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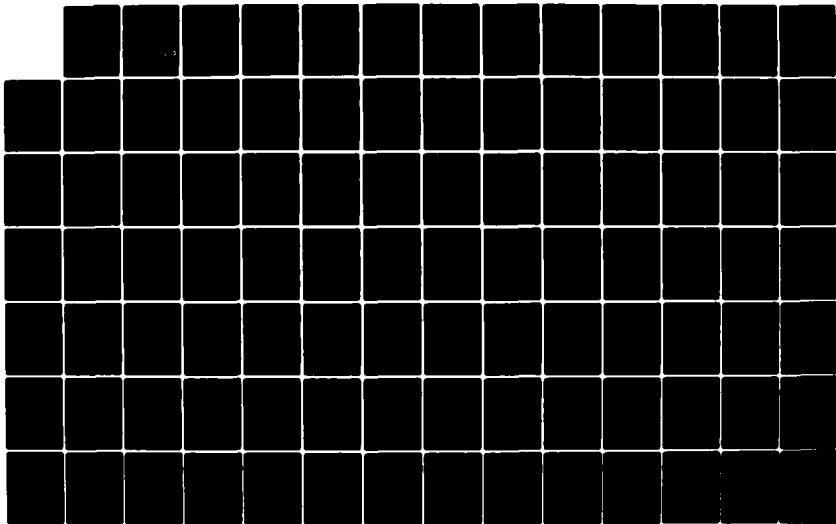
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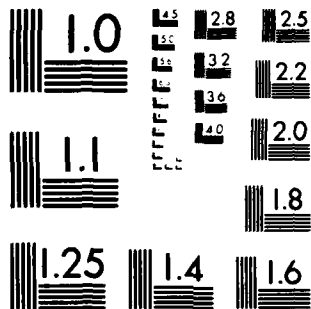
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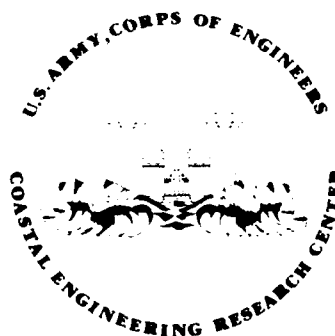
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A Numerical Model to Simulate Sediment Transport in the Vicinity of Coastal Structures

by
Marc Perlin and Robert G. Dean

MISCELLANEOUS REPORT NO. 83-10

MAY 1983



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Prepared for
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM						
1. REPORT NUMBER MR 83-10	2. GOVT ACCESSION NO. AD-A130197	3. RECIPIENT'S CATALOG NUMBER						
4. TITLE (and Subtitle) A NUMERICAL MODEL TO SIMULATE SEDIMENT TRANSPORT IN THE VICINITY OF COASTAL STRUCTURES		5. TYPE OF REPORT & PERIOD COVERED Miscellaneous Report						
7. AUTHOR(s) Marc Perlin and Robert G. Dean		6. PERFORMING ORG. REPORT NUMBER						
9. PERFORMING ORGANIZATION NAME AND ADDRESS Coastal and Offshore Engineering and Research, Inc., 70 S. Chapel Street Newark, DE 19711		8. CONTRACT OR GRANT NUMBER(s) DACW72-80-C-0030						
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CEREN-EV) Kingman Building, Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS C31551						
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE May 1983						
		13. NUMBER OF PAGES 119						
		15. SECURITY CLASS. (of this report) UNCLASSIFIED						
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE						
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release, distribution unlimited.								
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)								
18. SUPPLEMENTARY NOTES								
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <table border="0"> <tr> <td>Bathymetric response</td> <td>Numerical model</td> <td>Shoreline evolution</td> </tr> <tr> <td>Littoral barrier</td> <td>Sediment transport</td> <td>Wave transformation</td> </tr> </table>			Bathymetric response	Numerical model	Shoreline evolution	Littoral barrier	Sediment transport	Wave transformation
Bathymetric response	Numerical model	Shoreline evolution						
Littoral barrier	Sediment transport	Wave transformation						
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An implicit finite-difference, n-line numerical model is developed to predict bathymetric changes in the vicinity of coastal structures. The wave field transformation includes refraction, shoaling, and diffraction. The model is capable of simulating one or more shore-perpendicular structures, movement of offshore disposal mounds, and beach fill evolution. The structure length and location, sediment properties, equilibrium beach profile, etc., are user-specified along with the wave climate.								

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PREFACE

The purpose of this report is to provide coastal engineers and researchers with a numerical model which predicts sediment transport and the resulting bathymetry in the vicinity of coastal structures. The work was carried out under the U.S. Army Coastal Engineering Research Center's (CERC) Numerical Modeling of Shoreline Response to Coastal Structures work unit, Shore Protection and Restoration Program, Coastal Engineering Area of Civil Works Research and Development.

This report was written by Marc Perlin and Robert G. Dean, Coastal and Offshore Engineering and Research, Inc., under Contract No. DACW72-80-C-0030. The CERC contract monitor was Dr. F. Camfield, Chief, Coastal Design Branch, under the general supervision of Mr. N. Parker, Chief, Engineering Development Division.

Technical Director of CERC was Dr. Robert W. Whalin, P.E.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Billy D. Bishop, LTC, CE
for TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director



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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins ¹

¹To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9) (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9) (F - 32) + 273.15$.

A NUMERICAL MODEL TO SIMULATE SEDIMENT TRANSPORT IN THE VICINITY OF COASTAL STRUCTURES

by
Marc Perlin and Robert G. Dean

I. INTRODUCTION

1. General.

The need for reliable predictions of shoreline response to man-made or natural modifications is increasing due to environmental concerns and the rising cost of remedial measures. The capability of numerical modeling in addressing problems of shoreline response has advanced with improvements in wave climatology, programs to better understand sediment transport relationships, and improvements in numerical modeling. In-situ and remote sensing technology for the measurement of directional wave characteristics has been developed and applied, primarily within the last two decades. In addition to providing the necessary climatology, the resulting measurements have provided the basis for evaluation and refinement of directional wave prediction procedures. Studies such as the Channel Islands Harbor Longshore Sand Transport Study (Bruno, et al., 1981) and the Nearshore Sediment Transport Study (NSTS) (Gable, 1979) have yielded a better understanding of surf zone dynamics and the resulting sediment transport. The increased capacities of large computers and reduced computing costs combined with improved numerical modeling algorithms have resulted in an extremely promising potential for the numerical modeling of shoreline problems.

Although it is doubtful that numerical modeling will ever replace completely the use of movable-bed physical models, the former type offers many advantages. The modeling of shoreline response is somewhat analogous to the problem of simulating storm surges in the coastal zone in which the scale effects and measurement difficulties essentially preclude physical modeling. For shorelines, the scale effects inherent in modeling sediment are well recognized and the costs of representing a substantial length of shoreline may be prohibitive. The laboratory representation of a realistic wave climate is at the forefront of technology.

The investigation of shoreline response can best proceed by several approaches, with each approach selected for the particular strengths which it offers. Field programs are costly, usually because of the considerable equipment and the extensive time required, but these programs are essential for quantifying the values of constants or parameters, the forms of which may be available from laboratory measurements or theoretical considerations. Laboratory studies occupy a special niche by allowing the wave conditions and independent variables to be controlled readily, experiments to be repeated, and selected measurements to be conducted. Although, as noted before, scale effects are present in laboratory measurements of sediment transport, the physics governing the process should be the same. However, the relative magnitudes of suspended versus bedload transport in the laboratory and field may differ. Laboratory studies can also provide an excellent base for evaluating certain aspects of a numerical model, including wave refraction and diffraction and the resulting shoreline patterns due to, for example, the placement of a littoral barrier. Numerical modeling offers the capability to

incorporate all the hydrodynamic wave-surf zone and sediment transport knowledge that is available from laboratory and field studies. Numerical modeling has the potential of providing accurate predictions of shoreline response to various structural and nourishment alternatives. Additionally, the possibility exists of employing numerical models and available field measurements to learn more about sediment transport mechanisms. In this latter mode, various candidate mechanisms or coefficients would be evaluated by determining the best match between measured and predicted shorelines and the bathymetry. Generally, this mode would require high-quality measurements of the forcing function (waves and nonwave-related currents) and the associated response (sediments) as well as the knowledge of appropriate conditions at the boundaries of the model.

