The Common Thread in Inlet-Induced Erosion : Basic Theory and Florida Examples

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1) This paper was published in the Proceedings of the 1995 National Conference on Beach Preservation Technology, published by The Florida Shore & Beach Preservation Association, Tallahassee, FL, 32301, pp. 227-242.

2) The author's e-mail address is as follows : Emmett.Foster@dep.state.fl.us (as of jan. 2000).

4) 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

It is widely recognized that there are many inlets with downdrift erosion problems. It is intended here to show that there is a common thread in many of the inlet-induced erosion patterns in Florida that can be understood with the help of general case numerical modeling. This paper compares some actual inlet induced erosion patterns with those predicted from numerical modeling.

INTRODUCTION - BASIC THEORY

Two cornerstones of coastal engineering are : (1) the essential form of the equation describing longshore sand movement by waves, and (2) the need for a balanced sand budget. Calculations using equations for sand transport and conservation of volume are today made much easier with the aid of computers, and this practice is called longshore modeling. This type of modeling yields, along with many other applications, definite predictions regarding what types of erosion patterns should be found on the downdrift side of inlets with jetties, or similarly on the downdrift side of inlet ebb shoal sinks. Example comparisons will be given of generalized model predictions with the history of shoreline erosion at a sampling of eight Florida inlets. It is contended that the erosion patterns associated with at least 33 inlets in Florida are essentially the same as that indicated from the modeling. It is further contended that observed differences are due to local conditions which act to modify the base pattern. Such conditions can usually be simulated and the effects reproduced in more specific case modeling.

A one-line, two-season, finite difference model can be used to generate a base case. To include as many inlet erosion examples as possible in this paper, the model will not be discussed in detail here. The model and its use in various case studies are discussed in Refs. 1, 2, and 3.

The erosion of the mean high water (mhw) line will be modeled. The assumptions include a straight beach with net sand transport from north to south, caused by greater seasonal wave energy out of the northeast. An inlet is assumed to be cut in that shoreline, with jetties that act as complete littoral barriers. This is a situation similar to that often found along Florida's east, Atlantic coast. However, the directions are arbitrary; the results apply in any directional framework with similar conditions, as will be seen. The model parameters used are as follows:

- x interval = 200 feet
- time interval = 43200 sec = 12 hours
- depth of parallelogram cross-section = 12 feet
- season 1 or "winter" = 90 days of waves with breaking height 2 feet and attack angle 3 degrees
- season 2 or "summer" = 30 days of waves with breaking height 1 foot and attack angle 3 degrees.

It is not essential that these specific parameters or this particular model be employed. Any reasonably similar model and set of conditions will produce similar results. For simplicity, the effects of any wave refraction and diffraction in the lee of the jetty, or any losses into the inlet through or around the jetty are not considered. It is noted that these factors will have only relatively minor effects on the basic results (Ref. 3).

Figure 1A shows in plan view the mhw erosion downdrift from an inlet as generated by the base case model. Figure 1B shows shoreline response over time relative to selected reference points along the beach, in distance versus time plots. Both figures show patterns that can be considered as characteristic of the erosion to be expected in actual cases. The instantaneous slope on any curve in Figure 1B at any given time and location represents the erosion rate at that time and location. A downward slope is erosion; a zero slope is stability; a positive slope would be accretion. Note that the shoreline response is distinctly non-linear : the rate of erosion is not

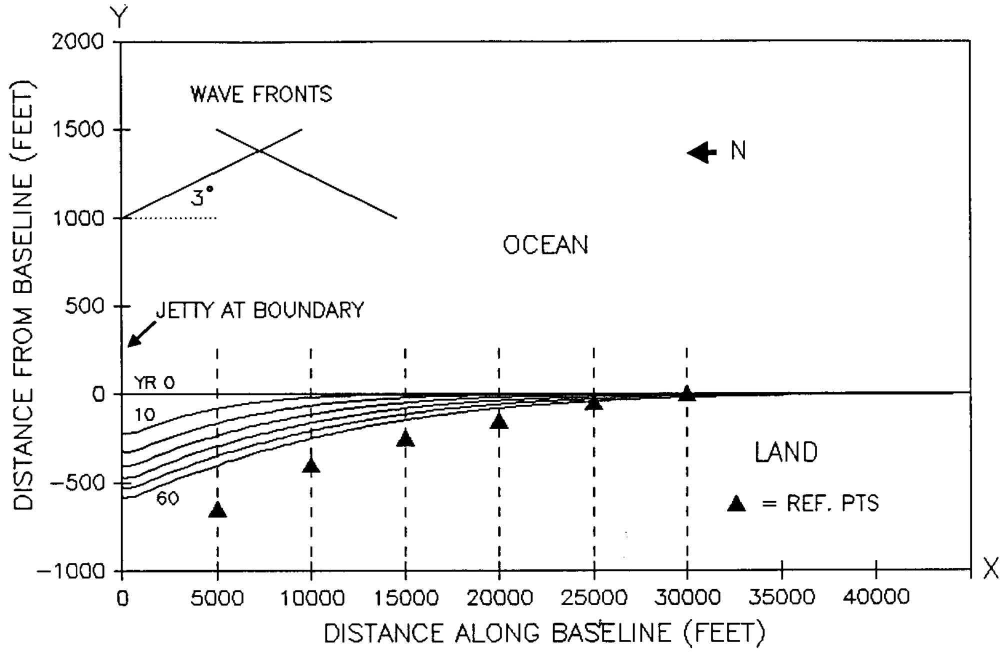

FIGURE 1A - MODEL PLAN VIEW SHORELINES

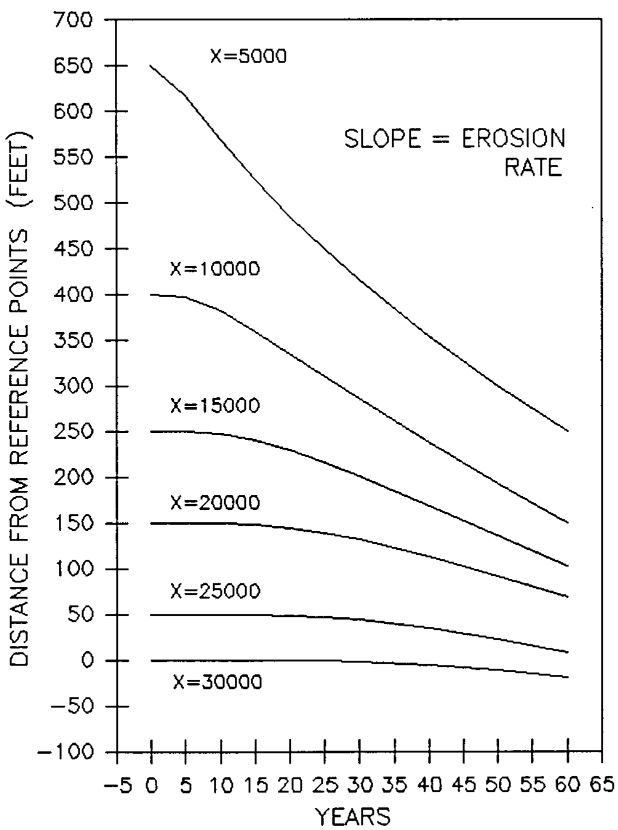

FIGURE 1B - MODEL DISTANCE VS. TIME PLOTS constant over time and the erosion spreads downdrift over time. It is, however, possible to approximate erosion rates as constant values for limited periods of time at a given location.

