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Louisiana Barrier Island Erosion Study

Asbury H. Sallenger, Jr.*, Shea Penland**,
S. Jeffress Williams*, and John R. Suter**

Abstract

During 1986, the U.S. Geological Survey and the Louisiana Geological Survey began a five-year cooperative study focused on the processes which cause erosion of barrier islands. These processes must be understood in order to predict future erosion and to better manage our coastal resources. The study area includes the Louisiana barrier islands which serve to protect 41% of the nation's wetlands. These islands are eroding faster than any other barrier islands in the United States, in places greater than 20 m/yr. The study is divided into three parts: geological development of barrier islands, quantitative processes of barrier island erosion and applications of results. The study focuses on barrier islands in Louisiana although many of the results are applicable nationwide.

Introduction

Coastal erosion and wetland loss are serious national problems with long-term economic and social consequences. Developed areas face billions of dollars in property damage and potential loss of life as a result of long-term erosion and storm impacts, and valuable wetlands are being altered at rapid rates. Of the 30 states bordering an ocean or Great Lake, 26 presently experience a net erosion of their shores (May and others, 1983). Erosion will likely accelerate in the future in view of the National Academy of Sciences and the Environmental Protection Agency forecasts of increasing rate of sea level rise (Hoffman and others, 1983).

Louisiana has the highest rates of coastal erosion and wetland loss of any of the United States. In the Mississippi River delta plain, rates of wetland loss exceed 102 square kilometers per year (Gagliano and others, 1981). Louisiana's barrier islands, which serve to protect wetlands, are eroding in places up to 20 m/yr (Penland and Boyd, 1981). These barriers are not simply migrating landward while maintaining a constant length and

* U.S. Geological Survey, 914 National Center, Reston, VA 22092
** Louisiana Geological Survey, University Station, Box G, Baton Rouge, LA 70893

width. Rather, the islands are decreasing in area as they migrate landward. For example, between 1890 and 1979, Louisiana barriers decreased in area by 37%, from 92 to 58 square kilometers (Penland and Boyd, 1981; 1982). If this rate of land loss continues, the barrier islands will disappear, which in turn will accelerate the destruction of valuable wetlands. Louisiana contains 41% of the nation's wetlands which support a one billion dollar a year fishery. The magnitude of barrier island erosion and wetland loss in Louisiana is a problem of national significance.

Many of the processes contributing to barrier island erosion are poorly understood and are not quantifiable with any degree of confidence. These processes must be better understood in order to predict the future shoreline response and, thus, allow better management of our coastal resources. In 1986, the U.S. Geological Survey (USGS) and Louisiana Geological Survey (LGS) began a 5-year study focused on the processes causing barrier island erosion. In this paper, we discuss the objectives of the ongoing study, present the approach that we are taking, and outline some results from our initial efforts.

Study Overview

Long-term erosion of Louisiana's barrier islands is due both to sea level rise relative to the land and diminishing sand supply. The primary objectives of the study are to better quantify processes related to sea level rise and sand supply, and to present the results in a form so that they can be applied to practical problems, such as prediction of future changes. The study is divided into three overlapping parts: geologic development of barrier islands, quantitative processes of barrier island erosion, and applications of results. Each part of the study will be discussed in subsequent sections.

Basic data required by each part of the study include historical measures of volumetric changes in sediment on the islands and offshore. Previous studies have documented shoreline changes and wetland loss in Louisiana (e.g. Morgan and Larrimore, 1957; Penland and Boyd, 1981; and Gagliano and others, 1981). Since the most recent bathymetric survey of coastal Louisiana was prepared in the 1930's, there have been few studies which compared historical charts for volumetric changes. Our initial work included resurveying bathymetry in the vicinity of Isles Dernieres, a barrier island arc that extends for 35 km along the central Louisiana coast (Figs. 1, 2, and 3). These barriers are eroding faster than any of the other barrier islands in Louisiana. In 1887, Isles Dernieres was nearly a continuous island, whereas by 1985 the barrier was cut into a series of smaller islands separated by wide inlets (Fig. 4). During this same period, the Gulf front shoreline retreated more than a kilometer (Figs. 4