The present report documents the development and application of an n-line numerical model to investigate bathymetric response to time-varying wave conditions and shoreline modification. The model includes both longshore and onshore-offshore sediment transport. Based on laboratory results, a new distribution of longshore sediment transport across the surf zone is used. The wave climate is specified on the model boundaries which do not need to extend to deep water. Efficient algorithms are employed for representing wave refraction and diffraction. The equation of sediment continuity and transport are solved by a completely implicit algorithm which allows a large time-step. Specified sediment transport values or specified contour positions can be accommodated at the model boundaries. The model is suitable for investigating the shoreline response to a variety of modifications such as one or more groins, terminal structures, structures with variable permeability, and beach nourishment with or without terminal structures.

2. Study Objectives.

The objectives of the present study include (a) the documentation of state-of-the-art models, (b) the development and documentation of an improved model which includes the capability to represent n-contour lines and (c) the application of the model to several relevant coastal engineering problems.

II. BACKGROUND

This discussion describes significant contributions which either address numerical modeling of shorelines directly or provide improved capability for modeling.

1. Wave Refraction (Noda, 1972).

Noda developed an algorithm for solving the following steady state equation for wave refraction

$$\vec{\nabla} \times \vec{k} = 0 \quad (1)$$

in which $\vec{\nabla}$, the horizontal vector differential operator, and $\vec{k}$, the wave number, are defined in terms of their components as

$$\vec{\nabla} = \vec{i} \frac{\partial}{\partial x} + \vec{j} \frac{\partial}{\partial y} \quad (2)$$

$$\vec{k} = \vec{i} k_x + \vec{j} k_y \quad (3)$$

where $\vec{i}$ and $\vec{j}$ are the unit vectors in the x and y directions respectively. Equation (1) can be expressed as

$$\frac{\partial(k \sin \theta)}{\partial x} = \frac{\partial(k \cos \theta)}{\partial y} \quad (4)$$

in which θ is the direction of the vector wave number relative to the x-axis and k denotes $|\vec{k}|$. Noda expanded Equation (4) to the following form

$$k \cos \theta \frac{\partial \theta}{\partial x} + \sin \theta \frac{\partial k}{\partial x} = -k \sin \theta \frac{\partial \theta}{\partial y} + \cos \theta \frac{\partial k}{\partial y} \quad (5)$$

Since $\frac{\partial k}{\partial x}$ and $\frac{\partial k}{\partial y}$ are known from the angular frequency σ , the water depth h , and the dispersion equation

$$\sigma^2 = g k \tanh kh \quad (6)$$

Equation (5) can be solved numerically, although there are problems of directional stability. The primary advantage of Equation (5) is that it allows the wave direction θ to be determined on a specified grid, compared to unspecified locations that would be obtained by, for example, wave ray tracing.

2. Crenulate Bays (LeBlond, 1972).

LeBlond attempted to model the evaluation of an initially straight shoreline between two headlands into a crenulate bay. The model constitutes a one-line (shoreline) representation. The transport equation employed related the total sediment transport to total water transport in the surf zone as predicted by the formulation provided by Longuet-Higgins (1970). The initial shoreline patterns resemble crenulate bays in nature; however, the predictions were found to be unstable for reasonably long periods of computational time and did not approach a realistic planform.

3. Crenulate Bays (Rea and Komar, 1975).

Rea and Komar employed a rather ingenious system of orthogonal grid cells to provide a cell which locally is displaced perpendicular to the general shoreline orientation. A one-line representation was employed. A simple and approximate representation of wave diffraction was employed. Although the model yielded reasonable results for the examples presented, the unique coordinate system would not be suitable for a general model as the coordinate system must be "tailored" to some degree to conform to the expected shoreline configurations.

4. General One-line Shoreline Model (Price, Tomlinson, and Willis, 1972).

Price, Tomlinson, and Willis' formulation consists of the sediment continuity equation and the total sediment transport equation

$$Q_s = \frac{0.70 E_b (nC)_b \sin \alpha_b \cos \alpha_b}{\gamma_w (1 - p) (S_s - 1)} \quad (7)$$

in which E represents the wave energy density, (nC) the group velocity, α the angle between the breaking wave front and the shoreline, γ_w the specific weight of water, p the in-place sediment porosity, and S_s the specific gravity of the sediment relative to the water in which it is immersed. The subscript "b" represents values at breaking.

Two formulations were presented by Price, Tomlinson, and Willis (1972). In the first, Equation (7) was substituted into the continuity equation and the results cast into a finite-difference form. In the second, the two equations were employed separately. The latter formulation was selected due to its simplicity and used for the results presented.

Computations were carried out for the case of beach response due to the placement of a long impermeable barrier. The total sediment transport equation by Komar (1969) was used and the planform was calculated at successive times. Refraction was apparently not accounted for in the numerical model. To verify the computations, a physical model study was carried out for the same conditions using crushed coal as the modeling material. The comparison was interpreted as good for up to 3 hours; however, for greater times, substantial differences occurred and these were interpreted as being due to wave refraction not being represented. The crushed coal was supplied to the model at the updrift end at a rate based on the Komar equation, and the results were interpreted as substantiating this relationship. However, the updrift end of the model beach receded substantially both in the numerical and physical models. In the physical model, this can only be interpreted as due to the Komar equation predictions being less than the actual transport rate, possibly due to the low specific gravity (1.35) of the crushed coal. The predicted recession of the updrift beach is puzzling, although it could be due to a problem in properly representing the updrift boundary condition.

Other one-line models for shoreline changes in the vicinity of coastal structures were developed by LeMehaute and Soldate (1977) and Perlin (1978). Perlin also developed a two-line model formulation, with one-line representing the shoreline and the second the offshore. Dragos (1981) developed an n-line model for bathymetric changes due to the presence of a littoral barrier.

III. THE NUMERICAL MODEL

1. Description.

There are several methods of modeling bathymetric changes due to the presence of a littoral barrier. An attempt can be made to either model the complete hydrodynamics and the resulting sediment transport or model using a combination of analytical and empirical sediment transport equations. The second method was chosen due to past relative success.

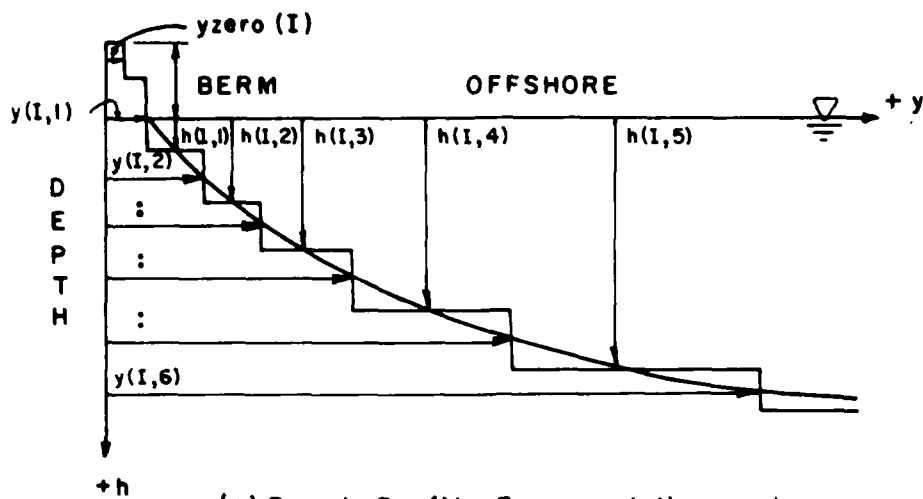
At least two methods of employing sediment transport equations exist: a fixed longshore and cross-shore grid system where the depth is allowed to vary or a fixed longshore and depth system where the cross-shore distance is allowed to change. Although it may seem somewhat awkward, the latter system was chosen for the model. This method allows the modeler to think of bathymetric changes due to a littoral barrier in terms of the effect on the contours; i.e., the contour realinement due to the structure's presence is observed. One limitation of this approach, at least as it was applied here, is that each depth contour must be single-valued; it is not possible to represent bars.

