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An Analysis of Shoreline Erosion Along the Northern Coast of East Galveston Bay, Texas[1]

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ABSTRACT

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Shoreline erosion was measured along a portion of East Galveston Bay, Texas over a period of five years. These short-term measurements were consistent with erosion estimates obtained from aerial photographs spanning almost 40 years. The erosional impact of a major hurricane (Alicia) was not as severe as expected. It appears that many factors are responsible for the current erosional trend in this area, both natural and man-induced. It is unlikely that this trend will be reversed due to the effects of compactional subsidence and rising sea level.

ADDITIONAL INDEX WORDS: *Erosion, Galveston Bay, Gulf coast, shoreline changes*

INTRODUCTION

The Texas shoreline encompasses over 2250 km (1400 miles) of bay, estuary and lagoon shorelines in addition to 603 km (375 miles) of Gulf of Mexico coastline. Although only 6% of the state's area is within this coastal zone, it is responsible for over a third of the economic resources of Texas (FISHER *et al.*, 1972). Much attention is focused on Gulf beach erosion as a result of the prime development potential of these areas. However, erosion of bay shorelines is equally important, especially when the loss of highly productive marshes and estuarine nursery grounds is considered.

Historically, coastlines are in a continual state of change; present shore locations are the result of erosional and depositional forces. Shorelines are influenced by numerous factors including changes in sea level, tidal regime, sediment supply, periodic storms, and human modification. Recent studies in various geographic regions indicate that shoreline erosion has become a major problem. For example, HOBBS *et al.* (1981) estimated that the Virginia Chesapeake Bay shore lost over 8500 hectares from 1850 to 1950. DELAUNE *et al.* (1978) estimated in excess of 4000 hectares of land is lost per year in Louisiana. SHABICA *et al.* (1984) reported extremely high erosion rates (4.7 to 7.4 m/y^{-1}) along barrier islands in Louisana. In Texas, MORTON (1975) measured historical changes in the shorelines along Bolivar Peninsula using topographical maps and aerial photos. He reported an erosional trend from 1882 to 1930 and from 1956 to 1974. There was evidence of accretion in this area only between 1930 and 1956. Overall loses during 92 years averaged 0.6 m/y^{-1}.

Due to immense development pressure, it is likely that cultural modifications have altered the natural equilibrium of erosion and accretion. For example, damming of rivers and building levies can drastically change the sediment budget of a coastal system. While some of the obvious shoreline erosion could be due to the cyclical nature of coastal processes, it is possible that man's actions are responsible for a considerable amount of this loss.

Our study was initially implemented to measure short-term erosion rates and to identify the major factors affecting local erosional processes. In addition, aerial photos were employed to determine if the observed erosion along our study site was indicative of a long term trend. Conflicting data for this area have been published. FISHER *et al.* (1972)

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classify this shoreline as depositional while CLARK (1976) indicated erosion could increase in this area as a result of Rollover Fish Pass. This channel from the Gulf of Mexico into East Bay was cut through Bolivar Peninsula in 1955. Immediate changes in salinity, currents, tidal regime, and species composition were evident (REID, 1956).

Loss of land along this shore is affected by many factors: (1) compactional subsidence associated with heavy groundwater withdrawal has increased from approximately 0.4 cm/y^{-1} (1906-1978) to over 1.0 cm/y^{-1} (1978-1983) (Harris-Galveston Coastal Subsidence District, personal communication), (2) sea level rise is reported to be 0.4 to 1.6 cm/y^{-1}, (3) the Texas Gulf coast is continually at risk from tropical storms and hurricanes, and (4) the area is subjected to rapid development pressure and human modification.

METHODS

Description of Study Site

Our study site is located along the northern shore of East Galveston Bay, Chambers County, Texas (Figure 1). Brackish marshes and coastal prairies are the dominant vegetation types. The climate is subtropical, with precipitation averaging 130 cm/y^{-1}, mild temperatures and an average growing season of 261 days. Tides are semidiurnal and diurnal, ranging from less than 0.3 m to 0.8 m. Currents within the bay are controlled by strong southeasterly winds from March through November with northerly winds dominating December through February.

