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Utilizing the shoreline modeling system to simulate shoreline change with altered nearshore bethymetry at Long Beach Island, New Jersey

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Utilizing the Shoreline Modeling System to Simulate Shoreline Change with Altered Nearshore Bathymetry at Long Beach Island, New Jersey

By

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ABSTRACT

This thesis presents an investigation into using the Shoreline Modeling System to simulate the influences of altered nearshore bathymetry on predicted shoreline positions and sand transport rates on Long Beach Island, New Jersey. The shoreline change model, GENESIS, and the external wave transformation model, RCPWAVE, are discussed. The information necessary to complete the investigation is reviewed. Model calibration and verification efforts are discussed. Two dominant shoals present in the nearshore area of the model shoreline reach are removed from the bathymetric data. The altered bathymetry affects the predicted characteristics of waves approaching the model shoreline reach. The altered approaching wave characteristics influence predicted shoreline positions and sand transport rates.

1.0 INTRODUCTION

This chapter will introduce the reader to some general background information pertaining to this investigation. First, the primary objectives of this study will be introduced. Information regarding the Shoreline Modeling System (Gravens 1992) will then be presented. Finally, the reader will be introduced to the region surrounding the shoreline reach being used in this study and to the specific shoreline being modeled.

1.1 Objectives of Study

The objectives of this study are:

1. To collect and assemble the data and other information necessary to complete shoreline change simulations utilizing the Shoreline Modeling System, including the data necessary to apply the external wave transformation model RCPWAVE.
2. To run shoreline change simulations, calibrating and verifying the models input parameters.
3. To investigate the effects of altering the local bathymetry on nearshore wave characteristics, shoreline positions and sand transport rates predicted by the modeling system.

1.2 Introduction to the Shoreline Modeling System

The Shoreline Modeling System refers to a specific collection of computer programs used to predict shoreline position change and longshore sand transport due to oblique wave attack on a beach. The System contains two primary numerical models and approximately 15 support programs. The two models are the GENEralized model for SImulating Shoreline change (GENESIS) (Hanson 1987; Hanson and Kraus 1989; Gravens, Kraus, and Hanson 1991), and the Regional Coastal Processes WAVE model

(RCPWAVE) (Ebersole 1985; Ebersole, Cialone, and Prater 1986). GENESIS is the shoreline change model used to predict longshore sand transport rates and shoreline position changes. RCPWAVE is the external wave transformation model used to predict wave conditions nearshore by transforming offshore wave conditions over arbitrary bathymetry. GENESIS can then apply the transformed wave conditions to the shoreline change predictions. The GENESIS and RCPWAVE models will be discussed further in Chapters 2 and 3. The other support programs contained in the shoreline modeling system are primarily used for sorting, formatting, arranging and visualizing input and output data. Several references are made to the support programs, however, in depth discussion is beyond the scope of this report and the reader is directed to Hanson and Kraus (1989); Gravens, Hanson, and Kraus (1991); and Graves (1992) for greater detail.

1.3 Site Discussion

Long Beach Island, New Jersey was the region focused on in this investigation. (Figure 1.1) This area was chosen primarily for the abundance of data available on shoreline positions and offshore bathymetry. Long Beach Island (LBI) is an 18 mile long barrier-island situated on the East Coast of the United States. LBI stretches from 39°30' North Latitude, 74°17' West Longitude at the southern end to 39°46' North Latitude, 74°06' West Longitude at the northern end. Located north of Atlantic City, New Jersey, LBI is bounded to the north by Barnegat Inlet and to the south by Little Egg Inlet. The year round population of the island is 6714 (1990 census).

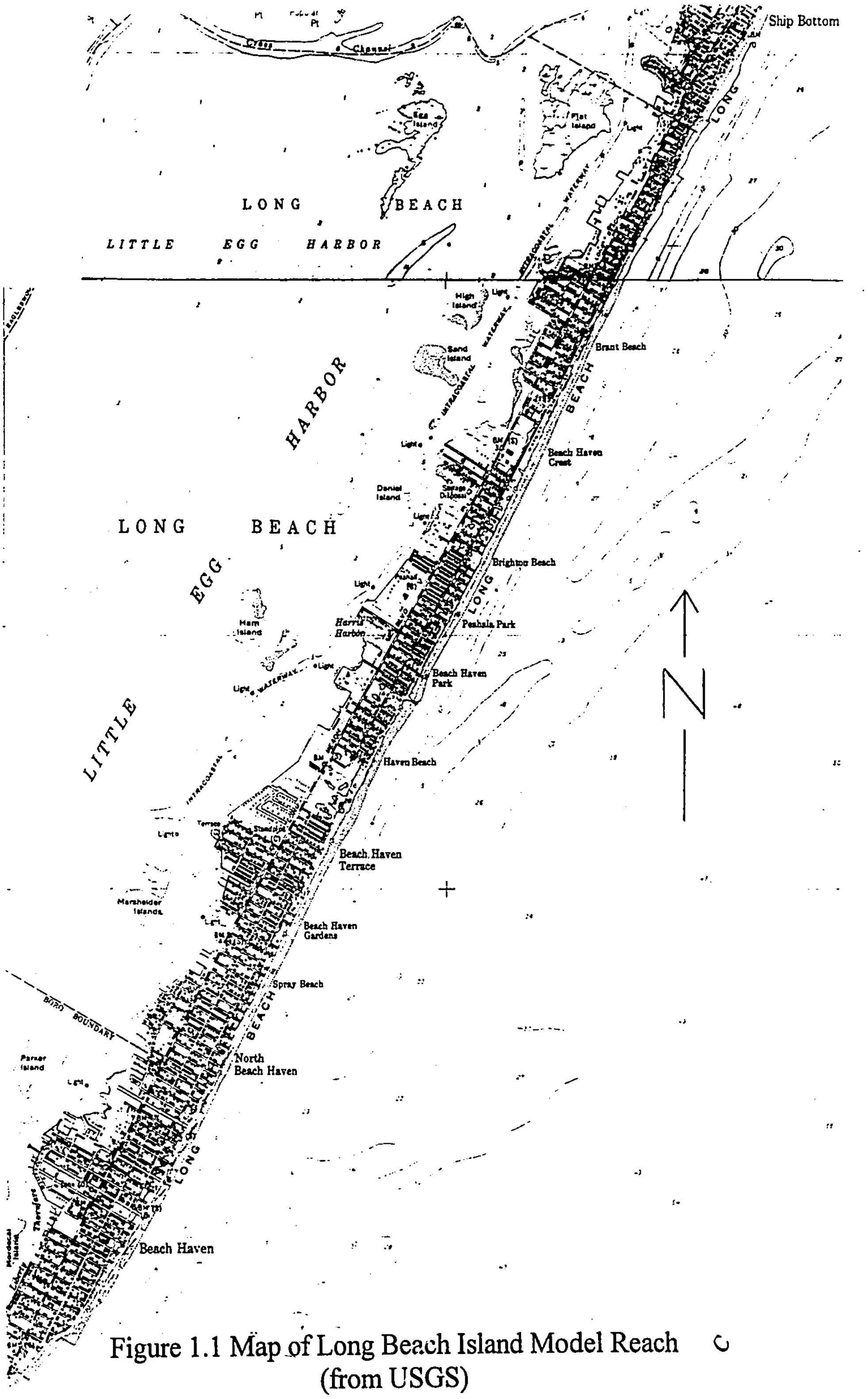


Figure 1.1 Map of Long Beach Island Model Reach
(from USGS)

This investigation utilized a 6.8 mile stretch of beach situated on the southern half of LBI. This shoreline model reach is located between 39°33' North Latitude, 74°14' West Longitude and 39°38' North Latitude, 74°10' West Longitude. The three major towns with the closest proximity to the model reach are Beach Haven, North Beach Haven, and Ship Bottom, New Jersey. The shore parallel orientation of this beach is approximately 30 degrees east of north. The beach face is open to wave attack from the Atlantic Ocean and is not sheltered from waves by other landmasses or offshore structures. The primary make up of the beach material on LBI is quartz sand with a representative median grain diameter ranging from 0.24 to 0.39 mm (McCormick 1997). An extensive groin field has been constructed on the island to reduce beach erosion caused by longshore transport.

2.0 GENESIS

The GENEralized model for Simulating Shoreline change (GENESIS) is a numerical model for predicting shoreline position movement caused by longshore sand transport. Wave action is the primary cause of longshore sand transport on beaches open to wave attack. The spatial and temporal variations in longshore sediment transport are the main causes of shoreline position fluctuation. The variations in sand transport rate through space and time are related to a variety of factors including: irregular bottom bathymetry, wave diffraction, boundary conditions, line sources and sinks of sand, and constraints on longshore sand transport (such as shore protection structures). GENESIS uses information on measured shoreline positions, predicted wave conditions, structures present in the model reach, and properties of the beach to predict shoreline position change and sand transport rates (Hanson and Kraus, 1989). Chapter 4 of this thesis discusses the collection and assembly of the information needed to complete model simulations.

This Chapter begins by discussing the assumptions and limitations of the GENESIS model, the governing equations of shoreline change, the grid system and finite difference solution scheme used by the model, and the calculation techniques used to determine longshore transport rates. This chapter concludes by discussing the wave transformation model internal to GENESIS, the numerical solution scheme used by the model, and the lateral boundary conditions used by GENESIS.

2.1 Assumptions and Limitations

Several assumptions and limitations are applied to GENESIS. One limitation of the model is that a single shore-normal beach profile is assumed along the entire model reach. As the plan form of the shoreline changes due to accretion or erosion of sand, the beach profile remains unchanged. This type of model is referred to a "one line" model, due to the fact that the shoreline position can then be defined by a single contour line. This line is typically referred to as the "zero contour" line, and can be visualized as the meeting point between the undisturbed water level and the beach face.

A second assumption is that sediment transport occurs between two distinct elevation points, the active berm height and the depth of closure. The active berm height is the maximum elevation above the undisturbed water level at which sediment transport can occur. This can be visualized as the maximum elevation of wave run up on the beach face. The depth of closure defines the maximum depth at which sediment can be transported, and can be visualized as the depth where no significant changes in depth occur.

The model assumes that the longshore sand transport rate is a function of breaking wave height and direction alongshore. Calculation of predicted sand transport rates is discussed in Section 2.4. The model does not consider the net cross-shore movement of sand. It is assumed that the movement of sediment in the cross-shore direction will average out over time (i.e. that sand moved offshore during extreme wave events will eventually be returned to shore during less extreme wave conditions). The final assumption is that a long-term trend in shoreline behavior is clear. Shoreline change due to cyclical and random events must be separated from the clear trend of shoreline behavior. (Hanson and Kraus, 1989)

2.2 GENESIS Grid system

Measured shoreline positions are placed onto a grid for input into GENESIS as shown in Figure 2.1. The origin of the coordinate system used by GENESIS is positioned so that the alongshore (x) axis is landward of the shoreline positions and the offshore (y) axis is on the left-hand side of the viewer. Therefore, grid cell 1 is positioned on the left-hand side of the plotted shoreline and grid cell N is on the rights side. The model reach is bounded on the left and right by implementing boundary conditions at cell walls 1 and N+1 (first and last cell walls). Shoreline positions are defined at the center of each grid cell (y-points). Approaching wave conditions are calculated at each cell wall (cell boundaries or Q-points) and are used to predicts and transport rates at each cell wall, Q_1 through Q_{N+1}. The changes in shoreline positions can then be calculated as discussed in Section 2.3.

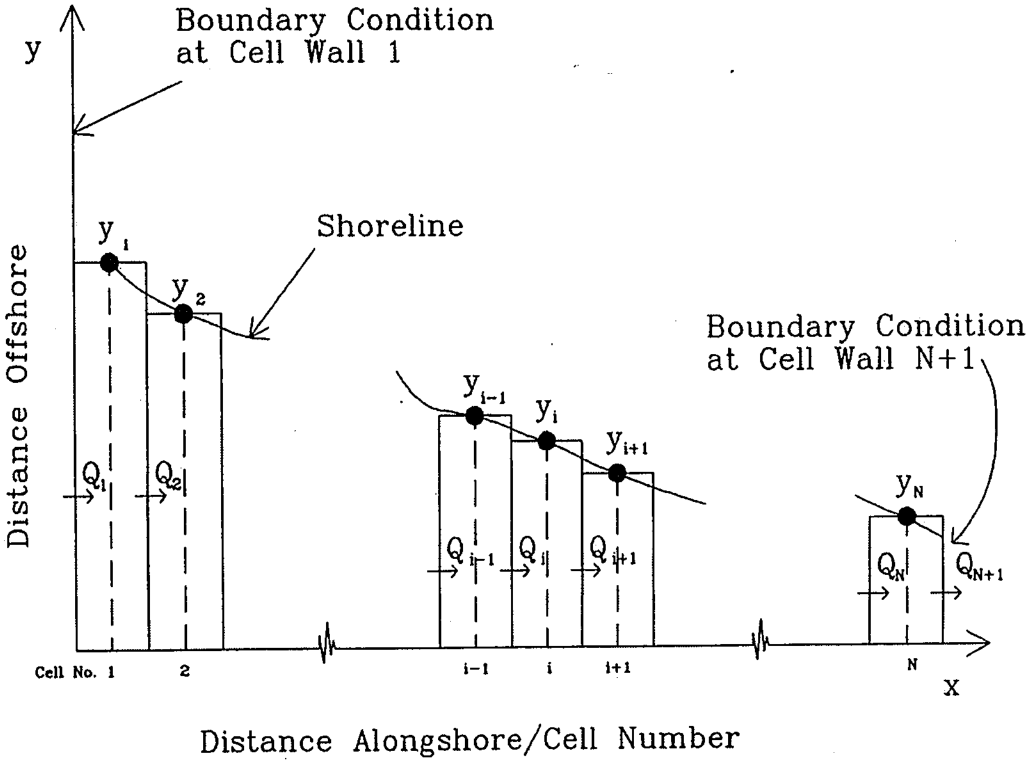


Figure 2.1 GENESIS finite difference grid

(from Hanson and Kraus, 1989)

2.3 Governing Equation of Shoreline Change

The principle of conservation of sand volume in the alongshore direction is used to formulate the governing equation for the prediction of shoreline position change. Figure 2.2 defines the coordinate system and parameters for predicting shoreline position change. The shore-normal beach profile is assumed to remain constant along the shoreline model reach as stated in Section 2.1. Using this assumption, the translation of plan form shoreline positions in the seaward or landward direction can be calculated using the difference in volume of sand entering and leaving each grid cell. The governing equation that defines shoreline position change can be written as:

$$\frac{\partial y}{\partial t}+\frac{1}{(D_B+D_C)}\left(\frac{\partial Q}{\partial x}-q\right)=0 \qquad (2.1)$$

where:

Δy = shoreline position change

t = time

D_B = berm elevation

D_C = depth of closure

$D_B + D_C$ = vertical extent over which shoreline position change occurs

Q = longshore sand transport rate

Δx = length of shoreline segment

q = contribution of line source or sink

Values of t, D_B, D_C, x and q are defined by the user (Hanson and Kraus, 1989). Q is calculated by an empirical predictive formula discussed in the Section 2.4. The new shoreline position, y, is then calculated for each grid cell.

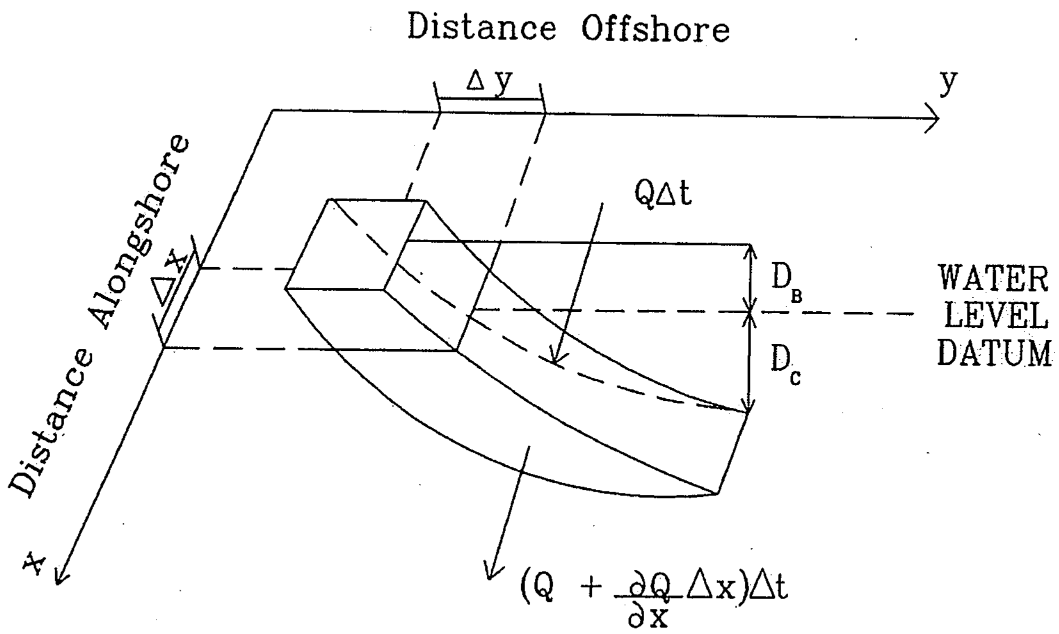


Figure 2.2 Definition sketch for shoreline change

(from Hanson and Kraus, 1989)

2.4 Calculation of Sand Transport Rates

The Modified CERC equation is used in order to calculate longshore transport rates at grid cell boundaries, given as:

$$Q = \left(H^2 C_g\right)_b \left[a_1 \sin 2\theta_{bs} - a_2 \cos\theta_{bs} \frac{\partial H}{\partial x} \right]_b \tag{2.2}$$

where:

H = wave height

C_g = wave group celerity found using linear wave theory

b = subscript denoting wave breaking condition

θ_{bs} = angle of breaking wave to the local shoreline

Non-dimensional parameters, a_1 and a_2, are given by:

$$a_1 = \frac{K_1}{16\left(\frac{\rho_s}{\rho} - 1\right)(1-p)(1.416)^{\frac{5}{2}}} \tag{2.2a}$$

and,

$$a_2 = \frac{K_2}{8\left(\frac{\rho_s}{\rho} - 1\right)(1-p)\tan\beta(1.416)^{\frac{7}{2}}} \tag{2.2b}$$

where:

K_1, K_2 = empirical coefficients, treated as calibration parameters

ρ_s = density of sand (taken to be 2.65 E 3 kg/m^3 for quartz sand)

ρ = density of water (taken to be 1.03 kg/m^3 for seawater)

p = porosity of sand of the bed (taken to be 0.4)

$\tan\beta$ = average bottom slope from the shoreline to the depth of the active longshore transport

The first term on the right hand side of Equation 2.2 is the "CERC formula", as presented in the Shore Protection Manual (U.S. Army Engineer Waterways Experimentation Station, 1984). Using the concept of "wave energy flux" the CERC formula calculates potential transport rates produced by incident oblique breaking waves (Galvin and Schweppe, 1980). The second term on the right hand side of Equation 2.2 is not found in the CERC formula. This term describes the effect of the longshore gradient of breaking wave height, $\partial H_b/\partial x$, on the longshore transport rate. This term becomes important in the vicinity of structures, where diffraction causes a significant change in breaking wave height along the shoreline. (Hanson and Kraus, 1989)

The values of K_1 and K_2 are determined empirically. They are referred to as "transport parameters," and are treated as calibration coefficients. The K_1 transport parameter controls the time scale of the simulated shoreline change, as well as the magnitude of the longshore sand transport rate. A value of $K_1 = 0.77$ was determined by Komar and Inman (1970). A value of $K_1 = 0.58$ was suggested by Kraus et al. (1982). A Range of K_1 between these two suggested values is typical. The transport parameter K_2 controls the distribution of sediment in the cell and typically varies between 0.5 K_1 and 1.0 K_1. (Hanson and Kraus, 1989)

The average bottom slope, tanβ, can be obtained from bathymetric surveys or predicted through the use of equations. An equation developed by Brunn (1954) and Dean (1977) can be used to calculate the bottom slope and is given as:

$$\tan\beta = \left[\frac{A^3}{D_{LTo}}\right]^{1/2} \tag{2.2c}$$

where:

$A = 0.41(d_{50})^{0.94}$, for d_{50} less then 0.4 mm (Moore, 1982)

and,

$$D_{LTo} = (2.3 - 10.9H_o)\frac{H_o}{L_o} \tag{2.2d}$$

(from Hallermeir, 1983)

where:

D_{LTo} = maximum depth of longshore transport

H_o/L_o = deep water wave steepness

H_o = deep water significant wave height

L_o = deep water wave length, calculated as

$$L_o = \frac{gT^2}{2\pi} \tag{2.2e}$$

where:

g = acceleration of gravity

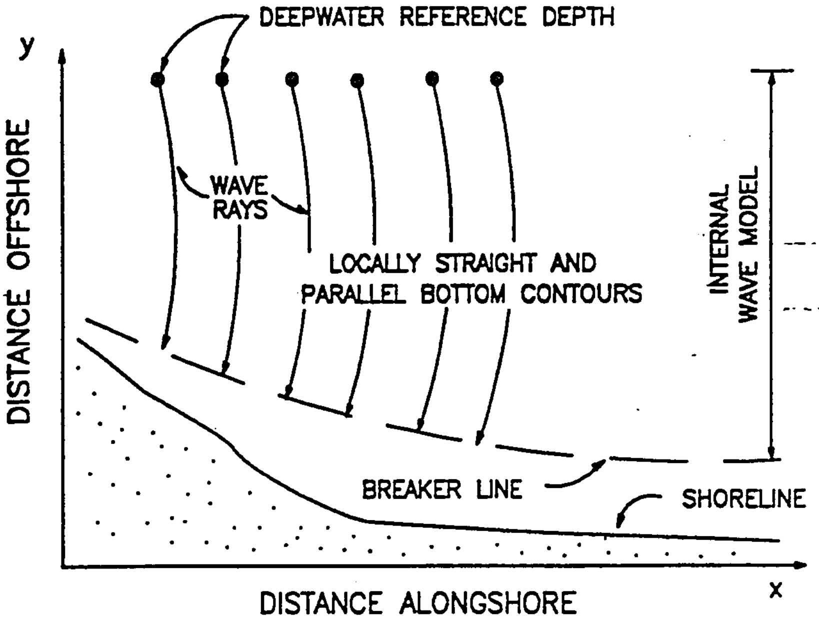
T = wave period (peak spectral period or period associated with significant wave height)

(Hanson and Kraus, 1989)

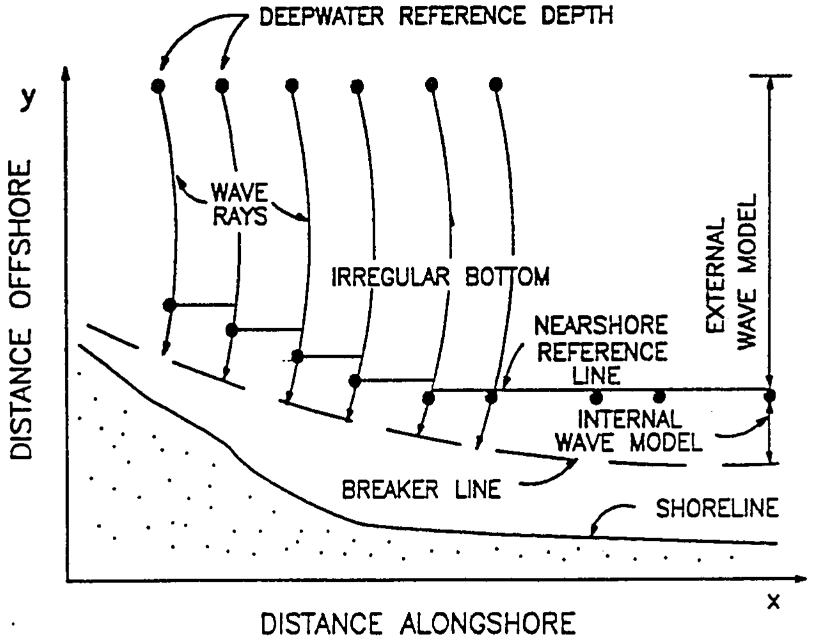
2.5 Internal Wave Transformation Model

GENESIS requires a time series of breaking wave heights and directions along the shoreline model reach. Breaking wave data is obtained by transforming offshore wave time series data to the breaking condition alongshore, as depicted in Figure 2.3a. The wave transformation model internal to GENESIS transforms waves from an offshore location using the assumption that bottom contours are straight and parallel. Monochromatic wave theory is used to shoal wave heights to the breaking point and to determine wave ray directions at the alongshore cell boundaries. Wave periods remain constant during transformations as is consistent with monochromatic wave theory.

An external wave transformation model can be used to transforms wave characteristics over the actual bathymetry to a point prior to breaking as depicted in Figure 2.3b. The wave model internal to GENESIS then takes over the for the external wave model and transforms the waves to the breaking point. The line at which the external wave transformation model stops and the internal model begins is defined at a particular depth contour line, referred to as the nearshore reference line. The Shoreline Modeling System links GENESIS to the external wave transformation model, RCPWAVE. The RCPWAVE model will be discussed in Chapter 3.



a. Transformation by internal wave model only



b. Transformation by external and internal wave models

Figure 2.3 Operation of wave transformation models

(from Hanson and Kraus, 1989)

The internal wave transformation model predicts the three unknowns needed to calculate potential sediment transport rates: breaking wave height, breaking wave direction, and breaking wave water depth. The unknowns are determined by initially assuming that there are no structures are present in the model reach, thus neglecting diffraction. If structures are present the results are modified to account for diffraction. The equation used to calculate the breaking wave height accounting for shoaling and refraction is:

$$H_2 = K_R K_S H_{ref} \tag{2.3}$$

where:

H_2 = breaking wave height at a point alongshore
K_R = refraction coefficient at the breaking point
K_S = shoaling coefficient at the breaking point
H_{ref} = wave height at the offshore reference depth or the nearshore reference line depending on wave model is being used

The refraction coefficient, K_R, is a function of both the offshore wave direction and the wave direction at breaking. The shoaling coefficient, K_S, is a function of wave period, offshore depth and breaking depth. Determination of the breaking wave height proceeds through an iterative process, in which the wave height, H_2, is calculated and then compared to the possible wave breaking condition. If the calculated wave height does not exceed the breaking wave condition the wave is positioned closer to shore and the wave height is recalculated.

The breaking wave angle is calculated using Snell's Law:

$$\frac{\sin\theta_b}{L_b} = \frac{\sin\theta_{ref}}{L_{ref}} \tag{2.4}$$

where, θ_b and L_b are the angle and wavelength at the breaker point, and θ_1 and L_1 are the angle and wavelength at an offshore point.

The breaking wave, depth-limited water depth is then calculated by:

$$H_b = \gamma D_b \tag{2.5}$$

where, D_b is the depth at breaking and γ is the breaker index. The breaker index is a function of deepwater wave steepness, H_0/L_0, and the average beach slope. The reader is referred to Hanson and Kraus (1989) for greater detail involving the calculation of breaking wave height, breaking wave angle and breaking wave depth.

In situations where diffraction may affect waves prior to breaking, an adjustment of the wave characteristics must be made prior to the application of the equations used to solve for breaking wave conditions. Diffraction may affect wave characteristics in the presence of structures that extend beyond the surf zone, such as detached breakwaters, long groins or jetties. The affect of these structures on wave characteristics may then affect the shoreline response to wave attack in the lee of the structure. The equation used to calculate the effect of diffraction is given as:

$$H_b = K_D(\theta_D, D_b)H_b^{'} \quad (2.6)$$

where:

K_D = diffraction coefficient

θ_D = angle between incident wave ray at P1 and straight line between P1 and P2, if P2 is in the shadow region, refer to Figure 2.4

H_b' = breaking wave height at the same cell without diffraction

GENESIS uses the method of Goda, Takayama, and Suzuki (1978) to determine the value of the diffraction coefficient. Equations 2.3, 2.4, and 2.5 are then solved by iteration in order to determine the three necessary unknowns, H_b, D_b, and θ_b. The reader should consult Hanson and Kraus (1989) for further details on the calculation breaking wave characteristics by GENESIS.

The internal wave model does not use the actual bathymetry; therefore, a set of representative offshore contours must be developed in order to calculate wave diffraction. A basic assumption used by GENESIS is that a shore-normal beach profile moves parallel to itself. Thus, the assumed representative offshore contours also move parallel to the shoreline. Without some modification of the representative offshore contours, this would create an unrealistic set of contours in the area offshore of abrupt shoreline change, for example, in the area offshore of a structure. In order to overcome this limitation a smoothing procedure is performed on the offshore contours as seen in Figure 2.5.

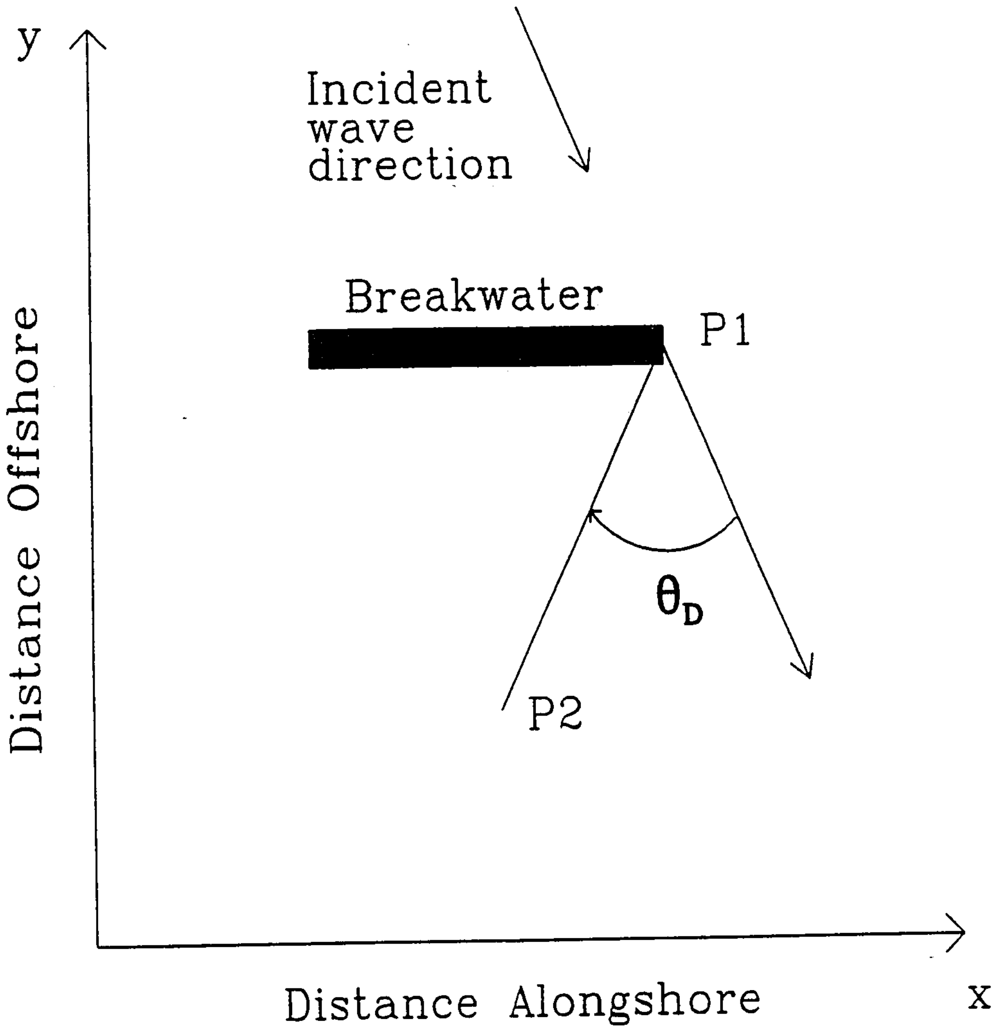


Figure 2.4 Definition sketch for diffraction coefficient calculation
(from Hanson and Kraus, 1989)

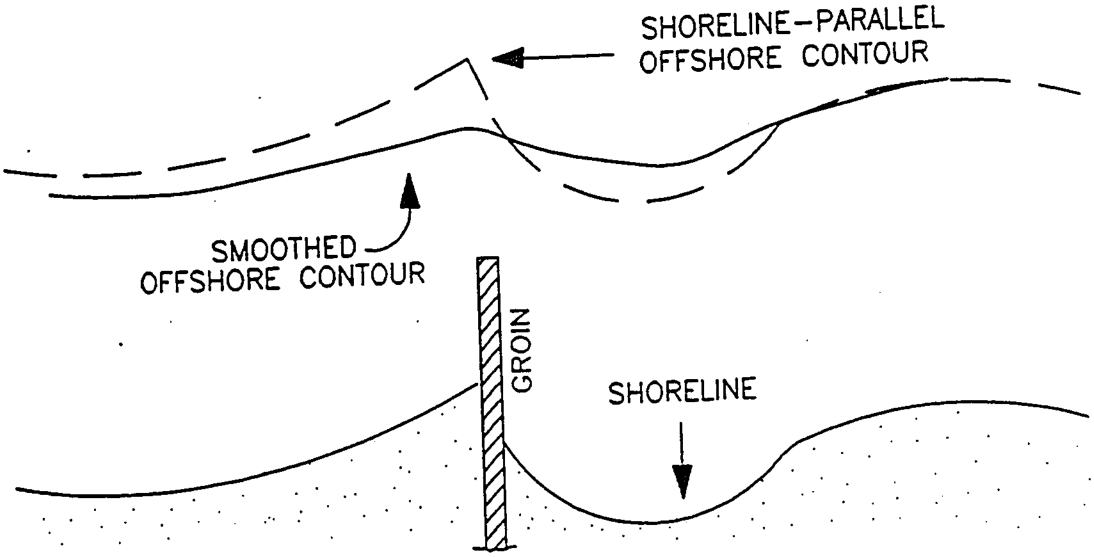


Figure 2.5 Example of representative contour
(from Hanson and Kraus. 1989)

The shoreline plan form changes with time as a result of spatial and temporal differences in longshore sand transport. Changes in the shoreline positions will in turn influence wave diffraction. The internal wave model of GENESIS accounts for this effect in two ways. First, as the position of the shoreline changes the distance from the breaking point to the form that is causing the refraction (P_1, in Figure 2.5) will change, thus the ray starting angle, θ_1, will change. Next, as the shoreline position changes with time the offshore contours will attempt to align themselves to the beach plan shape. This is accounted for by allowing the plane and parallel contours to change their orientation as a function of the shoreline positions. (Hanson and Kraus, 1989)

2.6 Numerical Solution Scheme

Once the information necessary to solve equations 2.3,2.4, and 2.5 has either been gathered, assumed or calculated, GENESIS can perform the computations to simulate shoreline response to wave attack. The shoreline position is predicted through the use of a numerical solution scheme using the finite difference grid described in Section 2.2.

GENESIS uses an implicit solution scheme developed by Kraus and Harikai (1983) based on a method given by Perlin and Dean (1978). A stability parameter is also calculated by GENESIS, shown by Kraus and Harikai, used as an indication of numerical accuracy of the solution. If the stability parameter is violated, GENESIS issues a warning message in order to alert the user.

The Crank-Nicholson scheme (Crank 1975) is the solution scheme used by GENESIS. For reference, a subscript i denotes a quantity located at an arbitrary cell number. A prime, ('), denotes a quantity at the new time step and an unprimed quantity denotes a known value at the present time step. The values of y' and Q' are then solved for. Quantities such as q' and D_B' are known data, input by the modeler. This method expresses the derivative ∂Q/∂x at each grid point as an equally weighted average between the present time step and the next time step, given as:

$$\frac{\partial Q_i}{\partial x} = \frac{1}{2}\left[\frac{Q'_{i+1} + Q'_1}{\Delta x} + \frac{Q_{i+1} - Q_i}{\Delta x}\right] \qquad (2.7)$$

Substitution of Equation 2.7 into Equation 2.1 and linearization of the wave angles in Equation 2.2 in terms of ∂y/∂x results in two systems of equations for the unknowns y_1' and Q_1', given as:

$$y'_1 = B'\left(Q'_i - Q'_{i+1}\right) + yc_i \qquad (2.8)$$

and,

$$Q'_1 = E_i\left(y'_{i+1} - y'_i\right) + F_i \qquad (2.9)$$

where:

B' = Δt / [2 (D_B + D_c') Δx]
yc_i = function of known quantities, including q_i' and q_i
E_i = function of the wave height, wave angle, and other known quantities

F_i = function similar to E_i

For further information on the solution procedure used by GENESIS the reader is referred to Kraus and Harikai (1983), Hanson (1987), Hanson and Kraus (1986) and, Kraus (1988).

2.7 Lateral Boundary Conditions

The lateral boundary conditions for the model reach are defined at cell walls 1 and N+1. Calculation of shoreline response depends directly on the choice and input characteristics of the boundary conditions. Boundaries are used to control the amount of sediment entering or leaving the study reach. The ends of a littoral cell, such as headlands extending well beyond the surzone, or jetties defining an inlet, are ideal boundary conditions. This is not always possible due to the size of the reach, or the number and length of grid cells. Therefore, other situations can be used to define the boundaries of the study reach. Two possible boundary conditions that can be used are the pinned boundary condition and the gated boundary condition.

A pinned boundary condition is likely to be identified by simultaneously plotting shoreline position data acquired at several different times. By plotting multiple shoreline plan views, a point on the beach where the shoreline position does not move appreciably with time can be identified and used as a pinned boundary condition. The premise behind the pinned boundary condition is that the volume of sediment entering the grid cell will leave the grid cell. Therefore, the position of the shoreline at the grid cell does not change with time, pinning the position of the shoreline. It is favorable to locate this boundary condition as far from the study reach as possible to assure that the changes that take place in the project area do not affect the area in the vicinity of the boundary. (Hanson and Kraus 1989)

A gated boundary condition is placed at a point on the shoreline where the movement of sand alongshore is completely or partially interrupted. A situation such as this occurs where a "significant structure", man made or natural, is situated. Structures such as groins, jetties, shore-connected breakwaters, and headlands make suitable gated boundary conditions. The amount of sand that can pass a structure used as the gated boundary condition determines its affect on shoreline positions. Sediment both leaving and entering the study reach must both be considered. The two mechanisms by which sand may pass a gated boundary are bypassing and transmission. Bypassing, is the movement of sand around the seaward tip of the structure. This occurs when the depth of longshore transport exceeds the depth at the tip of the structure. Transmission, is the movement of sand over, through, and landward of the structure. A permeability factor, PERM, is used to model this type of sand movement. The modeler must use information that can be gathered about a structure to determine the input factor for each structure. During the calibration procedure the PERM factor can be used to further fine-tune the model. (Hanson and Kraus, 1989)

The reader is referred to Hanson and Kraus, 1989 for further details regarding boundary conditions and the GENESIS model.

3.0 RCPWAVE

The internal wave transformation model contained within GENESIS can be used to transform waves from offshore to the breaking point when the bottom contours are assumed to be straight and parallel. When plane and parallel bottom contours can not be assumed an external wave transformation model can be used with the actual bathymetry offshore of the shoreline model reach. GENESIS requires input of pre-breaking wave height and directions as well as the water depth of input wave time series. An external wave transformation model can be used to propagate wave characteristics from offshore to a nearshore reference line. The internal wave model contained in GENESIS then propagates the waves to their breaking condition. A schematic representation of an external and internal wave model was presented in Figures 2.3a, and b.

The external wave transformation model used in conjunction with The Shoreline Modeling System is RCPWAVE (Regional Coastal WAVE model) (Ebersole 1985; Ebersole, Cialone, and Prater 1986). One objective of this investigation was to predict the effects of altering the nearshore bathymetry on shoreline position change and longshore sand transport rates. In order to accomplish this the external wave transformation model was used in conjunction with GENESIS.

The advantages of using RCPWAVE in conjunction with GENESIS are:

1. RCPWAVE solves for wave heights and angles directly on a grid.
2. It includes diffractive and refractive effects produced by irregular bathymetry.
3. It has proven to be very stable.

RCPWAVE is the standard monochromatic wave transformation model for estimating nearshore wave conditions for input into GENESIS. It transforms waves from an offshore depth to a nearshore reference depth, while accounting for refraction, shoaling and diffraction due to local bathymetry. The governing equations solved by the model are a modified form of the "mild slope" equations for linear, monochromatic waves. Finite-difference approximations of these equations are preformed on a rectilinear grid in order to predict wave propagation outside the surf zone. The model is limited by the fact that it does not account for diffraction caused by structures and it neglects wave reflection outside the of the surf zone (Hanson and Kraus, 1989). These limitations should not pose a problem for this investigation.

3.1 Wave Transformation Equations

The governing equations solved by RCPWAVE are the modified form of the "mild slope" equations for linear, monochromatic waves (Berkoff, 1972 and 1976), and the equation specifying irrotationality of the wave phase function gradient. Berkoff's mild slope equation is:

$$\frac{\delta}{\delta x}(cc_g \frac{\delta \Phi}{\delta x} \frac{\delta}{\delta y}(cc_g \frac{\delta \Phi}{\delta y}) + \sigma^2 \frac{c_g}{c} \Phi = 0 \qquad (3.1)$$

where:

x, y = orthagonal horizontal coordinate directions

c = wave celerity

c_g = wave group celerity

Φ = complex velocity potential

σ = wave angular frequency

The equation specifying the irrotationality of the wave phase function gradient can be written as:

$$\frac{\partial(k \sin\theta)}{\partial x} - \frac{\partial(k \cos\theta)}{\partial y} = 0 \tag{3.2}$$

where,

k = wave number = 2π / L

θ = direction of wave propagation

Offshore wave characteristics, including wave height, period, and direction, as well as information regarding bathymetry offshore of the model reach are needed to solve the governing equations. For greater detail regarding RCPWAVE the reader is referred to Ebersole (1985); and Ebersole, Cialone, and Prater (1986).