The next step in formulating the model was choosing the specific representation of the bathymetry. The model is an n-line representation of the surf zone in which the longshore direction x is divided into equal segments each Δx in length. The bathymetry is represented by n-contour lines, each a specified depth, which change in offshore location according to the equation of continuity. There are two components of sediment transport at each of the contour lines, a longshore component, Q_x , and an offshore component, Q_y . Figure 1 is a definition sketch showing the beach profile representation in a series of steps and the planform profile representation and notations used.

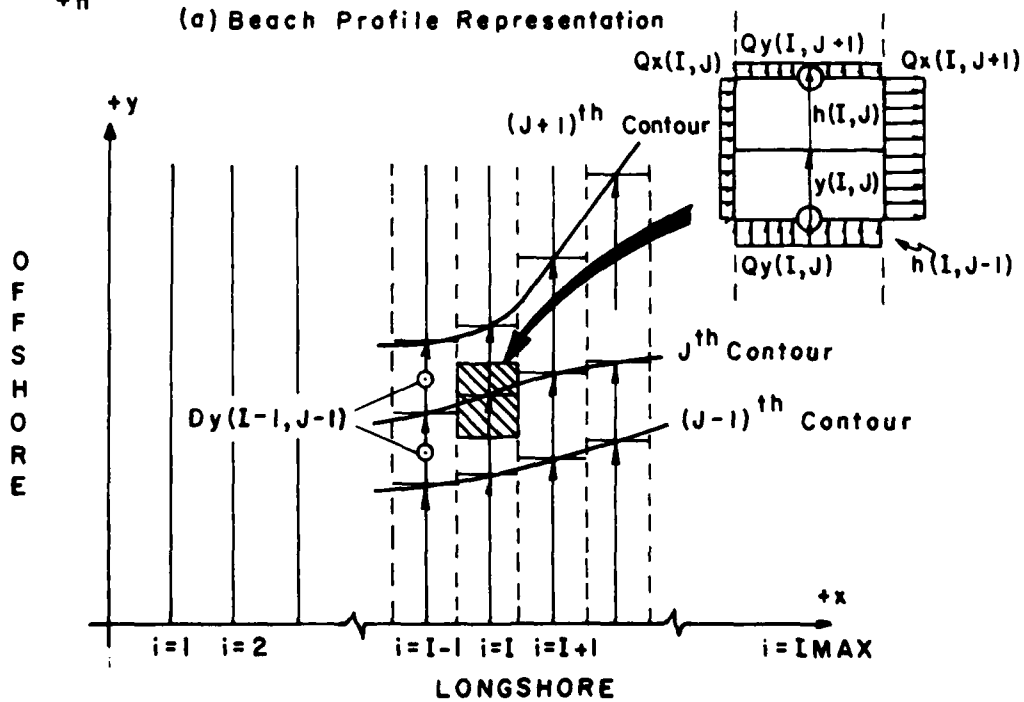
Implementation of the sediment transport equations requires knowledge of the wave field and the equilibrium offshore profile. A discussion of the refraction and diffraction schemes follows. The equilibrium profile is introduced when it is convenient. As an introduction to the logic used in the numerical model, a flow chart is presented in Figure 2.

2. Refraction.

A refraction scheme compatible with variable Δy 's was required because of the variable distance to fixed depth contours (as opposed to the more usual fixed grid system where a grid center has a longshore and offshore coordinate with a variable depth). One of the benefits of the n-line model is the ease with which the response of the contours to a particular wave and structure condition can be visualized. A fixed grid system and an interpolation scheme could have been used to obtain the wave field; however, this would have reduced accuracy and increased computation time. The scheme developed also saves computation time because it does not use differential products terms.



(a) Beach Profile Representation



(b) Beach Planform Representation

Figure 1. Definition sketch.

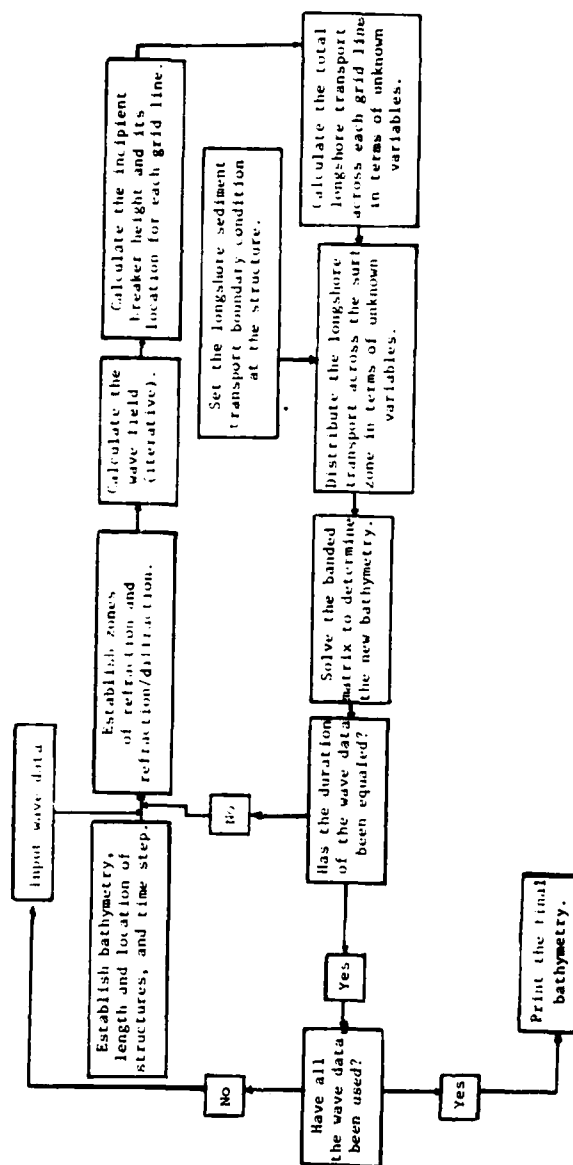


Figure 2. Flow chart.

The first of the governing equations used is the conservation of waves equation

$$\frac{d\sigma}{dt} + \vec{v}_H \times \vec{k} = 0 \quad (8)$$

where $\vec{v}_H$ is the horizontal differential operator equal to $\vec{i}(\partial/\partial x) + \vec{j}(\partial/\partial y)$ in which $\vec{i}$ and $\vec{j}$ are the unit vectors in the x and y directions, respectively, and x is the longshore direction, with positive to the right when facing the water, y the offshore direction, with positive seaward, and z the vertical coordinate, with positive defined as upwards. For the steady-state case, equation (8) yields

$$\frac{\partial}{\partial x} (k_y) - \frac{\partial}{\partial y} (k_x) = 0 \quad (9)$$

where k_x and k_y are the wave number projections in the respective directions. Defining θ as the angle k makes with the y-axis positive in the counter-clockwise direction, the equation can be written in final form as

$$\frac{\partial}{\partial x} (k \cos \theta) = \frac{\partial}{\partial y} (k \sin \theta) \quad (10)$$

where $\theta = \alpha + \pi$ (in radians). Noda (1972) and others have developed numerical solutions to expanded forms of equation (10). In the present study, equation (10) was initially central-differenced in the x-direction and forward-differenced in the y-direction with Snell's law used to specify the boundary conditions on the offshore boundary and one of the sides (i.e., the side of the wave angle approach). However, a numerical problem arose. The argument of the arcsine exceeded ± 1.0 for large $\Delta y/\Delta x$. To overcome this problem, a dissipative interface was used on the forward-difference term (after Abbott, 1979). The final finite-differenced form of equation (10) is

$$\theta_{i,j}^{n+1} = \sin^{-1} \left\{ \frac{1}{k_{i,j}} \left[\tau(k \sin \theta)_{i-1,j+1} + (1-2\tau)(k \sin \theta)_{i,j+1} + \tau(k \sin \theta)_{i+1,j+1} - \frac{\Delta y}{2\Delta x} \left((k \cos \theta)_{i-1,j} - (k \cos \theta)_{i-1,j} \right) \right] \right\} \quad (11)$$

where τ has been taken as 0.25. The past $\theta_{i,j}^n$ and the present $\theta_{i,j}^n$ wave angles are numerically averaged to give the $\theta_{i,j}$. Newton's method is used to compute the wave number via the linear wave theory dispersion relation. In addition, numerical smoothing is used at the conclusion of the wave field calculation. This approximates in an ad hoc manner diffractive effects (lateral transfer of wave energy along the wave) which exist in nature but have been omitted due to use of the equation for refraction (equation 8). The smoothing routine is

$$\theta_{i,j} = \frac{1}{4} \theta_{i-1,j} + \frac{1}{2} \theta_{i,j} + \frac{1}{4} \theta_{i+1,j} \quad (12)$$