EXAMPLES

Figure 2 shows a map of Florida locating the eight inlets that will be used for comparison with the model results. The historic data has been obtained from the Florida Bureau of Beaches and Coastal Systems historic shoreline data base, which is maintained by the author. A description of the data base is given in Reference 2. The historic shorelines in the plan views are connect-the-dot type plots using data relative to the Bureau's coastal monument system ("R" reference points).

A better example than the area adjacent to and south of St. Lucie Inlet in southeast Florida probably does not exist. Figures 3A and 3B show erosion patterns clearly similar to the model base case. The erosion here has been active for a very long time and is therefore clearly defined. The inlet was cut in 1892.

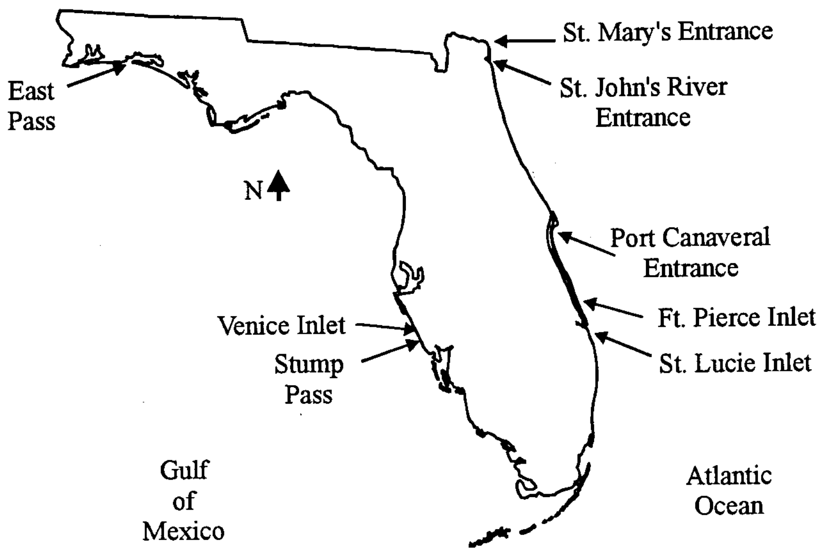

FIGURE 2 - FLORIDA INLET EXAMPLES,
LOCATION MAP

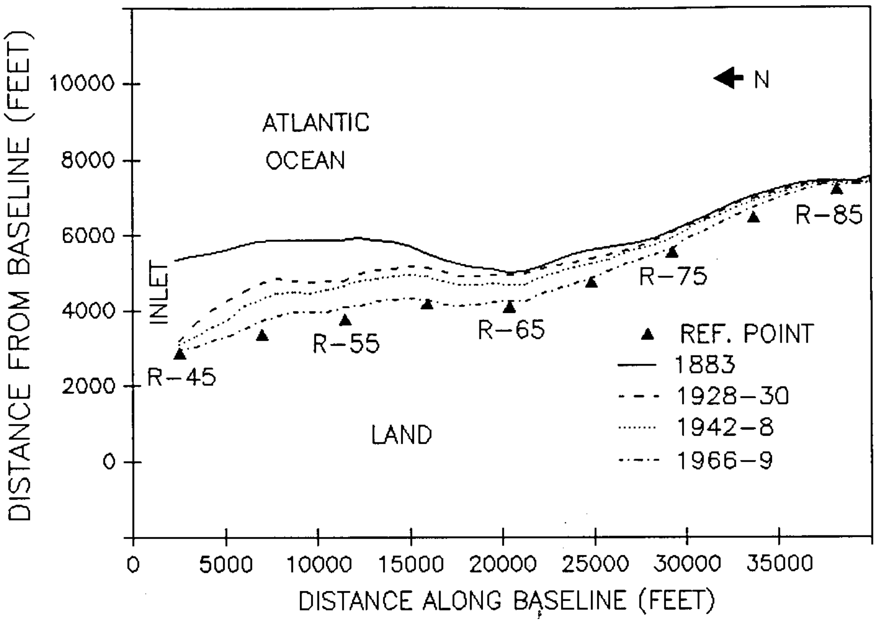

FIGURE 3A - ST. LUCIE INLET, PLAN VIEW, HISTORIC SHORELINES

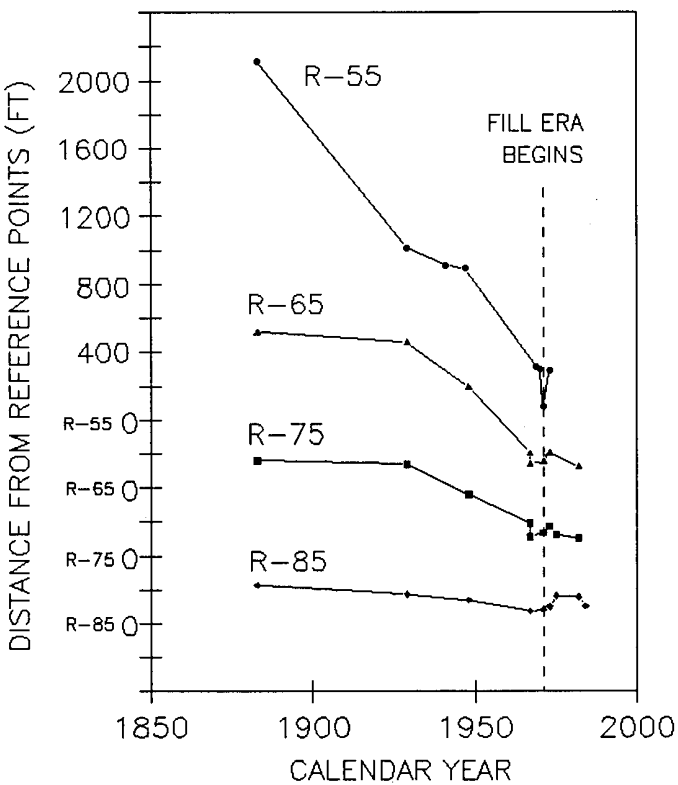

FIGURE 3B - ST. LUCIE INLET, DISTANCE VS. TIME PLOTS

The erosion pattern in the plan view can be seen to have been modified by the presence of "bumps" related to a shoal merging zone and rock/reef exposures. Multiple filling events have occurred in various locations and amounts southward of the inlet since the 1970's.

