INLET BEHAVIOR AND THE EFFECTS ON BEACH EROSION IN LEE COUNTY, FLORIDA

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Emmett R. Foster, P.E.

Florida Department of Natural Resources

Division of Beaches and Shores

Notes Added To The WEB Copy , 1/21/97, by E.F. :

1) This paper was published in the Proceedings of the 1991 National Conference on Beach Preservation Technology, published by The Florida Shore & Beach Preservation Association, Tallahassee, FL, 32301, pp. 178-193.

2) The agency name is now the Florida Department of Environmental Protection, Office of Beaches and Coastal Systems. The author's e-mail address is as follows : Emmett.Foster@dep.state.fl.us (as of jan. 2000).

3) The opinions expressed in this paper are those of the author and do not necessarily reflect those of the FDEP.

4) The conditions in this county have not remained static. In particular, there has been another renourishment project on Captiva, including northern Sanibel. There has also been a renourishment project around R-130 on Sanibel and another on the northern portion of Bonita Beach. The latter includes terminal groin structures.

5) The figures for the ASCII text version have been enclosed in the zipped total file as separate bitmap files, which can be viewed and printed via many software products, e.g., Wordperfect, Adobe, etc. The intent was to produce a document for general informational purposes which can be read independent of any particular software.

ABSTRACT

Coastal Lee County in Southwest Florida has eight inlets, ranging in size from the very small, such as Blind Pass, to the very large San Carlos Bay Entrance. In examining the extensive historic shoreline and aerial photographic records

available for the county area, certain similarities in inlet conditions and effects can be observed. As a result, the county can be theoretically divided into two distinct regions based on the controlling inlet processes. The patterns of shoal development, channel direction, and adjacent beach erosion are discussed for each of the two regions.

INTRODUCTION

Lee County is located in Southwest Florida on the Gulf of Mexico. The islands and inlets are located and identified in Figure 1.

In order to better understand the coastal processes in this area, a large data base of historic shoreline change information has been assembled by the author at the Division of Beaches and Shores. In essence, all the historic coastal topographic survey maps by the U.S. Coast & Geodetic Survey (USC&GS), National Ocean Survey (NOS), and U.S. Geologic Survey (USGS), have been carefully digitized and compared on standardized scale and coordinate systems. The digitizing work was done by researchers at Florida State University

