COASTAL PROCESSES NEAR CAPE SAN BLAS, FLORIDA:
A CASE STUDY USING HISTORIC DATA AND NUMERICAL MODELING

Emmett R. Foster, P.E.

Florida Department of Natural Resources

Division of Beaches and Shores

3900 Commonwealth Boulevard

Tallahassee,Florida 32399

Notes Added To The WEB Copy , 1/10/97, 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. 400-411. Minor revisions have since been made to the appendix.

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 (correct 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. The modeling procedures have since been advanced. The two volumetric numbers in this paper may not be reliable. However, subsequent beach surveys show continuing mean high water erosion very consistent with the predictions herein.

4) The figures and appendix for this ASCII text file 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

The Cape San Blas area of St. Joseph Peninsula is located in the Florida Panhandle on the Gulf of Mexico. The area adjacent to the Cape was known to be highly eroding from recent (1970's-1980's) aerial photography and beach profile surveys of the Florida Department of Natural Resources. An analysis of historic coastal topographic maps indicates that high erosion has continued in this zone over at least the last 110 years. The major forces causing the high erosion

are not obvious and are necessary to an understanding of the future of the peninsula area. A particular question is whether presently low erosion areas of the peninsula will eventually become high erosion areas, and if so, when and why. A large historical shoreline change data set has been carefully assembled on a common coordinate system and analyzed. A numerical model of the area has been developed and calibrated against the historic data. The results indicate that a certain combination of forces is necessary to have the model replicate the gross historic changes. It is suggested that this combination of forces helps define the major coastal processes occurring at the site and very reasonably explains the observed high erosion pattern. The model was run for a future 90 year period to show what may likely happen in the area should those forces persist. The results should prove useful for coastal regulatory and planning purposes.

INTRODUCTION TO THE SITE AND THE PROBLEM

St. Joseph Peninsula is located in Gulf County, Florida, on the Gulf of Mexico. Figure 1 shows the overall geographic location, some general bathymetry, and the Florida Department of Natural Resources (DNR) coastal monument reference points (designated as "R" monuments) in the area. Also shown is a pair of coordinate (X,Y) axes superimposed over the peninsula. The axes were arbitrarily selected to extend from the Cape to the northern tip of the peninsula and will be used as the reference axes for modeling purposes.

St. Joseph Peninsula, in the area between Cape San Blas and approximately R-88, is probably the most highly eroding section of beach in Florida. Comparative DNR beach profile surveys in 1973 and 1983 indicate an average erosion rate of approximately -10 ft/yr (-3 m/yr) between R-107 and R-90, with erosion tapering off toward the north. Conversely, the beach has been highly accreting between R-43 and R-33, at the northern tip of the peninsula. Fortunately, the peninsula is only lightly developed with single and multifamily residential structures, and has no coastal armoring. However, development pressure here as in most of coastal Florida can be expected to increase over time. The area north of R-75 is a state park. The area of most concern from a development standpoint is therefore between R-116 and R-75.

Erosion as measured by beach profile surveys over a 10 year period, such as 1973 to 1983, is obscured on the peninsula by a beach cusp pattern which can cause fluctuations in beach width on the order of 70 feet (20 meters). The wavelength can be shorter or longer than the average 1000 feet (300 meter) longshore distance between DNR profiles.

A longer time frame data set is now available for this and all other Gulf and Atlantic sandy beach areas of Florida. 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. This work was done by researchers at Florida State University 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 1973 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 1860'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

(1989). DNR aerial photographs of 1973 and 1983 also exist for this area. All this information is available at the Florida Department of Natural Resources, Division of Beaches and Shores.

An analysis of the historic shoreline change data base indicates that high erosion levels have continued along the peninsula over at least the last 110 years. It was not obvious to the author what the major forces causing the high erosion were, and if the high erosion should be expected to continue. A working understanding of this area is critical if development is to be fairly and rationally managed in this area. For these reasons, the author has modeled the peninsula shoreline with a numerical longshore model, used the historic shoreline data for calibration, and extended the model run to help predict future changes. The modeling and results are the primary subject of this paper.