A second good example is provided by the area south of Ft. Pierce Inlet in southeast Florida, about 22 miles north of the previous inlet example. Figures 4A and 4B show erosion patterns clearly similar to the model base case. The inlet was cut in 1920-1. The erosion pattern in the area actually started prior to the cutting of this jettied inlet because this area was within a similar downdrift erosion pattern of another older, natural inlet to the immediate north, which closed between 1892 and 1928. The south side ebb shoal of that natural inlet acted as a sand sink, as did the beach in its' sheltering influence. The effect of a sand sink can be very similar to that of a littoral barrier such as a set of inlet jetties. This will be seen in the next example. Note the presence of a "bump" in the plan view erosion pattern near R-44/45, related to rock/reef features which erode

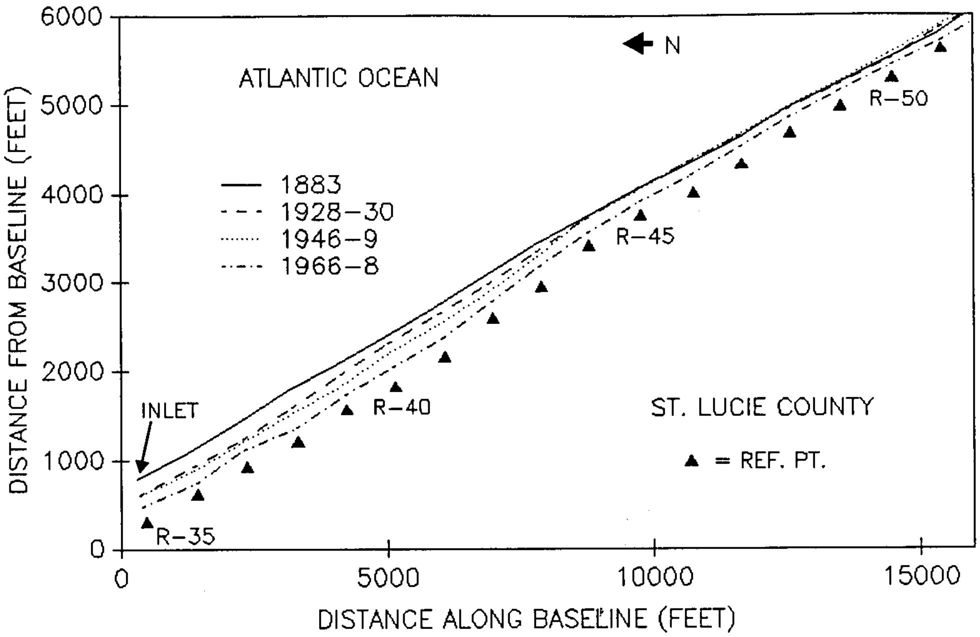

FIGURE 4A - FT. PIERCE INLET, PLAN VIEW, HISTORIC SHORELINES

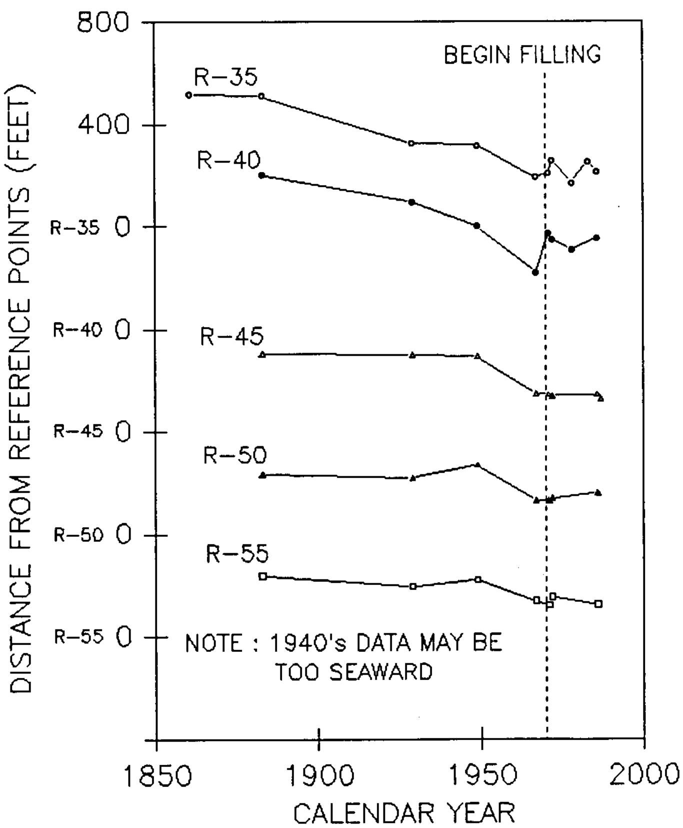

FIGURE 4B - FT. PIERCE INLET, DISTANCE VS. TIME PLOTS more slowly than sand.

The third example is the area south of Stump Pass in southwest Florida. This is a natural inlet with a southern ebb shoal which acts to create a sand sink. The sand sink both in the shoal and on the sheltered beach acts as a littoral barrier to the extent that a downdrift erosion pattern very similar to the model base case has occurred. This is shown in Figure 5. Notice that only relatively recent shoreline changes are shown. This general area has experienced drastic coastal changes over the last 100+ years : multiple inlets have opened and closed, and storms have been a major influence. However, the recent history of Stump Pass has been relatively well behaved, allowing sufficient time for the expected erosion pattern to develop.