3.2 Solution Scheme

A finite difference solution is applied to solve the governing equations for wave transformations. RCPWAVE initially estimates the values of wave height, wave group celerity, and wave angle for all grid points by implementing the following procedure (Cialone et al., 1992):

1. the wave number, k, is computed at every cell using the dispersion relationship,
2. the wave energy and wave group celerity is calculated at every cell as they are functions of the wave period and wave number,
3. the wave angle is estimated using the above information and Snell's law, and
4. wave height at each cell is estimated taking shoaling and refraction into account.

An iterative process is then used to solve for the wave characteristics at each grid cell. This iterative process continues until a convergence criterion is met. The wave characteristics arrived at for each cell are wave height and wave direction. The finite difference solution continues from row to row until the end of the RCPWAVE finite difference grid is reached. (Hanson and Kraus 1989)

3.3 Categorizing Wave Input

RCPWAVE calculations are based on monochromatic wave theory therefore, the equations governing shoaling and refraction do not depend on the initial wave height. A unit wave height can be used for calculations, thus, only wave direction and period need to be input. However, if every combination of offshore wave direction and period were used this would amount to thousands of individual wave events for a model involving several years of wave data. Therefore, it is convenient to categorize the wave events into "period bands" and "angle bands." Each combination of angle and period band that occurs in the input wave characteristic files can then be operated on by RCPWAVE for the specified bathymetry. Information on the transformed of wave characteristics is then saved for each combination of angle and period band (Hanson and Kraus 1989). The procedure used in order to apply wave transformation data is discussed in the Section 3.4.

3.4 Linking GENESIS and RCPWAVE

Special attention must be paid to the coordinate systems and conventions used by GENESIS and RCPWAVE as shown in Figure 3.1. The locations of the origins for each system are placed at opposite ends of the study reach. The orientation of the x and y-axis are also switched. This difference requires "end for end swapping" of wave and bathymetry data in the alongshore direction (Hanson and Kraus 1989). Once the correct grid systems have been used and the statistical wave properties have been transformed by RCPWAVE it is important to understand how GENESIS uses the wave transformation information.

Data on wave direction and wave height transformations produced by RCPWAVE is placed in a look up table to be referenced by GENESIS during the shoreline change calculations. Each wave in the offshore wave time series data file is input into GENESIS and categorized into its corresponding angle and period band. GENESIS then refers to the look up table for that specific wave condition in order to transform the wave to the nearshore reference line. GENESIS performs the necessary interpolation of wave transformation data for cells that do not directly correspond to a wave transformation grid cell. However, this requires that the RCPWAVE cell spacing be an even multiple of GENESIS alongshore grid cell spacing. The reader should note the sign convention used for approaching wave direction in Figure 3.1. (Hanson and Kraus, 1989)

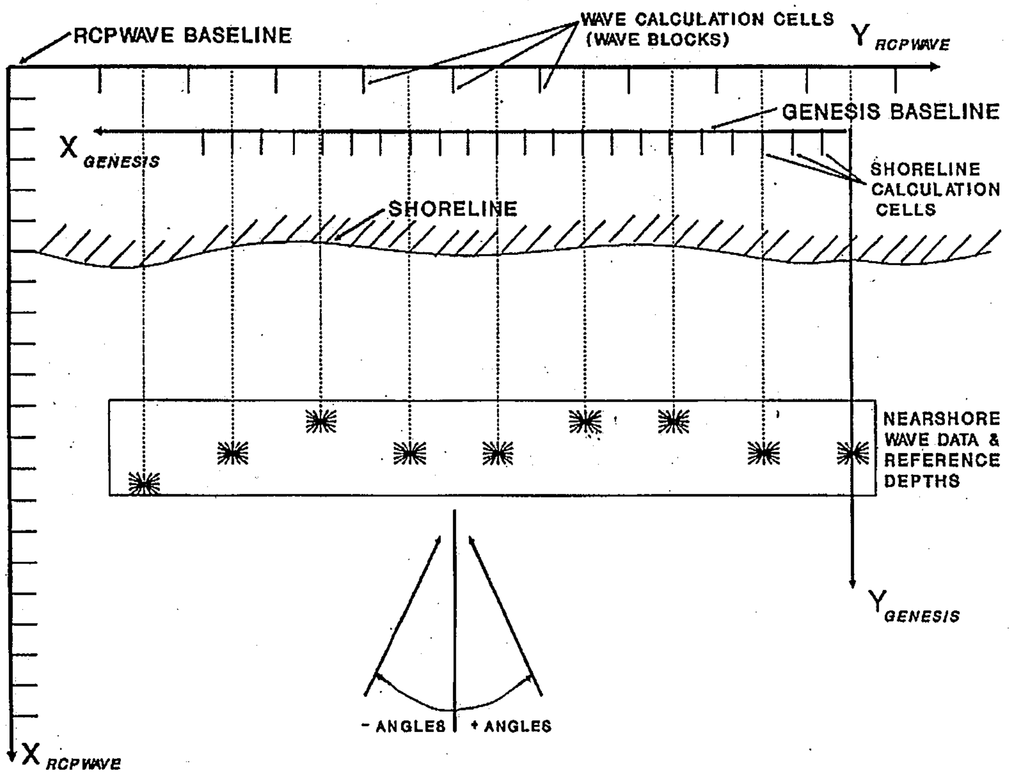


Figure 3.1 GENESIS and RCPWAVE coordinate system and conventions (from Hanson and Kraus, 1989)

3.5 Computational Stability

Waves approaching from extremely oblique wave angles can cause RCPWAVE to become unstable during wave transformation computations. The aspect ratio ($\Delta y/\Delta x$) of RCPWAVE alongshore grid cell spacing to offshore grid cell spacing can be used to predict the maximum allowable local wave approach direction in order to maintain the computational stability of the model. It has been empirically determined that the inverse tangent of the aspect ratio approximates the maximum local wave direction. An aspect ratio of 2 to 3 is recommended for RCPWAVE computational grid.

The reader is referred to Ebersole (1985) and Ebersole, Cialone and Prater (1986) for more information regarding the RCPWAVE external wave transformation model and the Hanson and Kraus (1989) for information regarding the relationship between of GENESIS and RCPWAVE.

4.0 DATA REQUIREMENTS FOR INVESTIGATION

A wide range of data is necessary in order to run an adequate shoreline change model. Information on measured shoreline positions at different points in time along the model reach is necessary, as well as, beach properties (including: active berm height, depth of closure, and median grain size), local wave climate, local bathymetry, and structures present in the model reach.

4.1 Shoreline Positions

Measured shoreline positions for the model reach at several points in time are needed to complete model simulations. LBI digitized shoreline positions data were obtained from the U.S. Army Corp of Engineers, Philadelphia District for selected years from 1836 to 1997 (McCormick 1997). The shoreline position data originated in New Jersey State Plane Coordinates, 1983 North American Datum. SURFER (Surface Mapping System), Version 6.03, from Golden Software Inc., was used in order to plot the shoreline positions and sort the shoreline data. SURFER was used throughout this study and became an invaluable tool when used in conjunction with bathymetric data. For further information regarding SURFER the reader is referred to the SURFER user's manual by Keckler (1994).

It is necessary to choose the time interval to run model simulations for calibration and verification of GENESIS input parameters. The time interval from June 1986 to November 1991 was used for calibration and the time interval from December 1991 to November 1993 for verification. These time intervals were selected because they are relatively recent. This tends to lend confidence to the accuracy of shoreline surveys conducted to obtain shoreline position data. Also, investigation of recent projects revealed an absence of construction of shore protection structures in the study area during this time frame (McCormick 1997). Also no beach nourishment projects were undertaken in the study area during this time frame (McCormick 1997). The preceding factors made the time interval from 1986 to 1993 a favorable period by simplifying the GENESIS input and easing the comparison of predicted shoreline positions.

It is necessary to choose a shoreline reach to be used for model simulations. One objective of this study was to investigate the effects of altering the nearshore bathymetry on the predicted shoreline evolution. Examination of LBI local bathymetry revealed an area with two prominent shoals in the nearshore area (the local bathymetry will be discussed further in Section 4.4). The shoreline reach to be used in this investigation was selected such that it was in the lee of waves passing over these two shoals.

A successful GENESIS model simulation is also dependent on the selection of adequate boundary conditions. Inspection of the simultaneously plotted shoreline positions with close proximity to the two prominent shoals for years 1986, 1991, and 1993, (Figure 4.1) revealed potentially strong boundary conditions. A pinned boundary condition was used to the north (left) and a gated boundary was used to the south (right) of the model reach. Discussion of these boundary conditions is provided in Section 4.8. The final model reach has a length of 36,500 feet.

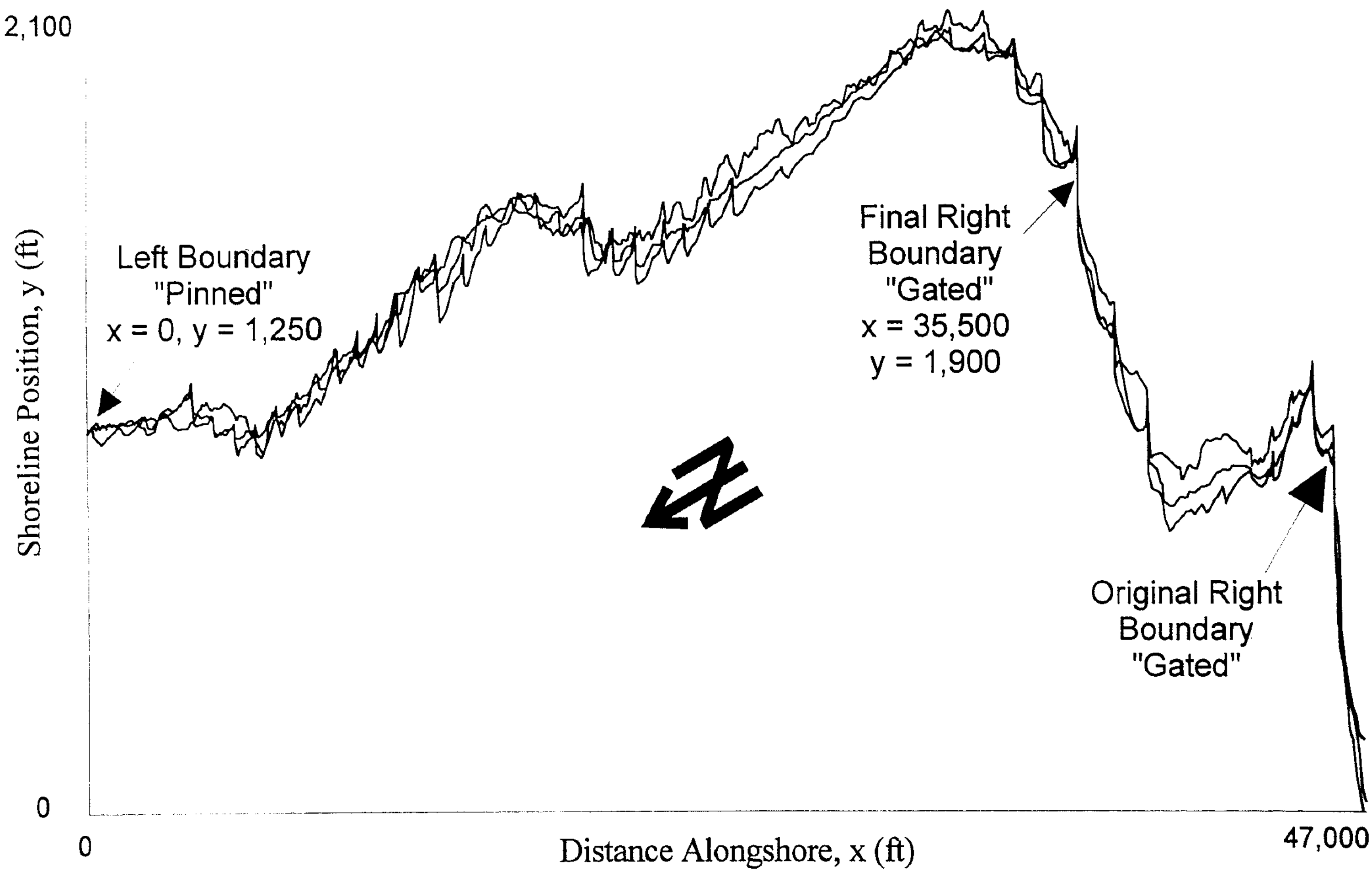


Figure 4.1 Shoreline positions and lateral boundary conditions

Once the model reach and boundary conditions for the simulation have been determined it is necessary to place the shoreline positions into the coordinate system used by GENESIS. This requires the rotation and translation of the shoreline position data. As seen in Figure 3.1, GENESIS requires the alongshore (x) axis to be aligned parallel to the general trend of the shoreline orientation. Figure 3.1 also shows that the origin of the alongshore (x) axis is placed landward of the shoreline positions and the offshore (y) axis crosses the shoreline at the left boundary condition. Shoreline position data originated in New Jersey State Plane Coordinates. The coordinates of LBI in NJSP horizontal coordinate system, NAD 1983 are on the order of 600,000, 350,000 Easting, Northing. The coordinate system was rotated 120 degrees in the clockwise direction in order that the y-axis is directed offshore and that the x-axis is directed alongshore, aligned with the general trend of shoreline positions. The origin was then translated 545,100 feet in the x-direction and –365,000 in the y-direction so that it was positioned in accordance with the GENESIS standards. After rotation and translation, the alongshore direction ranged from approximately 0 to 36,500 feet and the offshore direction ranged from 1,100 to 2,100 feet.

Shoreline positions must be placed onto the GENESIS finite difference grid for calculation of shoreline position change. An alongshore grid cell spacing of 500 feet was used. This was done in order to accommodate the maximum number of 100 GENESIS grid cells and still cover the entire study area. Linear interpolation was used in order to determine shoreline positions for input into GENESIS using the LINTP application including the SMS package. The linearly interpolated shoreline positions can be seen in

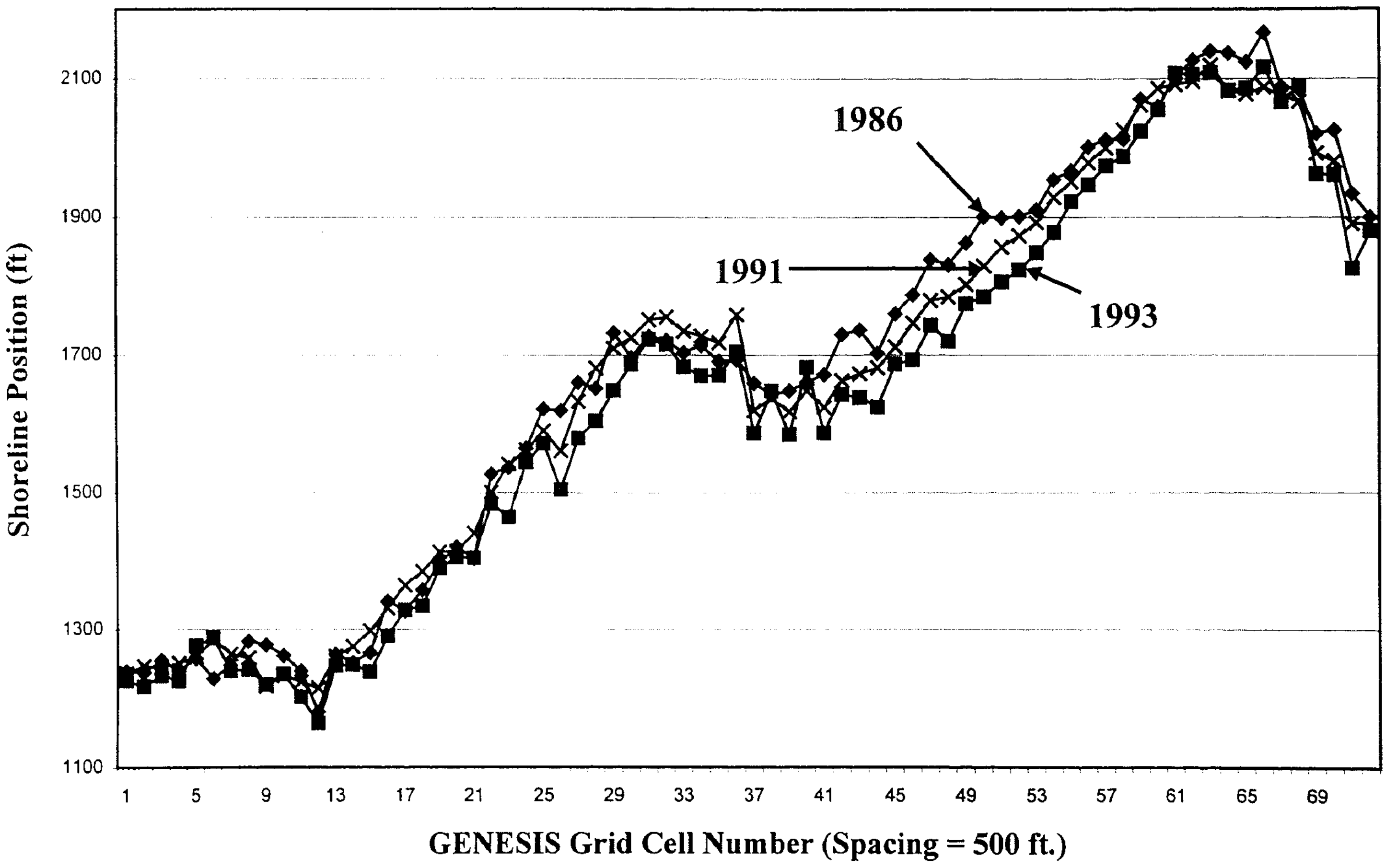


Figure 4.2 Linearly interpolated shoreline positions

Figure 4.2 for June 1986, November 1991 and November 1993. The files containing shoreline position data must be run through the WTSHO application in order to be placed in the proper format for use by GENESIS.

4.2 Active Berm Height, Depth of Closure, and Grain Size

Active berm height, D_B, and depth of closure, D_C, are necessary input values for the computation of predicted transport rates and shoreline position change. GENESIS assumes that these values remain constant at each time step and along the length of the model reach. Consultation with the U.S. Army Corp of Engineers, Philadelphia District, revealed an average active berm height throughout the study area of approximately 7.75 feet (NAVD) and an average depth of closure of approximately -29 feet (NAVD) (McCormick 1997). This creates a total vertical distance of 36.75 feet over which sediment can be transported. Correspondence with the U.S. Army Corp of Engineers, Philadelphia District, revealed an approximate mean grain diameter of 0.28 mm (McCormick 1997).

4.3 Wave Climate

GENESIS shoreline change simulations are driven by wave induced longshore transport. This necessitates the acquisition of the local wave climate data offshore of the model reach. The Wave Information Study (WIS) conducted by the USACE provides hindcast data on wave height, period and direction at selected locations along the US coast (Hubertz et al., 1993).

WIS data can be downloaded from the USACE Waterways Experimentation Stations website, http://bigfoot.cerc.wes.army.mil/c205.html. WIS data covers 20 years from 1976 to 1995. The data is given at three hour intervals and contains information on: significant wave height, peak period, peak direction, mean period, mean direction, primary component of height/ period/ direction, secondary component of height/ period/ direction, wind speed and wind direction. The primary and secondary components of wave data were used in this investigation. Data for the Atlantic coast of the United States is Phase 2 data. Phase 2 data is provided for a specific offshore depth.

WIS station 69 is located at 39.25 North Latitude and 74.25 West Longitude at a depth of 22 meters and corresponds to the station with the closest proximity to Long Beach Island. A FORTRAN algorithm was written in order to extract the 7.5 years of data corresponding to model study temporal span for calibration and verification. The total number of 16,072 time steps were used for calibration and 5,848 time steps for verification, with each time step containing data on a sea and swell events at three hour intervals. The data obtained from WIS was not compatible with the format utilized by the GENESIS version used for this investigation. A FORTRAN algorithm was writen in order to place the WIS data into a format compatible with GENESIS.

The formatted WIS data corresponding to the time interval of the model study is then adjusted for input into the Shoreline Modeling System. The primary modification begins by transforming the sea and swell data from the depth at which the data is given, to the average depth at the offshore edge of the RCPWAVE grid. For this study that is the transformation of the WIS data from the depth of 22 meters at Station 69 to a depth of 17.4 meters corresponding the average depth at the offshore edge of the RCPWAVE grid. This is accomplished by using the program WAVETRAN. One function of WAVETRAN eliminates waves that are not propagating in a direction towards the model reach. For further information on WAVETRAN see Hanson and Kraus (1989).