Two major soil series are found in this area (USDA, 1976). Harris soils are wet, saline, clayey soils formed in coastal sediments under water- and salt-tolerant vegetation. Veston soils are also wet, often saline, and formed under marsh vegetation. However, the texture of Veston soils is classified as silt loam as compared to the clay texture of the Harris series. Both of these soil types are used primarily for livestock pastures.

Historical Erosion Measurements

Aerial photos (1941-1980) of the coast from Smith Point to Oyster Bayou were obtained from the U.S. Soil Conservation Service and Texas Highway Department. Points were chosen which could be followed from time period to time period with reasonable accuracy. These included roads, permanent structures such as bridges and buildings, and some natural features which changed little over the time series available, such as outflows from lakes. The distance from these points to the sediment-water interface was measured to the nearest thousandth of an inch with a micrometer. Measurements were made by two independent observers and converted depending on the scale of the particular photograph. While there are obvious sources of error in this technique of historical monitoring, it can provide valuable information concerning long-term trends (MORTON, 1975).

Short-Term Erosion Measurements

During the winter of 1979, a series of wooden stakes was installed along a portion of the coastline which appeared to be experiencing extreme erosion (western site, Figure 1). This shore has been eroding in a consistent pattern of "points" and "cuts" (Figure 2). Stakes were placed both on points (minimal erosion) and cuts (maximum loss). Two stakes were driven at each position so that the angle of repeated measurements was as consistent as possible. A measuring tape was stretched from the back stake to the front stake, continuing in a straight line to the edge of the shore.

In the fall of 1979 an additional set of wooden stakes was placed along an adjoining area of shoreline (eastern site). These stakes were set at regular 20 m intervals, eliminating much of the bias present in the western site. Measurements at this site continued through the spring of 1983.

While measurements with these wooden stakes were very consistent, problems arose due to loss of stakes and difficulties in finding them among the dense marsh vegetation. In the fall of 1982, a series of 6-foot (1.83 m) metal fence poles was installed along another portion of the coastline (Figure 1; sites 1, 2, and 3). In contrast to the eastern and western sites which are located in Veston soils, these additional sites were chosen from areas with Harris and Veston soils. Poles were driven into the ground at 46.7 m (150 foot) intervals. During measurements, a line was stretched between adjacent poles and the distance from the line to the coastline was measured at three points; 0, 15.24 m (50 feet), and 30.48 m (100 feet). A T-shaped aluminum frame was utilized to insure that measurements were at right angles to the taut line. The use of these tall poles eliminated difficulties in finding stakes and enabled us to make more measurements in the same amount of time. The major problems we encountered with this