A fourth example is the area south of Venice Inlet in southwest Florida, about 16 miles north of Stump Pass. This was a natural inlet. Jetties were constructed in 1937-8, with subsequent modifications. As can be seen in Figure 6, the erosion pattern spread southward as expected but was modified by the rock exposure near

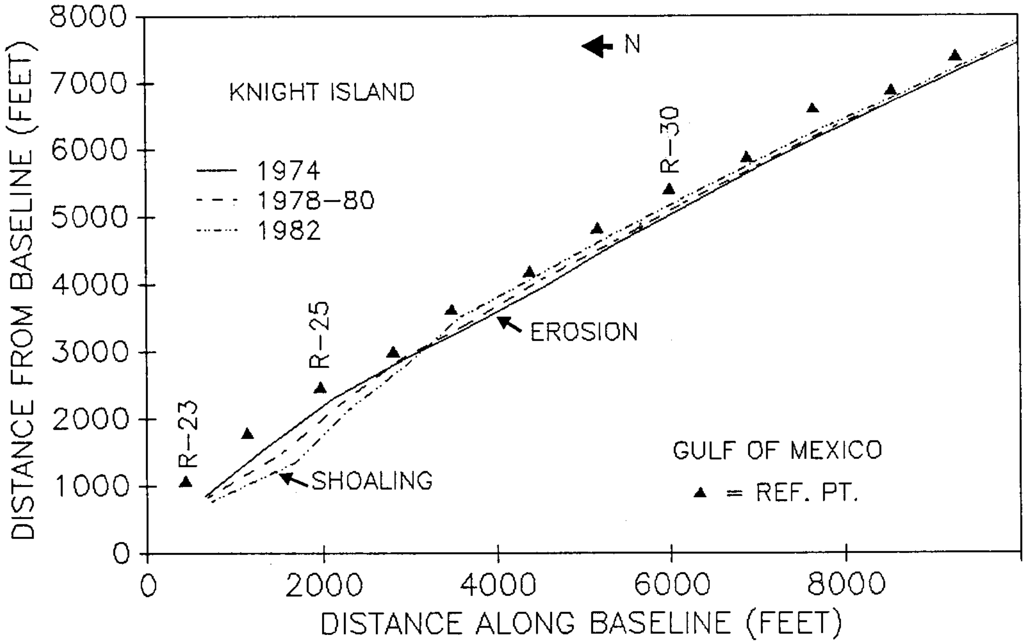

FIGURE 5 - STUMP PASS, PLAN VIEW, HISTORIC SHORELINES

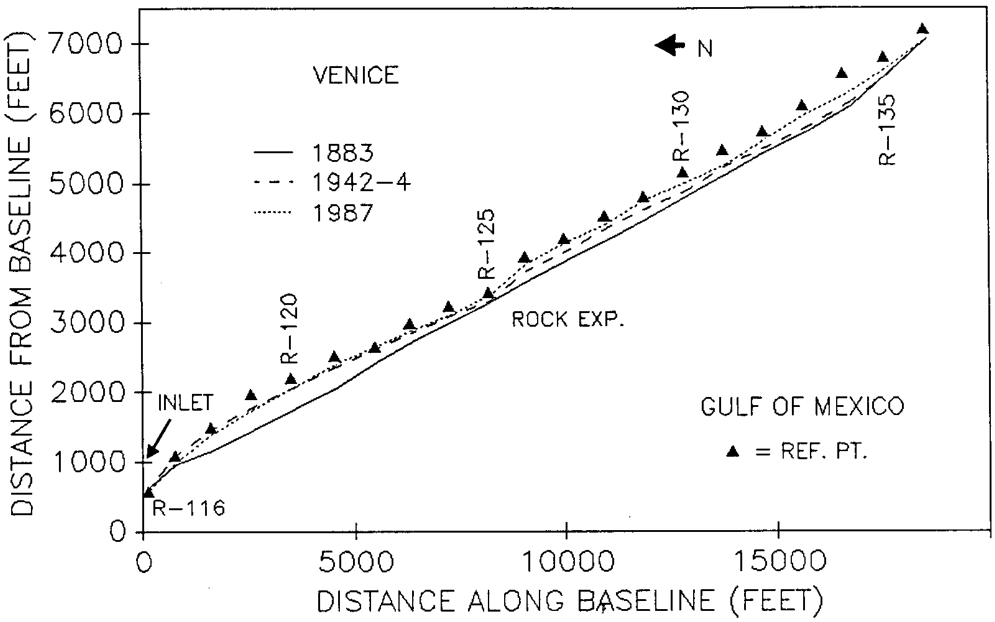

FIGURE 6 - VENICE INLET, PLAN VIEW, HISTORIC SHORELINES

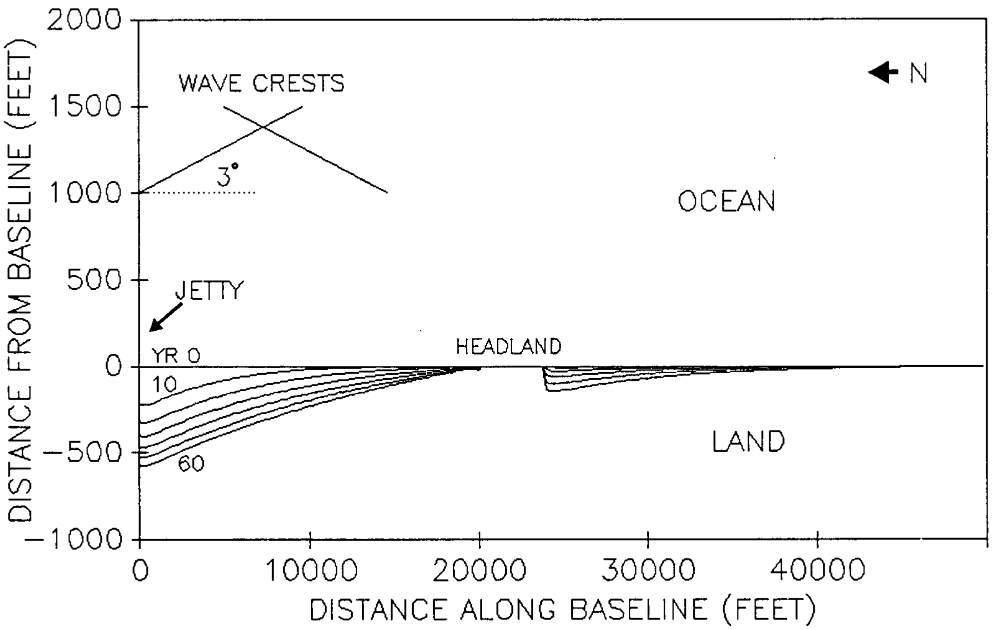

FIGURE 7 - MODEL WITH HEADLAND, PLAN VIEW SHORELINES

R-125. The erosion was also affected by large scale armoring along this entire zone. Figure 7 shows the base case model results when the erosion pattern is intercepted by a hard, headland type feature. The spreading of the erosion pattern downdrift of the headland is seen to have occurred at Venice as theory would predict.