The second governing equation used in the refraction scheme is conservation of energy. Neglecting dissipation of energy due to friction, percolation, and turbulence, this equation can be expressed as

$$\vec{\nabla} \cdot (E \vec{C}_G) = 0 \quad (13)$$

where E is the average energy per unit surface area and $\vec{C}_G$ the group velocity of the wave train. Performing the operation indicated and replacing $\vec{C}_G$ by its components ($C_G \sin \theta$) and ($C_G \cos \theta$) results in the following:

$$\frac{\partial}{\partial x} (E C_G \sin \theta) + \frac{\partial}{\partial y} (E C_G \cos \theta) = 0 \quad (14)$$

Assuming linear theory,

$$E = \frac{\rho g H^2}{8} \quad (15a)$$

where ρ is the mass density of water, g the gravitational constant, and H the wave height. Dividing the equation by $\frac{\rho g}{8}$, finite-differencing and weighting the forward-differenced term as before, and solving for the wave height, results in the following:

$$H_{i,j}^{n+1} = \left\{ \frac{1}{(C_G \cos \theta)_{i,j}} \left[(\tau)(H^2 C_G \cos \theta)_{i-1,j+1} + (1-2\tau)(H^2 C_G \cos \theta)_{i,j+1} + (\tau)(H^2 C_G \cos \theta)_{i+1,j+1} + \frac{\Delta y}{2\Delta x} [(H^2 C_G \sin \theta)_{i+1,j} - (H^2 C_G \sin \theta)_{i-1,j}] \right] \right\}^{1/2} \quad (15b)$$

This equation is also solved by iterative techniques and the $H_{i,j}^{n+1}$ and $H_{i,j}^n$ are averaged at the conclusion of each iteration.

C_G is determined by the linear wave theory relationship

$$C_G = \frac{C}{2} \left(1 + \frac{2kh}{\sinh 2kh} \right) \quad (16)$$

where h is the water depth, k the wave number, and C the wave celerity. Wave height boundary conditions are input along the same boundaries as the wave angles using linear theory shoaling and refraction coefficients. The θ 's have been previously determined. In both equations (11) and (15) for a variable grid system, the points $(i+1, j)$ and $(i-1, j)$ need to be determined (i.e., because the y coordinates are not fixed, adjacent values with the same subscripts can be farther or closer to shore, therefore interpolation must be used). The actual values are found by searching the $(i+1)$ and $(i-1)$ cross-shore lines, finding the adjacent values in the positive and negative y -direction, and interpolating to determine the value.

3. Diffraction.

The diffraction solution (in the lee of the structure) used in the model is based on the method of Penny and Price (1952). Assumptions used in this method include a semi-infinite breakwater, which is infinitesimally thin, linear wave theory and constant depth. A definition sketch for wave diffraction is shown in Figure 3. The quantity THETA0 represents the angle of wave incidence relative to the jetty axis, ANGLE represents the angle from the jetty at the point where the diffraction coefficient is to be computed, and RAD is the radial distance. The radial distance is then cast into a dimensionless parameter, RHOND ($= 2\pi \text{ RAD}/L$), where L is the wavelength. This is equivalent to multiplying the radial distance by the wave number k .

The diffraction coefficient AMP is expressed as the modulus of the diffracted wave

$$\text{AMP} = (\text{Sum 1})^2 + (\text{Sum 2})^2 \quad (17)$$

where

$$\begin{aligned} \text{Sum 1} = & [\cos (\text{RHOND} (\cos (\text{ANGLE}-\text{THETA0}))) \cdot \left(\frac{1}{2} (1.0 + C_F + S)\right)] + \\ & [\sin (\text{RHOND} (\cos (\text{ANGLE}-\text{THETA0}))) \cdot \left(-\frac{1}{2} (S - C_F)\right)] + \\ & [\cos (\text{RHOND} (\cos (\text{ANGLE}+\text{THETA0}))) \cdot \left(\frac{1}{2} (1.0 + C_F + S)\right)] + \\ & [\sin (\text{RHOND} (\cos (\text{ANGLE}+\text{THETA0}))) \cdot \left(\frac{1}{2} (S - C_F)\right)] \quad (18) \end{aligned}$$

$$\begin{aligned} \text{Sum 2} = & [\cos (\text{RHOND} (\cos (\text{ANGLE}-\text{THETA0}))) \cdot \left(-\frac{1}{2} (S - C_F)\right)] + \\ & [\sin (\text{RHOND} (\cos (\text{ANGLE}-\text{THETA0}))) \cdot \left(\frac{1}{2} (1.0 + C_F + S)\right)] + \\ & [\cos (\text{RHOND} (\cos (\text{ANGLE}+\text{THETA0}))) \cdot \left(-\frac{1}{2} (S - C_F)\right)] + \\ & [\sin (\text{RHOND} (\cos (\text{ANGLE}+\text{THETA0}))) \cdot \left(\frac{1}{2} (1.0 + C_F + S)\right)] \quad (19) \end{aligned}$$

In Equations (18) and (19), C_F and S represent Fresnel integrals and are computed in the model by means of an approximation after Abramowitz and Stegun (1965).

Having obtained AMP, the wave height at the location in question is simply the product of the specified partially refracted incident wave height and AMP. The angle of the wave crest is computed assuming a circular wave front along any radial; this angle is then refracted using Snell's law.

Throughout the refraction and diffraction schemes, the local wave heights are limited by the value, $0.78 \times \text{depth}$.