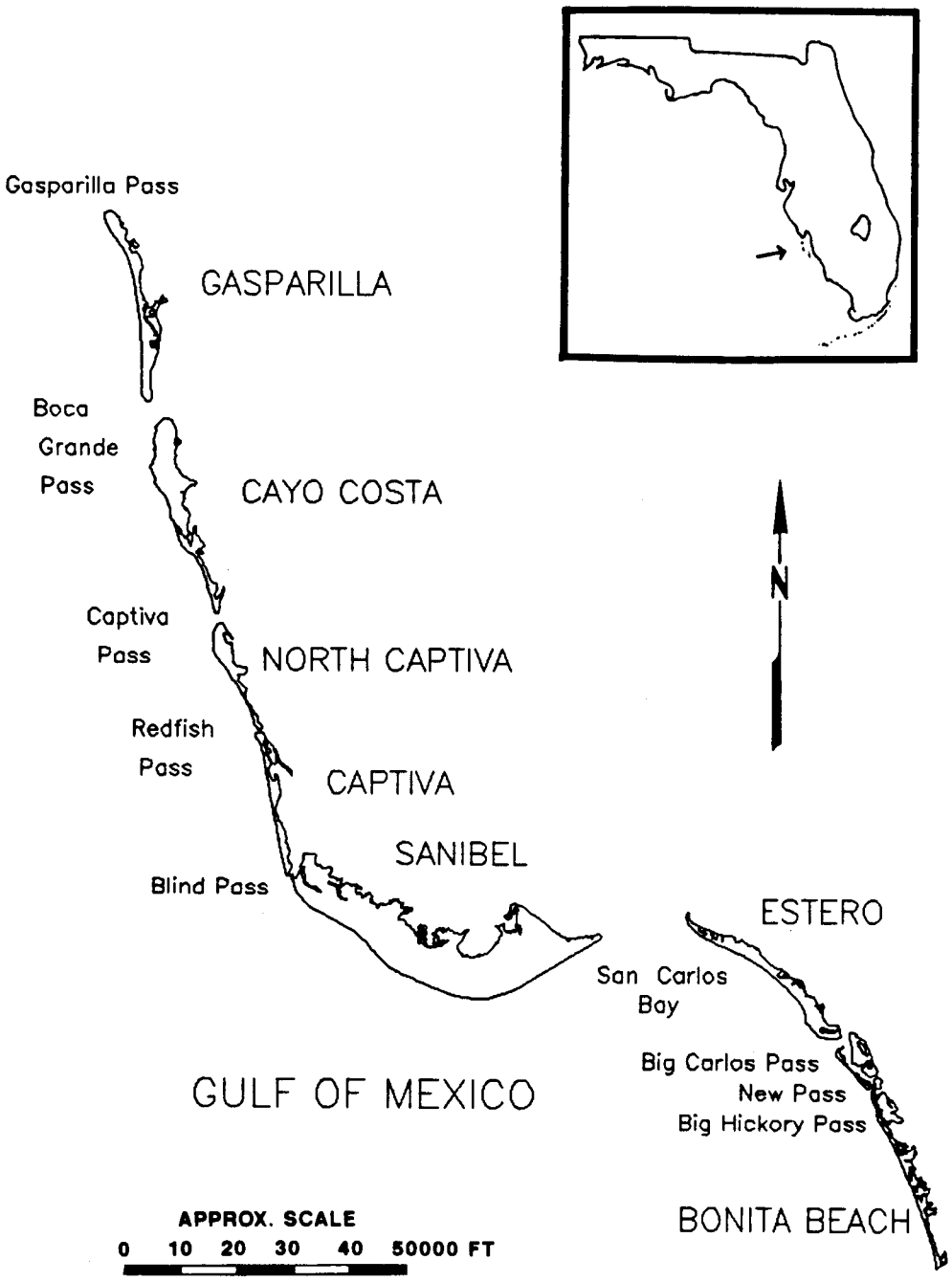

FIGURE 1. LOCATION MAP

under contract with the Florida Department of Natural Resources (DNR). The DNR coastal survey monument and beach profile set was used as a shoreline sampling pattern with approximate 1000 feet (300 meter) spacing. DNR beach profile survey data from 1974 to the present were added by the author to the data sets. The result is a set of computer©generated composite maps showing all the digitized shorelines, and tabulated data sets of quantitative changes along profile bearings from the 1850's to the present. The shoreline changes are all relative to the location of the approximate Mean High Water (MHW) contour. This data base and some of the methods developed for analysis are generally described by Foster and Savage (1-1989). DNR aerial photographs of 1974, 1982-3 and 1988 also exist for this area. All this information is available at the Florida Department of Natural Resources, Division of Beaches and Shores.

This paper is intended to present some interpretations of the Lee County data base with particular reference to inlet behavior and erosional effects. A complementary discussion regarding the coast from Lee County northward through Manatee County is given by Foster and Savage (2-1989). A prior study of the Lee County area was performed by the U.S. Army Corps of Engineers (1969).

REGIONAL PERSPECTIVE

Figures 2A, 2B, 2C, and 2D are photographs of Landsat images of this coast in 1986. These images are useful in examining the area as a whole, and especially in viewing the shoal systems of the larger inlets and their relationship to shoreline shape. Based on these images and the other historic shoreline change data, this coast can be theoretically divided into two geographic regions. The regions differ in the controlling coastal processes.

Region 1 - Gasparilla to Northwestern Sanibel :

In the last 100 years of record the present inlets have existed in essentially their present locations, with the exception of Redfish Pass which was opened by a hurricane in 1926. However, there are old inlet channels visible in the aerial photography along the southern sections of Cayo Costa and North Captiva, as well as the central part of Captiva. These suggest an earlier arrangement of islands much different from that of today.


Fig. 2a

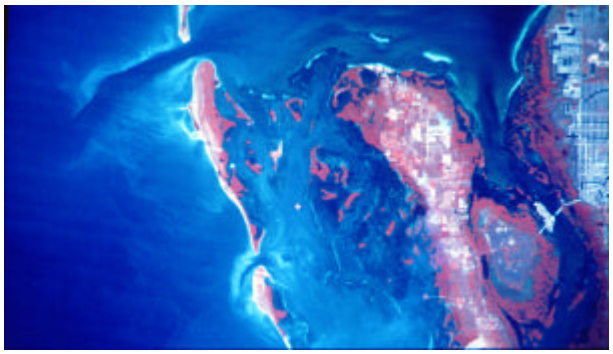
Fig. 2b

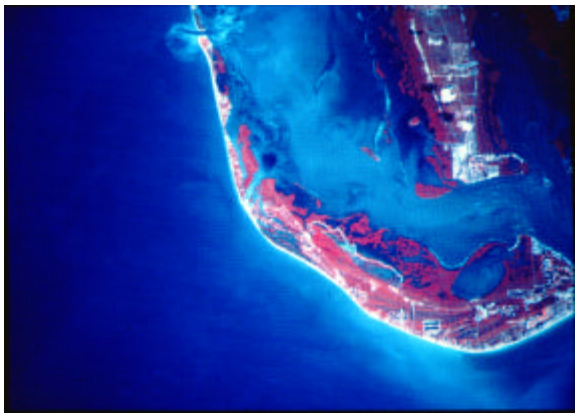
Fig. 2c

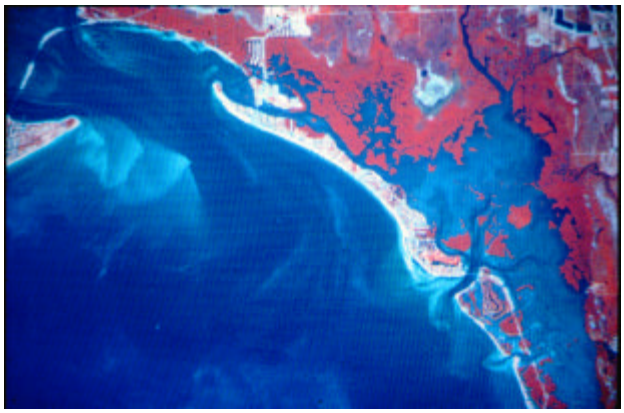
Fig. 2d

In the last 100 years the island shapes have evolved in a rational although only partly predictable pattern, in response to storms and prevailing wave and tide conditions. The changes make sense but would have been difficult to accurately predict due to the random affects of storms and shoal rearrangements.