The fifth example is the area south of the Port Canaveral Entrance on the central east Florida coast. The inlet was cut in 1951, but not through to the lagoon. This example will be used to show that both historic erosion and fill behavior may be analyzed for similar erosion patterns. Looking at the fill first, Figure 8 shows the plan view erosion pattern that occurred for a renourishment project in 1974-5. This may be compared favorably with that of Figure 9, which shows how fill reacts when placed within the model erosion pattern. Note that when the fill is eroded away, the original erosion pattern is expected to resume. Also notice that this example inlet is not located on a straight coast but is instead on a highly concave coast.

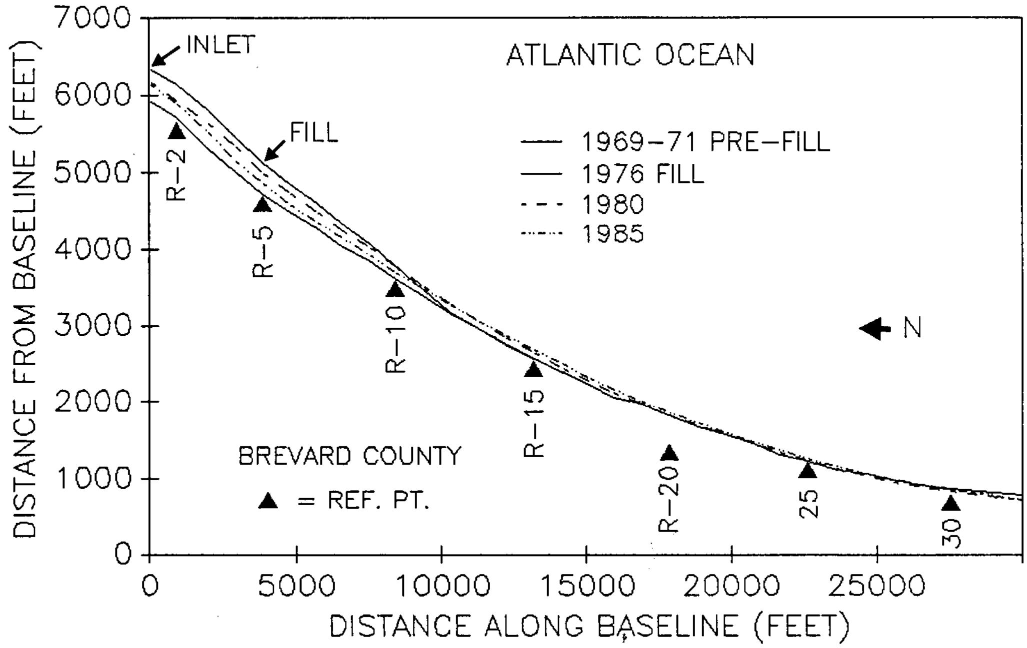

FIGURE 8 - PORT CANAVERAL ENTRANCE, PLAN VIEW, HISTORIC SHORELINES

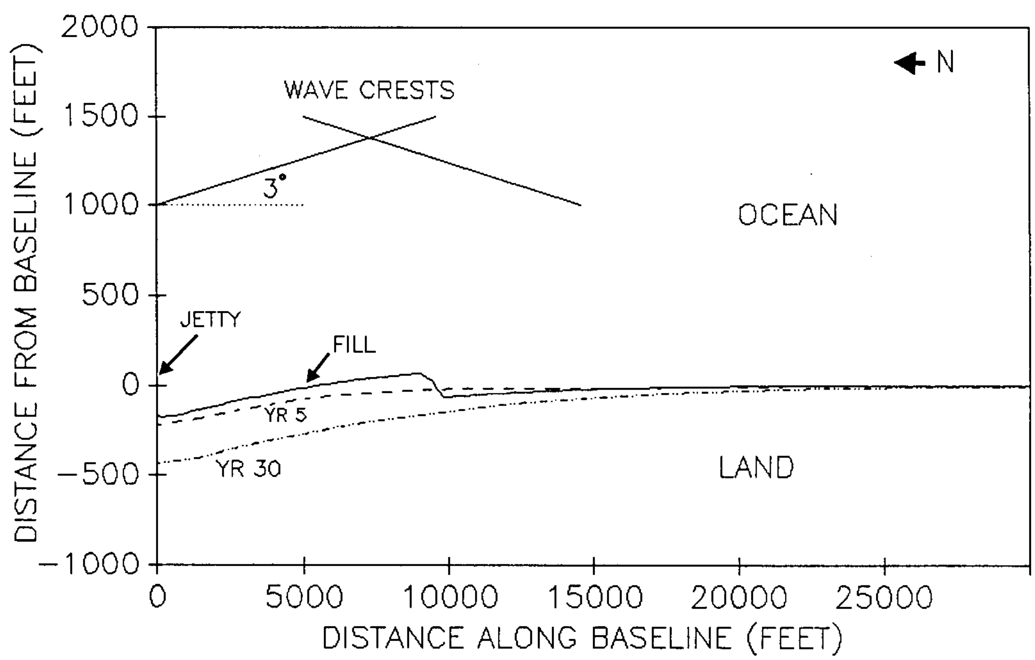

FIGURE 9 - MODEL WITH FILL, PLAN VIEW SHORELINES

It will be observed here and in the following examples that a concave shoreline orientation and a favorable wave climate can modify the expected downdrift shoreline change pattern by allowing accretion to occur for a distance ahead of the progressing erosion zone. In the Port Canaveral case, as shown in Figure 10, local conditions were such that the beach in the vicinity of the present inlet and for a considerable distance southward was accreting before the inlet was cut. A portion of the downdrift beach continued to accrete mildly after the inlet was cut, probably because supply remained sufficient and not yet drastically reduced by the progressing erosion pattern. Then the renourishment occurred next to the inlet. Careful examination of Figure 8 suggests that supply from the accelerated erosion of the fill may have been adequate for the effect to continue at a mild level in the R-15 to R-25 area from 1976 to 1985. Concave curvature is a factor in the remaining examples as well, and the effects will be further explored.

