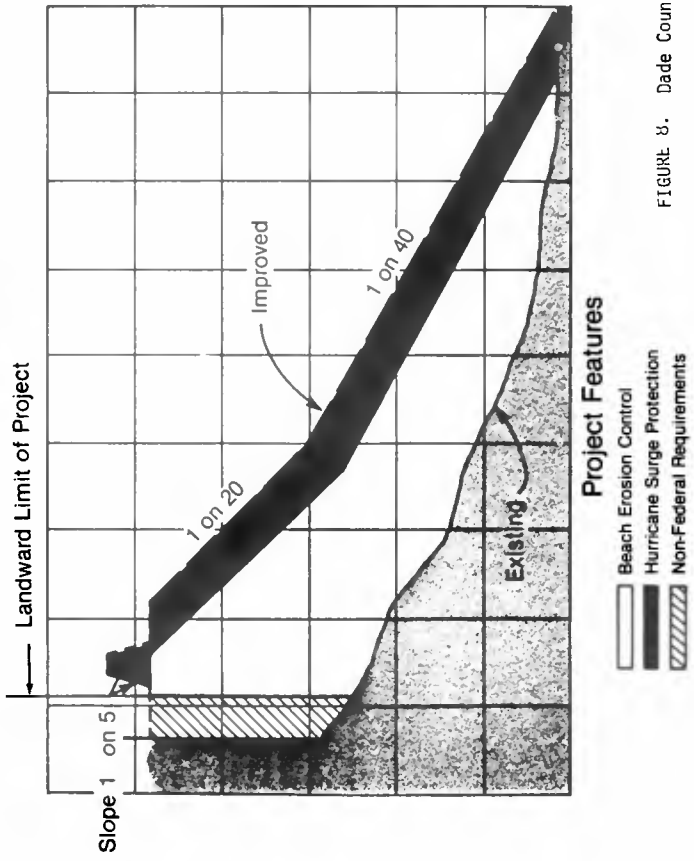



FIGURE 8. Dade County, Florida

FIGURE 9. Miami Beach, Dade County, Florida. Storm Wave Attack before project construction.

FIGURE 10. Miami Beach, Dade County, Florida, before project construction

FIGURE 11. Miami Beach, Dade County, Florida, after project construction.

What is the public receiving for the investment? To begin with, the beach (see Figures 9, 10 and 11), at a cost to date of $2.4 million per kilometer, is protecting property valued at $146 million per kilometer. Protection inherently enhances property by increasing its value on the market, by optimizing its income potential, and by increasing its tax contribution to government. Over one million international tourists visited the beach in 1980 and spent over $200 million, and combined with domestic tourist spending, this amount grows to $500 million, or $29.6 million per kilometer per year. All these factors account for a benefit to the public of $23.1 million per year. Miami Beach represents an excellent example of the merging of governmental functions, private investment, disparate interests, and public demands in providing a high degree of protection and a recreation resource for the maximum use and enjoyment by the greatest number of people. By duplicating nature's own process, the beach fill remains in reasonable harmony with nature while protecting property and enhancing recreational opportunities (Adams, 1981).

This brief review illustrates that coastal erosion and catastrophic flooding can, in fact, be controlled. With proper mitigating actions, the coastal area can be utilized commercially and recreationally. Where circumstances warrant, the beach can be restored and maintained. The Corps of Engineers procedures insure that such efforts are only undertaken in cases that will produce greater economic efficiency than relocation, "no action," or other alternatives. Further, 1980's decision-making insures that social and environmental impacts are within acceptable limits. With almost 13,000 kilometers of the United States shoreline experiencing significant erosion, there are numerous areas where rescue of the shore is not only possible, but economically desirable (HD No.93-121,1973). At the same time, today's improved understanding of coastal processes makes it unlikely that costly mistakes will be made.

## CONCLUSIONS

The processes active at the ocean's shores range in scale from granular to global and from seconds to centuries. Our planning, design, and construction in the coastal zone improves with an ever increasing understanding of this very dynamic environment. Society, through governmental, benevolent, and market-place mechanisms, makes the decisions on how the coasts will be used. Coastal engineers and other scientists must maintain a continuous, objective pursuit of factual information and make it available in an unbiased way for the judgment of society in arriving at the decisions that must be made. By supporting research and investigative efforts focused on better understanding the dynamic and wide range of processes present at the shore, and by utilizing this knowledge in guiding our activities, we can better plan and design to save our shores for ourselves and future generations.

## ACKNOWLEDGEMENT

The authors wish to thank Dean M. P. O'Brien for his generous assistance and many helpful suggestions. We also wish to thank the other Corps of Engineers employees for their efforts in typing, editing, and illustrating the paper. Many constructive comments were provided by the

staff of the South Pacific Division, Galveston District, Jacksonville District, the Waterways Experiment Station, and the Coastal Engineering Research Center. The views expressed in the paper are our own and should not be construed as reflecting official U.S. Army Corps of Engineers policy.

## BIBLIOGRAPHY

Adams, Colonel James W. R., 1981, "Florida's Beach Program at the Crossroads," Shore and Beach, Journal of the American Shore and Beach Preservation Association, V. 49, No. 2, Apr 81, pp. 10-14.

Allen, Dennis R. and Mayuga, Manuel N., 1969, "The Mechanics of Compaction and Rebound, Wilmington Oil Field, Long Beach, CA, USA", in Symposium of Tokyo, 1969-Land Subsidence, Vol. 2, International Association of Hydrologic Scientists, Pub. 89, pp. 410-422.