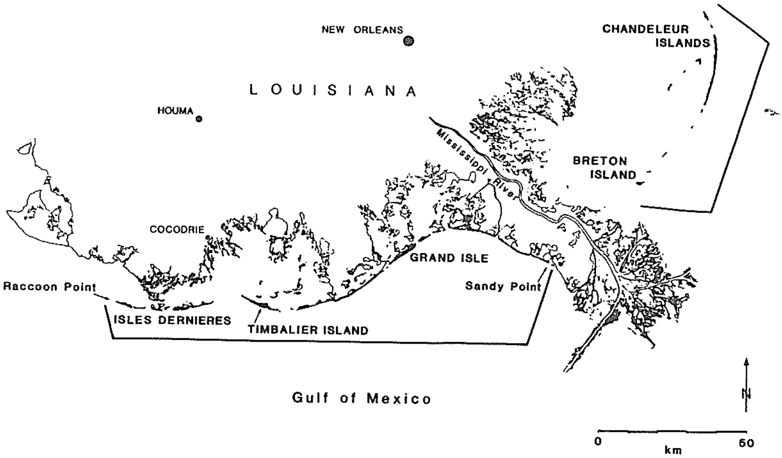

Figure 1. Location of the USGS/LGS Barrier Island Erosion Study.

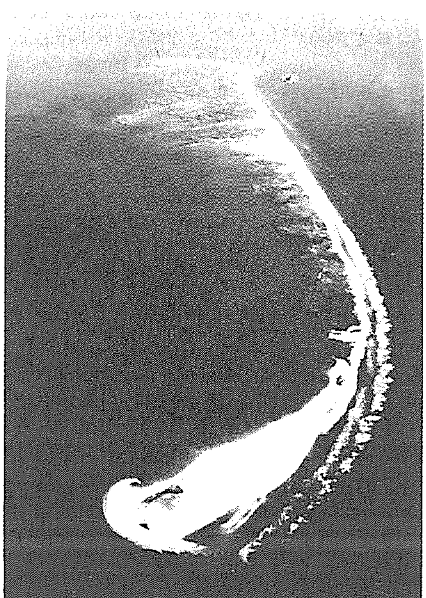

Figure 2. Aerial photograph of part of the Isles Dernieres.

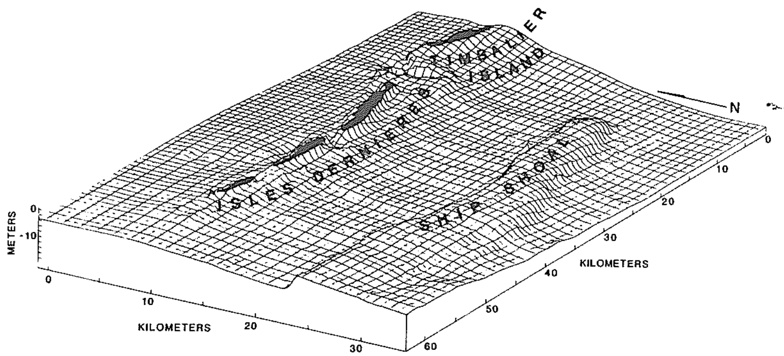

Figure 3. Mesh perspective plot of bathymetry in the vicinity of the barrier islands known as Isles Dernieres. Bathymetry from a new survey conducted by the USGS/LGS study during May-June 1986.

and 5). Over a 92 year period, the Isles Dernieres have decreased in area 63%, from 48 to 18 square kilometers, a rate of 0.33 square kilometers per year (Penland and Boyd, 1981). Projecting this rate into the future, the Isles Dernieres will disappear by the year 2034.

I. Geological Development of Barrier Islands

A first step in evaluating causes of barrier island erosion is to establish the geologic framework within which the barriers formed and migrated landward. These studies, which involve both stratigraphy and geomorpholgy, are providing a broad regional understanding of the historical development of the islands and are contributing to a conceptual understanding of the processes involved.