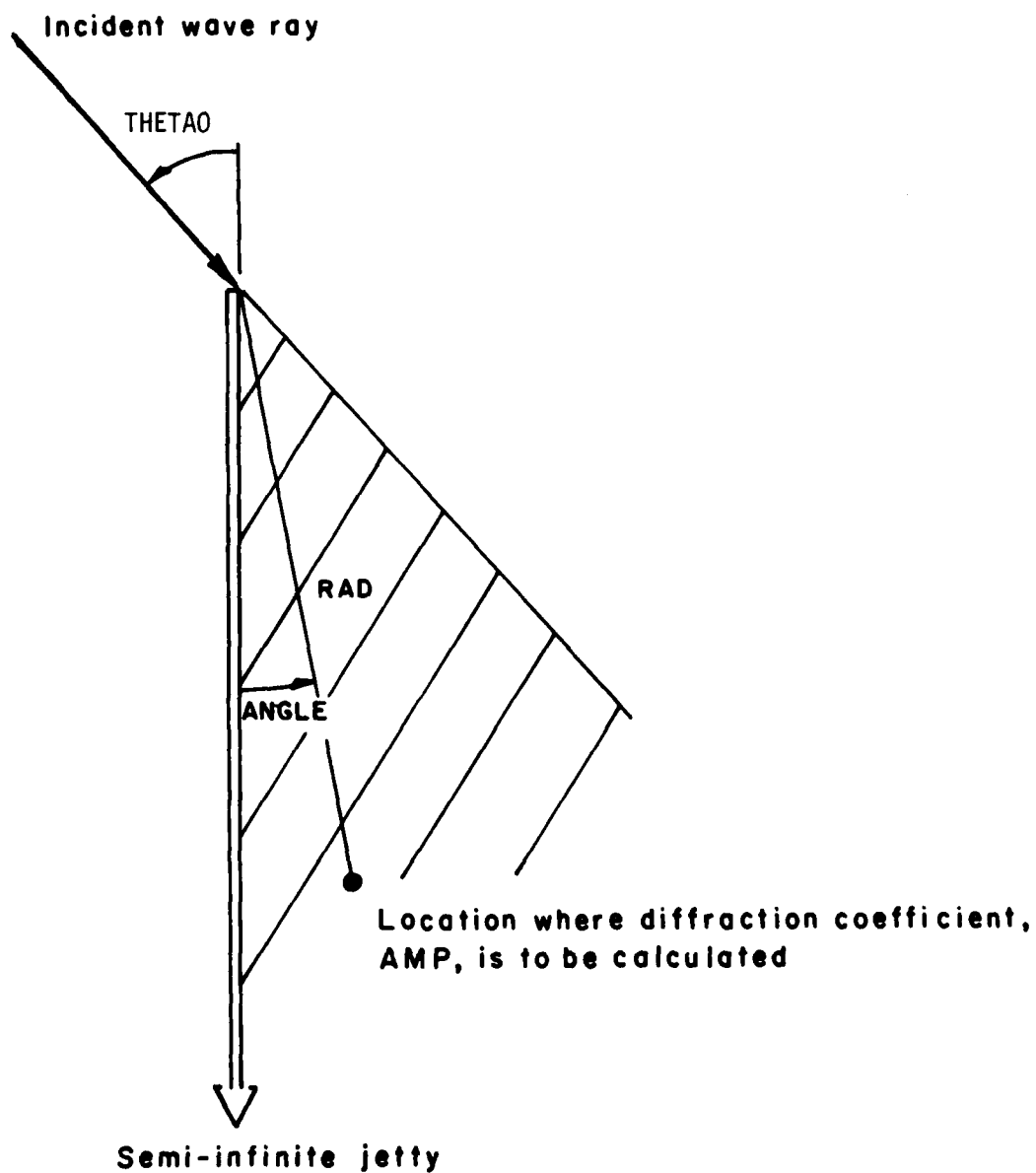


Figure 3. Definition sketch for wave diffraction.

4. Sand Transport Model.

a. Governing Equations. Three basic equations are used to simulate the sediment transport and bathymetry changes according to the wave field. The equation of continuity

$$\frac{\partial y}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = 0 \quad (20)$$

requires as input, knowledge of the longshore and cross-shore components of sediment transport. The total transport alongshore has been measured by several investigators and many equations exist; however, the distribution of the transport across the surf zone is not well known. Fulford (1982) based on laboratory data from Savage (1959), developed a distribution of longshore sediment transport across the surf zone for the case of straight and parallel contours. Fulford's use of Savages experiment was based on two assumptions: 1) the structure must be a total littoral barrier and 2) onshore-offshore sediment transport could be neglected. Test 5-57 was chosen because the two criteria were nearly met. Savage reported that the groin acted as a total littoral barrier for the first 35 hours of the test (i.e., no bypassing occurred prior to 35 hours). This does not mean that no onshore-offshore transport occurred because as the profile steepens on the updrift side, onshore-offshore transport does occur. However, it was assumed to be negligible. In addition, the initial profile had been molded to an equilibrium profile via 150 hours of waves. Thus, the two criteria required to develop an inferred longshore distribution of sediment transport were nearly satisfied. This distribution is shown as a dashline in Figure 4. The smaller "maximum" is believed to be an extraneous effect of a groin downdrift from the location in the experiment where the data were taken. Therefore, this feature was replaced by a monotonically decreasing, smooth curve as shown by the "altered" curve. To analytically represent this distribution, a function of the following form was chosen

$$q_x(y) = (B) (y)^{n-1} e^{-(y)^n} \quad (21)$$

This type of equation is convenient because it is easily integrable, and by properly choosing the constant, B, the integral of the equation from zero to infinity can be required to equal a particular value. This too is highly desirable because, as was done in the model, the integral is set equal to one and then multiplying by the value of the well-known longshore transport equation, the value of the transport at any location across the surf zone can be determined. Further investigation suggested a value of $n = 3$ to produce a curve similar to Fulford's curve. A more general form of the equation which allows more flexibility and curve fitting is

$$q_x(y) = B(y + a)^2 e^{\left\{ -\left[\frac{y+a}{cy_b} \right] \right\}^3} \quad (22)$$

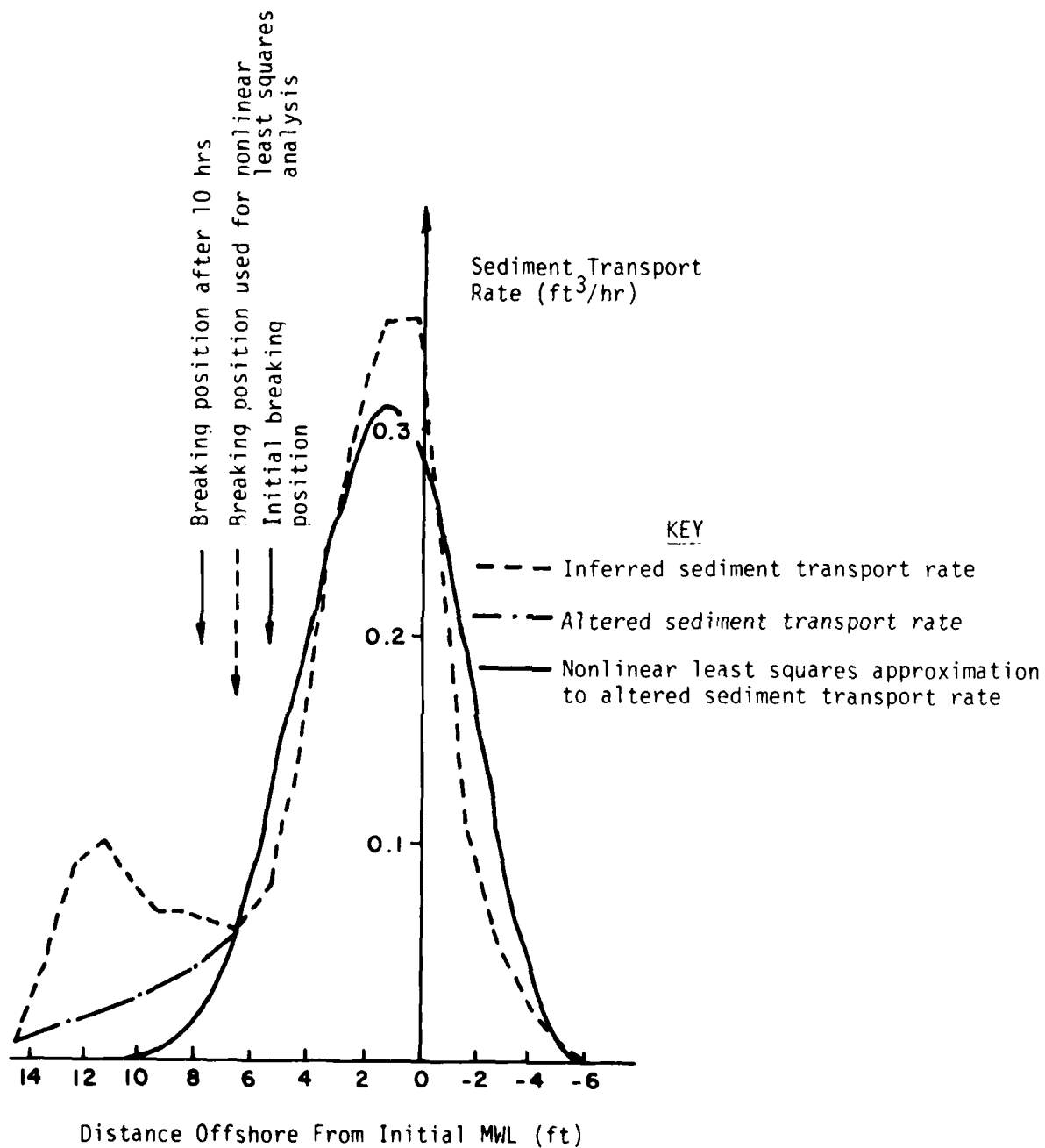


Figure 4. Distribution of sediment transport across the surf zone.