As an initial step in understanding the area, it is observed that the peninsula is exposed to waves from the southwest through the northwest directions. Waves from the southwest have a much larger fetch over deeper water in the Gulf. The prevailing weather patterns also favor higher energy waves from the southwest during the winter and from tropical storms in the Gulf during the summer. Offshore hindcast wave data (U.S. Army Corps of Engineers, 1988) yields a mean significant wave height of 0.9 meters in 59 meters water depth, with predominant energy from the southwest over the period 1956 to 1975.

The sand on this Peninsula consists of a varying mixture of relatively fine grain quartz and coarse shell fragments. The elevation of the frontal dune is very low in the south end, +6 to +10 feet NGVD, but rises to elevations of +20 ft NGVD near R-90. As seen from the air, the dune ridges on the Peninsula exhibit a complex set of patterns indicating the possible existence of previous barrier islands which joined to form the present peninsula with deltaic features of the Appalachicola River to the east. These are discussed by Stapor (1973), and can be seen in the DNR aerial photography. Offshore of Cape San Blas at the southern terminus of the peninsula, there are vast deltaic shoals which interact with waves to shape the Cape. There are frequent shoreline changes at the tip of the Cape and this section is particularly vulnerable to hurricanes. DNR aerial photographs of 1973 and 1983 indicate some refraction of southwest waves by the offshore shoals at Cape San Blas, as would be expected.

THE MODEL

A general one-line, two-season, longshore numerical model has been developed by the author and is applied in this case. The basic outline of the model is described in the Appendix at the end of this paper. The model equations were developed from LeBlond (1972) and Bakker (1968), although there are many similar references available in the literature. In general, a set of coordinate (X,Y) axes are selected such that the coastline runs in an approximate horizontal (x axis) direction, and is viewed from a landward vantage point. The shoreline is represented by positive (X,Y) points at equal X intervals. The model is run for two successive seasons, which can be termed "winter" and "summer", to equate to one year of wave activity. The angle of wave attack, relative to the shoreline orientation of each segment, and the breaking wave energy act to change the shoreline location over time. For most places in Florida, it is the opinion of the author that the wave climate can be simplified into two basic seasons of directional wave energy, typically the winter and summer seasons. By experience in the use of this model, and in conversation with other model researchers, it appears necessary and reasonable to factor seasonality into a model if good calibration results are to be obtained. This model is simplified to two "seasons" only, and uses a basic form of the sand transport equation (Dean and Grant, 1989). The model inputs are the initial shoreline positions, the number of 24 hour days per year of waves of specified breaking wave height per each segment for each of two seasons, and a closure depth. The outputs are files of shoreline position changes and sand transport volume changes over time for each segment. These can be used in almost any graphic software to produce plots of the results.

The shoreline locations are taken from the historic shoreline (MHW) data base. The initial trial conditions of average seasonal breaking wave height , duration, and direction along each segment are developed from aerial photographs, available wave data, and personal on-site observations over several years. These are modified as necessary and reasonable to achieve the desired calibration to successive historic shorelines. The final wave conditions necessary to achieve calibration tell a great deal about the major wave forces controlling shoreline change in the modeled area.

The model is not intended to achieve absolute exactness in calibration or predictive ability. It is intended to be generally correct in modeling the major forces, relatively easy to use, and a useful tool in understanding coastal processes. Programming ability and knowledge of coastal processes remain necessary. Setting up boundary conditions that achieve desired results is a critical part of the modeling.