The five inlets included in this area are, from north to south, Gasparilla Pass (just north of the Lee County Line, in Charlotte County), Boca Grande Pass, Captiva Pass, Redfish Pass, and Blind Pass. Three basic similarities in the first four of these inlets are: 1) there are large ebb shoal deposits on the south sides of the inlets, indicative of net southerly sand transport; 2) there are large bulbous-shaped accretion/fluctuation beaches located on the south side of the inlets, and 3) there is refraction of the predominant northwesterly waves in the winter season around the south ebb shoals which results in a sand deficit and therefore erosion at some distance on the southerly beaches. The latter process is sketched in Figure 3. The four inlets, excluding Blind Pass, all exhibit these features in slightly different variations. The variations are due to differences in the size and configuration of the inlets and the ebb shoals, the

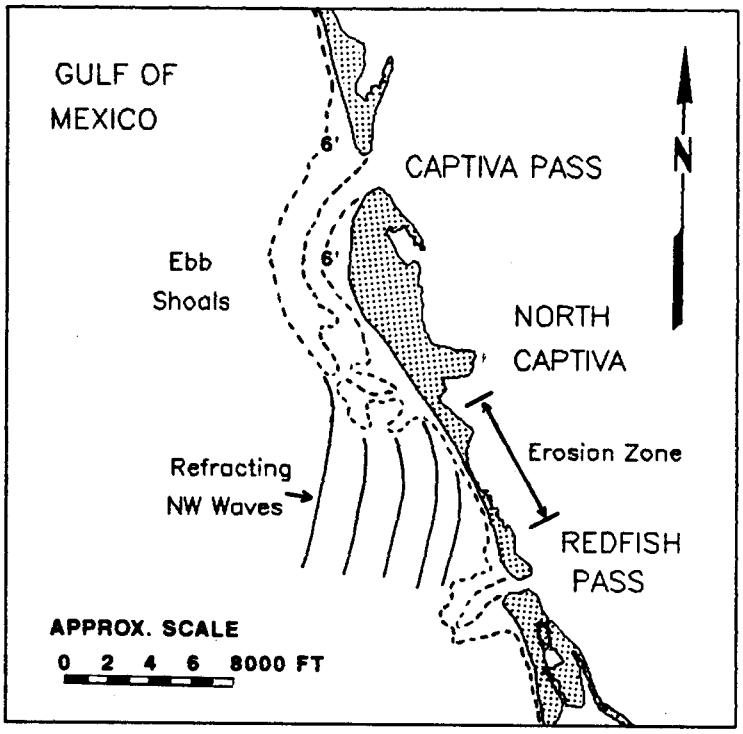

FIGURE 3. SKETCH OF NW WAVE REFRACTION AND DOWNDRIFT EROSION PROCESS

amount of sand passed southward, and the orientation of the rest of the island with respect to the prevailing wave energy.

The bulbous-shaped beach areas on the south side of the inlets developed for several reasons: the large ebb tidal shoals on the south side of the inlets shelter the areas from high energy wave activity except during high water level storms; the shoals occasionally merge onto the shoreline; and the shoals can refract or bend waves such that sand transport is generally directed into the area from the south during all seasons. Frequent and random shoal re-orientations result in extremely unstable beaches in these areas. The north sides of the inlets are equally or more unstable since they are protected by lesser shoals.

The ebb flow of Blind Pass has a strong directional preference which is also complementary to the strong net southerly direction of sand transport in that area. The result is an inlet that has repeatedly migrated large distances southward before a stabilizing groin/jetty was built in 1972. The inlet is now marginally stable.

Changes in the amount of tidal prism, as shared among a group

of geographically close inlets, is a strong factor controlling inlet throat cross-section and stability (O'Brien and Dean, 1972), e.g. Blind Pass. Also, the pressure of predominate wave energy on the ebb shoals affects the shape of the shoals and the outside ebb channel direction, e.g. Captiva Pass. Each inlet appears to have its' own combination of these forces in an occasionally shifting balance.

Region 2 - Southeastern Sanibel to Bonita Beach :

This is the San Carlos Bay area, and it is a distinctly different region. The satellite imagery of Figure 2D suggests that this area can best be considered as one very large and complex tidal inlet system. In the image it appears that there are two sets of shoals at the Entrance: those extending from the eastern point of Sanibel, and those deposits which are building the south end of Estero Island. Waves appear to be only secondary modifying forces in this region due to limited fetch and shoaling in the relatively shallow waters. Tidal flows appear to be predominate, gradually moving and depositing large amounts of littoral material. Consistent with this theory, the sands in this area are generally very fine quartz, mixed with shell in

various locations. The finest deposits are in those areas closest to the inlet mouth: all along Estero and southern Sanibel.

Over the last 100 years the most significant changes have occurred in the area between southern Estero and northern Bonita Beach (R-201 to R-230). A succession of emergent shoals and reworked sandbars have been both added onto Estero and formed as new islands. Occasionally a major storm has rearranged the small islands and inlets in this area.

The source and mechanism of sand supply in this area and southward is not obvious or resolved. This is due to conflicting indications as to the net direction of sand transport by waves, and an apparent imbalance in the gross sand budget if only waves are considered. Some mechanism of offshore sand supply, related to the tidal flows of the large San Carlos Bay inlet system, may be at work in carrying sand to the Bonita Beach, Big Hickory Island, and Lover's Key areas. It would be desirable to investigate this region with a time series of satellite images showing the turbidity, shoaling, and flow patterns over several tidal cycles and seasons. This is a promising subject for future research.

ISLAND REVIEW

In each region of Lee County, coastal problems appear to result either from storm damage to structures simply located too far seaward, or where development intersects the large scale continuing evolution of the islands. The following is a discussion of the erosion situation on each of the islands in the county, relative to the previous comments on regional characteristics and the DNR coastal reference monument system ("R" monuments).

Plan views are provided in Figures 4 through 11, for each island, showing selected historic shorelines which best outline the pattern of changes described in the text. These figures are connect-the-dot drawings of the changes at the DNR monuments. The vertical scale has been used to visually emphasize the recession/accretion over the much larger distance of island length.