where y_b = distance to the point of breaking

a = constant to allow sediment transport above mean water line (MWL) (swash transport or transport in region of wave setup) to be represented

c = a constant establishing the width of the curve (to be determined)

$$B = \frac{3}{c^3 y_b^3} \quad (\text{causes } \int_0^{\infty} q_x(y) dy = 1.0)$$

Based on Fulford's (1982) results and considering a to be proportional to the breaking height divided by the beach slope, the constant of proportionality was determined to be unity; i.e., $a = h_b/(\partial h/\partial y)$. Using equation (22) and a digitized version of the curve shown in Figure 4, a nonlinear least squares regression was carried out to determine the value of c . A Taylor's series expansion of the form

$$f^{k+1}(c,y) = f^k(c,y) + \frac{\partial f}{\partial c} \Delta c \quad (23)$$

where k and $k+1$ represent the number of the iteration carried out. Least squares regression minimizes the square of the difference between observed and predicted values with respect to a change in the parameter being computed, or

$$\frac{\partial}{\partial(\Delta c)} \left\{ \sum_{n=1}^N \left[f_{OBS} - (f^k(c,y) + \frac{\partial f}{\partial c} \Delta c) \right]^2 \right\} = 0 \quad (24)$$

where f_{OBS} represents the observed values, which in this case is $q_x(y)_{OBS}$. Carrying out the differentiation indicated and manipulating terms, Δc can be solved in terms of known quantities.

An iterative procedure was then used by updating the values of $f^k(c,y)$, $\partial f/\partial c$, and c until an acceptably small change in c results. For the data herein, the value of c was determined to be 1.25. The final form of sediment transport of a y location in the surf zone results for a shoreline with straight and parallel contours, as

$$q_x(y) = \frac{3}{(1.25)^3 (y_b)^3} (y+a)^2 e^{-[(y+a)/(1.25 y_b)]^3} \quad (25)$$

This equation, which is also presented in Figure 4, predicts the relative transport at point y . To obtain the fraction of transport between two y coordinates, the integral of equation (25), from y_1 to y_2 , must be used.

$$Q_{xND} = Q_x \Big|_{y_1}^{y_2} = \int_{y_1}^{y_2} q_x(y) dy = e^{-[(y_1 + a)/(1.25 y_b)]^3} - e^{-[(y_2 + a)/(1.25 y_b)]^3} \quad (26)$$

$Q_x[ND]$ is dimensionless; therefore, to compute a value in, say, cubic feet per second, it must be multiplied by the total transport along a perpendicular to the shoreline obtained from the total longshore transport equation used in the model

$$Q = C' H_b^{5/2} \sin(2 \alpha_b) \quad (27)$$

See Appendix A for a discussion of the constant C' . It is noted that the transformation of $q_x(y)$ to $q_x(h)$ can be effected by multiplying by the one-dimensional Jacobian ($\Delta y/\Delta h$). This latter form ($q_x(h)$) is more useful here because the present model simulates the changes in contour position (Δy) rather than changes by depth (Δh).

In the numerical model, $Q_x(I,J)$ (see Fig. 1) is determined using equation (26) except for the shoreline contour, $J=1$, and the farthest offshore contour simulated, $J = JMAX$. The shoreline contour longshore transport, $Q_x(I,1)$, in order to include swash transport, uses equation (16); however, the first term is set equal to 1.0. The seawardmost contour transport, $Q_x(I,JMAX)$, in order to include any longshore transport not yet accounted for, neglects the second term of equation (26) (i.e., it accounts for transport from $y(I,JMAX)$ to infinity). The dimensionless numbers are then multiplied by Q determined from equation (27). This method is based on parallel contours which may not exist. In order to compensate for the nonparallel nature of the contours (note that refraction does account for it as far as the wave field is concerned), the term $\sin(2\alpha_b)$ of equation (27) is replaced by $\sin(2\alpha_l)$ shoreward of the breakpoint, where α_l represents the angle between the "local" wave angle and the "local" contour. It can be argued that for a spilling breaker, the remaining surf zone at any point "sees" a total transport similar to equation (27), where α_b and H_b are the local values. The problem is that the constant of proportionality was determined for the entire surf zone and for nearly straight and parallel contours. This not being the case, the equation was altered on intuitive grounds to reflect the fact that the contours are no longer straight and parallel.

The second input required by the continuity equation to predict the bathymetric changes is the cross-shore sediment transport. The governing equation for onshore-offshore transport (after Bakker, 1968) is

$$Q_{y_{i,j}} = \Delta x C_{OFF_{i,j}} \left[y_{i,j-1} - y_{i,j} + W_{EQ_{i,j}} \right] \quad (28)$$

where C_{OFF} is an activity factor (inside the surf zone = 10^{-5} feet per second for the prototype simulation herein, 10^{-4} feet per second for the physical model simulation) (see App. A. for a discussion) and $W_{EQ(i,j)}$ is the positive equilibrium profile distance between $y(i,j)$ and $y(i,j-1)$, determined from the equilibrium profile used in the numerical model $h = Ay^{2/3}$ (Dean, 1977). See Appendix A for discussion of the value of A. The physical interpretation of equation (28) is that as this profile steepens (flattens), sediment is transported offshore (onshore).

b. Methods of Solution. Three separate finite-difference techniques were used to solve the equations:

- (1) Explicit longshore-continuity and explicit cross-shore continuity;
- (2) Implicit longshore-continuity and explicit cross-shore continuity for half a time-step then vice versa; and
- (3) Implicit longshore-cross-shore continuity.

An explicit formulation was first developed which used the refraction scheme, the distribution of longshore sediment transport across the surf zone, and the onshore-offshore sediment transport equation. Problems in addition to the usual ones which are encountered with explicit methods (e.g., computation time and cost) were immediately realized. In the explicit method, both transport computations are based on the former values of the contour locations and are completely uncoupled. Stability of an explicit scheme requires a small time-step. In addition, the noncoupled nature of the equations, in some cases, resulted in crossing of the contours due to the transport computed.

It is logical to assume that an implicit formulation of the longshore transport equation used as input to the continuity equation along with the explicit onshore-offshore transport component would help the numerical stability (on the other half time-step, the longshore component would be computed explicitly and the onshore-offshore transport equation would be solved implicitly with the continuity equation). Although this scheme would be superior to the explicit procedure, it still would be susceptible to crossing contours. It should be noted that the magnitude of the coefficient used in the onshore-offshore equation is very important to the extent that the simulation models natural phenomena. If the coefficient is very small or vanishes, sediment will not move offshore and contours will cross because of the variation in the distribution of longshore sediment transport across the surf zone. If the coefficient is too large, the onshore-offshore transport, may become large enough that on a particular time step, an offshore contour

would move too far shoreward, thereby crossing an inshore contour or vice versa. Once the contours cross, not only does the bathymetry become unrealistic, but mathematically, the equation which computes the longshore distribution across the surf zone changes signs at some locations and the entire model becomes physically unrealistic.