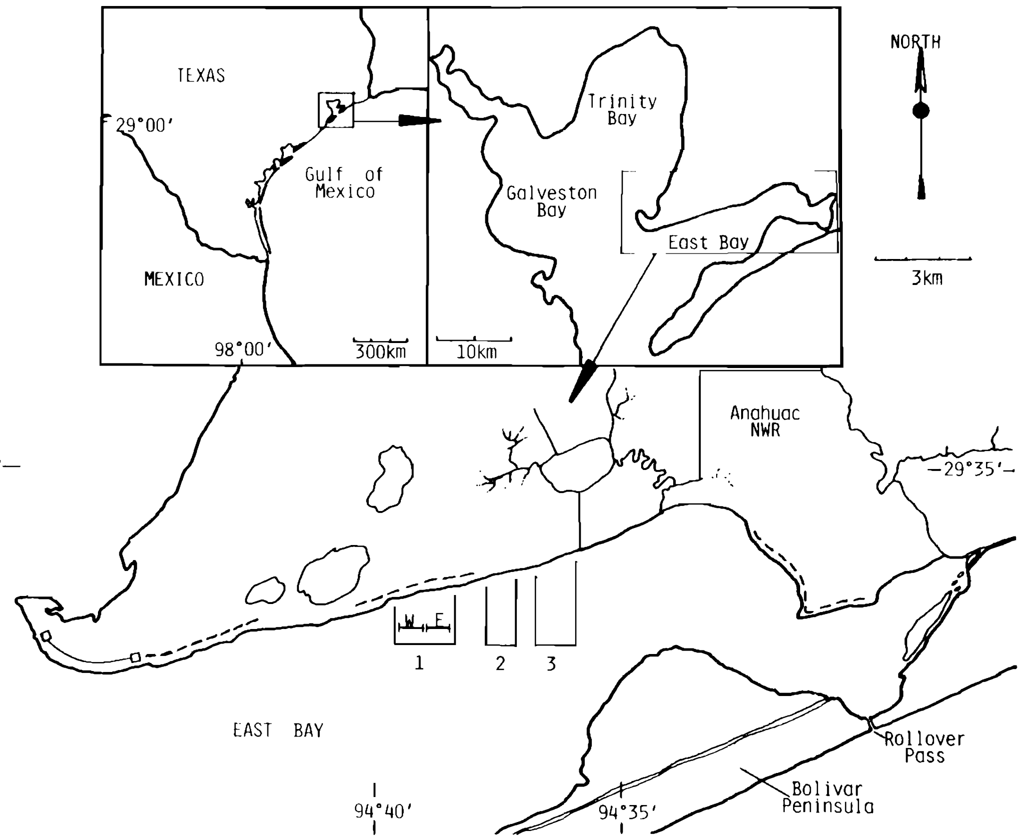

Figure 1. Map of the Texas Gulf of Mexico Coastal Zone (left inset), map of the Galveston Bay system (right inset), and the location of the study area on East Bay. Key: Harris soil type (unmarked shoreline); Veston soil type (broken line); 'other' (solid line) ; W = west and E = east.

method were associated with the greater visibility of the poles; cattle frequently used them as rubbing posts and they were also susceptible to human vandalism.

Measurements of the shoreline with the metal poles continued through the fall of 1983. In August, 1983, Hurricane Alicia came ashore on Galveston Island. We were able to make one more set of measurements after the storm, however, a large number of the poles were badly rusted and bent. This final measurement allowed us to assess the effect of a major storm on shoreline changes compared to erosion rates we recorded during the previous five years.

RESULTS AND DISCUSSION

Historical Measurements

Table 1 summarizes the rates of erosion calculated from aerial photograph measurements. We classified the points measured according to the soil type, Harris or Veston, and found the rate of erosion to be significantly greater on Veston soils than on Harris. An exception to this trend occurred during the time period from 1963 to 1970. Overall loss on Veston sites was 50-75% greater than the erosion which occurred on Harris soil areas. In most cases, there was fairly good agreement between rates calculated from the measurements of different