Gasparilla Island - Refer to Figure 4 :

The north end of the island (R-58 to R-68) is in Charlotte

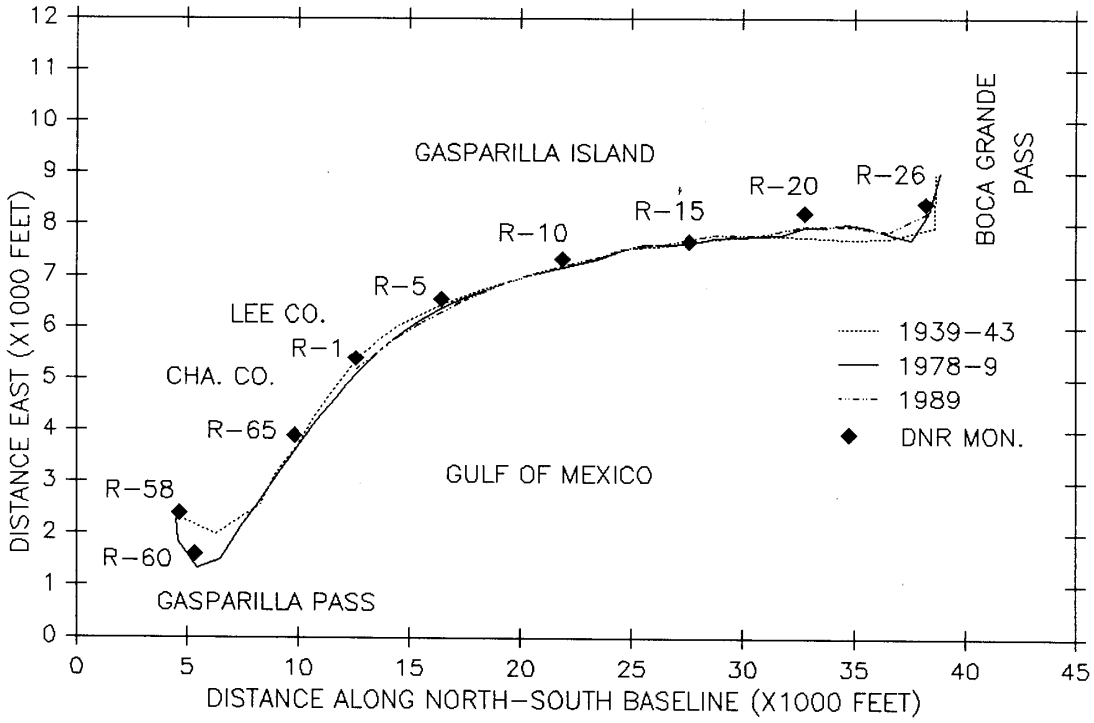

FIGURE 4. HISTORIC CHANGES, GASPARILLA ISLAND

County. It appears that the shoal in recent decades has supplied sufficient sand towards the south to keep that immediate area relatively stable. However, most of the Lee County section of this island (R-1 to R-26) has been armored with seawalls, revetments, and groinfields since at least the 1950's. There is some point, probably around R-10, where the amount of sand brought into the area is less than that required by the northwesterly wave energy, and erosion begins. It is not certain how much this area would have eroded without the armoring; there is not sufficient data prior to the 1950's to be conclusive in this regard. There are also numerous beachrock outcroppings along the shoreline which would likely have modified the erosion pattern. Aerial photographs of 1988 show that a sharp wave angle can still occur along this shoreline in the winter months from the northwest, the predominant high wave energy season and direction. With such wave attack, erosion to the south would most likely have continued to some extent. The armoring has thus far acted to hold the shoreline; mild erosion on the order of -1 to -2 ft/yr continues to occur in the small pockets of beach remaining between the armoring, groins, and rock outcrops. A large seawall structure has existed since at least the 1950's at R-25 near the south end of the island, and acts as a stabilizing jetty. The island is very similar

in shape and historic changes to Anna Maria Island in Manatee County.

Cayo Costa Island - Refer to Figure 5 :

The island is essentially undeveloped and a large portion is owned by the state. There are no known development related problems. There has been channel erosion on the north tip of the island. However, the primary areas of erosion concern are south of the first shoals (R-59 to R-62), and south of the second (relic) set of shoals (R-59 to R-62). The erosion in each case results from the predominant northwesterly waves refracting around each of two sets of shoals. Erosion rates are on the order of -9 to -14 ft/yr in the first area and -5 ft/yr in the latter area.

North Captiva Island - Refer to Figure 6 :

This island has two erosion areas. Along Captiva Pass on the north end of the island (R-66 to R-70) there has been erosion resulting from channel migration on the order of -5 ft/yr since the 1950's. The bulbous north-central area of the island results from and is sheltered by the ebb tidal shoals of Captiva Pass. Like all shoal-protected areas, it is