To circumvent these problems, an implicit scheme that simultaneously solves the three governing equations, was developed. Utilizing equation (26), and the one-dimensional Jacobian ($\Delta y/\Delta h$) to convert to $Q_x(h)$, the total longshore transport equation (27), the following equation is obtained,

$$Q_{x_{i,j}} = \left\{ \left[\exp \left(- \left(\frac{(h_{i,j-1})^{3/2} + H_{b_i} A^{3/2}}{1.25 h_{b_i}} \right)^3 \right) - \exp \left(- \left(\frac{(h_{i,j})^{3/2} + H_{b_i} A^{3/2}}{1.25 h_{b_i}} \right)^3 \right) \right] \right. \\ \left. \times \left(C' H_{b_{i,j}}^{5/2} \right) \right\} \times \sin (2\theta - 2\alpha_c) \quad (29)$$

$Q_x(i,j)$ represents the sediment transport between depths $h(i,j)$ and $h(i,j-1)$ (see Fig. 1). The term in brackets represents the normalized distribution of longshore transport between $h(i,j)$ and $h(i,j-1)$; θ is the averaged wave angle at the location of $Q_x(i,j)$ and α_c is the local contour orientation angle. Defining everything except $\sin (2\theta - 2\alpha_c)$ as $v(i,j)$ and using a superscript to denote a time step, this equation can be written

$$Q_{x_{i,j}}^{n+1} = v_{i,j} \sin (2\theta - 2\alpha_c^{n+1}) \quad (30)$$

The assumption has been made that the wave field (H and θ) do not vary during the bathymetric changes over the time-step. Using the following trigonometric identities,

$$\sin (2a - 2b) = \sin 2a \cos 2b - \cos 2a \sin 2b \quad (31a)$$

$$\cos 2a = 2 \cos^2 a - 1 \quad (31b)$$

$$\sin 2a = 2 \sin a \cos a \quad (31c)$$

and recognizing that the following expression is an approximation

$$\sin (\alpha_c^{n+1})_{i,j} = \frac{\frac{1}{2} (y_{i,j}^{n+1} - y_{i-1,j}^{n+1} + y_{i,j}^n - y_{i-1,j}^n)}{\left((\Delta x)^2 + (y_{i,j} - y_{i-1,j})^2 \right)^{1/2}} \quad (32)$$

along with assuming that the change in the denominator is small for a reasonable time-step (the numerator has been averaged over the n^{th} and $n + 1^{th}$ time-steps), equation (30) results in

$$Q_{x,i,j}^{n+1} + (S3)_{i,j} y_{i,j}^{n+1} - (S3)_{i,j} y_{i-1,j}^{n+1} = (RHS1)_{i,j}^n \quad (33)$$

$$\text{where } (S3)_{i,j} = \left(\frac{1}{2}\right) (v_{i,j}) \cos(2\theta) (2 \cos \alpha_c) \frac{1}{(\Delta x^2 + \Delta y^2)^{1/2}}$$

$$(RHS1)_{i,j}^n = (v_{i,j}) (2 \sin \theta \cos \theta) (\cos^2 \alpha_c - 1) - (S3)_{i,j} (y_{i,j}^n - y_{i-1,j}^n)$$

Here it has also been assumed that $\cos^2 \alpha_c$ does not change over the time step. Equation (33) is the final form of the longshore sediment transport equation prior to its use in conjunction with the other equations.

Averaging y values on the n^{th} and $(n+1)^{th}$ time-steps, equation (29) can be rewritten as

$$Q_{y,i,j} = \text{Const6}_{i,j} \left\{ \frac{1}{2} \left(y_{i,j-1}^{n+1} + y_{i,j-1}^n - y_{i,j}^{n+1} - y_{i,j}^n \right) + W_{EQ,i,j} \right\} \quad (34)$$

where $\text{Const6}(i,j) = \text{Coff}(i,j) \cdot \Delta x$. This is the final form on the onshore-offshore sediment transport equation.

The equation of continuity, finite-differenced for the n^{th} and $(n+1)^{th}$ time-steps, can be written as

$$\frac{y_{i,j}^{n+1} - y_{i,j}^n}{\Delta t} = \frac{1}{2\Delta x \Delta h} \left\{ Q_{x,i,j}^{n+1} + Q_{x,i,j}^n - Q_{x,i+1,j}^{n+1} - Q_{x,i+1,j}^n + Q_{y,i,j}^{n+1} + Q_{y,i,j}^n - Q_{y,i,j+1}^{n+1} - Q_{y,i,j+1}^n \right\} \quad (35)$$

Defining $R_{i,j}$ as $1/(2\Delta x \Delta h)$, inserting equations (33) and (34) into equation (35), and transferring all known quantities for the n^{th} time-step to the right-hand side of the equation result in

$$\begin{aligned} y_{i,j}^{n+1} + (\Delta t R_{i,j}) S3_{i,j} y_{i,j}^{n+1} - (\Delta t R_{i,j}) S3_{i,j} y_{i-1,j}^{n+1} - (\Delta t R_{i,j}) S3_{i+1,j} y_{i+1,j}^{n+1} \\ + (\Delta t R_{i,j}) S3_{i+1,j} y_{i,j}^{n+1} - (\Delta t R_{i,j} \text{Const6}_{i,j}) \left(\frac{1}{2} [y_{i,j-1}^{n+1} - y_{i,j}^{n+1}] \right) \\ + (\Delta t R_{i,j} \text{Const6}_{i,j+1}) \left(\frac{1}{2} [y_{i,j}^{n+1} - y_{i,j+1}^{n+1}] \right) = (AWARE)_{i,j} \quad (36) \end{aligned}$$

Equation (36) can be rewritten as

$$(1 + U + V + Z1 + Z2) y_{i,j}^{n+1} - (U)y_{i-1,j}^{n+1} - (V)y_{i+1,j}^{n+1} - (Z1)y_{i,j-1}^{n+1} - (Z2)y_{i,j+1}^{n+1} = (AWARE)_{i,j} \quad (37)$$