Regional Stratigraphy

The formation of the Louisiana barrier islands is closely related to the development and subsequent erosion of abandoned Mississippi River deltas (Kolb and Van Lopik, 1958; Fisk, 1944; Frazier, 1967; and Penland and Boyd, 1981). The changing course of the Mississippi River over the past six thousand years has lead to the development of at least four delta complexes which overlap and create complicated sedimentary facies relationships (Coleman and Gagliano, 1964; Frazier, 1967). Our objective is to map the stratigraphy and facies relationships between each transgressive barrier shoreline and its associated delta, both onshore and offshore. The three-dimensional geometry and sediment texture of facies are being defined by analyzing high resolution geophysical profiles and vibracores, supplemented by surface sampling and drilling.

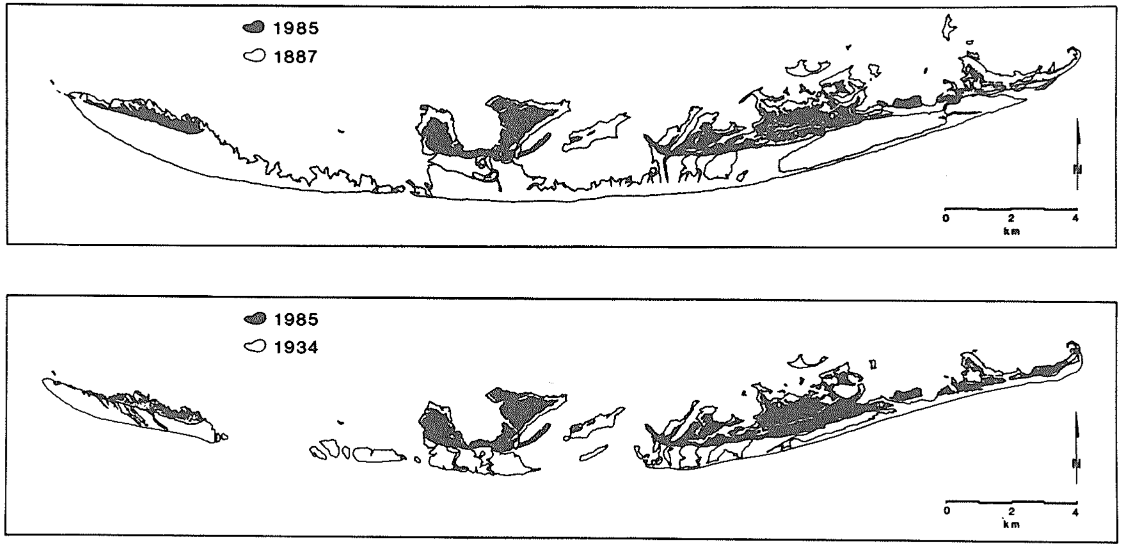

Figure 4. Shoreline of the Isles Dernieres from surveys of 1887, 1934, and 1985. The 1887 and 1935 shorelines were digitized from historical maps of the NOAA National Ocean Survey. The 1985 shoreline was digitized from USGS/LGS vertical photography that had been corrected for distortion and printed in map format.