CALIBRATION AND PREDICTION MODEL RUNS

The historic shorelines available for calibration are as follows, from the indicated sources:

1868	USC&GS	1:20000	scale
1902	USC&GS	1:20000	scale
1934	USC&GS	1:20000	scale
1973	DNR Profile Survey		
1976	USGS	1:24000	scale
1977-8	NOS	1:20000	scale
1983	DNR Profile Survey		

For calibration purposes, the 1868 shoreline was modeled over 108 years to try to obtain the 1977-8 shoreline. The model is set up to run for a total number of years divisible by six, for convenience reasons; hence 108 years instead of

1868-1978 = 110 years. It was decided to use the same type of data, i.e. topographic survey map data for the beginning and end of the calibration run. However, the entire sequence of historic data will be compared against the results at several points along the shoreline to show that the pattern of change is correct.

Figure 2 shows the 1868 and 1977-8 shorelines in the chosen coordinate system, to be used for calibration. The area to be modeled extends from zero to 50,000 feet (0-15 km) along the x axis. This is approximately from DNR monument R-112 to R-65. It was not attempted to model the shoaling and accretion north of that area or the complex shoaling south of that area. A non-interfering boundary condition was imposed north (to the right of) x = 60,000 feet (18 km). At the south (left) boundary, sand transport in and out was set equal to zero. For calibration, the model was run for 108 years with the following input conditions:

Season 1 = 95 days; 30 degree wave angle relative to x axis; 1.7 foot (0.52 m) breaking wave height; 16 feet (4.9 m) closure depth; wave attack angle starting at x = 38,000 feet (11.6 km, approx. R-75); 26.7 degree wave attack angle starting at x = 48,000 feet (14.6 km, approx. R-66); and a

25.2 degree wave attack angle starting at x = 58,000 ft (17.7 km, approx. R-56). The latter three conditions simulate a gradual refraction pattern in the northern area.

Season 2 = 30 days; 5 degree wave attack angle throughout; and 1.0 foot (0.3 m) breaking wave height.

The time step was set at 24 hours. The x interval was 200 feet (61 m).

The calibration results are graphically shown in Figure 3. Each successive dotted/dashed line between the 1868 and 1977-8 solid line shorelines represents a shoreline location at 36 year intervals. The last year, 1976, of the model is quite close to the 1977-8 shoreline, with the greatest deviation near the left boundary.

The model was run again, using the 1977-8 shoreline as input with the same conditions, for a future 90 years. The model results are graphically shown in Figure 4. Each successive dotted/dashed line represents a shoreline location at 30 year intervals.

The results of both runs are compared in Figure 5 at five locations along the shoreline with the historic sequence of data. It appears from the figures that the model performs well within x = 10,000 feet (3 km) to x = 50,000 feet (15 km), but underestimates the erosion near the left boundary, i.e. closest to the Cape San Blas shoals. Apparently the boundary condition there is not absolutely correct: significant sand moves southward and there are refraction/diffraction effects of a complex nature. It is also noted that the rate of shoreline change over time is not constant, although it can be estimated at constant levels over certain time segments. This type of pattern is commonly observed in the longªterm erosion data throughout the state.

There are, of course, other combinations of conditions which can produce a similar match between the 1868 and 1977-8 shorelines, e.g. the unknown actual conditions. However, those conditions should not physically be that significantly different from the input conditions. The very close match in the total pattern of erosion, and the fact that the shape of the shoreline is evolving to face the direction of the assumed primary incoming wave energy, both strongly argue for the basic truth of the input conditions. A set of drastically different conditions will not form the same erosion pattern. However, on-site observations suggest that much of the erosion may be episodic, i.e. due to storms in the Gulf.

In this wave climate scenario, the model estimates net annual sand transport to the north which varies in a systematic manner along the modeled area. The maximum estimated annual drift within the modeled area is on the order of 200,000 cu. yds. (150,000 cu.m) to the north, in the present decade. This suggests that the shoreline changes at Cape San Blas are supplied primarily by sand from the shoals and possibly from the east, rather than by large quantities of sand from the north. This appears consistent with the dune ridge pattern on the accreting tip of the Cape, which runs east-west, and is also consistent with the growth of the north end of the peninsula and its' shoals.