Berghinz, Carlo, 1971, "Venice is Sinking into the Sea," Civil Engineering, March 1971, pp. 67-71.

Bruun, P.,"Sea Level Rise as a Cause of Erosion," Journal of the Waterways and Harbors Division, American Society of Civil Engineers, V. WWI, Feb 1962, pp. 117-133.

Committee for Investigation of Earth Level Subsidence in Niigata, 1958, "On Subsidence of the Earth Level in Niigata Area, Report No. 1: Niigata, Japan," Bureau of 1st Harbor Construction, Ministry of Transportation, 50 p.

Davis, Albert B., Jr., 1961, "The Galveston Sea Wall," Shore and Beach, Journal of the American Shore and Beach Preservation Association, V. 29, No. 2, Oct 61, pp. 6-13.

Edelman, T., 1954, "Tectonic Movements as Resulting from the Comparison of Two Precision Levelings," Geol. in Mijnboww, V. 16, No. 6, pp. 209-212.

Gabrysh, Robert K., 1969, "Land-Surface Subsidence in the Houston-Galveston Region Texas," in Symposium of Tokyo, 1969-Land Subsidence, V. 1, Interna. Assoc. Sci. Hydrology, Pub. 88, pp. 43-54.

Global future: Time To Act, Council on Environmental Quality, United States Department of State, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, January 1981.

Hands, Edward B. (1977), Implications of Submergence for Coastal Engineers, Coastal Sediments '77 Proceedings, Fifth Symposium of the Waterways, Port, Coastal, and Ocean Division of the A.S.C.E., pp. 149-166.

Hands, Edward B., 1981, "Predicting Adjustments in Shore and Offshore Sand Profiles on the Great Lakes," Coastal Engineering Technical Aid No. 81-4, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Virginia, Jan 81.

Hicks, Steacy D., 1978," An Average Geopotential Sea Level Series for the United States, Journal of Geophysical Research, V. 83, No C3, pp 1377-1379, Mar 20, 1978.

Holdahl, S. R. and Nancy L. Morrison, 1974, "Regional Investigations of Vertical Crustal Movements in the U.S., Using Precise Relevelings and Marograph Data," Tectonophysics, V. 23, pp. 373-390.

House Document No.93-121, 93d Congress, 1st session, National Shoreline Study, Vol.I, U.S. Government Printing Office, Washington, D.C., 1973. H.D. No.93-121

Iida, K., K. Sazanami, T. Kuwahara, and K. Ueshita, 1976,"Subsidence of the Nobi Plain, "Abstract., Proceedings of the 2nd International Symposium on Land Subsidence, Anaheim, California, Dec. 1976.

Kazamann, R. G., and M. M. Heath, 1968, "Land Subsidence Related to Ground-Water Offtake in the New Orleans Area,"Gulf Coast Assoc. Geol. Soc. Trans., V. 18, pp. 108-113.

Keehn, Stephen, 1982, "Can Mean Sea Level Changes be Predicted?", paper prepared for Prof. R.L. Wiegel, University of California, Berkeley, California, Winter 1982.

Mayuga, M. N. and D. R. Allen, 1969, "Subsidence in the Wilmington Oil Field, Long Beach, California, USA', Symposium of Tokyo, 1969-Land Subsidence, Vol. 1, International Association of Scientific Hydrology, Pub. 88, ppp. 66-79.

Nunez, O. and D. Escojido, 1976, "Subsidence in the Bolivar Coast," Abstract, Proceedings of the 2nd International Symposium on Land Subsidence, Anaheim California.

O'Brien, Murrough P., 1982, "The Shoreline Debate, "Shore and Beach, Journal of the American Shore and Beach Preservation Association, V.50, No.2, Apr 82, pp.3-8.

Penfield, Wallace C., 1960, "The Oldest Periodic Beach Nourishment Project," Shore and Beach, Journal of the American Shore and Beach Preservation Association, V. 28, No. 1, April 1960, pp. 9-15.

Poland and Davis, 1969, "Land Subsidence Due to Withdrawal of Fluids," in Varnes, D. Jr., and George kiersch, eds., Reviews in Engineerng Geology, V. 2, p. 187-269, Geol. Soc. Am., Boulder, Colorado.

Poland, J. F., 1973, "Subsidence in the United States Due to Ground-Water Overdraft-a Review," Proceedings of the ASCE Irrigation and Drainage Division Specialty Conference, August, Fort Collins, Colorado, pp. 11-38.

Pratt, W. E., and D. W. Johnson, 1926, "Local Subsidence of the Goose Creek Field," Jour. Geology, V. 54, No. 7, pp. 577-590.

Small, J. B., 1963, "Interim Report on Vertical Crustal Movement in the United States," U.S. Coast and Geol. Survey, pp. 14.

Stanley, Kirk W., 1968, "Effects of the Alaska Earthquake of March 27 1964 on Shore Processes and Beach Morphology," U.S. Geological Survey Professional Paper 543-J.

U.S. Army Corps of Engineers, Jacksonville District, Our New Beach, How It Works, Dade County Beach Erosion Control and Hurricane Protection Project Brochure, 1980.

U.S. Army Corps of Engineers, Wilmington District, Manteo (Shallowbag) Bay, North Carolina, General Design Memorandum Phase II, Design Memorandum 2, September 1980.

U.S. Department of Commerce, U.S. Ocean Policy in the 1970's status and issues. Government Printing Office, 1978.