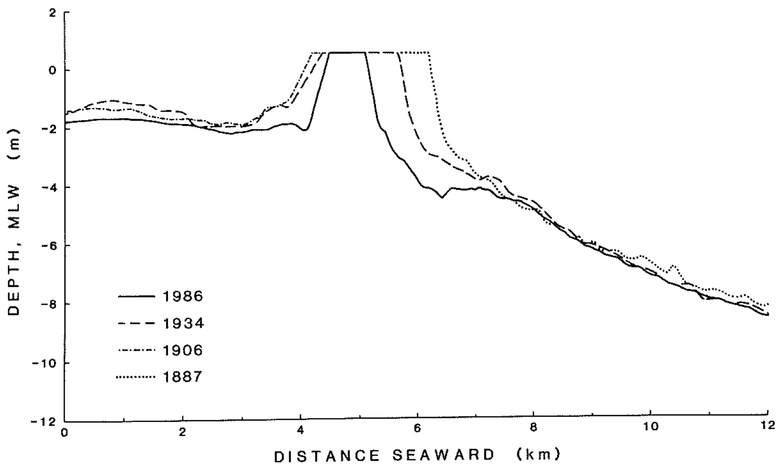

Figure 5. Example of historical shoreface erosion from the Isles Dernieres. Profile location is 12 km west of eastern end of Isles Dernieres. The 1887 and 1935 bathymetry have been digitized from historical surveys of the National Ocean Survey, and the 1986 bathymetry is from the May-June survey funded by this study. The vertical datum is mean low water at the time of the survey and has not been adjusted for historical changes associated with relative sea level rise.

Age relationships and sea-level history are being determined through geochronological techniques. These studies are supplying data needed by the quantitative process investigations, such as the distribution of sands both surficially and in the subsurface.

Between 1982 to 1985, the USGS and LGS have collaborated to collect more than 10,000 line-km of high-resolution seismic-reflection profiles in coastal Louisiana. These profiles are part of a regional data base used to provide information on the shallow geologic framework of the Louisiana inner shelf and to locate nearshore sand resources (Penland and Suter, 1983; Penland and others, 1985). In 1986, as part of the study discussed here, an additional 1200-line km of geophysical data were surveyed off the Isles Dernieres and 148, 40 foot-long vibracores were obtained (Fig. 6).

Geomorphology

Hurricanes, tropical storms, and cold fronts all contribute to erosion of Louisiana's barrier islands. The effects of these storms on the geomorphology of the

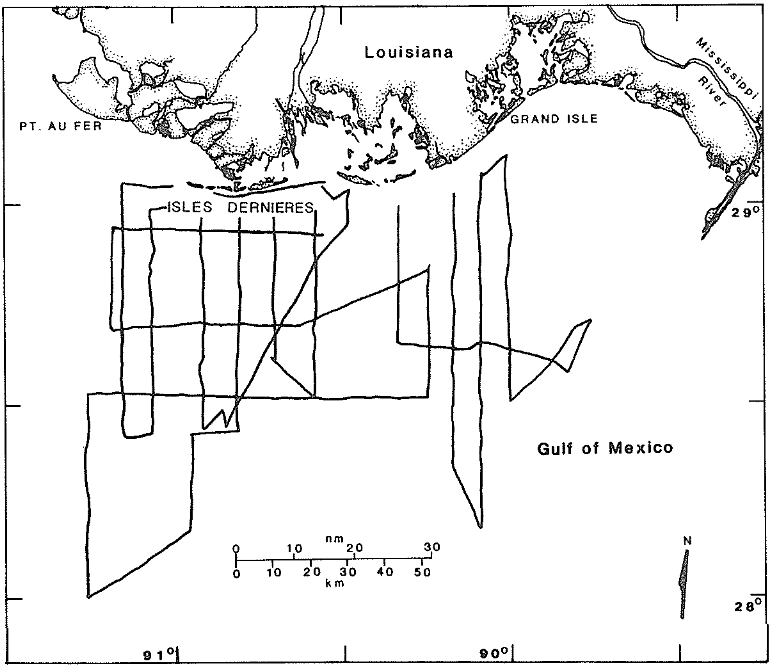

Figure 6. Track lines of the 1986 geophysical cruise. Seismic systems used in the 1986 cruise include an ORE Subbottom Profiler and an ORE Geopulse.

islands are being investigated using pre- and post-storm aerial videotapes, mapping photography, and beach profiles. Offshore, the response of the shoreface to storms are being examined through repetitive bathymetric profiles and sediment sampling. Processes are being qualitatively assessed through examining water levels, offshore wave conditions, and meteorological data. These studies are providing regional scale information on the variability of erosion and the different processes at work, and are contributing to determining relative roles of infrequent but severe hurricanes to the more frequent but less severe cold fronts. The results of these studies are identifying processes to be addressed by the quantitative studies.