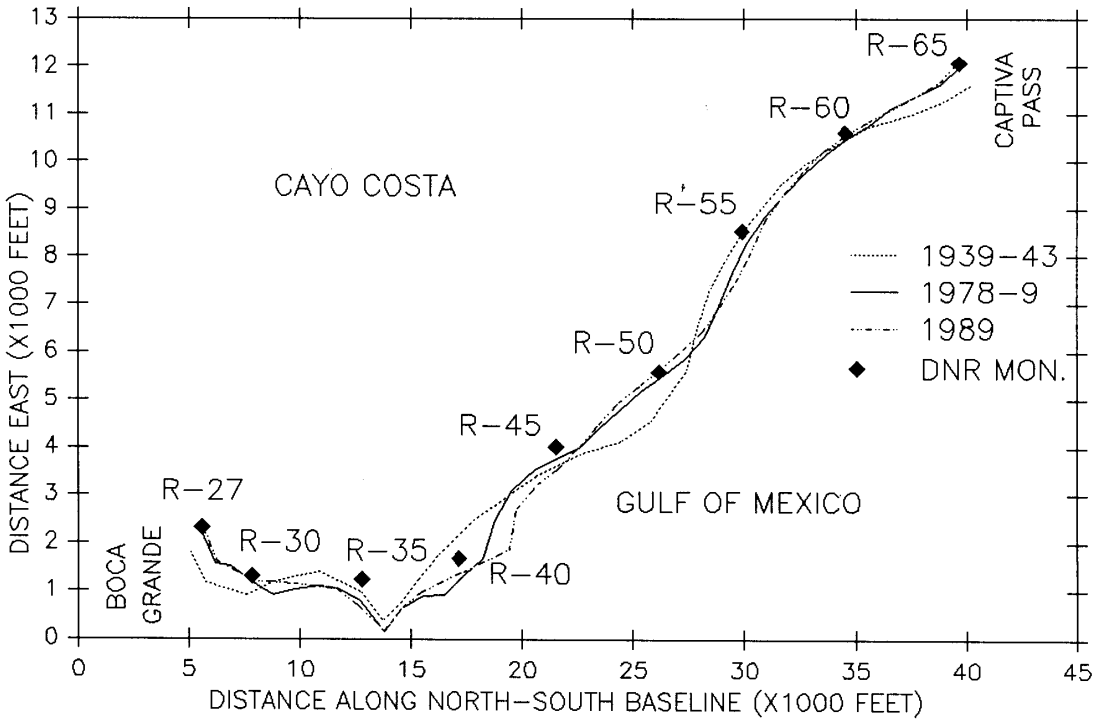

FIGURE 5. HISTORIC CHANGES, CAYO COSTA ISLAND

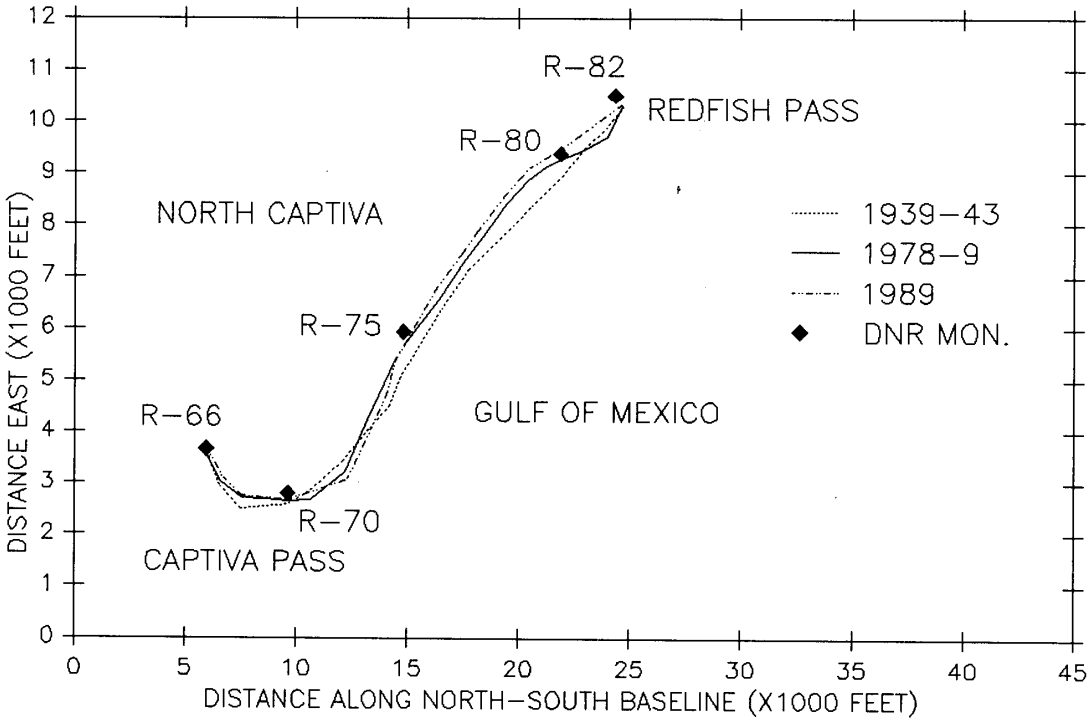

FIGURE 6. HISTORIC CHANGES, NORTH CAPITVA ISLAND

unstable during high water level storms and can be frequently and drastically rearranged. South of the shoals (R-75 to R-80), refraction of northwest waves results in a sand deficit and high erosion on the order of -15 ft/yr. Overtopping is frequent and the island is very narrow here.

The stability of the very south end of the island (R-81 to R-82) depends on the protection of the northern ebb shoals of Redfish Pass. Since these shoals were mined in 1988©89 for the Captiva renourishment project, the stability of the south end is presently uncertain. As with all inlets, a major storm surge could drastically erode both sides of Redfish Pass. The pass was opened by a hurricane in 1926.

Captiva Island - Refer to Figure 7 :

This island's beach is presently in very good condition due to the major renourishment of the north end in 1980-81, and of the entire island in 1988-89. Prior to the filling, essentially all of Captiva was either eroding or heavily armored with no beach. The post-1926 erosion of this island is generally due to the high northwest wave attack angle with respect to the shoreline orientation. Here, as with the other islands, the shoreline south of Redfish Pass shoals has