The next task in preparing the wave data for input into GENESIS uses the program RCRIT contained in the Shoreline Modeling System. RCRIT "flags" wave events that are considered below the energy threshold for producing longshore sediment transport. The reader is once again referred to Hanson and Kraus (1989) for more information on the RCRIT program. The program WTWAVTS can then be used to modify wave data further. The time step of the input waves or the time period to be used can be adjusted. For example, the time span to be used can be extracted for the wave data or the time step changed from 3 hours to 6 hours. In the past, the need to reduce calculation time of GENESIS necessitated increasing the time step. Computer technology in use at the time of this project compared to that in use at the time of publication of the technical support manual for GENESIS have essentially made the need to increase the time step of the wave input an unnecessary step.

The utility program WHEREWAV is used to compute statistical properties of input wave data. Table 4.1 and Table 4.2 summarize the statistical properties of the wave data used for calibration and verification for time intervals June 1986 to November 1991 and December 1991 to November 1993 respectively. WHEREWAVE categorizes offshore

Classification of Combined (Primary and Secondary) Wave Events				
Classification of Combined Wave Events by Angle Band				
Angle Band Number	**Range w.r.t. Shore-Normal (degrees)**	**Number of Events**	**Average Wave Angle (degrees)**	**Period Bands**
1	90.00 : 78.75	47	79.81	1 2
2	78.75 : 56.23	1043	68.29	1 2 3 4
3	56.25 : 33.75	1029	44.68	1 2 3 4 5
4	33.75 : 11.25	3594	21.51	1 2 3 4 5 6 7 8
5	11.25 : -11.25	2881	0.35	1 2 3 4 5 6 7 8
6	-11.25 : -33.75	2585	-22.05	1 2 3 4 5 6 7 8
7	-33.75 : -56.75	3572	-45.08	1 2 3 4 5 6 7 8
8	-56.75 : -78.75	2146	-65.73	1 2 3
9	-78.75 : - -90.00	22	-79.35	1 2
Classification of Combined Wave Events by Period Band				
Period Band Number	**Range of Wave Period (seconds)**	**Number of Events**	**Average Period (seconds)**	**Angle Bands**
1	0.0 < T < 5.0	1601	3.85	1 2 3 4 5 6 7 8 9
2	5.0 < T < 7.0	4584	5.55	1 2 3 4 5 6 7 8 9
3	7.0 < T < 9.0	4699	7.49	2 3 4 5 6 7 8
4	9.0 < T < 11.0	3349	9.46	2 3 4 5 6 7
5	11.0 < T < 13.0	1662	11.42	3 4 5 6 7
6	13.0 < T < 15.0	726	13.38	4 5 6 7
7	15.0 < T < 17.0	192	15.39	4 5 6 7
8	17.0 < T < 23.0	106	18.2	4 5 6 7

Table 4.1
Statistical wave data for June 1986 to November 1991

Classification of Combined (Primary and Secondary) Wave Events				
Classification of Combined Wave Events by Angle Band				
Angle Band Number	Range w.r.t. Shore-Normal (degrees)	Number of Events	Average Wave Angle (degrees)	Period Bands
1	90.00 : 78.75	18	79.74	1 2
2	78.75 : 56.23	368	67.50	1 2 3 4
3	56.25 : 33.75	446	44.68	1 2 3 4
4	33.75 : 11.25	1394	21.86	1 2 3 4 5 6 7 8
5	11.25 : -11.25	1065	0.90	1 2 3 4 5 6 7
6	-11.25 : -33.75	934	-22.66	1 2 3 4 5 6 7
7	-33.75 : -56.75	1235	-45.19	1 2 3 4 5 6
8	-56.75 : -78.75	610	-65.91	1 2 3
9	-78.75 : - -90.00	7	-79.19	1 2
Classification of Combined Wave Events by Period Band				
Period Band Number	Range of Wave Period (seconds)	Number of Events	Average Period (seconds)	Angle Bands
1	0.0 < T < 5.0	621	3.86	1 2 3 4 5 6 7 8 9
2	5.0 < T < 7.0	1658	5.54	1 2 3 4 5 6 7 8 9
3	7.0 < T < 9.0	1637	7.47	2 3 4 5 6 7 8
4	9.0 < T < 11.0	1049	9.39	2 3 4 5 6 7
5	11.0 < T < 13.0	713	11.47	4 5 6 7
6	13.0 < T < 15.0	345	13.36	4 5 6 7
7	15.0 < T < 17.0	53	15.17	4 5 6
8	17.0 < T < 23.0	1	17.00	4

Table 4.2
Statistical wave data for December 1991 to November 1993

wave events into "period bands" and "angle bands." The output file contains statistical data on each period and angle band including the average period and angle for each band. This data is then used in the RCPWAVE program to calculate the wave transformation characteristics for each combination of bands. Further adjustment of the statistical wave data will be discussed in section 4.5. The program WTWAVES is used to format the wave data for input into GENESIS.

4.4 Bathymetry

Bathymetric data offshore of the model reach is required to run RCPWAVE. This data is needed order to complete wave transformations from offshore, using actual bathymetry, to the nearshore reference line. The USACE provided digitized bathymetric data for the area offshore of the southern region of LBI. The bathymetry data file contained approximately 185,000 individual data points. Figure 4.3 is a contour plot of the local bathymetry offshore of southern LBI, the position of the nearshore reference line and area used for RCPWAVE simulations are also plotted for reference. The bathymetric data offshore of the model reach must then be placed onto a grid for use by RCPWAVE.

100 grid cells were used in the alongshore direction (the maximum allowed by RCPWAVE) with a grid cell spacing of 1000 feet. 75 grid cells were used in the offshore direction (the maximum allowed by RCPWAVE) with a grid cell spacing of 500 feet. The grid covered a total offshore area of 134.5 square miles (18.9 by 7.1 miles) for RCPWAVE wave transformations. In the alongshore direction, 6.9 miles corresponded to the model reach, the remaining 12 miles were evenly divided to the north and south of

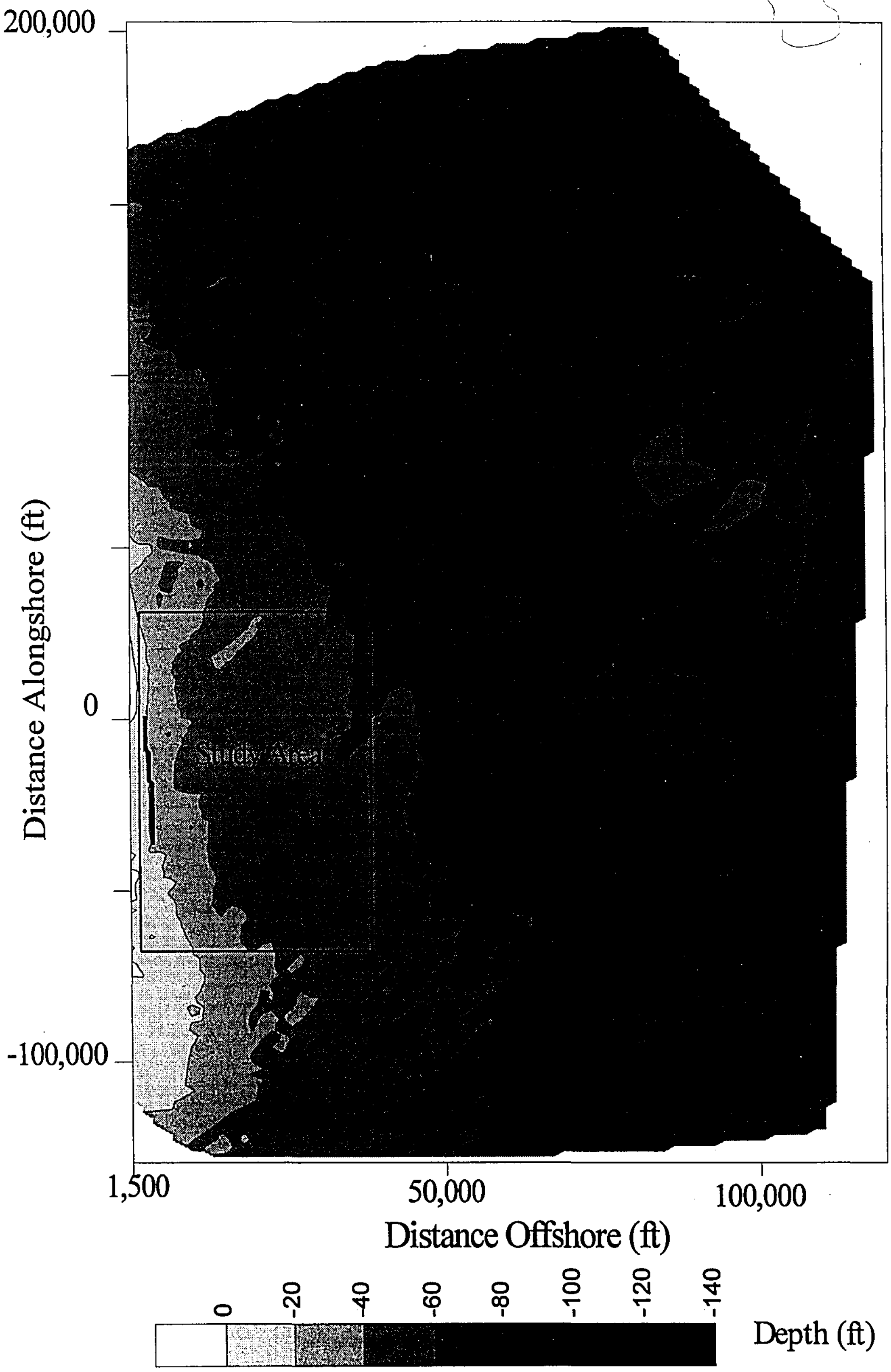


Figure 4.3 Long Beach Island local bathymetry

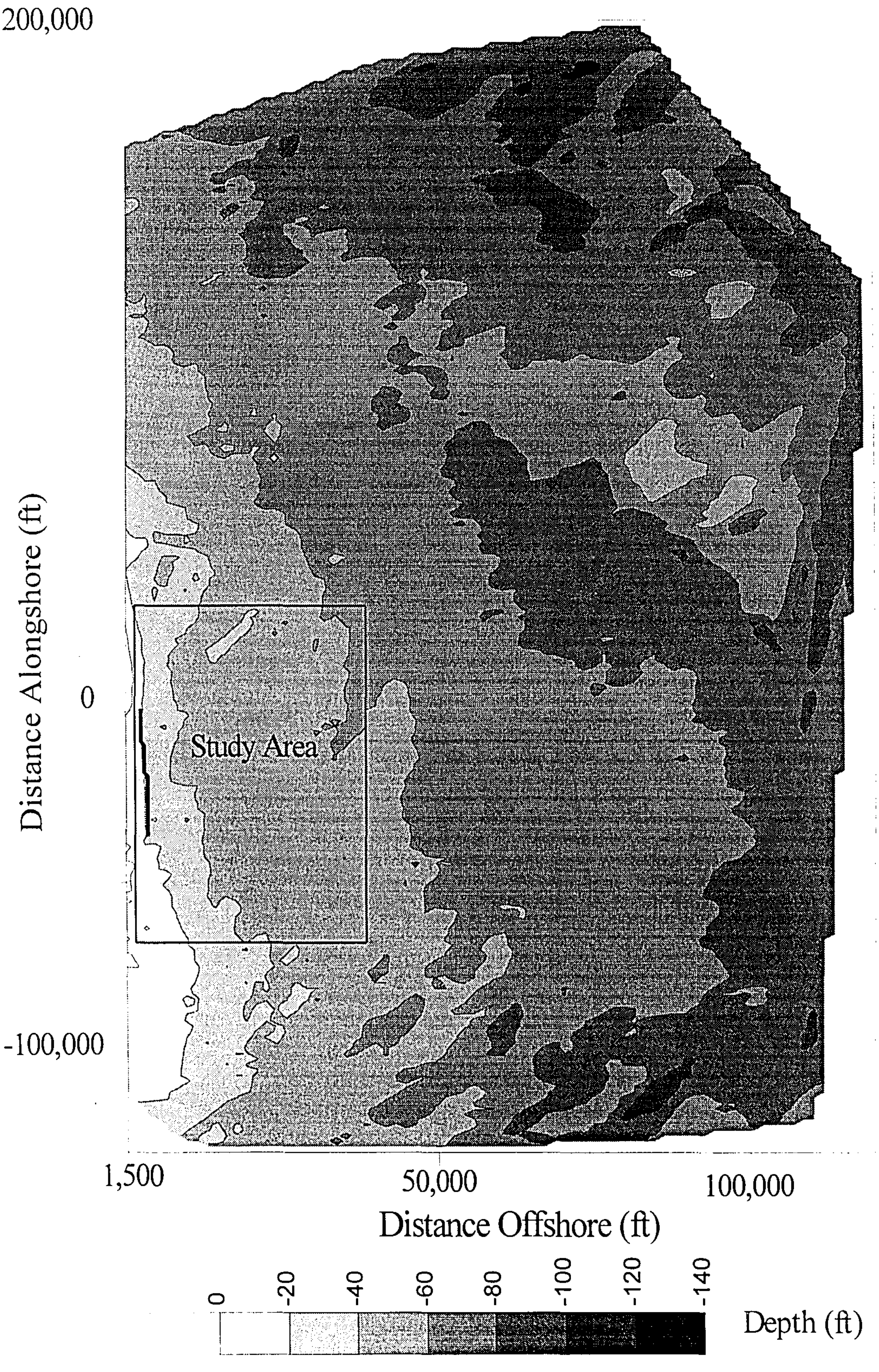


Figure 4.3 Long Beach Island local bathymetry

the model reach. The bathymetry area extended from a point one third of a mile offshore to approximately 7.1 miles offshore. The average depth at the offshore edge of the RCPWAVE grid was 58 feet (17.4 meters).

The alongshore grid cell spacing of 1000 feet and the offshore grid cell spacing of 500 feet produces an aspect ratio of two. The approximate maximum local approaching wave direction is calculated as 63.4 degrees from shore perpendicular. Inspection of input wave data revealed waves with a direction greater then +/-63.4 degrees from shore perpendicular. The two most extreme angle bands corresponding to waves approaching shore from between 90 to 78.75 and –78.75 to -90 degrees from shore perpendicular can not be used by RCPWAVE and maintain stability. The adjustment of input wave data in order to overcome this problem is discussed further in section 5.0. The reader is referred to Hanson and Kraus (1989) for more information regarding stability parameters and maximum local wave angles.

Manipulation of the bathymetry data was accomplished using SURFER. A tool intrinsic to SURFER is the interpolation of scattered three-dimensional surface data onto a grid, which can then be used to create surface and contour plots. The user can specify the positions of the cell nodes used by SURFER to create surface plots. Therefore, the modeler can use SURFER to interpolate bathymetric data onto a grid exactly corresponding to the grid desired for RCPWAVE simulations. This data can then be extracted from SURFER and manipulated for input into RCPWAVE. The amount of data, which Surfer is able to handle, is limited only by the amount of free memory available on the computer. These characteristics made SURFER a very useful program to deal with the large amount of data used to create the bathymetry grid for input into RCPWAVE.

Kriging was the gridding method used to interpolate scattered bathymetry data onto a grid.

> Kriging is a geostatistical gridding method which has been found to be very useful in many fields. Kriging attempts to express trends that are suggested in your data, so that, for example, high points might be connected along a ridge, rather than isolated by bull's-eye type contours. (Keckler, 1994)

The resulting plot of bathymetry can be seen in Figure 4.4. For more information on SURFER and the Kriging method of interpolation the reader is referred to Keckler (1994).

4.5 Nearshore Reference Line

The 23 ft. depth contour line was used as the nearshore reference line. The calculated wave transformation data is saved along this line and input into GENESIS as described in section 3.4. The position of this line was determined by visual inspection of the bathymetry data on the grid required by RCPWAVE. Each row of data in the bathymetry grid corresponds to a specific alongshore grid cell position and each column of data corresponds to specific offshore grid cell position. Each row of data is inspected in order to find the column position corresponding to the contour depth of 23 feet. Not every row of data contains a node point with a depth of 23 feet. Therefore, the column

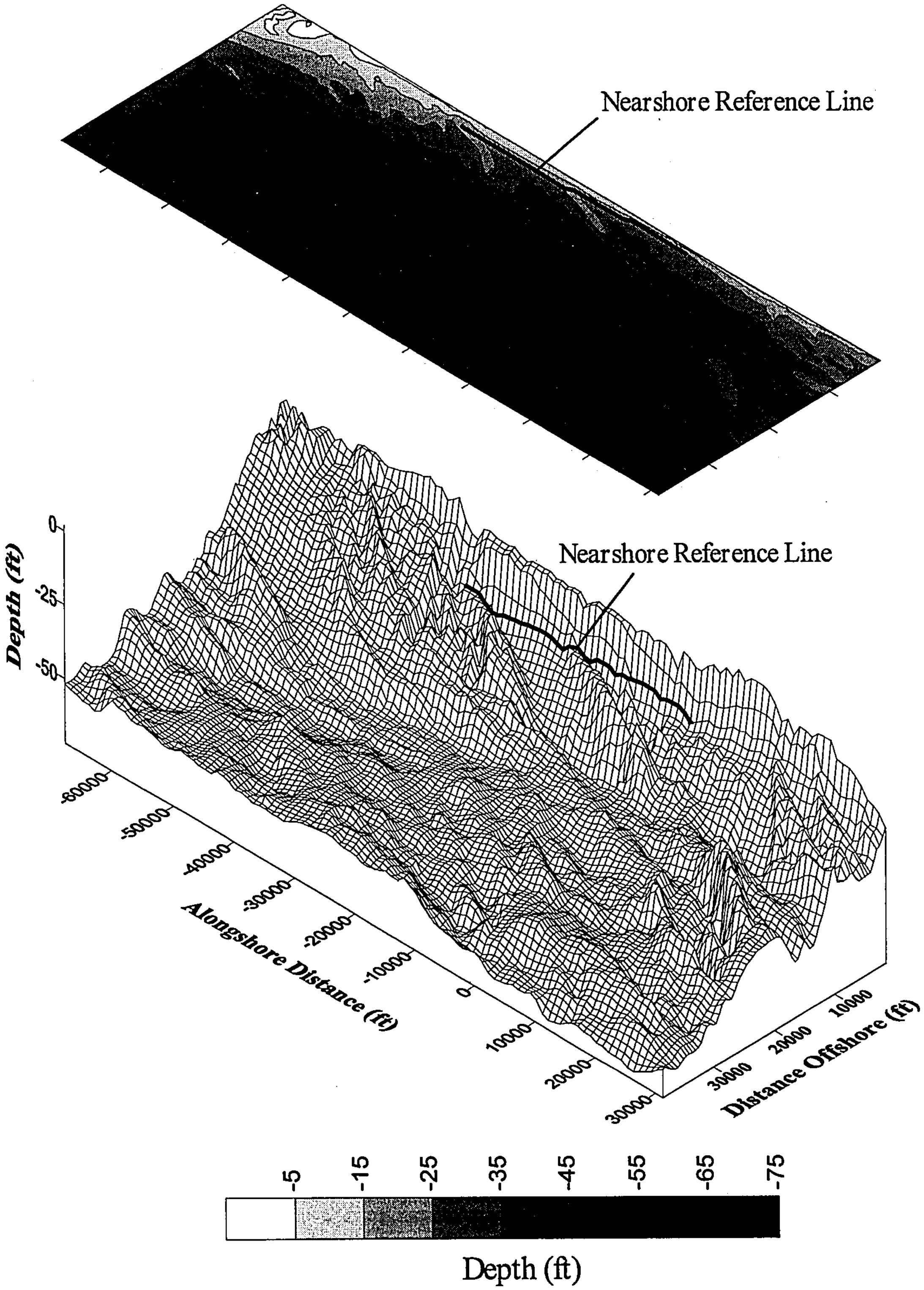


Figure 4.4 RCPWAVE unaltered bathymetry

corresponding to the depth closest to but not less then 23 feet was chosen to represent the position of the nearshore reference line.

4.6 Altered Nearshore Bathymetry

A major objective of this study was to alter the nearshore bathymetry and investigate the affects on predicted transformed wave characteristics, shoreline positions and sediment transport rates. This was accomplished by running RCPWAVE and GENESIS simulations for both unaltered and altered bathymetry while holding all other input parameters constant. Alteration of the offshore bathymetry for input into RCPWAVE was accomplished by using SURFER. The "grid node editor" function of SURFER was used to view and edit individual bathymetric data points on the original grid created for input into RCPWAVE.

The bathymetric features that the author decided to investigate the effects of altering were the two major shoals existing directly offshore of the model reach. The author simulated the "dredging" of the two major shoals, straightening out the nearshore contour lines and creating two "plateaus" where the shoals presently exist. A total volume of 18.5 million cubic yards of material was "removed" from the site. The "dredged" material was not used in the model as beach fill. This would have complicated the comparison of shoreline change and transport rates for unaltered and altered bathymetry. Figure 4.5 shows a contour and surface plot of the altered bathymetry. Contour plots comparing the bathymetry prior to and after alteration can be seen in Figure 4.6.