The sixth example is the area south of the St. Johns River Entrance in northeast Florida. This was a

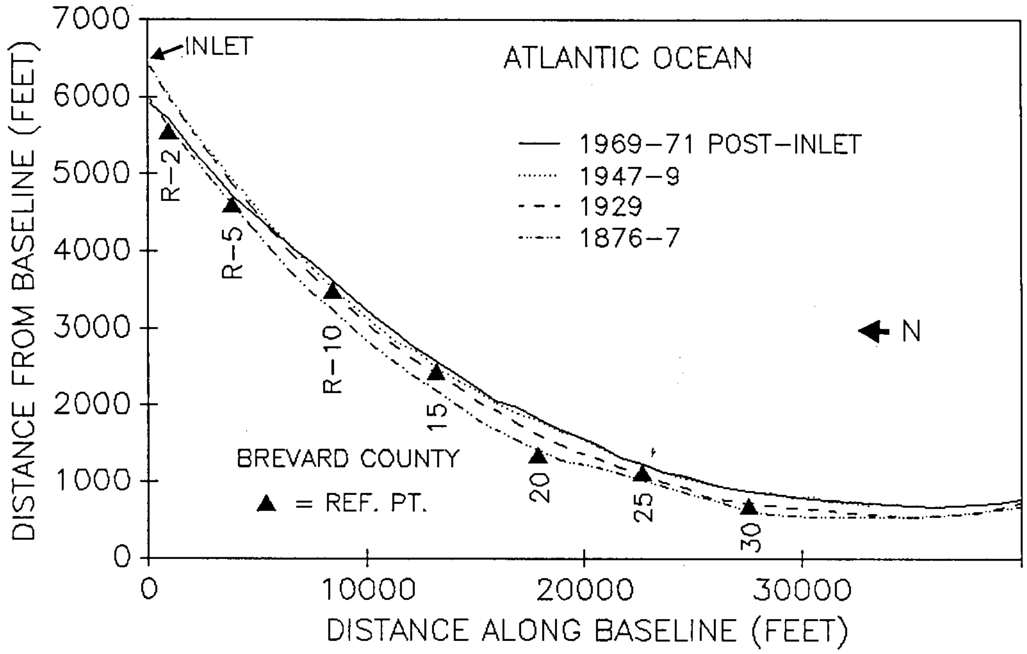

FIGURE 10 - PORT CANAVERAL AREA, PLAN VIEW, HISTORIC SHORELINES

natural inlet. Jetties were built during the period 1881-90. Figures 11A and 11B show erosion patterns very similar to the expected patterns. The local region is concave in shape. The 1924 shoreline may show that a downdrift accretionary zone temporarily occurred in the R-50 to 60 area, although this could be a structural effect from groins or an error in that data. Assuming the 1924 data to be correct, it would be an effect consistent with the shoreline curvature.

The seventh example is the area south of St. Marys Entrance in northeast Florida, about 20 miles north of the St. Johns Entrance. This was a natural inlet. Jetties were constructed in 1881-1904. There was a long period when ebb shoal sand apparently came ashore and filled in a large depression in the shoreline orientation just south of the inlet. By the 1950's, and probably a decade or so earlier, this effect ceased to be significant and the erosion pattern we would expect to see began occurring south of the inlet. The erosion severly threatened the developed area of Fernandina Beach, so a large area south of the inlet was armored with a continuous revetment in 1964, after the added influence of Hurricane Dora. Figure

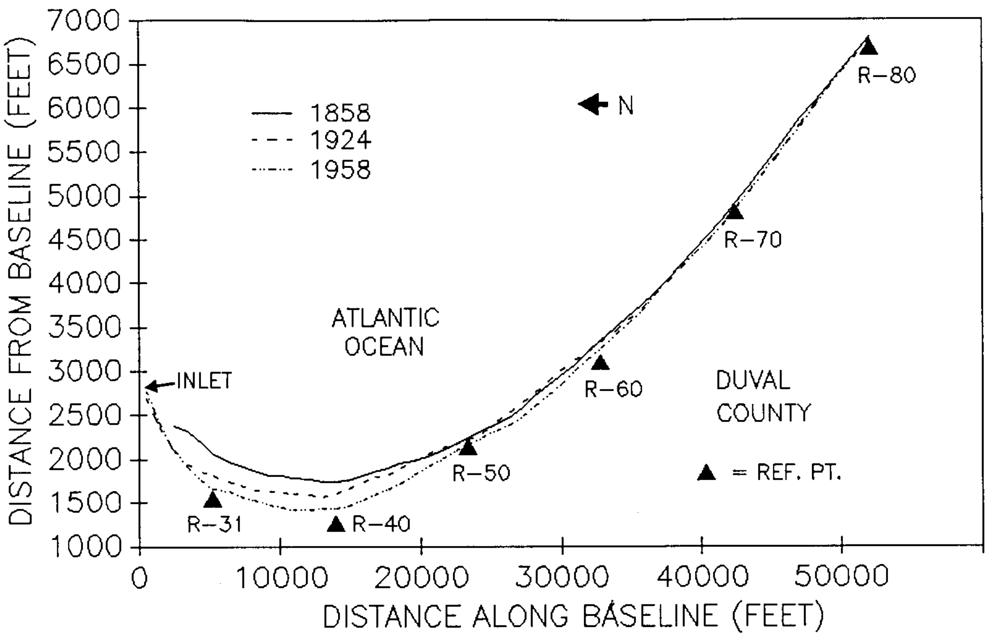

FIGURE 11A - ST. JOHNS RIVER ENTRANCE,
PLAN VIEW, HISTORIC SHORELINES

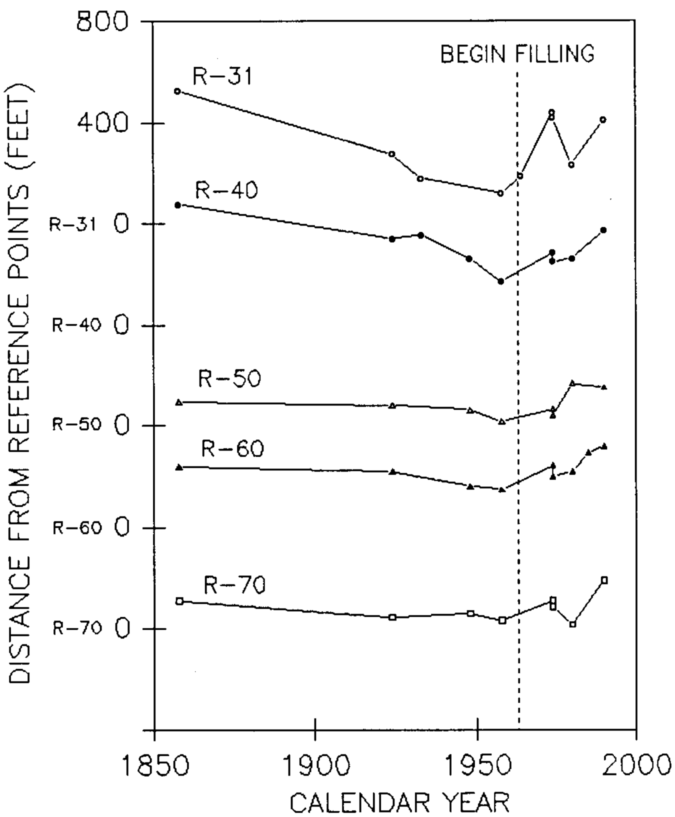

FIGURE 11B - ST. JOHNS RIVER ENTRANCE,
DISTANCE VS. TIME PLOTS

12A shows the historic erosion comparable to the expected pattern, as modified by the armoring. The area has been repeatedly filled since 1978.