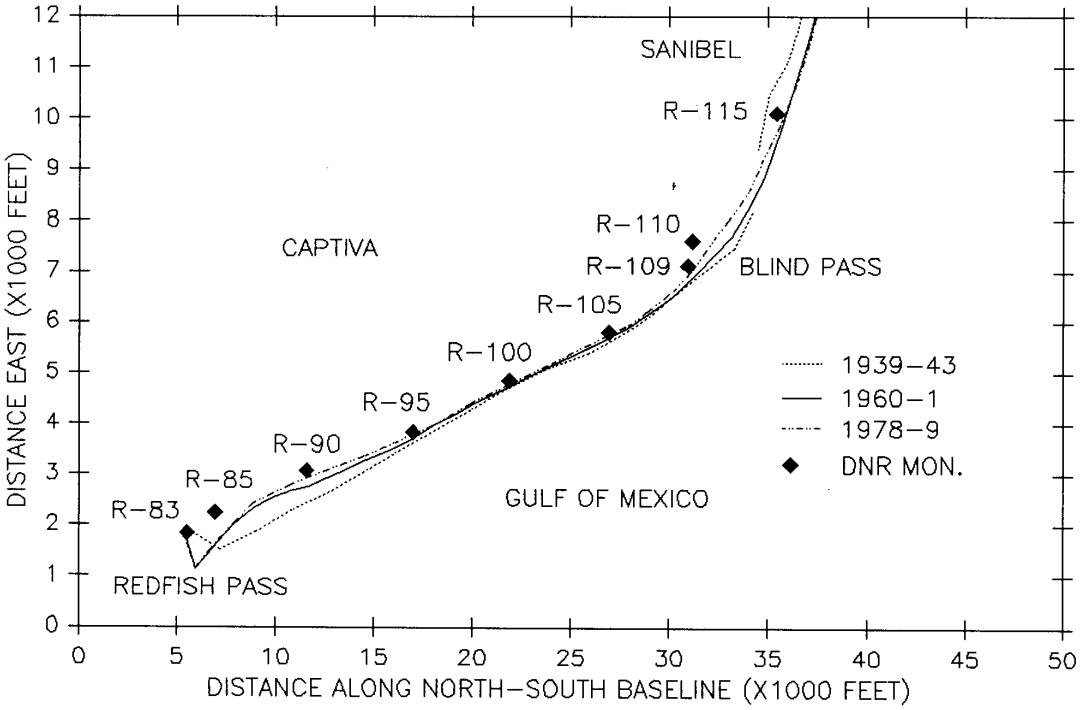

FIGURE 7. HISTORIC CHANGES, CAPTIVA ISLAND

been eroding to achieve a lesser angle of orientation with the predominant northwest waves.

Sanibel Island, Northwest Section - Refer to Figures 7 and 8:

The shoreline makes an abrupt change in orientation at the intersection of Captiva with Sanibel, at R-109, the location of Blind Pass. Before Redfish Pass opened, Blind Pass apparently carried a much larger share of tidal flow than today. Blind Pass is a marginal inlet now, which has closed on occasions. Sand eroded from Captiva has historically been carried by waves around the abrupt orientation change and formed into a series of long parallel spits by Blind Pass. The extended inlet channel would eventually become too long, the pass would break through at a weak point, and another spit would form. The entire northwest section of Sanibel was a cavity in 1859 which has since been filled with sand spits in this manner.

As the northern part of Captiva receded to form a lesser wave attack angle, the shoreline of southern Captiva and northern Sanibel began to recede in a transition to a flatter curvature. However, a terminal groin was built at R-109 at Blind Pass (probably in 1972, after Hurricane Agnes in June

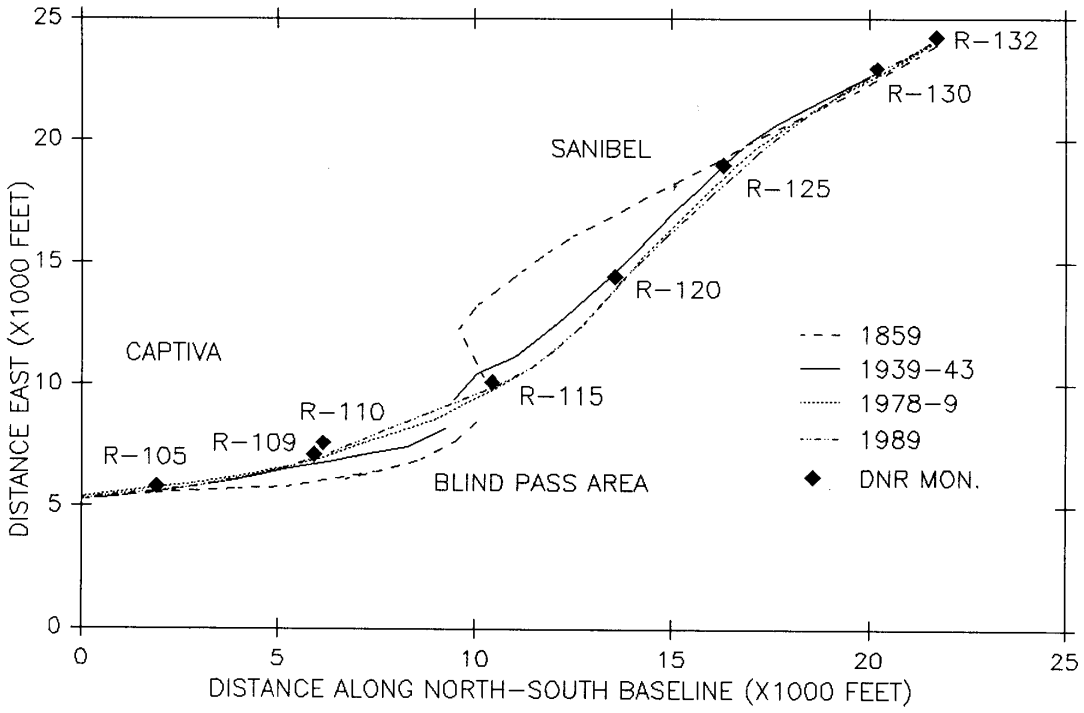

FIGURE 8. HISTORIC CHANGES, BLIND PASS AREA

1972) which acted to stabilize the southern end of Captiva, to protect the road and bridge, to stabilize the location of the inlet, and to shift the erosion zone southward. The latest sand spit began to erode faster and now from the point of greatest supply deficit, R-109, instead of gradually as part of the recession of the larger area to the north. In November 1988 the terminal groin was lengthened 100 feet in order to stabilize the design profile of the new Captiva fill project. The erosion pattern south of the groin remains inevitable and roughly predictable: the shoreline from R-111 to R-120 will recede and the area from R-120 to R-130 will accrete and then stabilize. In essence, the shoreline will be transformed to a flatter overall orientation. High erosion rates will be in the -10 to -30 ft/yr range. It is noted that the region is bounded on the south by a natural rock formation between R-132 and R-135. Without this stable boundary the erosion pattern would be significantly different on much of Sanibel.