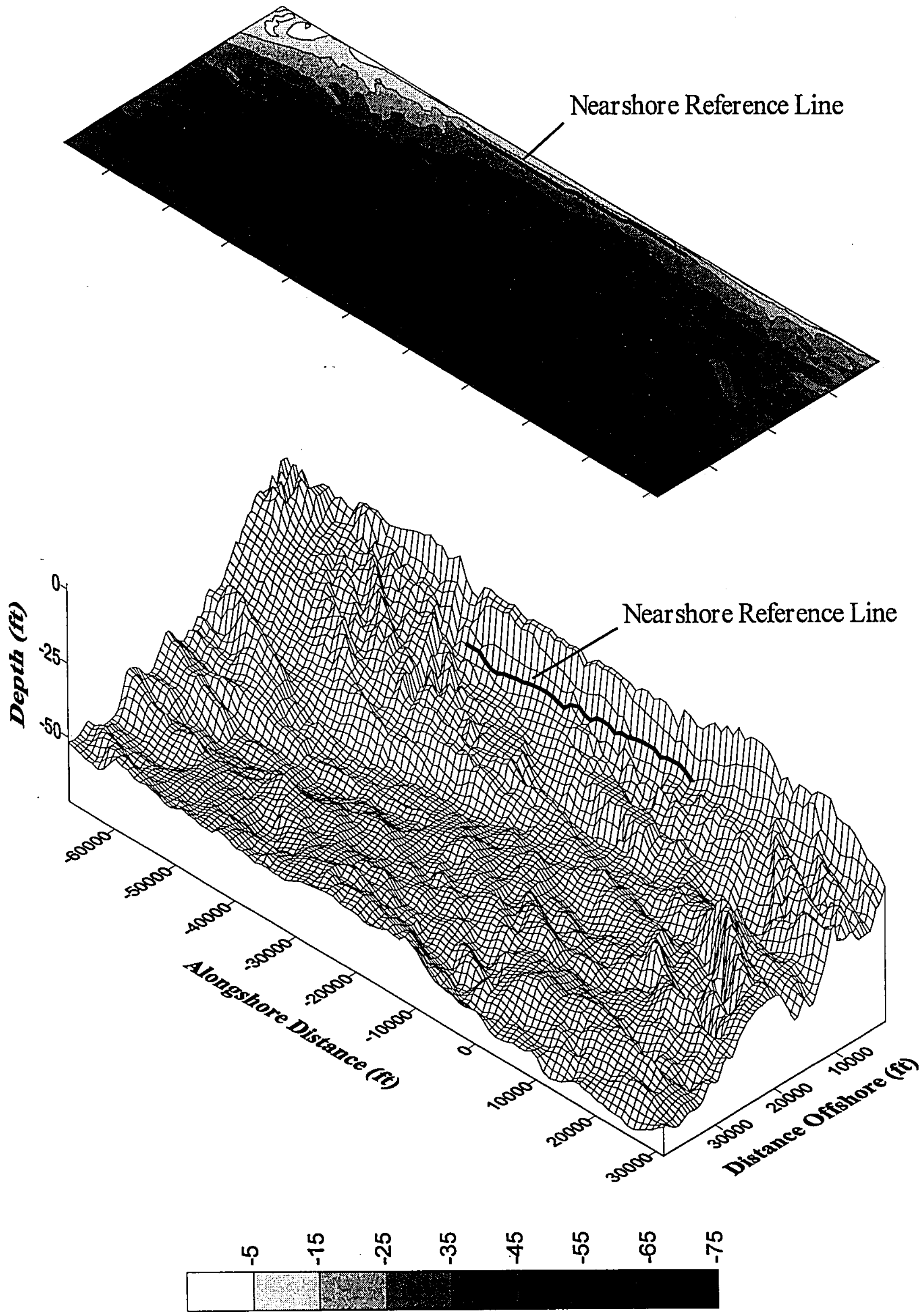


Figure 4.5 RCPWAVE altered bathymetry

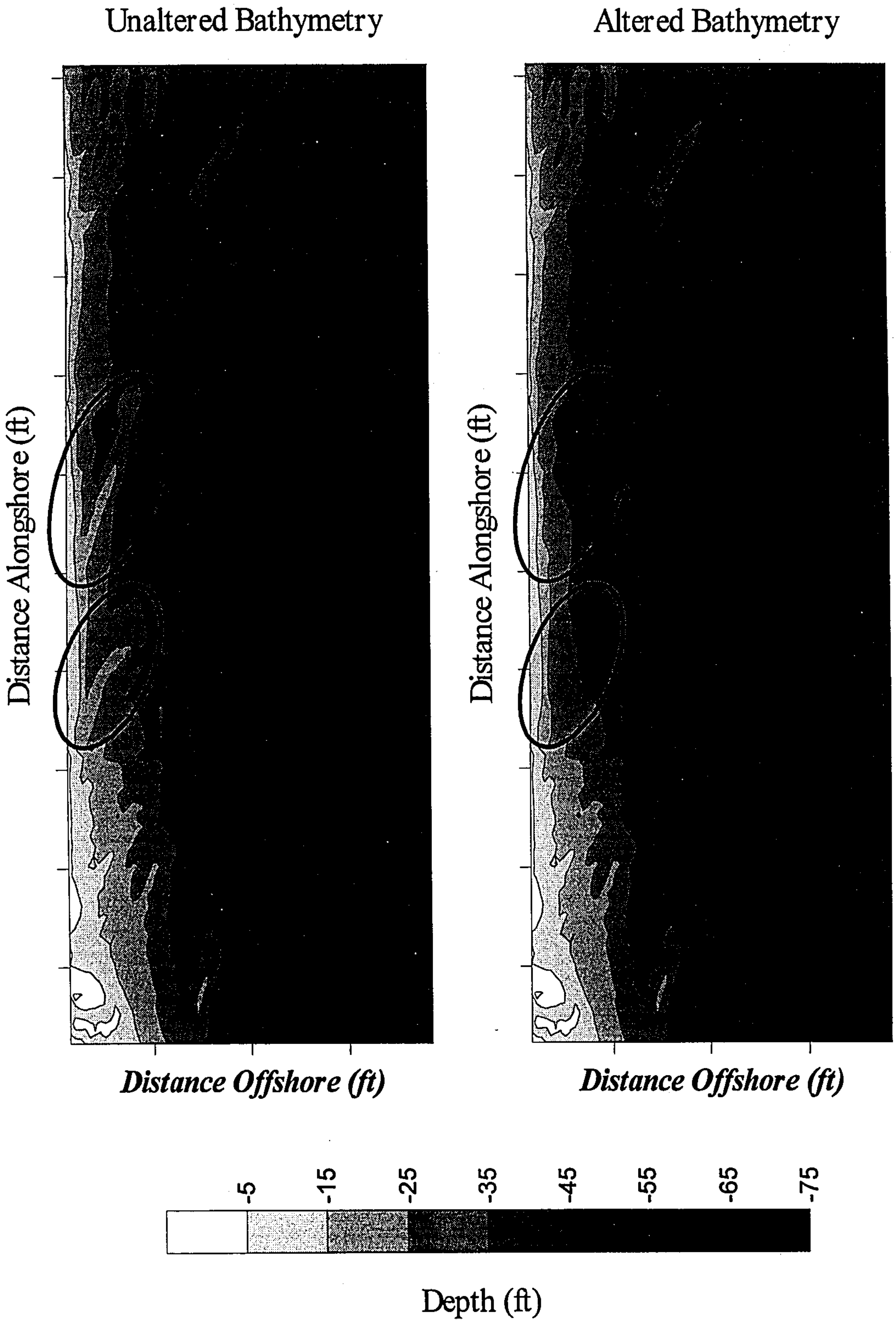


Figure 4.6 RCPWAVE unaltered and altered Bathymetry

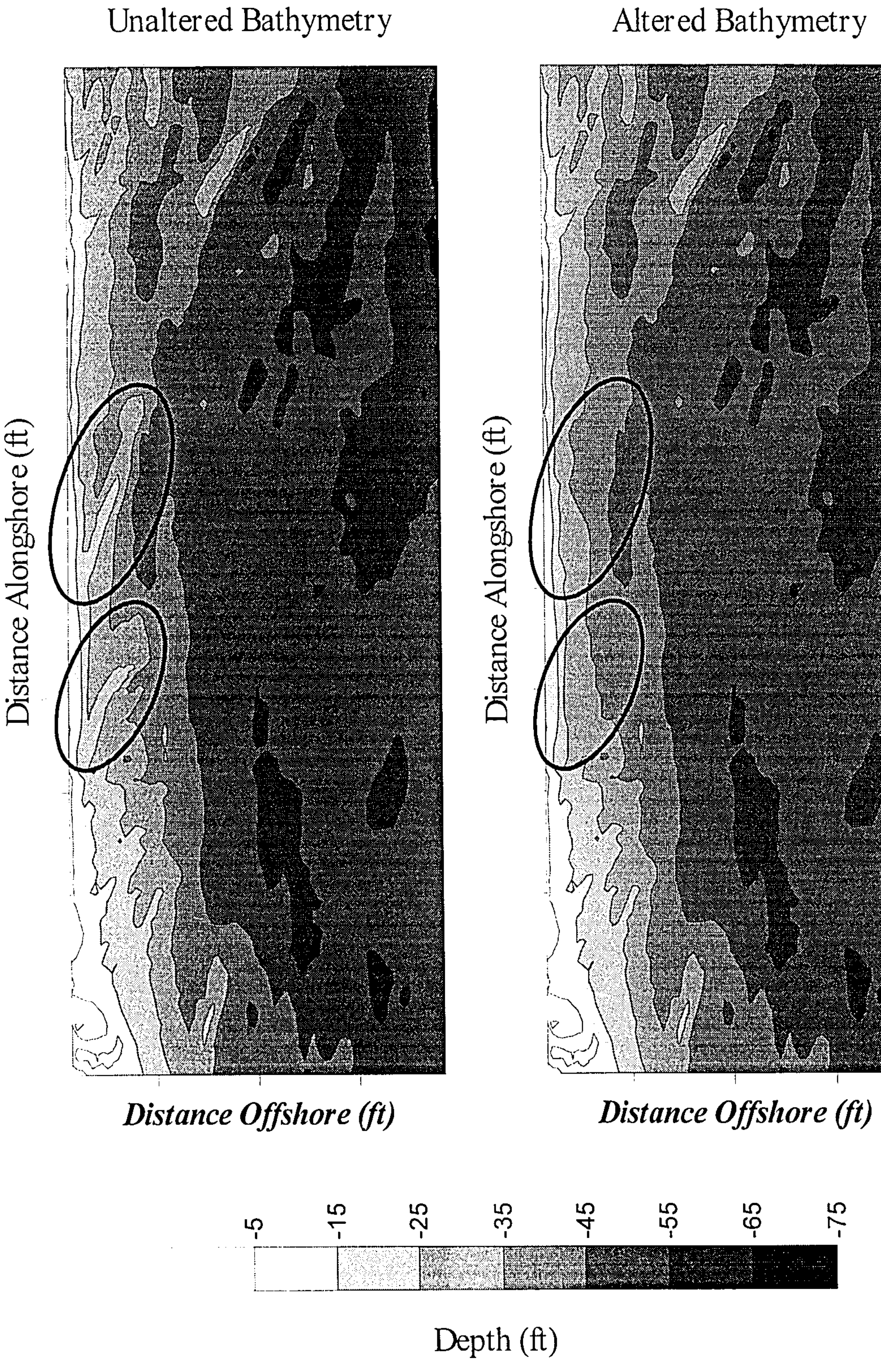


Figure 4.6 RCPWAVE unaltered and altered Bathymetry

The time series of wave data originally used for calibration and verification of GENESIS input parameters were then transformed from offshore to the nearshore reference line using the altered bathymetric data. The transformed wave characteristics for the altered bathymetry were then input into GENESIS to obtain predicted shoreline positions and sand transport rates using the same input parameters arrived at during the calibration process. The effects of altering the bathymetry are presented in Chapter 5.

4.7 Structures Present in the Model Reach

The locations and dimensions of both hard and soft structures are required to accurately predict shoreline evolution. A series of groins on LBI are the only structures of consequences to shoreline evolution in the model reach used in this study. USACE provided data containing the seaward and landward limits of 99 groins on LBI, 40 of which exist in the model reach (McCormick 1997). Table 4.3 provides data on the measured seaward and landward limits of each groin in the study area as well as the grid cell boundary where each groin was placed for model simulations. The alongshore position, and the offshore position of the seaward limit of each groin are input into GENESIS.

A limitation of GENESIS is the alongshore location of a groin must be placed at a grid cell wall. This restricts the positions at which a groin can be placed for input into GENESIS. Additionally, two grid cells must exist between each groin placed into GENESIS. Therefore, a minimum of 1000 feet between each groin is required for an alongshore grid cell spacing of 500 feet. Common sense was used in order to place

Acquired Groin Data				Closest	Groin Input Data		
Landward Limit		Seaward Limit		Cell Wall	Cell Wall	Cell Wall	Seaward
Alongshore	Offshore	Alongshore	Offshore	Position	Position	Number	Position
x (ft)	y (ft)	x (ft)	y (ft)	x (ft)	x (ft)		y (ft)
196	1349	180	1175	250	Not Used	Not Used	Not Used
1141	1351	1110	1175	1250	750	3	1351
2114	1354	2114	1195	2250	1750	5	1354
2896	1416	2891	1201	2750	2750	7	1416
3710	1350	3704	1200	3750	3750	9	1350
4510	1349	4521	1156	4750	4750	11	1349
5324	1324	5321	1138	5250	Not Used	Not Used	Not Used
6126	1349	6115	1174	6250	5750	13	1349
6877	1413	6855	1235	6750	6750	15	1413
7624	1464	7595	1240	7750	7750	17	1464
8372	1467	8371	1278	8250	Not Used	Not Used	Not Used
9133	1568	9119	1336	9250	8750	19	1568
9868	1539	9862	1357	9750	9750	21	1539
10615	1587	10619	1414	10750	10750	23	1587
11438	1692	11433	1485	11250	11750	25	1692
12064	1672	12046	1510	12250	Not Used	Not Used	Not Used
13087	1756	13087	1574	13250	12750	27	1757
13977	1796	13974	1626	13750	13750	29	1796
15018	1810	15012	1654	15250	14750	31	1810
15862	1828	15852	1666	15750	15750	33	1828
16703	1840	16685	1646	16750	16750	35	1840
17578	1853	17564	1623	17750	17750	37	1853
18683	1750	18661	1571	18750	18750	39	1750
19509	1771	19499	1557	19750	19750	41	1771
20573	1823	20572	1581	20750	20750	43	1823
21308	1811	21300	1629	21250	Not Used	Not Used	Not Used
22227	1847	22227	1683	22250	22250	46	1847
23120	1893	23113	1712	23250	23250	48	1893
24013	1940	23995	1718	24250	24250	50	1940
24928	1961	24928	1764	25250	25250	52	1961
26008	1991	26004	1831	26250	26250	54	1991
27004	2020	27003	1911	27250	27250	56	2020
28018	2106	27996	1950	28250	28250	58	2106
29220	2178	29227	2025	29250	29250	60	2178
30227	2198	30217	2078	30250	30250	62	2198
31246	2236	31246	2095	31250	31250	64	2236
32533	2265	32526	2069	32750	32750	67	2265
33651	2224	33638	2012	33750	33750	69	2224
34679	2112	34671	1893	34750	34750	71	2112
35981	2069	35982	1668	35750	35750	73	2069

Table 4.3

Summary description of acquired groin data and GENESIS groin input data groins at strategic points in order to mimic reality as closely as possible. Due to the minimum spacing required between groins, some groins could not be used in model simulations.

The input parameter used by GENESIS to calculate the amount of sediment passing through or over a groin is quantified by assigning a permeability factor to each groin. A permeability factor of 0 implies an impermeable groin, while a factor of 1.0 refers to an ineffective groin. Various values of permeability can be used for each groin as a fine tuning option once the "major" calibration coefficients have been determined. All groins present in the model reach were assumed to be functioning and permeability factor of 0 was assigned to each groin.

4.8 Boundary Conditions

The reach being studied must be bounded on the left and right. Determination of boundary conditions was accomplished by visual inspection of the measured shoreline positions. The three years of shoreline data to be used in the study were plotted simultaneously (Figure 4.1) and the offshore-directed axis was exaggerated in order to visualize tendencies of the shoreline positions.

Inspection the shoreline positions to the north (left) revealed a section where, for the three years (Figure 4.1), the positions converged and remained relatively close together, not moving significantly with the passage of time. This type of shoreline lends itself to a pinned boundary condition. Inspection of the right end of the study area revealed two sections where the change in shoreline position increased dramatically as seen in. These points correspond to the positions of groins where erosion just south of each groin is dramatic. Situations such as this are often referred to as terminal groins which dramatically restricting movement of sand in one direction, this condition lends itself to a gated boundary condition. The terminal groin farther to the north was used order to reduce the total length of the model reach.

Gated boundary conditions allow flexibility in adjusting the movement of sand into and out the model reach and require additional input of variables for calibration of GENESIS. The amount of sand entering the model reach around the tip of the groin, at the gated boundary, is controlled by the distance from the shoreline to the seaward end of the groin outside the grid, Y_{G1}. The greater this distance the more difficult it becomes for the sand to be transported around the end of the groin and into the model reach. The value of Y_{G1}, equal to 400 feet, was measured from shoreline positions. The amount of sand leaving the grid is controlled by the distance from the shoreline position at the particular time step, calculated by GENESIS, to the seaward end of the groin inside the grid, $GL - y_1$.

4.9 Transport Parameters

Calibration efforts for this study focused on the transport parameters K_1 and K_2. Three sets of values were initially used: $K_1 = 0.77$ and $K_2 = 0.38$ as suggested by Komar and Inman (1970), $K_1 = 0.58$ and $K_2 = 0.29$ as suggested by Hanson and Kraus (1989), and $K_1 = 0.2$ and $K_2 = 0.17$ as suggested by Tibbets (1995). A fourth set of transport parameters, $K_1 = 0.1$ and $K_2 = 0.05$, was also used during calibration efforts. This set of transport parameters corresponds to lowest suggested values which can be used. All other input parameters for GENESIS were measured or provided by the USACE and were assumed to be reasonably accurate. In order to test the sensitivity of the model, modifications to input parameters other then K_1 and K_2 were made and the model was run in order to examine the effects.

5.0 RCPWAVE Results for Unaltered Bathymetry

Input of statistical properties of offshore approaching wave directions, heights and periods in conjunction with offshore bathymetry into RCPWAVE yields approximate wave transformation characteristics of direction, period and height along a nearshore reference line. Input statistical wave properties are determined from the program WHEREWAVE as seen in Tables 4.1 and 4.2. However, the computational stability of RCPWAVE limits the maximum local wave approach direction. Examination of the statistical wave properties in Table 4.1 and 4.2 reveals wave conditions which exceed the approximated maximum local wave approach direction of +/-63.4 degrees. The angle band numbers of 1 and 9 corresponding to angles with respect to shore normal of 90 to 78.75 degrees and –78.75 and 90 degrees and average wave angles of 79.81 and –79.35 respectively can not be input into RCPWAVE and remain stable. A total of 94 wave events are contained in these two angle bands. Rather then eliminating these waves from the offshore input wave data series, the offshore wave angle for each of these wave events were set to 78 degrees or -78 degrees with respect to shore normal. This was done so that each wave event would fall into the next stable angle band. The adjusted statistical wave properties can be seen in Table 5.1 and 5.2.