CONCLUSIONS

The model appears to simulate the historic erosion pattern reasonably well. The results can be interpreted as follows:

- The erosion is primarily caused by higher-energy southwesterly waves which attack at a high angle of incidence with the shoreline. These waves are from the longest fetch distance. Some refraction of the southwest waves occurs over the northern section of the peninsula and at the Cape.

- The shoreline in the modeled area is apparently eroding to achieve a lesser angle with the primary attacking waves.

- The pattern of erosion is non-linear. The rate of erosion is very gradually diminishing in time over the southern area, and increasing towards the northern area. The rate should remain high, approximately -10 feet/yr in the R-112 to R-90 area, for the next 30 years at least.

- The high levels of erosion on the peninsula have occurred for at least the last 110 years and are expected to continue for at least the next 90 years. The conditions causing the erosion are basic and not expected to significantly change.

REFERENCES

Bakker, W.T., 1968. "The Dynamics of a Coast with a Groyne System", Proceedings of the 11th Conference on Coastal Engineering, Vol. 2, Chapter 31, American Society of Civil Engineers, New York, N.Y., pp. 492-517.

Dean, R.G., and Grant, J., 1989. "Development of Methodology for Thirty©Year Shoreline Projections in the Vicinity of Beach Renourishment Projects", University of Florida, Coastal and Oceanographic Engineering Department, Gainesville, FL., p. 20, prepared for Florida Department of Natural Resources, Division of Beaches and Shores, Tallahassee, FL.

Foster, E.R., and Savage, R.J., 1989. "Methods of Historical Shoreline Analysis", Coastal Zone '89, Vol. 5, Session 72, American Society of Civil Engineers, New York, N.Y., pp. 4434- 4448.

LeBlond, P.H., 1972. "On the Formation of Spiral Beaches", Proceedings of the 13th Coastal Engineering Conference, Vol. 2, Chapter 73, American Society of Civil Engineers, New York, N.Y., pp. 1331-1345.

Stapor, F.W., Jr., 1973. "Coastal Sand Budgets and Holocene Beach Ridge Plain Development, Northwest Florida", Ph. D. Dissertation, Florida State University, Tallahassee, FL., pp. 78-88, 129-132, 158-168.