Since 1984, the LGS has conducted annual videotape surveys of the Louisiana coastline. As we prepared for our study in the summer and fall of 1985, three hurricanes impacted the Gulf Coast between Louisiana and Florida. Pre- and post-storm aerial videotape surveys showed that barrier shorelines underwent repeated intense overwash, and beach and dune erosion exceeding 30 m (Penland, Suter, and Nakashima, 1986). The effects of Hurricane Danny on the barrier islands west of the Mississippi River are summarized in Figure 7.

II. Quantitative Processes of Barrier Island Erosion

Many processes contributing to barrier island erosion can not be accurately quantified. In some cases, it is even difficult to assess whether one process is more important in causing erosion than another. In this study, we focus our efforts and resources on several processes that are not well understood, but are approachable experimentally.

Sea Level Rise

In coastal Louisiana, relative sea level is rising rapidly as a result of land subsidence and world-wide sea level (eustatic) rise. Erosion due to sea level rise is not entirely due to inundation, but includes a readjustment of the nearshore profile (e.g. Bruun, 1962) that is not well understood. Critical processes controlling erosion due to sea level rise, such as the distances offshore and onshore to which sand is exchanged with the beach during the storm/recovery cycle, are being determined. Models which predict erosion due to sea level

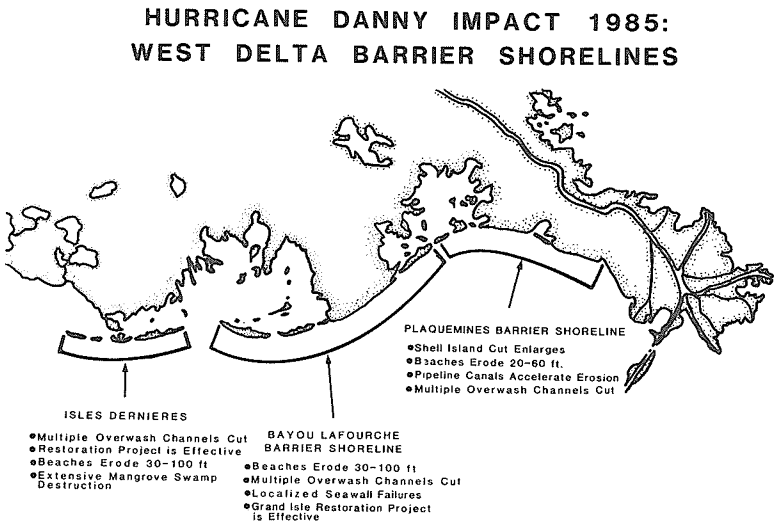

Figure 7. Summary of shoreline effects of Hurricane Danny which occurred in 1985 (adapted from Penland and others, 1986).

rise (e.g. Everts, 1985) are being tested against historical measures of erosion.

Our first step was to determine as accurately as possible the magnitude of relative sea level (RSL) rise (Fig. 8). At tide stations in both Houma and Grand Isle, linear regression of the entire record indicates RSL rise of 1.3 cm/yr. This is significantly greater than the eustatic rise, or world wide sea level rise, of about 0.01 cm/yr (Gornitz and others, 1982). Interestingly, there appears to be a recent acceleration in RSL rise that also occurs around the U.S. coast of the Gulf of Mexico, although at different magnitudes (Penland and others, in press).

Overwash Processes

It is well known that overwash during storms contributes to the net landward transport of sediment and the landward migration of Louisiana's barrier islands (Ritchie and Penland, 1985). However, the magnitude of the contribution of overwash to shoreline erosion is not