Each combination of angle and period band is then input into RCPWAVE. A total of 44 combinations of angle and periods were used in this study. The average wave angles for angle bands 2 and 8 have approximately the same value as the approximate maximum local wave angle of 63.4 degrees. Therefore, it is important to examine the output from RCPWAVE to determine if the program was able to converge to a solution for the

Classification of Combined (Primary and Secondary) Wave Events				
Classification of Combined Wave Events by Angle Band				
Angle Band Number	**Range w.r.t. Shore-Normal (degrees)**	**Number of Events**	**Average Wave Angle (degrees)**	**Period Bands**
1	90.00 : 78.75	-	-	-
2	78.75 : 56.23	1090	68.7	1 2 3 4
3	56.25 : 33.75	1029	44.68	1 2 3 4 5
4	33.75 : 11.25	3594	21.51	1 2 3 4 5 6 7 8
5	11.25 : -11.25	2881	0.35	1 2 3 4 5 6 7 8
6	-11.25 : -33.75	2585	-22.05	1 2 3 4 5 6 7 8
7	-33.75 : -56.75	3572	-45.08	1 2 3 4 5 6 7 8
8	-56.75 : -78.75	2168	-65.85	1 2 3
9	-78.75 : - -90.00	-	-	-
Classification of Combined Wave Events by Period Band				
Period Band Number	**Range of Wave Period (seconds)**	**Number of Events**	**Average Period (seconds)**	**Angle Bands**
1	0.0 < T < 5.0	1601	3.85	2 3 4 5 6 7 8
2	5.0 < T < 7.0	4584	5.55	2 3 4 5 6 7 8
3	7.0 < T < 9.0	4699	7.49	2 3 4 5 6 7 8
4	9.0 < T < 11.0	3349	9.46	2 3 4 5 6 7
5	11.0 < T < 13.0	1662	11.42	3 4 5 6 7
6	13.0 < T < 15.0	726	13.38	4 5 6 7
7	15.0 < T < 17.0	192	15.39	4 5 6 7
8	17.0 < T < 23.0	106	18.2	4 5 6 7

Table 5.1
Adjusted statistical wave data for June 1986 to November 1991

Classification of Combined (Primary and Secondary) Wave Events				
Classification of Combined Wave Events by Angle Band				
Angle Band Number	**Range w.r.t. Shore-Normal (degrees)**	**Number of Events**	**Average Wave Angle (degrees)**	**Period Bands**
1	90.00 : 78.75	-	-	-
2	78.75 : 56.23	386	67.97	1 2 3 4
3	56.25 : 33.75	446	44.68	1 2 3 4
4	33.75 : 11.25	1394	21.86	1 2 3 4 5 6 7 8
5	11.25 : -11.25	1065	0.90	1 2 3 4 5 6 7
6	-11.25 : -33.75	934	-22.66	1 2 3 4 5 6 7
7	-33.75 : -56.75	1235	-45.19	1 2 3 4 5 6
8	-56.75 : -78.75	617	-66.05	1 2 3
9	-78.75 : - -90.00	-	-	-
Classification of Combined Wave Events by Period Band				
Period Band Number	**Range of Wave Period (seconds)**	**Number of Events**	**Average Period (seconds)**	**Angle Bands**
1	0.0 < T < 5.0	621	3.86	2 3 4 5 6 7 8
2	5.0 < T < 7.0	1658	5.54	2 3 4 5 6 7 8
3	7.0 < T < 9.0	1637	7.47	2 3 4 5 6 7 8
4	9.0 < T < 11.0	1049	9.39	2 3 4 5 6 7
5	11.0 < T < 13.0	713	11.47	4 5 6 7
6	13.0 < T < 15.0	345	13.36	4 5 6 7
7	15.0 < T < 17.0	53	15.17	4 5 6
8	17.0 < T < 23.0	1	17.00	4

Table 5.2
Adjusted statistical wave data for December 1991 to November 1993

extreme values of approaching wave angles. For the average wave angle of 68, period bands 3 and 4 were not able to converge to solution. The input wave angle had to be reduced to 61 and 59 degrees respectively in order to gain stability in RCPWAVE transformation computations.

The transformed wave characteristics for three input wave conditions will be examined more closely in order to gain an understanding of the effects of the spatial differences in alongshore wave heights and wave angles. Condition 1, corresponds to offshore wave characteristics of unit height with a 9 second period approaching from 59 degrees to the left of shore perpendicular. Conditions 2, corresponds to offshore wave characteristics of unit height with a 13.5 second period approaching from shore perpendicular. Condition 3, corresponds to offshore wave characteristics of unit height with a 7.5 second period approaching from 66 degrees to the right (negative) of shore perpendicular.

5.1 Approaching Wave Directions

Figure 5.1 shows the spatial variation of approaching wave direction along the GENESIS grid cell boundaries used for sediment transport rate computations. The greatest variation in approaching wave direction occurs for wave condition 1 approaching from 59 degrees. The approaching wave direction varies between 52 and 30 degrees for GENESIS grid cell boundaries 61 and 69. An-in depth analysis of the nearshore wave characteristics and their affects on the longshore transport rate is beyond the scope of this study.

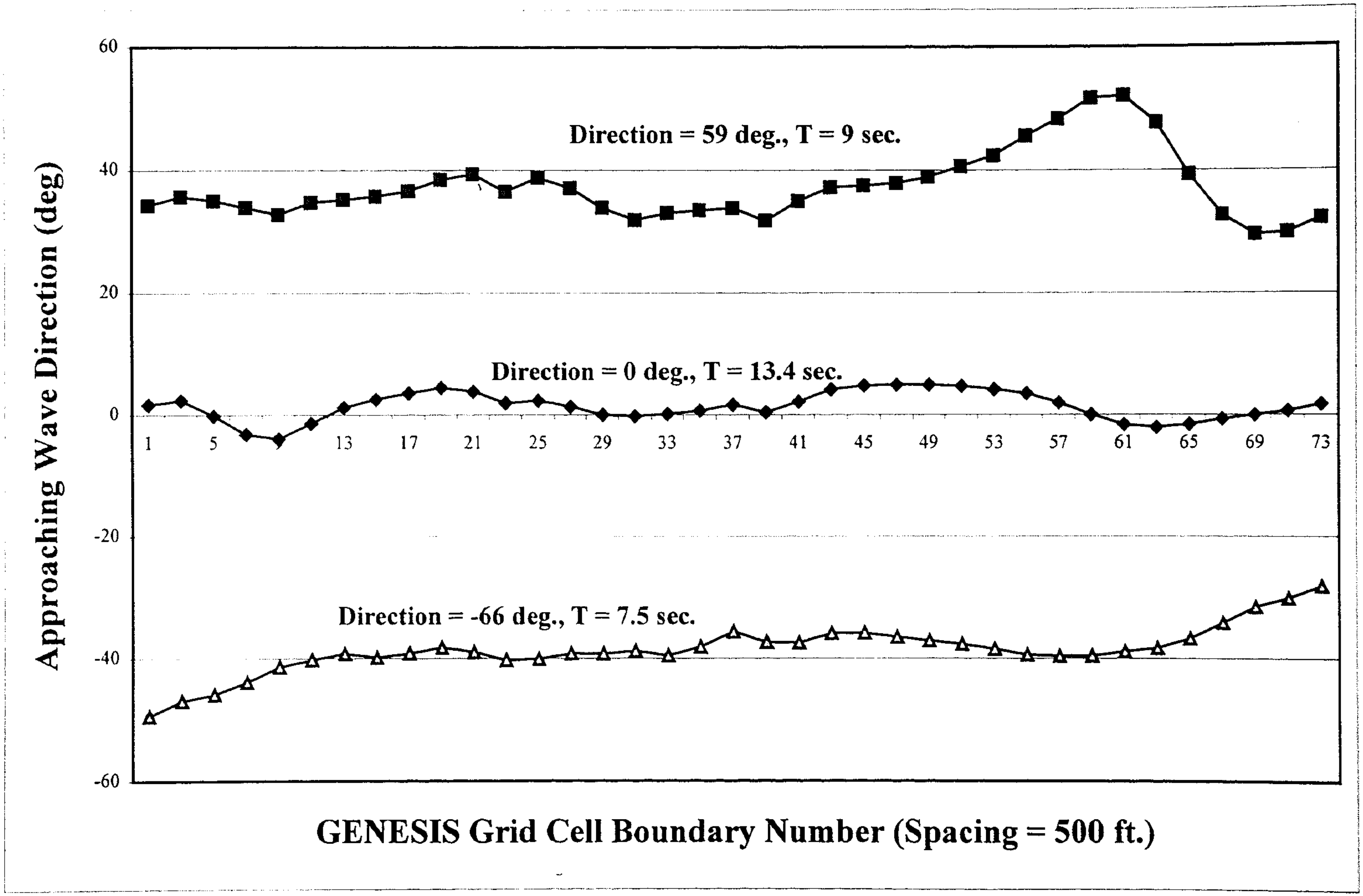


Figure 5.1 Transformed wave directions at nearshore reference line for unaltered bathymetry, offshore wave conditions given

5.2 Approaching Wave Heights

Figure 5.2 shows the spatial variation of approaching wave height along the GENESIS grid cell boundaries used for sediment transport rate computations. The greatest variation in approaching wave height occurs for wave condition 1 approaching from 59 degrees. The transformed approaching wave height varies between 0.45 and 2.05 feet for GENESIS grid cell boundaries 1 and 64. An in-depth analysis of the nearshore wave characteristics and their influences on the longshore transport rate is not within the scope of this study.

5.3 Discussion of RCPWAVE Results

Transformation of offshore wave conditions over the actual bathymetry using RCPWAVE produces spatial variations in the approaching wave direction and height along the nearshore reference line. Equation 2.2 is then used by GENESIS to approximate longshore sand transport for each cell in the GENESIS grid system. Equation 2.2 is in terms of breaking wave direction and breaking wave height. Therefore, the spatial variations in the predicted approaching wave direction and height alongshore produced by the bathymetry will cause spatial variations in the predicted longshore transport rates and shoreline positions.

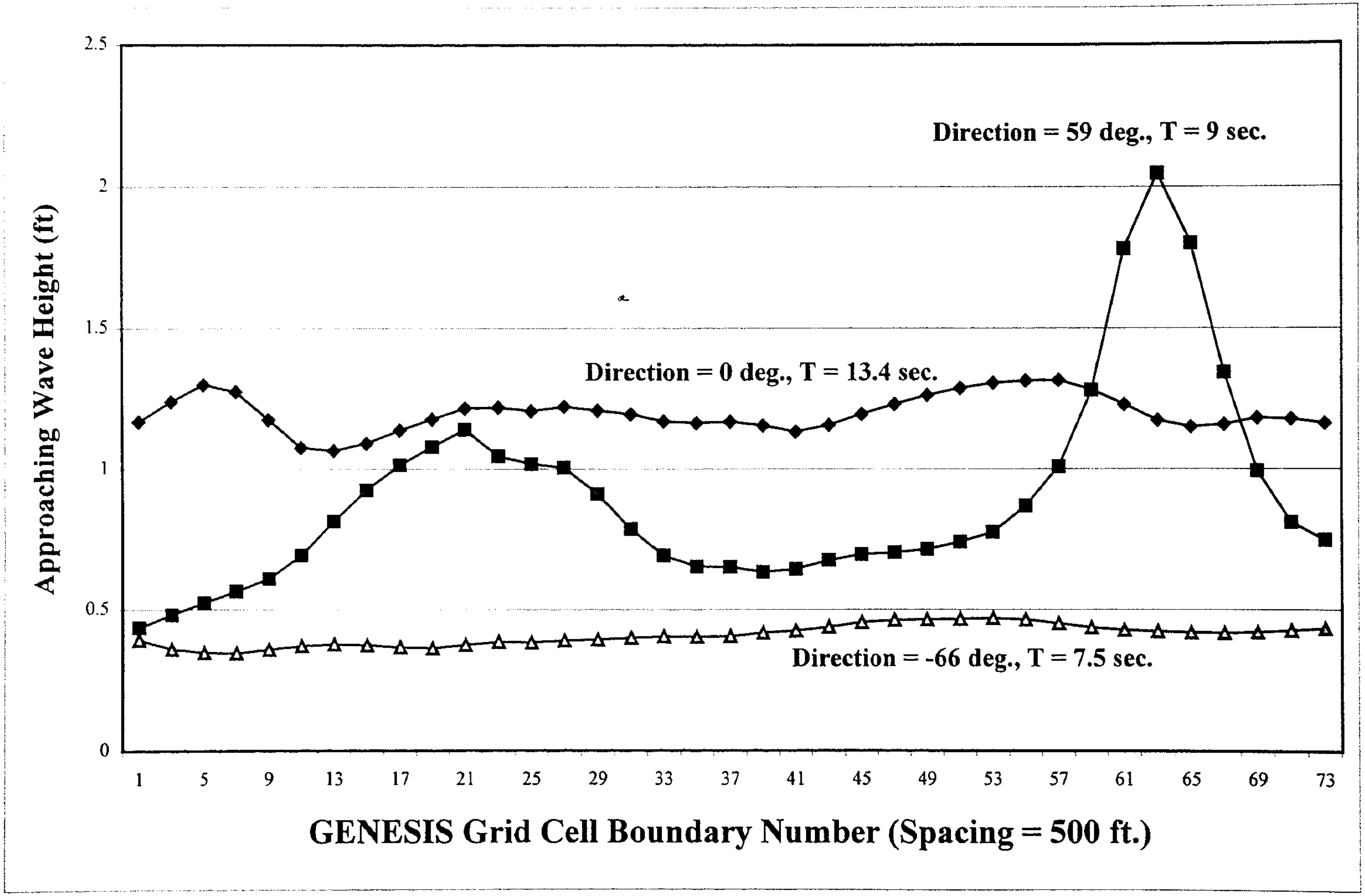


Figure 5.2 Transformed wave heights at nearshore reference line for unaltered bathymetry, offshore wave conditions given

6.0 CALIBRATION AND VERIFCATION OF GENESIS

Calibration of GENESIS involved running multiple model simulations for the time interval between June 1986 and November 1991. Initially, three sets of transport parameters were input into GENESIS and the model was run. The primary GENESIS outputs to inspect are the shoreline positions predicted for November 1991 and compare these to the shoreline measured at November 1991. Comparison of the predicted and actual measured shorelines is accomplished conveniently if somewhat subjectively by graphical means. The predicted transport rates can also provide valuable insight into the predicted coastal processes for the model reach.

Calibration of the GENESIS involves a complex arrangement of variables in order to obtain predicted shoreline position change which simulate, as closely as possible, actual shoreline position change. The two transport parameters, K_1 and K_2, traditionally have the greatest affect on the predicted shoreline positions and sand transport rates. Variables such as depth of closure, effective berm height, slope of bottom near groins and permeability of groins also have an impact predicted shoreline positions.

Verification is the procedure of running model simulations over a different temporal span using the same input parameters that were arrived at during calibration procedure. This is done in order to verify that coefficient variables used are independent of the time frame used for calibration. Verification of this model study was accomplished using the time interval from December1991 to November 1993.

6.1 Calibration through Predicted Shoreline Positions

The transport parameters, K_1 and K_2, are traditionally considered the most important calibration coefficients to be determined during the calibration procedure. The transport paramets not only affect the transport rates of sediment but also the shape of the predicted beach. Calibration of the model in this study involved the adjustment of the two transport parameters K_1 and K_2. Three sets of values of the transport parameters where initially used for calibration, running the model from June 1986 to November 1991. The other potential input parameters were set to values provided by the USACE discussed in Chapter 4. The three sets of values used where: $K_1 = 0.77$ and $K_2 = 0.38$ as suggested by Komar and Inman (1970), $K_1 = 0.58$ and $K_2 = 0.29$ as suggested by Hanson and Kraus (1989), $K_1 = 0.2$ and $K_2 = 0.17$ as suggested by Tibbets (1992), and $K_1 = 0.1$ and $K_2 = 0.05$. A final set of values, $K_1 = 0.1$ and $K_2 = 0.05$, were arrived at during the calibration process, and are the lowest suggested values that can be used.

The predicted shoreline positions for the four sets of transport parameters as well as the measured shoreline position in 1991 can be seen in Figures 6.1 and 6.2. Examination of these plots reveals important results of this study. The two higher values of the transport parameters predict massive erosion at grid cells 24 through 73 and minor accretion at grid cells 9 through 18. The two lesser of values of the transport parameters predict appreciable erosion between grid cells 27 through 36 and 55 through 68 and significant accretion between grid cells 37 through 46.

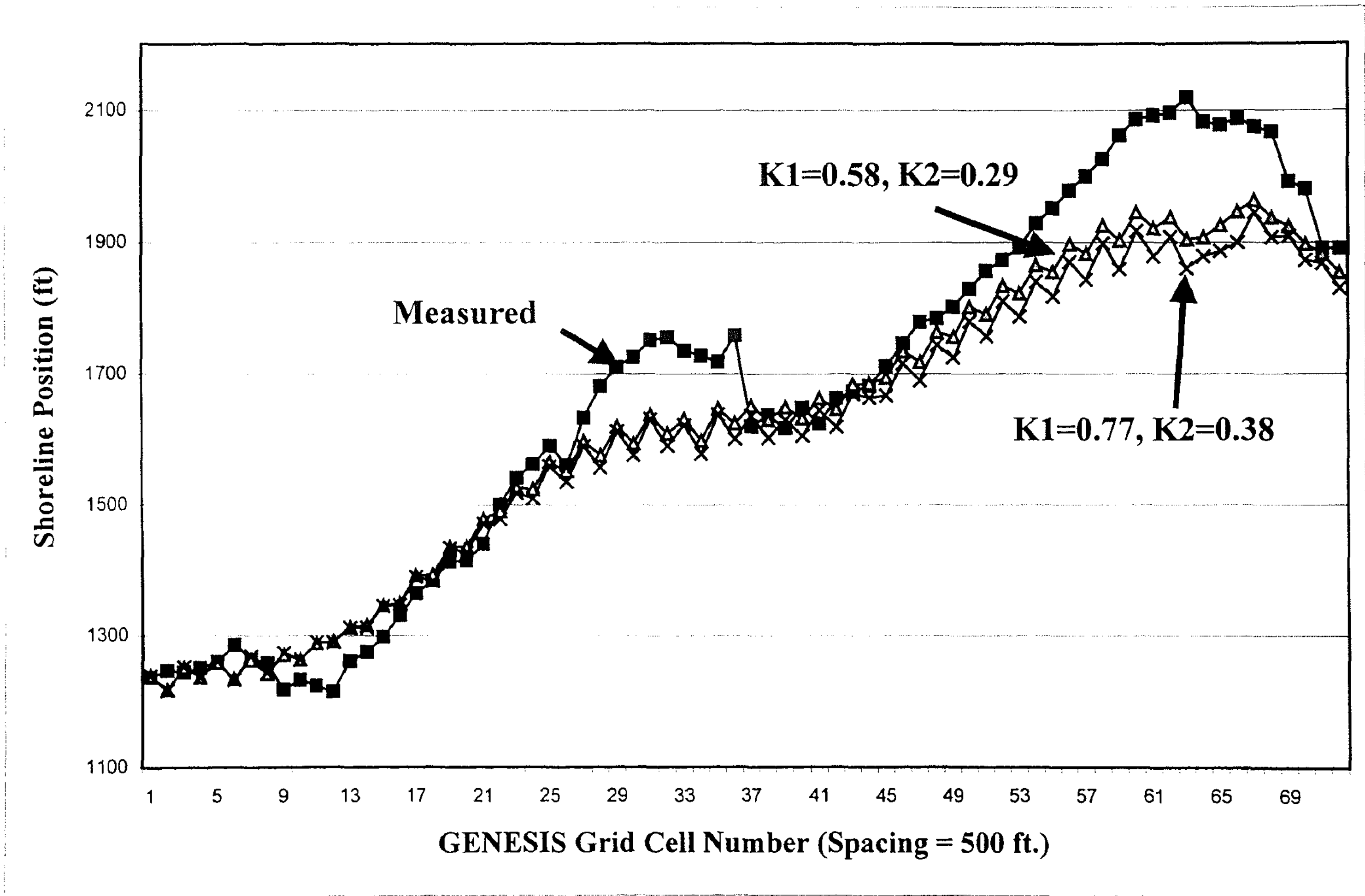


Figure 6.1 1991 measured and predicted shoreline posititions
using unaltered bathymetry and higher transport parameters

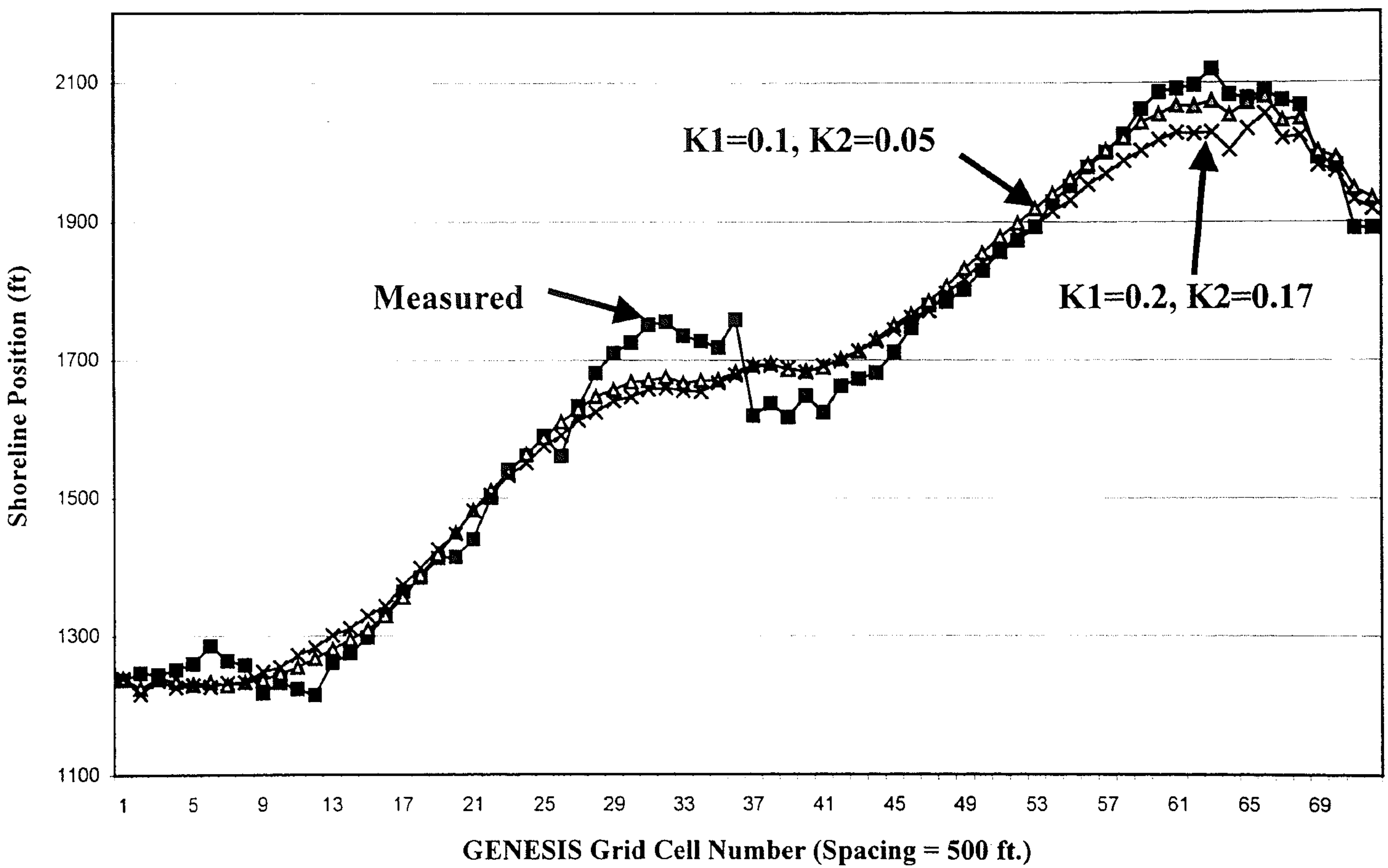


Figure 6.2 1991 measured and predicted shoreline positions
using unaltered bathymetry and lower transport parameters

Comparison of the predicted shoreline positions to the measured shoreline positions at 1991 reveals that the lower the value of the transport parameters more accurately predicted the measured shoreline positions. However, the tendency of predicted shoreline erosion well beyond the 1991 measured shoreline positions at grid cells 27 to 36 and 58 to 69 occurs regardless of the transport parameters used. The variation of the transport parameters influences the degree to which the predicted erosion occurs, but does not reverse the tendency. Attempts at adjusting other potential calibration coefficients revealed minor affects on the overall tendencies of the shoreline erosion and accretion.