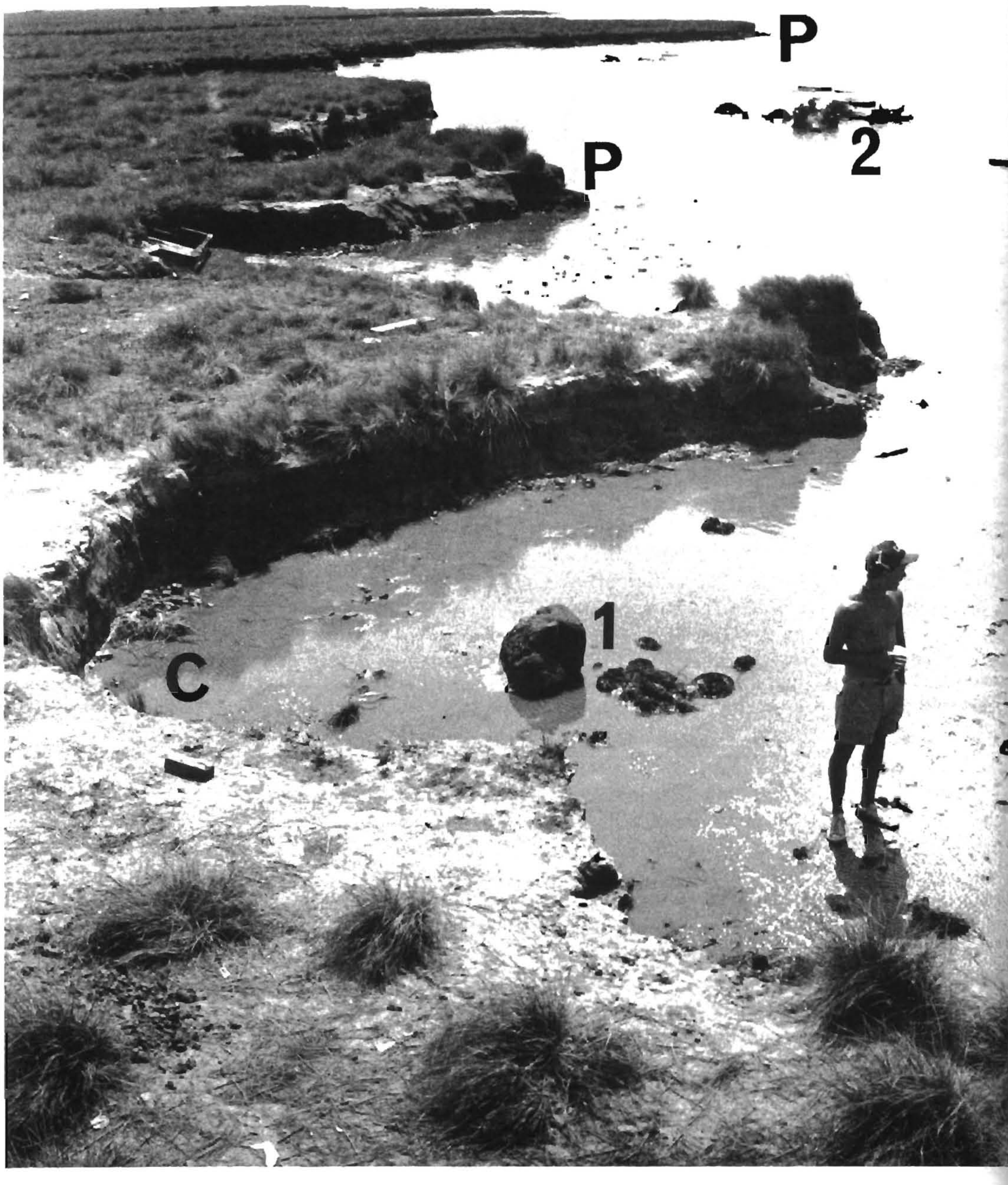

Figure 2. Photograph of northern shoreline of East Bay, Chambers County, Texas, illustrating wave cut cliff with prominent 'points' (P) and 'cuts' (C). Mud balls and sod clasts of *Spartina spartinae* can be seen in foreground (1). The debris visible in the background (2) represents a previous attempt to stabilize the shoreline. This debris was dumped into the bay in 1970, indicating the location of the shoreline at that time.

Table 1. Summary of Estimated Erosion Rates (m/y^{-1})†

Time Period	Harris Soils		Veston Soils	
	‡Obs. 1	Obs. 2	Obs. 1	Obs. 2
1941-1956	0.9		3.4	
1956-1963	2.4	1.5	4.9	3.7
1963-1970	5.2	6.7	3.4	3.4
1970-1976	1.2	0.0	4.0	8.8
1941-1976	1.5		2.7	
1976-1980	3.4	5.2	7.3	8.5
Total Loss				
1956-1980	74	78	111	137
x̄ Loss				
1956-1980	3.1	3.3	4.6	5.7

† Calculated from aerial photographs. ‡Obs. = Observer.

Table 2. Short–Term Erosion Rates (m/y^{-1})†.

Time Period	# Days	# Meas.	x̄	(sd)
Western Site				
2/3/79-4/30/79	86	14	4.1	(2.9)
4/30/79-7/24/79	85	28	3.8	(2.6)
7/24/79-9/13/79	51	25	6.7	(4.5)
9/13/79-3/07/80	175	20	1.0	(0.6)
3/07/80-7/28/81	508	25	2.0	(0.9)
7/28/81-11/10/81	105	47	1.7	(1.4)
11/10/81-4/29/82	170	47	0.8	(0.6)
4/29/82-6/02/82	35	41	7.6	(6.6)
Eastern Site				
9/13/79-3/07/80	175	21	0.7	(0.5)
3/07/80-8/11/81	522	18	2.1	(1.9)
8/11/81-11/10/81	91	44	2.5	(2.0)
11/10/81 5/04/82	176	21	0.6	(0.5)
5/04/82-4/29/83	359	16	2.0	(1.1)

† Estimated from wooden stakes.