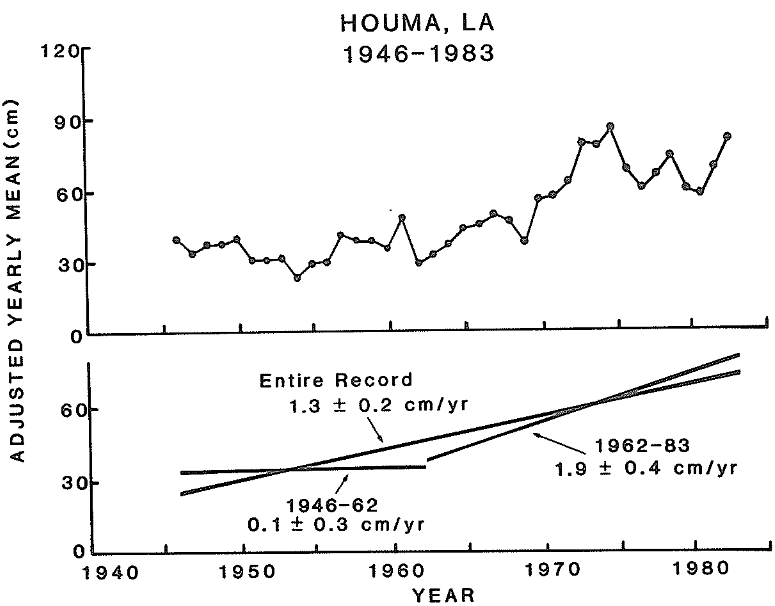

Figure 8. Water level time series for the U.S. Army Corps of Engineers tide gauge station at Houma (Intracoastal Waterway, #25). For location, see Figure 1. Note that there appears to be a recent acceleration in sea level rise. (Plot adapted from Penland and others, in press).

well known. Our objectives are to better quantify processes forcing overwash and to quantify landward sediment transport during overwash events. The plan includes monitoring overwash events with a variety of sensors, including wave and current meters, mounted on a barrier island. Additional assessments of sediment transport include measurements of morphological changes and tracer studies.

During the initial phase of the study, we have begun overwash experiments on the Isles Dernieres (Fig. 9). The experiment area is of very low relief with a berm about 1 to 1.5 m above MSL. Minor dunes occur in scattered locations, but overwash generally flows like a sheet over the barrier compared to channelized overwash that occurs when foredune ridges are well developed and breached (Ritchie and Penland, 1985). Figure 10 shows some of the instruments that have been deployed. The acoustic altimeter measures the distance, in air, between the altimeter and the sand surface. This provides measures of erosion and accretion immediately after storms, once the storm surge recedes. During overwash events, the altimeter measures the distance between the altimeter and the sea surface providing water depth and wave height data. Should the storm surge become too deep for the

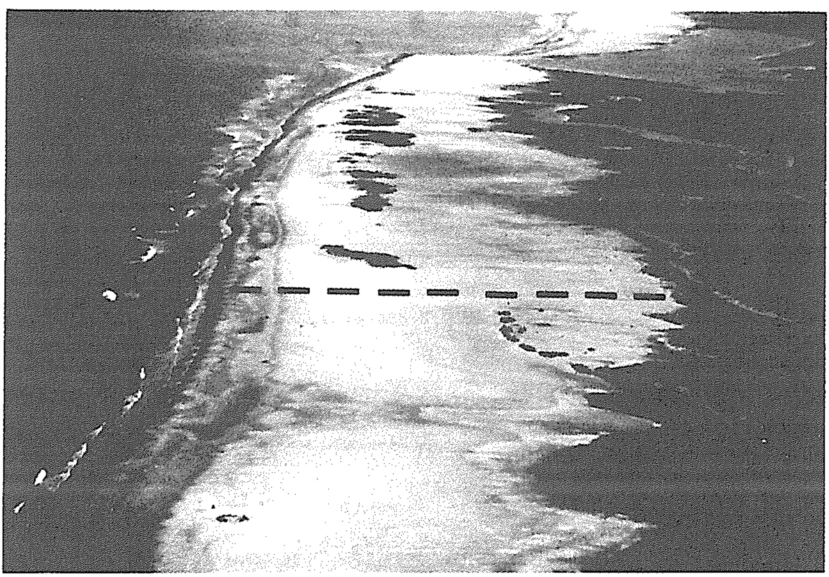

Figure 9. Oblique aerial photograph of the Isles Dernieres showing the transect across the island that is the location of overwash experiments.