Figure 12B shows in plan view all of Amelia Island, including the inlet-adjacent area of the prior figure, for the same historic shorelines. Notice the concave shape of the region south of R-30, and that accretion occurred there. Notice also in Figure 12B that the fit of a preliminary calibrated model of the island by the author quite closely matches the 1973-5 shoreline target throughout. This model reproduced the expected inlet-adjacent erosion zone and the further downdrift accretion zone, although more data from the fill era is needed to verify the calibration.

The eighth example is the area west of East Pass (Destin Harbor) in northwest Florida, on the Gulf Panhandle coast. The inlet broke through in roughly its' present location in 1928. Jetties were constructed in the 1960's. Notice in Figure 13 the appearance of erosion of a similar pattern to the expected after the inlet opened in the present location. Notice also that this is a concave-shaped

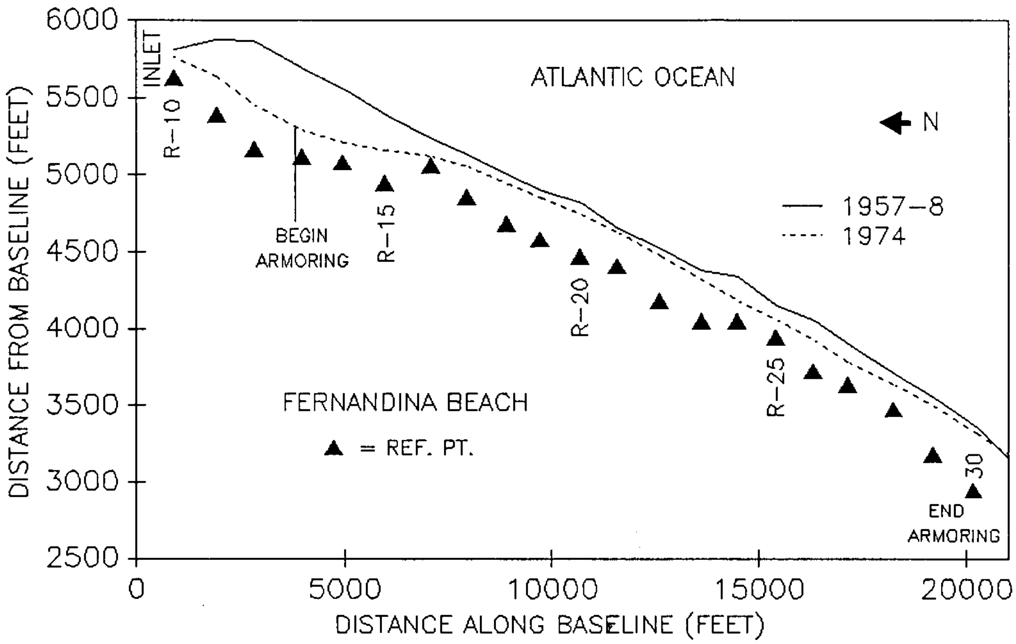

FIGURE 12A - ST. MARYS ENTRANCE, PLAN VIEW, HISTORIC SHORELINES

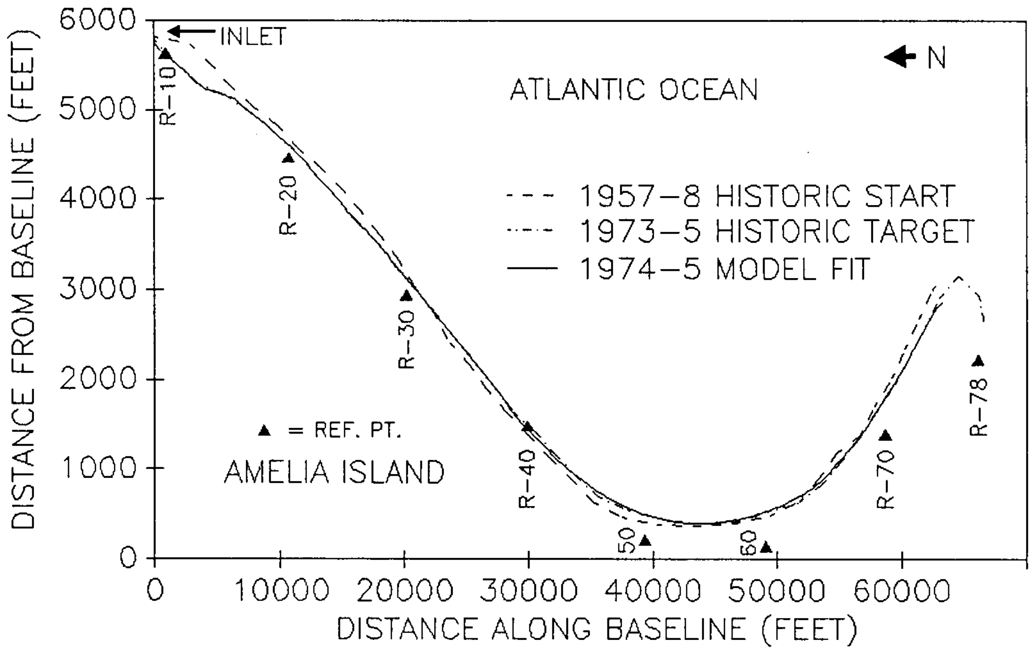

FIGURE 12B - AMELIA ISLAND, PLAN VIEW, HISTORIC AND MODEL SHORELINES

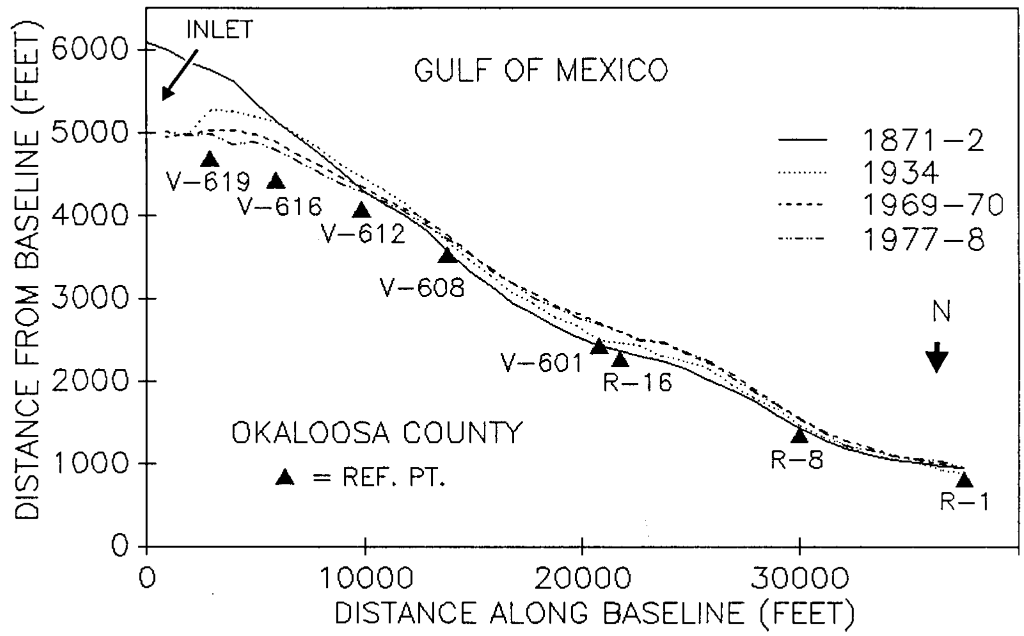

FIGURE 13 - EAST PASS, PLAN VIEW, HISTORIC SHORELINES

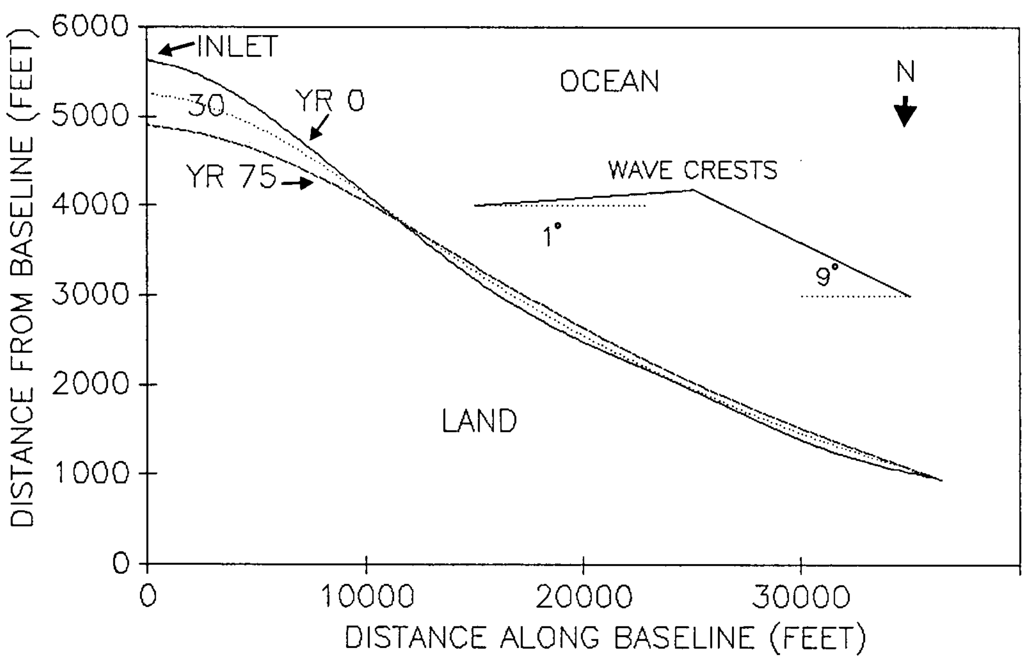

FIGURE 14 - MODEL WITH CONCAVE COAST, PLAN VIEW SHORELINES

coastal region. An accretional area developed downdrift of the inlet-adjacent erosion zone and was gradually being eroded by the westward progressing erosion zone.

Can a erosion/accretion pattern be reproduced in a general case model with results similar to those observed above for a concave-shaped coastal region ? A coast similar to that of the East Pass area was modeled, with the results shown in Figure 14. As can be seen in that figure, a shoreline change pattern closely resembling the observed can be generated with little difficulty. The accretion zone can develop as a result of a relatively acute concave regional shape in combination with favorable wave conditions. In some areas there may be assistance from local bathymetry or rock/reef effects. The model and the historic data suggest suggest that usually the erosion zone can be expected to spread into the accretion zone and eventually destroy it, unless controlled by artificial sand supply.