Table 3. Short–Term Erosion Rates (m/y^{-1})†

Site	Time Period	x̄	(sd)	Max. Loss (m)
1	9/14/82-3/09/83	2.4	(2.2)	22.8
	3/09/83-9/15/83	3.1	(4.4)	13.1
2	9/23/82-3/23/83	2.3	(2.6)	6.7
	3/23/83-10/06/83	2.4	(2.5)	4.2
3	10/05/82-4/06/83	1.6	(1.5)	2.3
	4/06/83-10/06/83	2.0	(1.9)	4.9

† Measured from metal poles.

observers. Unfortunately, there is only one set of measurements using the 1941 photos. Thus we have no way of knowing if these values are reasonable.

There have been several tropical storms and hurricanes during the time span of these measurements (FEW, 1976). Between 1956 and 1963, three hurricanes passed close to this area: 1957, Audrey; 1961, Carla; 1963, Cindy. The period from 1963 to 1970 saw no major hurricanes, and yet, there was considerable erosion during this time. It is curious that this is the only time when estimated erosion was greater on Veston soils than on Harris clays. No major hurricanes affected this area again until Alicia, which occurred August 18, 1983.

Short-Term Measurements

The erosion estimates using wooden stakes (eastern and western sites) are summarized in Table 2. There was considerable variation in erosion during the year, with greater losses generally in the summer and fall. Lower rates of erosion occured during the winter months when the prevailing winds are from the north. At the western site, much greater erosion occurred during the summer of 1979 (6.7 m/y^{-1}) and the spring of 1982 (7.6 m/y^{-1}). The large loss in 1979 was probably due to tropical storm Claudette, which brought 1066 mm (42 inches) of rain to nearby Alvin, Texas in a 24-hour period. The erosion rate for the entire period of study averaged 1.9 m/y^{-1} (sd = 0.9) at the western site and 1.6 m/y^{-1} (sd = 0.8) at the eastern site. At both sites there was at least one period of measurement exceeding a year. These were quite consistent with the overall averages, ranging from 2.0 to 2.1 m/y^{-1}.

Using the measurements from the western site, 2/3/79 to 4/30/79, we were able to correlate the degree of erosion with the angle of the eroding cut. The average loss from areas with an angle between 130-160° was 4.1 m (sd = 0.4). This is significantly greater than the erosion from cuts of 170-180° ($\bar{x}$ = 1.2 m, sd = 0.7), or when the angle was > 180° ($\bar{x}$ = 0.5 m, sd = 0.2). However, we were unable to demonstrate any difference in soil texture or moisture between slowly eroding sites and high erosion areas.

Table 3 summarizes the erosion estimates from sites 1, 2, and 3. These measurements agree favorably with the data from measurement of the wooden stakes. The large standard deviations are due to the enormous variability in erosion at various points. Some points may loose only a few centimeters while others may loose up to 23 m over the course of six months.

The difference in soil type is reflected in the erosion rates for each site. In general, Site 1 experienced the largest amount of erosion. It is located entirely on Veston soil. Site 3, on the other hand, is located on Harris soil and showed the smallest amount of loss. Site 2 is also situated on Harris soil. However, it is an extremely narrow strip surrounded by Veston soils. Perhaps this is why erosion rates at Site 2 are closer to those estimated at Site 1 than at Site 3. The variation in soil type is also reflected in the dominant vegetation. The major species at Site 1 were *Spartina spartinae* and *Sporobolus indicus*. Site 2 was dominated by *Spartina patens* and *S. spartinae* as compared to Site 3 which consisted primarily of *S. patens* and *Distichlis spicata*. Thus even though Site 2 is classified as Harris type soil, the vegetation is intermediate between that found on the two soil types.