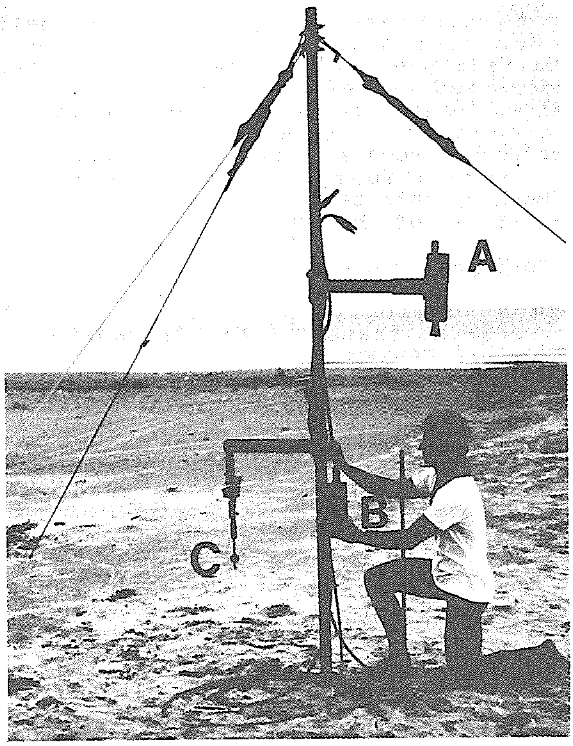

Figure 10. Examples of the instruments deployed as part of the overwash experiments. Shown are an experimental acoustic altimeter (A), a pressure sensor (B), and an electromagnetic current meter (C).

altimeter to function, a pressure senor (B) will measure sea surface elevations. All instruments are hardwired to a tower where the data, along with additional meteorological data, are digitized and transmitted to the Louisiana Universities Marine Consortium (LUMCON) in Cocodrie, LA, 32 km away.

Net Offshore Loss of Sediment

During storms, as a result of a variety of different processes, sediment can be transported across the surf zone to the inner shelf. For example, during a hurricane Murray (1970) measured very strong offshore mean flows that could contribute to transporting sand offshore. In the Gulf coast environment, where high-energy swell is generally absent, the potential for sand movement onshore following a storm is not as high as coasts where swell prevails under nonstorm conditions. The sand may be spread in thin sheets across the inner shelf and the buildup over time may be difficult to detect with traditional measures of bathymetry. Objectives are to better understand processes which might force strong offshore flows seaward of the surf zone during storms, and to assess sediment transport using a variety of independent means, such as direct measurement of suspended sediment, calculations, and measurements of bottom changes. Work on this task is planned to begin during the second year (1987) of the study.

Longshore Sediment Transport

The most commonly used models for predicting longshore sediment transport are integrated across the surf zone and the assumption is made that sand extends across the surf zone (e.g. Komar and Inman, 1970). In Louisiana, this assumption is commonly not valid. During a major storm, the surf zone can be extremely wide yet the sand may only be concentrated at the shoreline and perhaps in the form of nearshore bars. Our major objective here is to develop a better means for assessing longshore sediment transport in a sand/mud environment so that the role of gradients in longshore transport in causing erosion can be better determined. Work on this task is planned to begin during the third year of the study.

III. Applications of Results

Our ultimate objective is to present the results on the processes of barrier island erosion in a form so that they can be applied to practical problems. The types of applications include developing better techniques for determining the rate at which artificially nourished beaches should be renourished, finding potential sources of sand offshore for beach nourishment, and predicting future shoreline erosion so that coastal planners can properly locate new construction a safe distance landward from the eroding shoreline. This part of the study is being approached by working with coastal engineers and coastal planners.

Summary

In 1986, the U.S. Geological Survey and Louisiana Geological Survey began a new cooperative study on the processes causing barrier islands to erode. The study includes investigations of the geologic development of barrier islands, experiments on quantifying critical processes of erosion, and integration of results such that they can be applied to practical problems. The study is located in Louisiana, however, many of the results will be applicable nationwide.

References

Bruun, P., 1962, Sea level rise as a cause for erosion, J. Waterways and Harbors Div., ASCE, v. 88, p. 117-130.