U.S. Army Corps of Engineers, Waterways Experiment Station,

1988. Preliminary Gulf Coast Hindcast Wave Data for 1956-75, Vicksburg, Miss.

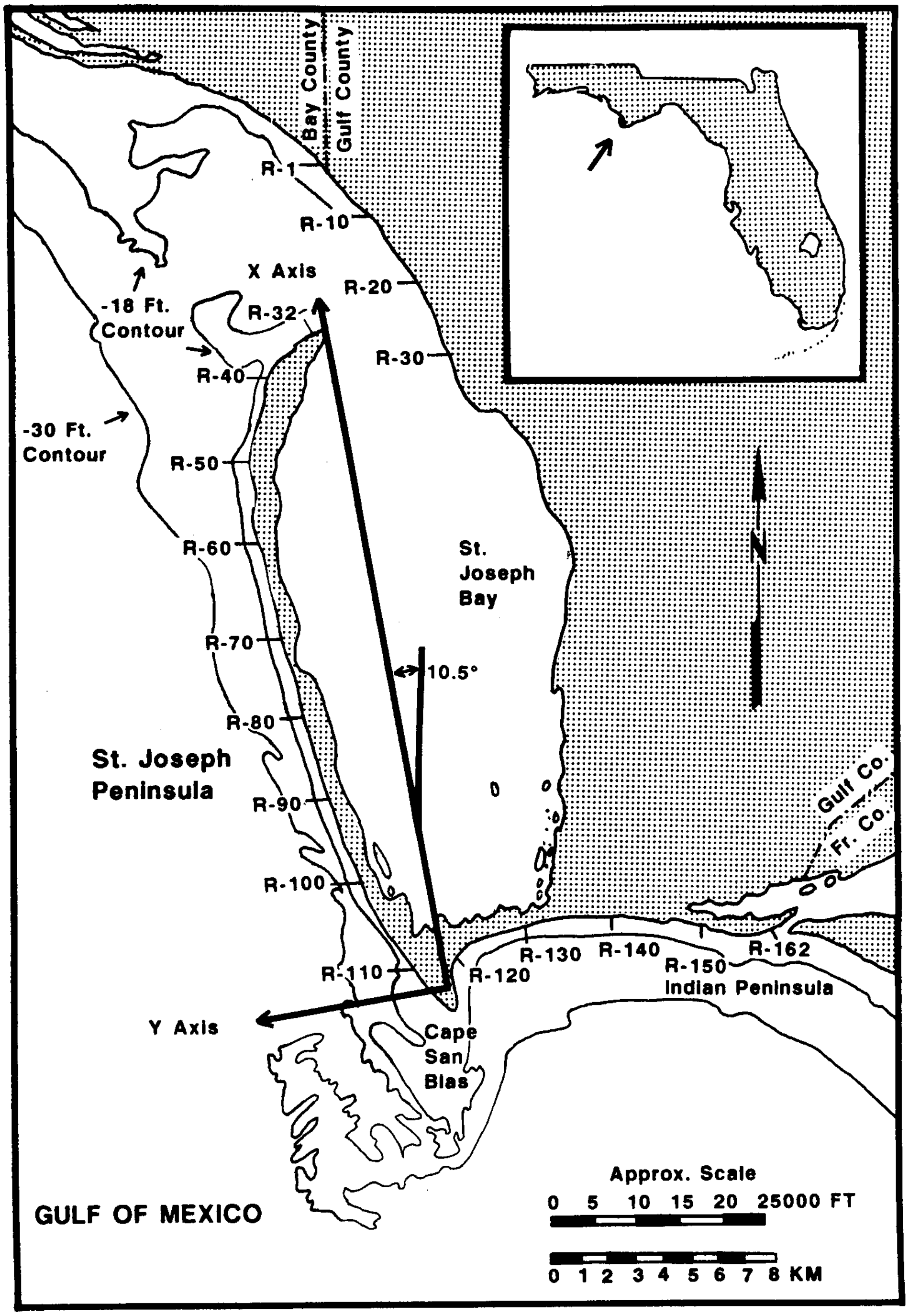


Figure 1. Location Map

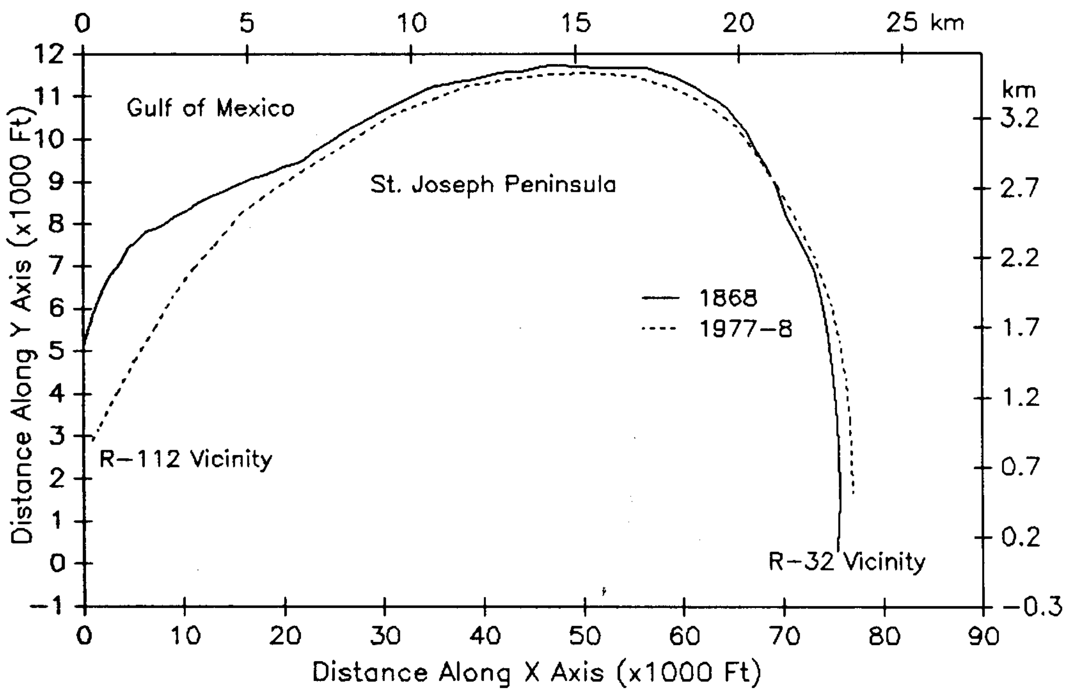


Figure 2. 1868 and 1977–8 Historic Shorelines

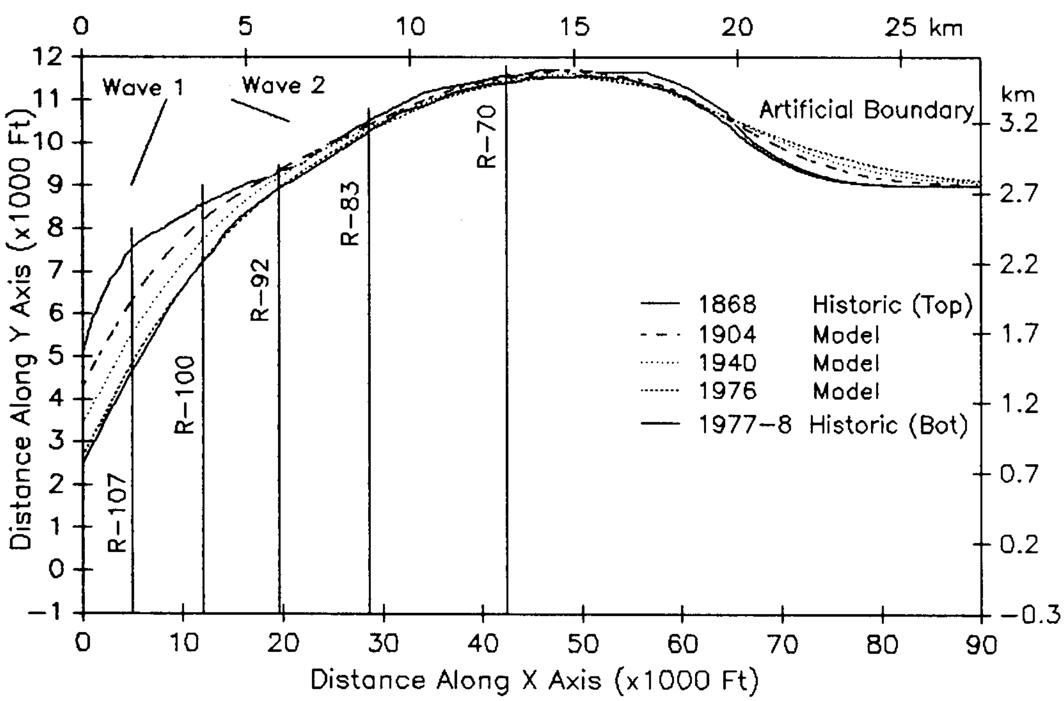


Figure 3. 108–Year Model Run, 1868 to 1976

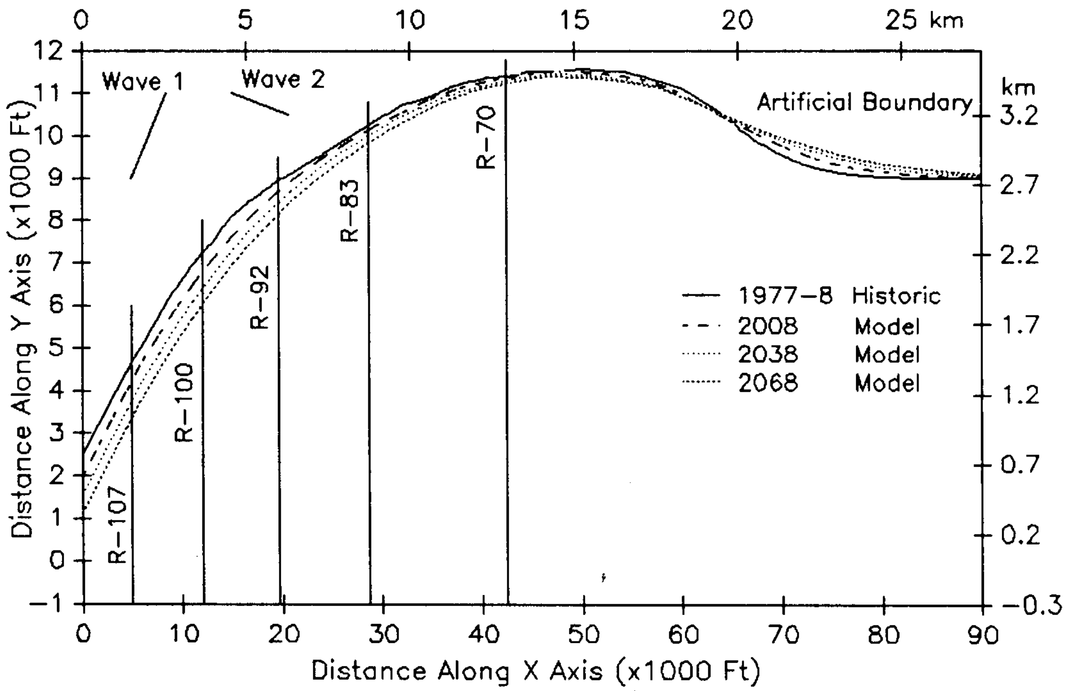


Figure 4. 90−Year Model Run, 1977−8 to 2068

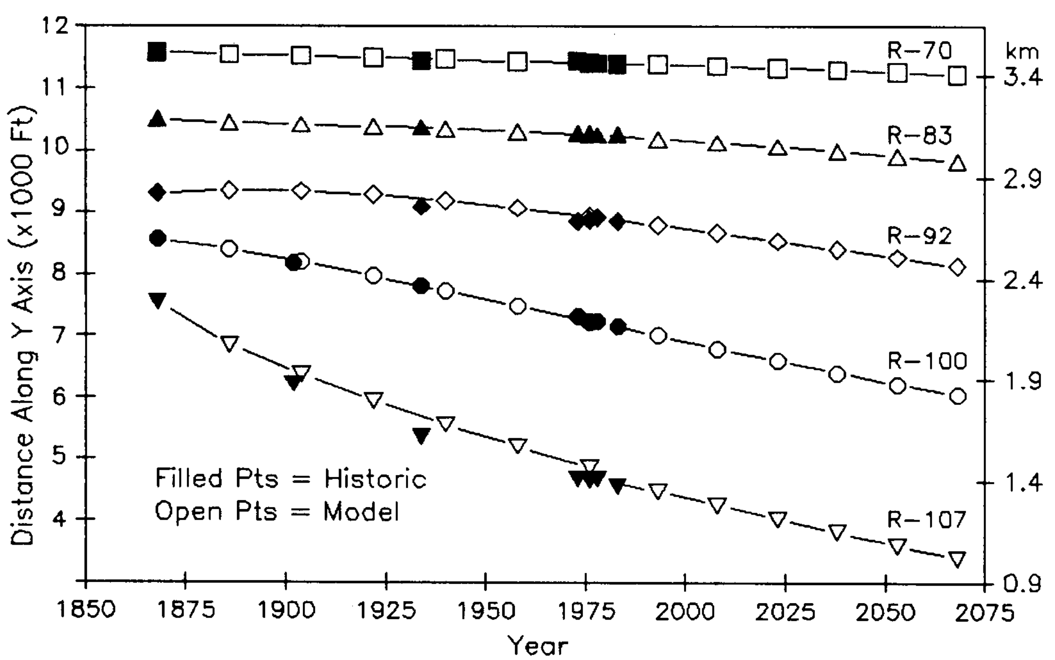
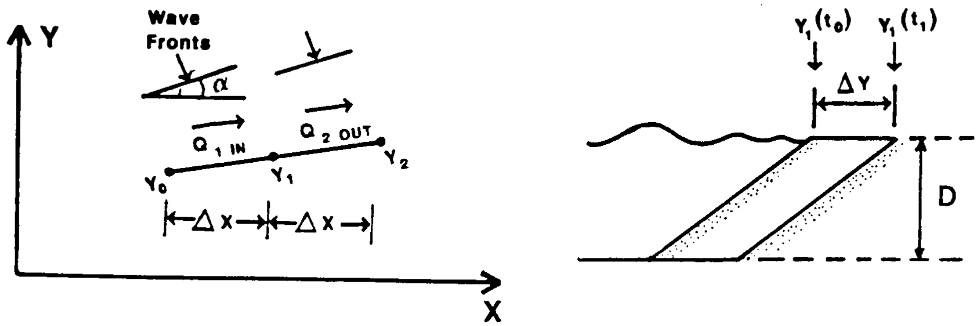