Sanibel Island, Southeast Section - Refer to Figure 9 :

There are apparently no significant erosion problems in this area. Sand supply into the area is sufficient and wave activity is limited. However, there are several places

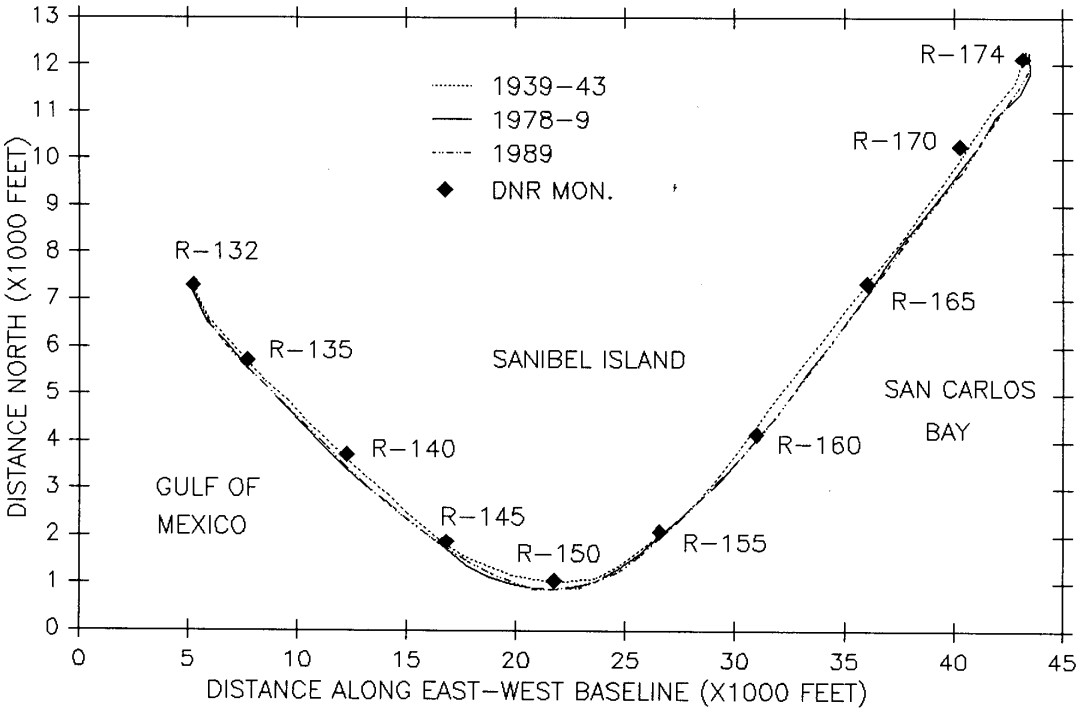

FIGURE 9. HISTORIC CHANGES, SANIBEL ISLAND

subject to storm damage because of seaward structure siting and/or inadequate foundation construction practices. Erosion can be conservatively estimated at -1 ft/yr throughout this area. Fluctuations can be expected at the eastern point of the island.

Estero Island - Refer to Figure 10 :

This island appears to be dominated by sand moved by tidal flows rather than by wave action. The areas of concern are in those spots where structures have been built too close to the water line and are therefore vulnerable to storms. The data indicate that over the last 15 years there have been no significant erosion problems on the Gulf-fronting portions of the island. Erosion is conservatively estimated at -1 to -2 ft/yr in this area. The placement of fill, from the occasional cutting and dredging of the north end of the island by the Army Corps of Engineers, onto the beaches in the vicinity of the pier and northward (R-179 to R-177), has helped keep that area stable. The data suggest that there would be an erosion problem there without the filling.

The south end of the island (R-200 to R-207) is accreting as large shoals merge with the shoreline. The exception is the