6.2 Verification through Predicted Shoreline Positions

Model simulations for verification typically use the set of transport parameters which provides the most accurate prediction of shoreline position change. Due to the generally poor accuracy in predicted shoreline positions for all four sets of the transport parameters during calibration, all four set were used for verification for the sake of comparison. The predicted shoreline positions for the four sets of transport parameters as well as the measured shoreline position in 1993 can be seen in Figures 6.3 and 6.4. The two higher values of the transport parameters predict massive shoreline erosion at grid cells 28 through 36 and 45 through 73 and appreciable shoreline accretion at grid cells 9 through 23. The two lower values of the transport parameters predict minor erosion between grid cells 30 through 33 and 59 through 68 and significant accretion between grid cells 9 through 23 and 37 through 54.

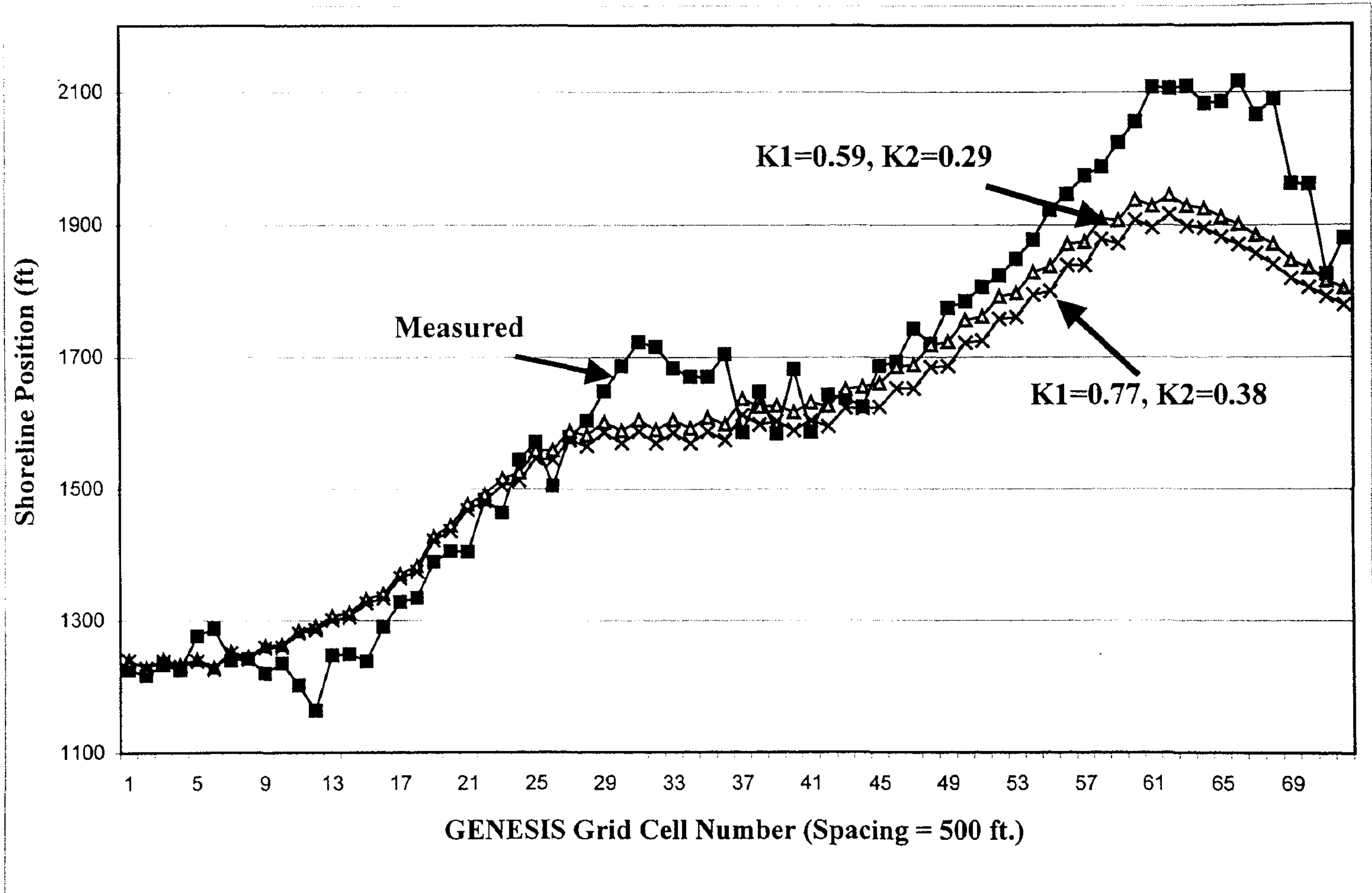


Figure 6.3 1993 measured and predicted shoreline positions
using unaltered bathymetry and higher transport parameters

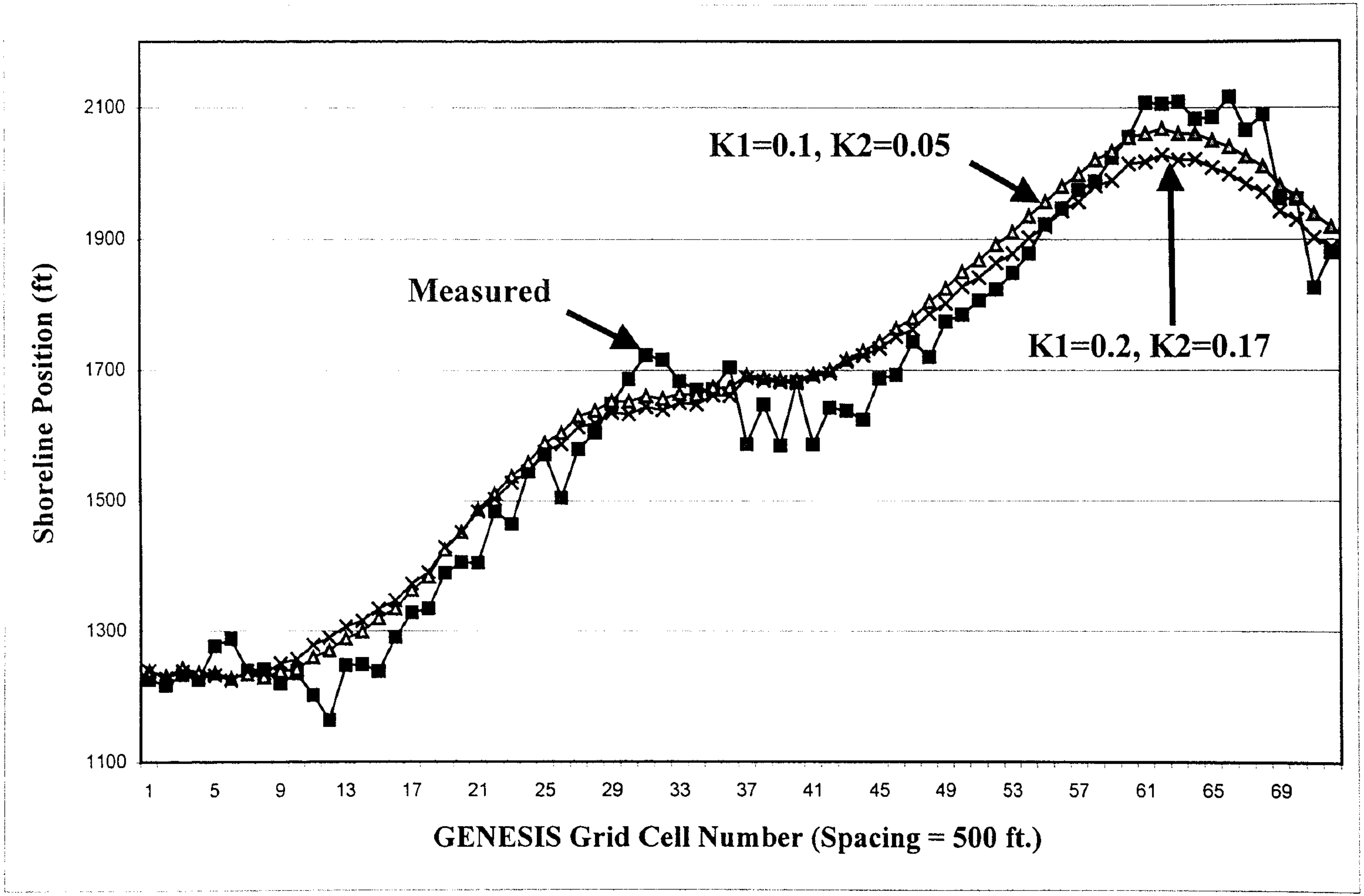


Figure 6.4 1993 measured and predicted shoreline positions using unaltered bathymetry and lower transport parameters

Comparison of the predicted shorelines to the measured shoreline at 1993 reveals that use of the lower set of transport parameters more accurately predict the measured shoreline positions. However, the tendency of predicted shoreline erosion and accretion well beyond the 1993 measured shoreline positions occurs regardless of the transport parameters used. The variation of the transport parameters affects the degree to which the predicted erosion and accretion occurs, but does not reverse the trends.

6.3 Examination of Predicted Sand Transport Rates

Figure 6.5 plots the predicted average annual sediment transport rate at each GENESIS grid cell boundary and the average annual transport rate for the model reach between 1986 and 1993 for $K_1 = 0.2$ and $K_2 = 0.17$ using the unaltered bathymetry. The predicted average annual transport rate is approximately 43,400 cubic yards per year. The predicted average annual transport rate for individual grid cell boundaries varies from –30,000 to 212,000 cubic yards per year.

Positive values of transport rates denote transport to the right (south) while negative values denote transport to the left (north). For positive values of transport rate, a positive gradient indicates increasing transport to the right and a negative gradient indicates decreasing transport to the right. For negative values of transport rate, a positive gradient indicates decreasing transport to the left and a negative gradient indicates increasing transport to the left.

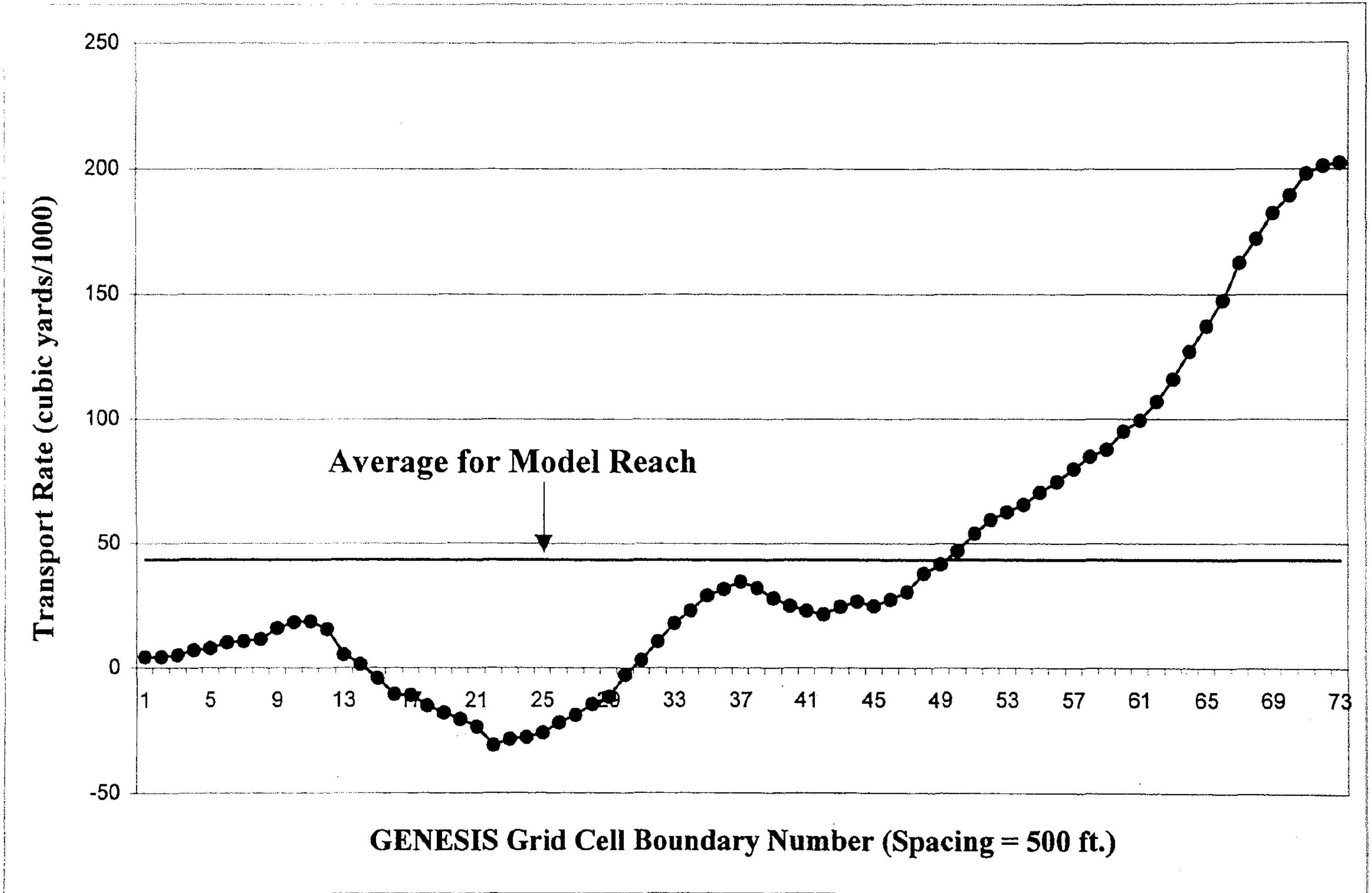


Figure 6.5 Average annual predicted sand transport rates from June 1986 to November 1993 for unaltered bathymetry, K1 = 0.2, K2 = 0.17

6.4 Discussion of Calibration and Verification Efforts

Comparison of the predicted shoreline positions for 1991 and 1993 to the measured shoreline positions at those times reveals that none of the transport parameters used produce an accurate prediction of shoreline evolution. Use of the larger values of the transport parameters resulted in massive shoreline erosion. Use of the smaller values of transport parameters produced more accurate predictions of shoreline positions. Efforts to adjust other input parameters such as depth of closure, berm height or average grain size did not result in significant improvements in predicted of shoreline positions. The transport parameters of $K_1 = 0.2$ and $K_2 = 0.17$ were determined to produce the best approximation of shoreline evolution while still allowing a reasonable amount of sediment transport. These transport parameters will be used throughout the remained of the report to compare shoreline evolution for unaltered and altered bathymetry.

7.0 EFFECTS OF ALTERED NEARSHORE BATHYMETRY

The effects of altering the nearshore bathymetry can be seen in the analysis of four aspects of the shoreline change model: predicted nearshore wave direction, predicted nearshore wave heights, predicted shoreline positions and predicted sand transport rates. A comparison will be made between each of these aspects of the shoreline change model for the unaltered and altered bathymetry.

7.1 Approaching Wave Directions

The three offshore wave conditions examined in Chapter 5 for unaltered bathymetry will be compared to the to the predicted transformed wave characteristics using the altered bathymetry. Figure 7.1 shows the predicted transformed wave directions at the nearshore reference line for unaltered and altered bathymetry. The effect of the altering the nearshore bathymetry can be observed in the separation of each of the plotted offshore wave conditions for unaltered and altered bathymetry.

The most drastic effect of altering the bathymetry on the approaching wave direction can be seen for the offshore wave characteristics of 59 degrees and 9 seconds in the vicinity of grid cell boundary numbers 53 through 73. Altering the nearshore bathymetry significantly reduces the variation of the approaching wave directions at the nearshore reference line. At grid cell boundary 63 the approaching wave direction is reduced from 52 to 41 degrees. Translating this to an actual wave event, an offshore wave approaching from 60 degrees transformed to nearshore would result in an approach direction of 53 degrees at the nearshore reference line for unaltered bathymetry, this drops to an angle of

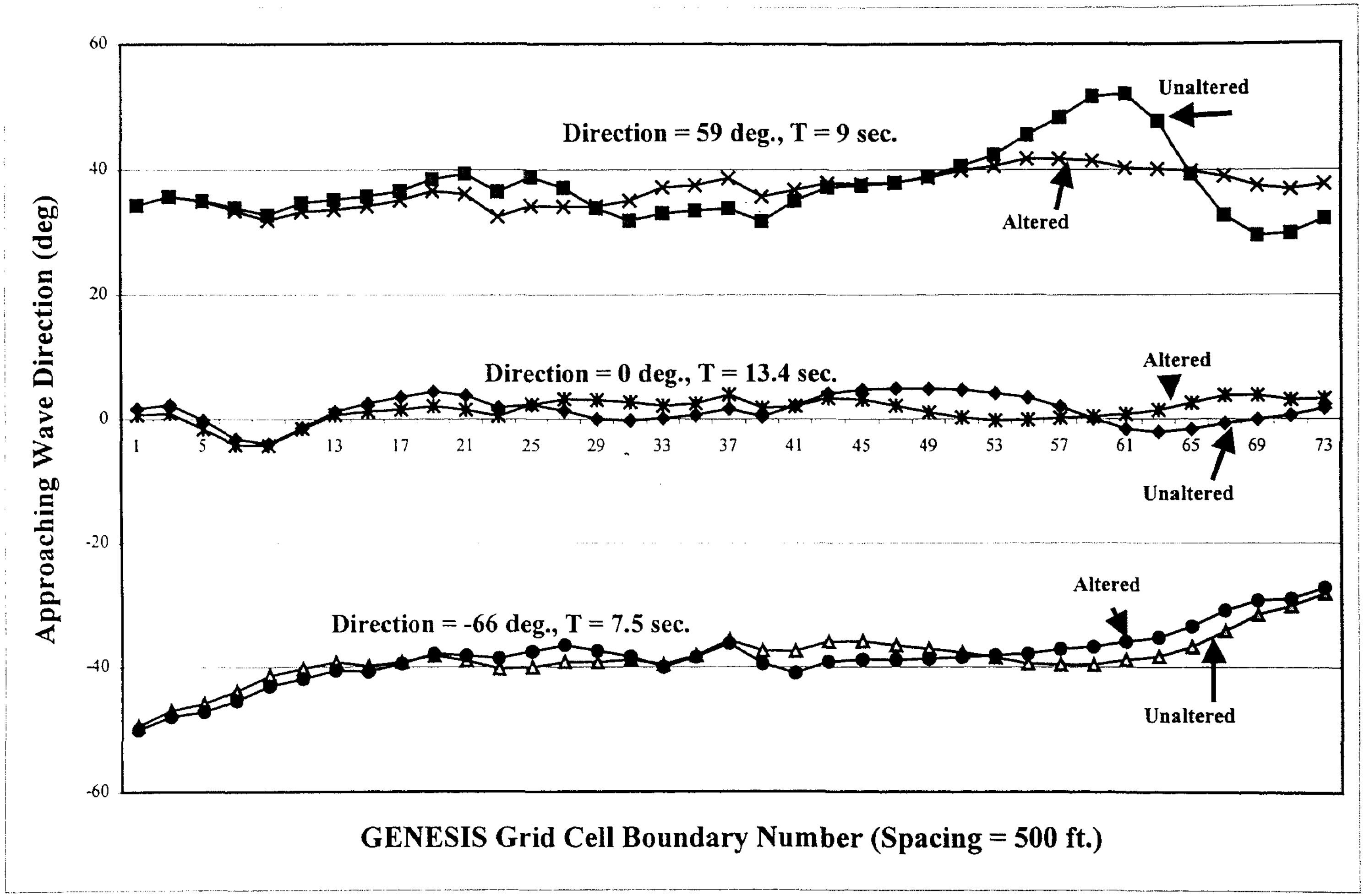


Figure 7.1 Transformed wave directions at nearshore refernce line for unaltered and altered bathymetry, offshore wave conditions given

42 degrees for the altered bathymetry. At grid cell boundary 69 the predicted approaching nearshore wave angle increases from 29 to 37 degrees due to altering the bathymetry. The effect of altering the bathymetry on an offshore wave approaching for 60 degrees would be a predicted increase of 8 degrees in the predicted nearshore wave angle. Similar effects of altering the bathymetry on the predicted wave direction exist throughout Figure 7.1

7.2 Approaching Wave Heights

Figure 7.2 demonstrates the effects of altering the bathymetry on nearshore wave heights. The nearshore wave height for the three wave conditions analyzed in Chapter 5 for unaltered bathymetry are plotted together with the nearshore wave heights predicted for the altered bathymetry. Similar to the changes caused in the approaching wave angles, a difference in the predicted wave heights occurs for the altered bathymetry.