OTHER FLORIDA INLETS

The additional Florida inlets which appear to exhibit downdrift erosion patterns similar to that presented here are listed in the next paragraph. There may be more. Data for some inlet areas is insufficient, and some areas are too complex for simple comparison. It is suggested that interested parties should attempt to see if an inlet's erosional history is consistent with the expected general pattern given the local conditions. If not, the reason should be that the local wave climate and (or) the sand supply situation are not sufficiently similar to the situations described here. Observing and understanding the role of local modifying factors is essential to correctly interpreting the erosion pattern.

The following inlet downdrift areas appear to exhibit the expected erosion patterns with local variations : St. Augustine, Sebastian, Jupiter, Lake Worth, South Lake Worth, Boca Raton, Hillsboro, Port Everglades, Baker's Haulover, Clearwater, Johns Pass, both Blind Passes (Pinellas and Lee), Passage Key, Longboat, New Pass (Sarasota), Gasparilla, Captiva, Redfish, Doctors, Gordon, Big Marco, St. Andrews (Panama City Harbor Entrance), Mexico Beach, and Sikes Cut.

CONCLUSIONS

The given examples appear to match theory with observations reasonably well. Since the equations used in the modeling are well established as being descriptive of the physical processes involved, i.e. waves acting on sandy beaches in defined regions, the comparison of observations with theory very much SHOULD work well in this application.

In the author's opinion there is definitely the common thread of consistent downdrift erosion patterns for many of Florida's inlets. It has been shown that local conditions will modify the erosion pattern in recognizable ways. It has also been shown that general case numerical modeling can be a useful tool in understanding coastal processes.

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