It is surprising that rates from the two time periods are so similar. Winter measurements on the eastern and western sites tended to be much lower than spring or summer erosion rates. While Sites 1 and 3 had somewhat higher rates for the summer measurements, they certainly do not reflect the anticipated effect of Hurricane Alicia. FISHER *et al.* (1972) emphasize the effect of hurricanes on accelerating coastal processes. Bay shorelines to the right of the eye are especially susceptible to erosion due to the large amount of water stacked in bays during the passage of the storm system. FEW (1976) predicted a worse case example for Chambers County in which the eye of a hurricane would make landfall 40 to 120 km (25 to 75 miles) to the southwest. Hurricane Alicia did just that, passing over Galveston Island approximately 80 km (50 miles) from our study sites. However, Alicia appears to have had little effect on erosion. Storm tides were 2.5 m on Bolivar Peninsula and 1.8 m at Smith Point (CASE and GERRISH, 1984). Thus waves generated during high water would have little effect on the submerged shoreline. Unlike many tropical storms which approach the Gulf coast, Hurricane Alicia moved ashore quickly and bay waters rose rapidly, allowing little opportunity for erosion of the normally exposed bank. Perhaps prolonged exposure to wind-generated waves is responsible for more erosion than the effects of submergence during a storm such as Hurricane Alicia.

CONCLUSIONS

(1) There is evidence of significant erosion along the northern shore of East Galveston Bay. Short-term and long-term estimates agree fairly well, ranging from 2 to 3 m/y^{-1}.

(2) The degree of erosion correlates well with the soil type. Clay soils appear to be more resistant to erosion than are loamy textured soils. This may be a function of the soil itself, or possibly the vegetation of the particular site.

(3) The effect of a hurricane on the erosional process was much less than expected. A rapid rise in water level over the exposed bank may protect it from severe wave action.

(4) A combination of factors appear to be responsible for much of the present day erosion. Sea level rise in conjunction with compactional subsidence in this area could result in an increase in water level by as much as 2.5 cm. Considering the average slope in Chambers County is less than 0.5%, this could result in the loss of a substantial amount of land area. In addition, land use practices in this area could be responsible for much of the shoreline erosion. The effects of heavy grazing are two-fold: not only is the protective function of the vegetation hampered, but mechanical slumping of the coastline by cattle accelerates the natural wind-generated erosion.

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LITERATURE CITED

CASE, R.A. and GERRISH, H.P., 1984. Atlantic hurricane season of 1983. *Monthly Weather Review*, 112, 1083-1092.

CLARK, H.C., 1976. Shoreline erosion in Chambers County, Texas. *In: Environmental Analysis for Development Planning Chambers County, Texas.* Houston, TX: Rice Center for Community Design and Research, 134-138.

DELAUNE, R.D.; PATRICK, W.H., Jr., and BURESH, R.J., 1978. Sedimentation rates determined by ^{137}Cs dating in a rapidly accreting salt marsh. *Nature*, 275, 532-533.

FEW, A.A., 1976. Hurricane incidence in Chambers County, Texas. *In: Environmental Analysis for Development Planning Chambers County, Texas.* Houston, TX: Rice Center for Community Design and Research, 126-133.

FISHER, W.L.; McGOWAN, J.H.; BROWN, L.F., Jr., and GROAT, C.G., 1972. *Environmental Geologic Atlas of the Texas Coastal Zone: Galveston-Houston Area.* Austin, TX: Bureau of Economic Geology, 91p.

HOBBS, C.H., III; BYRNE, R.J.; KERNS, W.R., and BARBER, N.J., 1981. Shoreline erosion: a problem in environmental management. *Coastal Zone Management Journal*, 9, 89-105.

MORTON, R.A., 1975. *Shoreline Changes Between Sabine Pass and Bolivar Roads. An Analysis of Historical Changes of the Texas Gulf Shoreline.* Austin, TX: Bureau of Economic Geology, 43p.

REID, G.K., 1956. Ecological investigations in a disturbed Texas coastal estuary. *Texas Journal of Science*, 8, 296-327.

SHABICA, S.V.; DOLAN, R.; MAY, S., and MAY, P., 1984. Shoreline erosion rates along barrier islands of the north central Gulf of Mexico. *Environmental Geology*, 5, 115-126.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1976. *Soil Survey of Chambers County, Texas.*