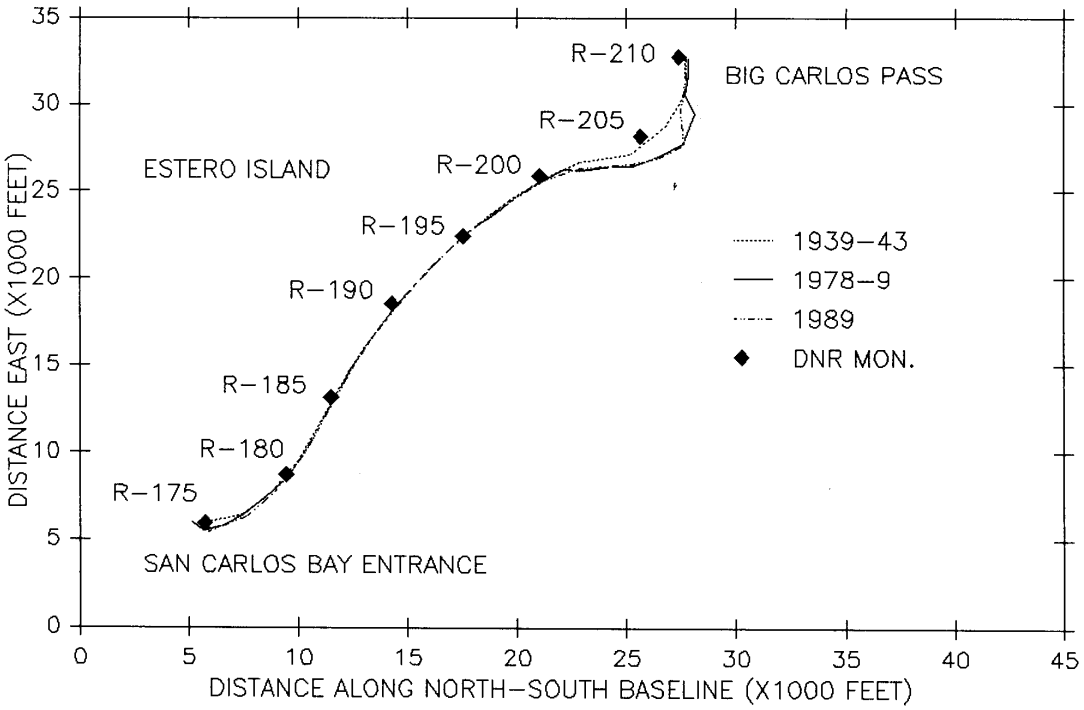

FIGURE 10. HISTORIC CHANGES, ESTERO ISLAND

armored area along Big Carlos Pass (R-208 to R-210) which is likely to remain vulnerable to erosion from the adjacent inlet flood channel and exposure to southwesterly storm waves.

Lover's Key, Big Hickory Island, and Bonita Beach - Refer to Figure 11 :

Lover's Key and Big Hickory Island are separated by New Pass between R-222 and R-223. These islands are the latest in a long series of emergent and reworked landforms in this area. Apparently, littoral material is carried here by tidal flows and wave action, and constantly reworked by storms and seasonal wave activity. The relationship between tides, waves, and sand supply in this area and southward to the end of the county is poorly understood at this time. Satellite images suggest a complex tidal/littoral transport relationship within San Carlos Bay as a whole, involving southern Sanibel and Estero as well as this area.

Rearrangement by major storms appears to be the dominant force in the long term in this small island group. Predictions of changes are not very reliable in the short term either, due to what appears to be significant changes in

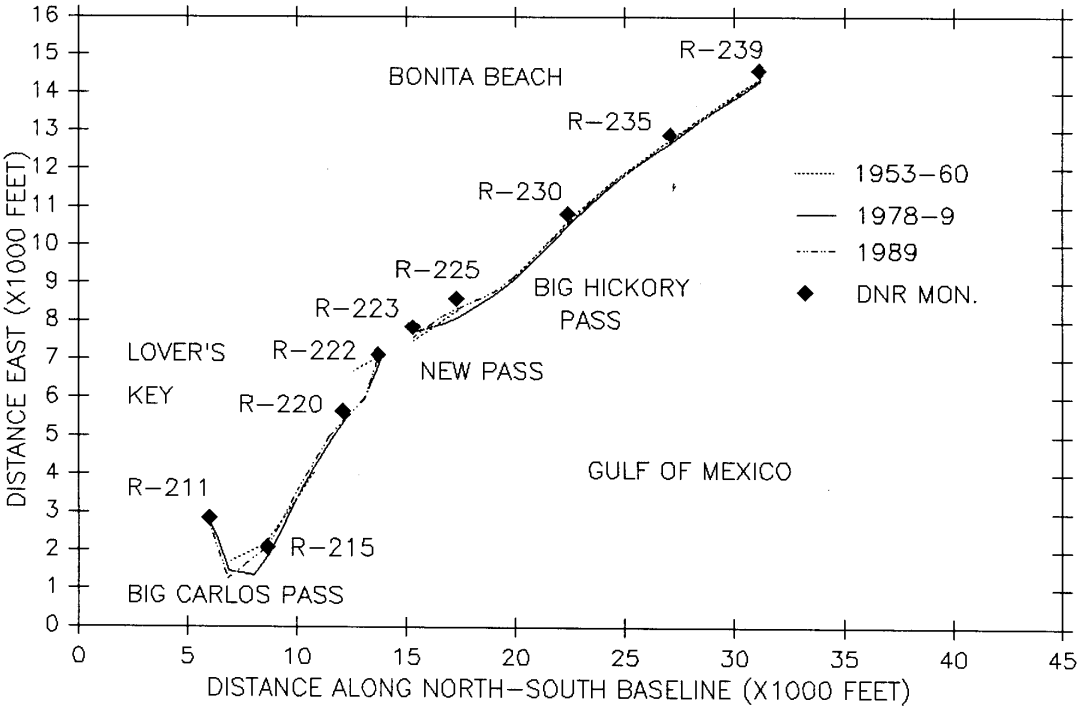

FIGURE 11. HISTORIC CHANGES, LOVERS KEY TO BONITA BEACH

the net wave energy direction from time to time, perhaps as one season dominates another on occasion. The islands may be regarded as generally unstable and moderately eroding in recent years.

Bonita Beach in general has remained relatively stable over the 100 year record. The one problem area is along the north end of Bonita Beach for approximately 3000 feet, R-226 to R-229. This was a dynamic spit-like landform associated with the northward migration of Big Hickory Pass, now located between R-225 and R-226. In the early and mid 1970's, multi-family high rise structures with seawalls were built out onto the temporary landform. The inlet has become very marginal over recent decades, possibly related to the construction of a causeway in the bay and the growth of New Pass to the immediate north. The narrow beach initially fronting the seawalls disappeared with the conditions that formed it, apparently in the mid to late 1970's. The site is highly vulnerable to storms.

Erosion is conservatively estimated at -1 ft/yr for the southern area of Bonita Beach. If the armoring were not in place, there would be a major shoreline reorientation at the north end.

CONCLUSIONS

The eight inlets in Lee County each appear to have a significant influence on the erosion pattern of their adjacent islands. The islands and inlets of northern Lee County exhibit some notable similarities in shape, behavior, and effect. Blind Pass, however, is a special case of an extensively migrating inlet which has now become marginal and somewhat anchored in position. The southern portion of the county appears dominated by the San Carlos Bay Entrance, although the patterns of sand transport within this system are not resolved.

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