Figure 5. Historic Data Versus Model Data

APPENDIX

Two Season, One Line, Longshore Model
Definition Sketch and General Equations



For any time step Δt:
if $Q_{1in} > Q_{2out}$, then Y_1 shoreline position advances;
if $Q_{1in} < Q_{2out}$, then Y_1 shoreline position recedes.

$$Q_{1in} = K \bullet \sin(2 \bullet (\alpha - \tan^{-1}(Y_1 - Y_0/\Delta X)))$$

$$Q_{2out} = K \bullet \sin(2 \bullet (\alpha - \tan^{-1}(Y_2 - Y_1/\Delta X)))$$

$$K = (k \bullet (g/k_d)^{0.5} \bullet H_b^{2.5})/(16 \bullet (s-1) \bullet (1-p))$$

$$Y_1(t_1) = Y_1(t_0) - ((\Delta t/(D \bullet \Delta X)) \bullet (Q_{2out} - Q_{1in}))$$

where:

Q = sediment transport in cu.ft./sec.
Y_i = shoreline location at x interval "i", in feet
g = 32.2 ft./sec^2 = gravity
k_d = 0.78 = ratio of breaking wave height to water depth
k = 0.77 = proportionality factor, recommended value
D = total depth of parallelogram cross-section, in feet
H_b = breaking wave height in feet
s = specific gravity of the sediment = 2.65
p = inplace porosity of the sediment = 0.35
t = time in seconds
Δt = time step in seconds
ΔX = x interval in feet
α = angle of the breaking wave crest with the x axis

Two Wave Climate Seasons:

The model is run for a selected number of days with waves from one direction in order to simulate season #1 (e.g. average winter conditions). The model is then run for another selected number of days with waves from another direction, to simulate season #2 (e.g. average summer conditions). The sequence of the two seasons represents one year of average wave activity. The model can be run for any number of years.

Rev. 1/93 - ERF