The most drastic effect of altering the bathymetry on the approaching wave height can be seen for the offshore wave characteristics of 59 degrees and 9 seconds in the vicinity of grid cell boundary numbers 47 through 73. Altering the nearshore bathymetry significantly reduces the variation of the approaching wave height. At grid cell boundary 63 the approaching wave height is reduced from 2.05 to 1.43 feet. Translating this to an actual wave event, a 7-foot offshore wave transformed to nearshore would result in a 14.35 foot nearshore wave for unaltered bathymetry, this drops to a height of 10.01 feet for the altered bathymetry. At grid cell boundary 69 the predicted approaching wave height increases from 0.87 to 1.14 feet due to altering the bathymetry. The effect of

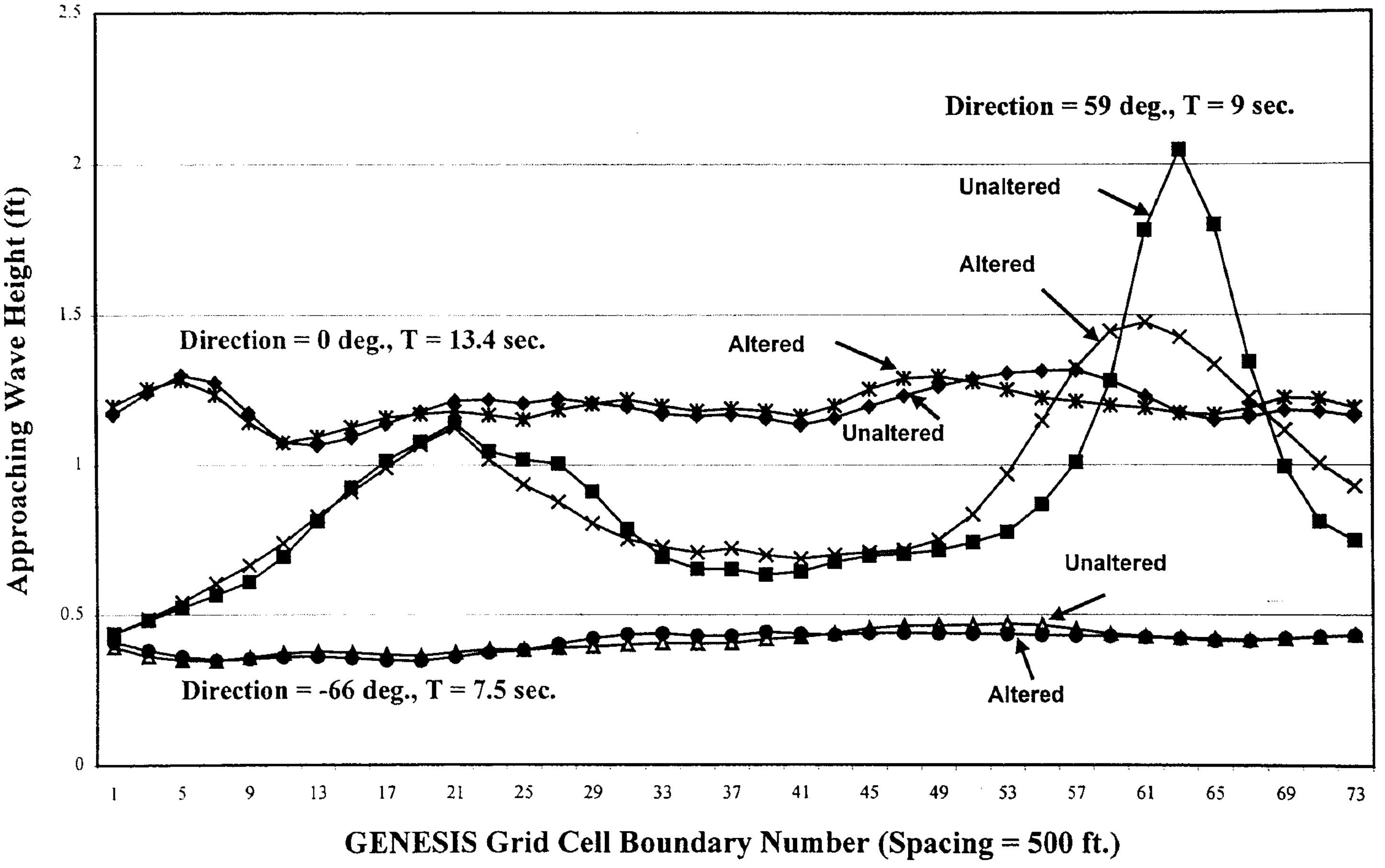


Figure 7.2 Transformed wave heights at nearshore reference line for unaltered and altered bathymetry, offshore wave conditions given

altering the bathymetry on a 7-foot offshore wave would be a predicted height increase of 1.89 feet in the predicted nearshore wave height. Similar effects of altering the bathymetry on the predicted wave heights exist throughout Figure 7.2

7.3 Predicted Shoreline Positions

Alteration of the nearshore bathymetry influences the predicted approaching wave directions and heights along the nearshore reference line. The predicted wave transformation characteristics are then used by GENESIS to predict changes in shoreline positions caused by spatial and temporal differences in longshore transport rates. Figure 7.3 displays the measured and predicted shoreline positions in 1993 for transport parameters, $K_1 = 0.2$ and $K_2 = 0.17$, for unaltered and altered bathymetry. Other input parameters were not altered.

Comparison of the predicted shoreline positions reveals areas of increased erosion and accretion caused by the altered bathymetry. Grid cells 15 through 32 and 55 through 73 show increased erosion, grid cells 34 through 51 show increased accretion. The 1993 predicted shoreline position at grid cell 64 for unaltered bathymetry is 2022 feet, for altered bathymetry the predicted shoreline position is 1905 feet, a difference of 117 feet of predicted erosion. The predicted shoreline position for grid cell 40 using unaltered bathymetry is 1680 feet, for altered bathymetry the predicted shoreline position is 1753 feet, a difference of 73 feet of predicted accretion. The contrasts between the predicted shoreline positions for unaltered and altered bathymetry is the direct results of the

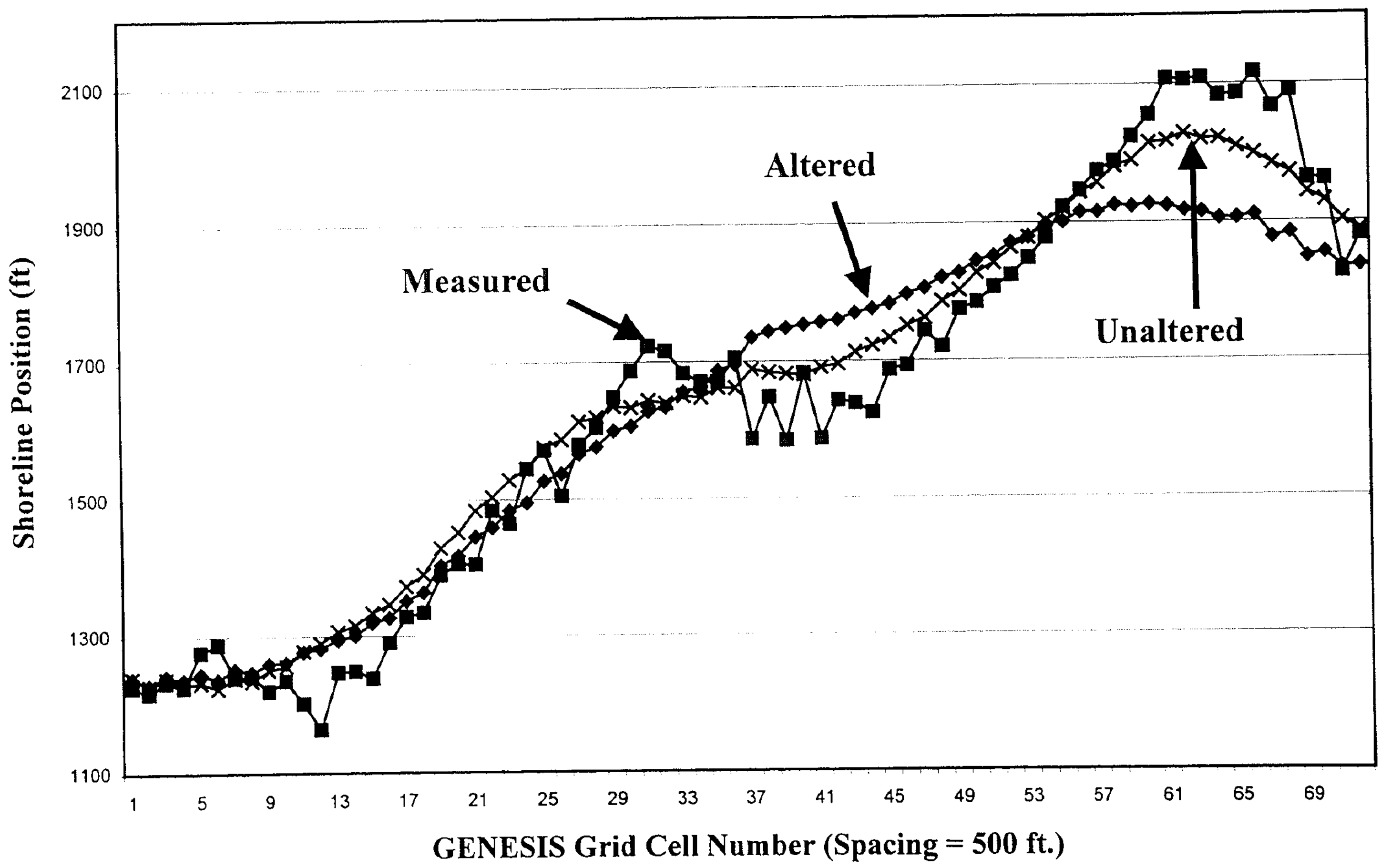


Figure 7.3 1993 measured and predicted shoreline positions for unaltered and altered bathymetry, K1 = 0.2 and K2 = 0.17

differences in predicted wave transformation characteristics between the two bathymetric configurations.

7.4 Sand Transport Rates

Examination of predicted sand transport rates for unaltered and altered bathymetry provides valuable insight into the effects of altering the bathymetry on shoreline evolution. Figure 7.4 shows the average annual transport rates for unaltered and altered bathymetry as well as the averages for the model reach. Altering of the bathymetry has influenced the predicted gradients in longhshore transport in many areas of the model reach, leading to differences in the predicted erosion and accretion of the shoreline. For altered bathymetry the predicted longshore sand transport rate increases by 40 cubic yards per foot between grid cell boundaries 64 and 65, for unaltered bathymetry the increase is 21 cubic yards per foot. For altered bathymetry the predicted longshore sand transport rate increases by -20 cubic yards per foot between grid cell boundaries 35 and 36, for unaltered bathymetry the increase is -10 cubic yards per foot.

The maximum predicted transport rates have increased due to the altered bathymetry, from 202,000 cubic yards per year to 280,000 cubic yards per year at grid cell boundary 73 and from –31,000 cubic yards per year to –45,000 cubic yards per year at grid cell boundary 22. In contrast, the average predicted sand transport rate for the model reach has fallen from 48,000 to 32,000 cubic yards per year. This contrast does not indicate that more material is being retained with in the model reach for altered bathymetry, more sediment may be escaping the model reach through the left boundary. The differences in

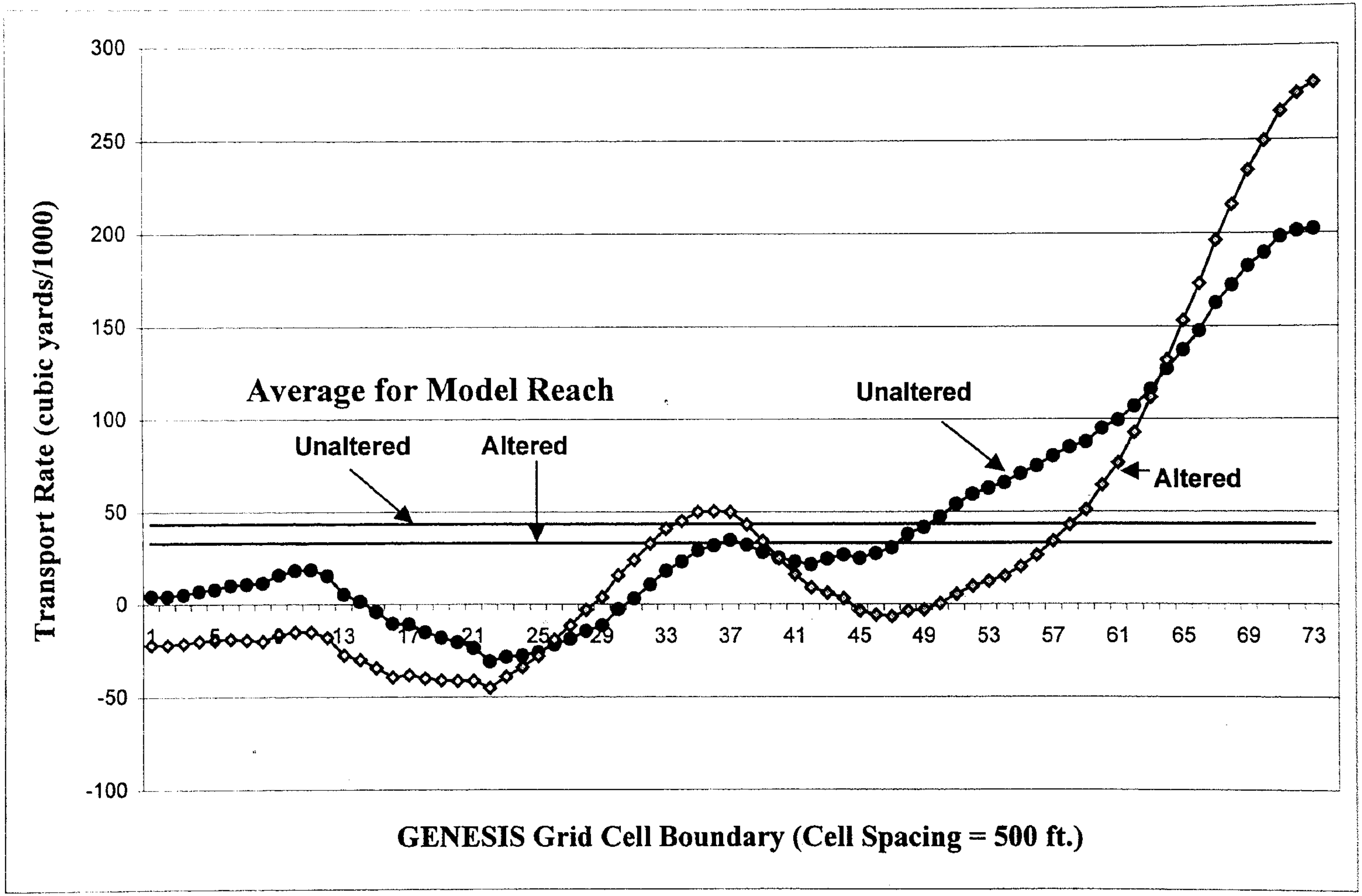


Figure 7.4 Average annual predicted sand transport rates from June 1986 to November 1993 for unaltered and altered bathymetry, K1 = 0.2 and K2 = 0.17

predicted sand transport rates are the direct result of the effects on the predicted approaching wave heights and wave angles caused by altering the nearshore bathymetry.

7.5 Discussion of Effects of Altered Bathymetry

The "removal" of the two prominent shoals directly offshore of the model reach has a direct impact on predicted approaching wave heights and approaching wave directions, these in turn affect the predicted shoreline positions and sand transport rates. Altering the bathymetry influences the predicted approaching wave directions and heights along the model reach. The equation used to predict longshore transport rates is a function of breaking wave direction and height. Therefore, the differences in approaching wave direction and height will have a direct affect on predicted transport rates and on shoreline positions. The predicted affects can be drastic, resulting in massive erosion or accretion of the shoreline material.

8.0 CONCLUSIONS

The objectives of this study are:

1. To collect and assemble the data and other information necessary to complete shoreline change simulations utilizing the Shoreline Modeling System, including the data necessary to apply the external wave transformation model RCPWAVE.
2. To run shoreline change simulations, calibrating and verifying the models input parameters.
3. To investigate the effects of altering the local bathymetry on nearshore wave characteristics, shoreline positions and sand transport rates predicted by the modeling system.

8.1 Collection and Assembly of Data

This investigation concentrated on Long Beach Island, New Jersey, due to an abundance of pertinent data on the area collected by the U.S. Army Corp of Engineers. Data pertaining to shoreline positions, shoreline structures, bathymetry, and properties of the local shoreline (including depth of closure, active berm height, and mean grain diameter) was collected. A shoreline reach with two large nearshore shoals was located and became the focus of this study. A suitable time frame from June 1986 to November 1993 was selected and the necessary data was sorted, arranged and formatted for input into the Shoreline Modeling System. Sea and swell wave data was retrieved from the U.S. Army Corp of Engineers, Wave Information Study for Station 69 at three hour intervals for a time interval corresponding to the model simulation period.

8.2 Calibration and Verification Efforts

Calibration and verification efforts commenced in order to determine appropriate values for the transport parameters K_1 and K_2. The external wave transformation model, RCPWAVE, was used to transform statistical wave characteristics from offshore to a nearshore reference line using the actual bathymetry offshore of the model reach. Four sets of values for the transport parameter were used for model calibration and verification runs. These values ranged from $K_1 = 0.78$, $K_2 = 0.38$ to $K_1 = 0.1$, $K_2 = 0.05$. Visual comparison of the predicted and measured shorelines revealed poor accuracy in the predicted shoreline positions. Values of $K_1 = 0.2$ and $K_2 = 0.17$ were determined to produce the best approximation of shoreline position change and were used in order to complete the next objective of the study.

Intuitively it can be reasoned that the Shoreline Modeling System has difficulty predicting shoreline evolution in the area of severely undulating bottom contours such as those present in the nearshore region of the model reach used in this study. The presence of the two large shoals in the nearshore area seems to pose a difficulty to the model in properly predicting shoreline evolution. Verification of this reasoning would require further investigation that is beyond the scope of this investigation.

8.3 Investigation into the Effects of Altering the Nearshore Bathymetry

The final objective of this study was to investigate the effects of altering the nearshore bathymetry on predicted shoreline positions and sand transport rates. Comparison of the predicted wave directions and heights approaching the model reach for altered and unaltered bathymetry revealed the impacts of modifying the bathymetry. Approaching wave directions and heights changed along the entire model reach for all examined approaching wave conditions. The differences in the nearshore wave characteristics for unaltered and altered bathymetry directly influence the predicted shoreline positions and sand transport rates.

GENESIS model simulations were completed using the predicted nearshore wave characteristics produced by the altered bathymetry, all other input parameters used for calibration and verification were held constant. The effect of altering the bathymetry on predicted shoreline positions was drastic. Erosion and accretion of sand were predicted at various sections along the model reach. Altering the bathymetry affected the predicted average annual longshore sand transport rates. Predicted sand transport rates increased and decreased at various sections along the model reach. The average annual predicted sand transport rate for the model reach was reduced.

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