Coleman, J.M. and Gagliano, S.M., 1964, Cyclic sedimentation in the Mississippi River deltaic plain, Trans., Gulf Coast Assoc. Geol. Soc., v.14, p. 67-82.

Everts, C. H., 1985, Sea level rise effects on shoreline position, J. Waterway, Port, Coastal and Ocean Engineering, ASCE, v. 111, n. 6, p. 985-999.

Fisk, H.N., 1944, Geologic investigation of the alluvial valley of the lower Mississippi River, U.S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS, 78p.

Frazier, D. E., 1967, Recent deltaic deposits of the Mississippi River: their development and chronology, Trans., Gulf Coast Assoc. Geol. Soc., v. 17, p. 287-315.

Gagliano, S. M., Meyer-Arendt, K. J., and Wickes, K. M, 1981, Land loss in the Mississippi River deltaic plain, Gulf Coast Association of Geological Societies, v. 31, p. 295-300.

Gornitz, V., Lebedeff, S., and Hansen, J., 1982, Global sea-level trend in the past century. Science, v. 215, p. 1611-1614.

Hoffman, J. S., Keyes, D., and Titus, J. G., 1983, Projecting future sea level rise: methodology, estimates to the year 2100, and research needs: U.S. Environmental Protection Agency, EPA 230- 09-007, 121 p.

Kolb, C.R. and Van Lopik, J.R., 1958, Geology of the Mississippi River deltaic plain, southeast Louisiana, U.S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS, 78 p.

Komar, P. D., and Inman, D. L., 1970, Longshore sand transport on beaches, J. Geophys. Res., v. 75, no. 30, p. 5914-27.

May, S. K., Dolan, R., and Hayden, B. P., 1983, Erosion of U.S. Shoreline, EOS, Trans. American Geophys. Union, August 30, p. 521-522.

Morgan, J.P. and Larrimore, P.B., 1957, Changes in Louisiana's shoreline, Trans. Gulf Coast Assoc. Geol. Soc., v. 7, p. 303-310.

Murray, S. P., 1970, Bottom currents near the coast during Hurricane Camille, J. Geophys. Res., v. 74, p. 4579-82.

Penland, S., and Boyd, R., 1981, Shoreline changes on the Louisiana barrier coast, IEEE Oceans, Marine Technology Soc., p. 209-219.

Penland, S., and Boyd, R., 1982, Assessments of geological and human factors responsible for Louisiana coastal barrier erosion, in Proc. Conf. on Coastal Erosion and Wetlands Modification in Louisiana: Causes, Consequences and Options (D. Boesch, ed.) U.S. Fish and Wildlife Service, Biological Services Program, FWS/OBS-82/59, p. 14-51.

Penland, S., Ramsey, K. E., McBride, R. A., Moslow, T. F., and Westphal, K. A., in press, Relative sea level rise and subsidence in Louisiana and the Gulf of Mexico, Louisiana Geological Survey, Coastal Geology Publication Series, Coastal Geology Technical Report, n. 3, 85p.

Penland, S. and Suter, J.R., 1983, Transgressive coastal facies preserved in barrier island arc retreat paths in the Mississippi River delta plain, Trans. Gulf Coast Assoc. Geol. Soc., v. 33, p. 367-382.

Penland, S., Suter, J.R., and Boyd, R., 1985, Barrier island arcs along abandoned Mississippi River deltas, Marine Geology, v. 63, p. 197-233.

Penland, S., Suter, J.R., and Nakishima, L., 1986, Protecting our barrier islands, Louisiana Conservationist, v. 38(1), p. 22-25.

Ritchie, W. and Penland, S., 1985, Overwash process-response characteristics of the Caminada-Moreau barrier shoreline, Louisiana, in Transgressive Depositional Environments of the Mississippi River Delta (S. Penland and R. Boyd, eds.), Louisiana Geological Survey, Guide Book Series, p. 141-176.

Suter, J.R., 1986, Buried late Quaternary fluvial channels on the Louisiana continental shelf, in P.A. Pirozzoli and J.R. Suter, eds., J. Coastal Research, Spec. Issue No. 1, p. 27-38.