where

$$U = \Delta t R_{i,j} S3_{i,j}$$

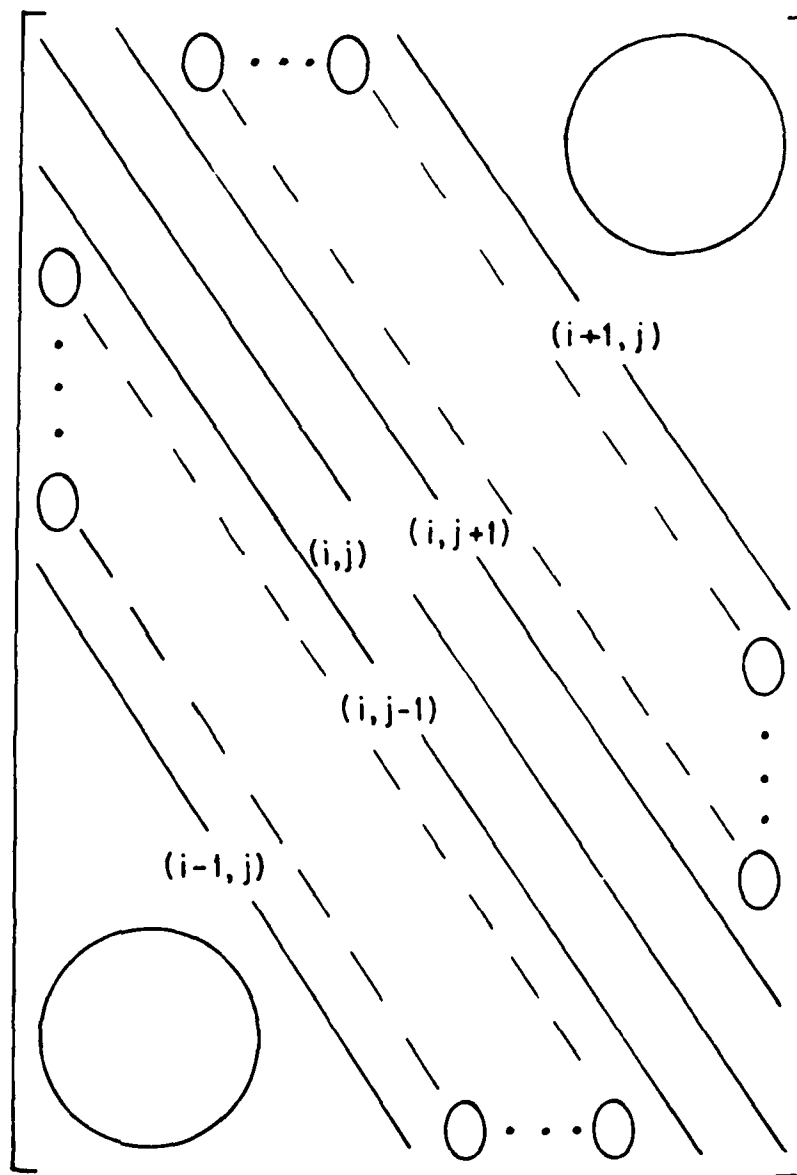
$$V = \Delta t R_{i,j} S3_{i+1,j}$$

$$Z1 = \left(\frac{\Delta t}{2}\right) R_{i,j} \text{Const6}_{i,j}$$

$$Z2 = \left(\frac{\Delta t}{2}\right) R_{i,j} \text{Const6}_{i,j+1}$$

Equation (37) is a weighted, centered scheme in which $y_{i,j}^{n+1}$ is computed using a weighting of itself and its four adjacent grid "neighbors". The weighting factors (U, V, Z1, and Z2) are functions of the wave climate, the slope between contours, and the variables included in the original formulation. An investigation of a small gridded system demonstrated that by writing simultaneous equations, one for each $y_{i,j}$, a banded matrix results. This matrix can be solved by LEQT1B, one of the available routines from the International Math and Statistics Library (IMSL). A schematic representation of the matrix A which results from the matrix equation $[A][y] = [B]$ is presented in Figure 5. In this schematic, the large zeros represent triangular corner sections of all zeros and the 0...0 represents bands of zeros, the number of which is dependent on the number of contours simulated (the number of zero bands between either remote nonzero bands and the tridiagonal nonzero bands equals two less than the number of contours modeled (in both the upper and lower codiagonals of the matrix)). An inspection of the subscripts in equation (29) yields the reason the zero bands are required. The more j values (contours) used, the more y grids there are along any perpendicular to shore. This causes zeros to appear in the matrix between bands as the weighting factors await being used to operate on $y_{i-1,j}^{n+1}$ and $y_{i+1,j}^{n+1}$. For this reason, the expense of simulating an increasing number of contours is exponential. The LEQT1B routine, utilizes banded storage and saves both storage and computation time; however, the routine has no special way of handling the interior zero bands. One refinement which would save computation time would be to develop an algorithm to solve and store the matrix by taking advantage of these inner zero bands; however, it is beyond the scope of this project.

Of course, the matrix requires boundary values on longshore extremities and on both onshore and offshore boundaries. The longshore boundary conditions are treated by modeling a sufficient stretch of shoreline so that effects of a structure's presence are minimal. The y values along these boundaries can therefore be fixed at their initial locations. In the onshore-offshore direction, boundaries are treated quite differently. The



Note: Size of matrix full storage mode
 $[(\text{IMAX}-2)(\text{JMAX}) \times (\text{IMAX}-2)(\text{JMAX})]$
 Size of matrix banded storage mode
 $[(\text{IMAX}-2)(\text{JMAX}) \times (2\text{JMAX} + 1)]$

Figure 5. Schematic representation of banded matrix if not stored in banded storage mode.

berm and beach face are assumed to move in conjunction with the shoreline position. The required sediment transport is then computed by the change in position of the shoreline. The two equations are

$$y_{i,0}^{n+1} = y_{i,0}^n + [y_{i,1}^{n+1} - y_{i,1}^n] \quad (38a)$$

$$Q_{y,i,1}^{n+1} = - \left[\frac{\text{Berm } \Delta x}{\Delta t} \right] [y_{i,1}^{n+1} - y_{i,1}^n] \quad (38b)$$

The offshore boundary is treated by keeping $y^{n+1}(i,j_{\text{max}})$ (the contour beyond the last simulated contour) fixed, until the angle of repose is exceeded. Then, the $y^{n+1}(i,j_{\text{max}}+1)$ is reset (at the conclusion of the $n+1$ time-step) to a position such that the slope equals the angle of repose. Note that $y^{n+1}(i,0)$ is represented in the program by YZERO_i .

There are also no-flow boundary conditions required at each of the structures being modeled. These are imposed on the adjacent y -grid points which are located downdrift (i.e., in the shadow zone) of the structure and shoreward of the structures' seaward extremities. They are imposed by setting $S3_{i,j}$ of equation (33) and $\text{DISTR}_{i,j}$ (the term in square brackets in equation (29)) equal to zero, thereby causing $Q_x(i,j)$ to be zero (i.e., the no-sediment flow condition). This boundary condition is imposed automatically for every shore-perpendicular structure.

It was found that even with the implicit formulation, high frequency oscillations occurred in the y values immediately updrift and downdrift of the structure. The solution did not "blow up"; however, on larger time-steps "sloshing" (oscillating) did occur. Part of this problem was due to the boundary condition at the structure which had been such that either no sand was allowed along a contour line or the sand determined by the equations was allowed to be transported. Because of the very large angle which existed around the tip of the structure when a contour first exceeded the length of the structure, very large amounts of sediment transport were predicted. In the nature where analog sand transport rather than digitized transport occurs, this does not happen. Therefore, the boundary condition was altered to constantly allow sand transport around the end of the structure in proportion to that part of the contour representation which exceeded the structure (i.e., the transport was calculated for the location at tip of the structure as if the structure was not there and then a proportion of this value was allowed to bypass). Although the transport around the tip of the structure is based on the values from the past time-step, it more closely simulated the natural phenomenon.

Additionally, a dissipative interface is used on the y values as follows:

$$y_{i,j} = (\tau) y_{i-1,j} + (1 - 2\tau) y_{i,j} + (\tau) y_{i+1,j} \quad (39)$$

where τ was again taken as 0.25. It is noted that only high frequency oscillations in y are affected by the use of equation (39); the total sum of y values is not affected. Also, in all the dissipative interface

schemes used, if a boundary point is being computed, either a forward-difference or a backward-difference of equation (39) is used (after Abbott, 1979):

$$\text{Backward: } y_{i,j} = (\tau)y_{i-1,j} + (1 - \tau)y_{i,j} \quad (40a)$$

$$\text{Forward: } y_{i,j} = (\tau)y_{i+1,j} + (1 - \tau)y_{i,j} \quad (40b)$$

IV. SIMULATIONS AND VERIFICATION

Several simulations were run; two were attempts at verifying the numerical model, the others were run to gain insight. Because a complete data set does not exist, only the available data are compared. The first modeling effort was to simulate the physical model tests of Savage (1959). A second set of cases was run for shore-perpendicular structures. Next, an effort was made to model sediment transport in the vicinity of a hypothetical dredge disposal site in the 11- to 14-foot depths off Oregon Inlet. Finally, the Channel Islands Harbor Longshore Transport Study (Bruno, et al., 1981) was modeled. Bathymetric changes were closely monitored during this study; however, the wave climate (H , θ , T) used was determined from the Littoral Environmental Observation (LEO) data and uncertainties exist as to the accuracy of the data.

1. Simulation of Savage's Physical Model Tests.

The numerical model was used to simulate one of the physical model tests of Savage (1959). Test 5-57 was simulated numerically for a 10-hour period. In this physical model, the mean sediment size was 0.22 millimeters, the wave height averaged 0.25 feet, the wave period was 1.5 second, the wave angle was 30° (at a depth of 2.3 feet), and the groin was approximately 9.5 feet from still water to its seaward limit. C_{off} was held constant at 10^{-4} feet per second throughout the profile for this simulation. The offshore profile is presented in Savage (1959). Figure 6 represents three of the eight contours simulated. Note that the initial 0.3- and 0.5-foot-depth contours, in the numerical representation are too far seaward by approximately 2 feet. This is due to the $h = Ay^{2/3}$ equation as compared to the equilibrium physical model profile. Realizing this, it is the shape of the contour which must be used as an indication of the numerical model predictions. The general trend of the contours is similar, although the numerical model contours are displaced farther seaward as expected. The major differences are in the diffraction zone.

2. Several Runs Using Shore Perpendicular Structures to Demonstrate Effects of Altering Some of the Pertinent Parameters.

In the following simulations, the models were run until their near-equilibrium values were achieved. Coefficient C_{off} was not a function of depth (beyond the surf zone) but was held constant throughout the simulated area. Important variables are as shown in the figures. Only one wave condition ($H_0 = 3$ feet, $T = 7$ seconds, and a deepwater wave angle α_0

Note: Discrepancy between initial Savage contours and initial model contours is due to use of the $h = Ay^{2/3}$ profile.

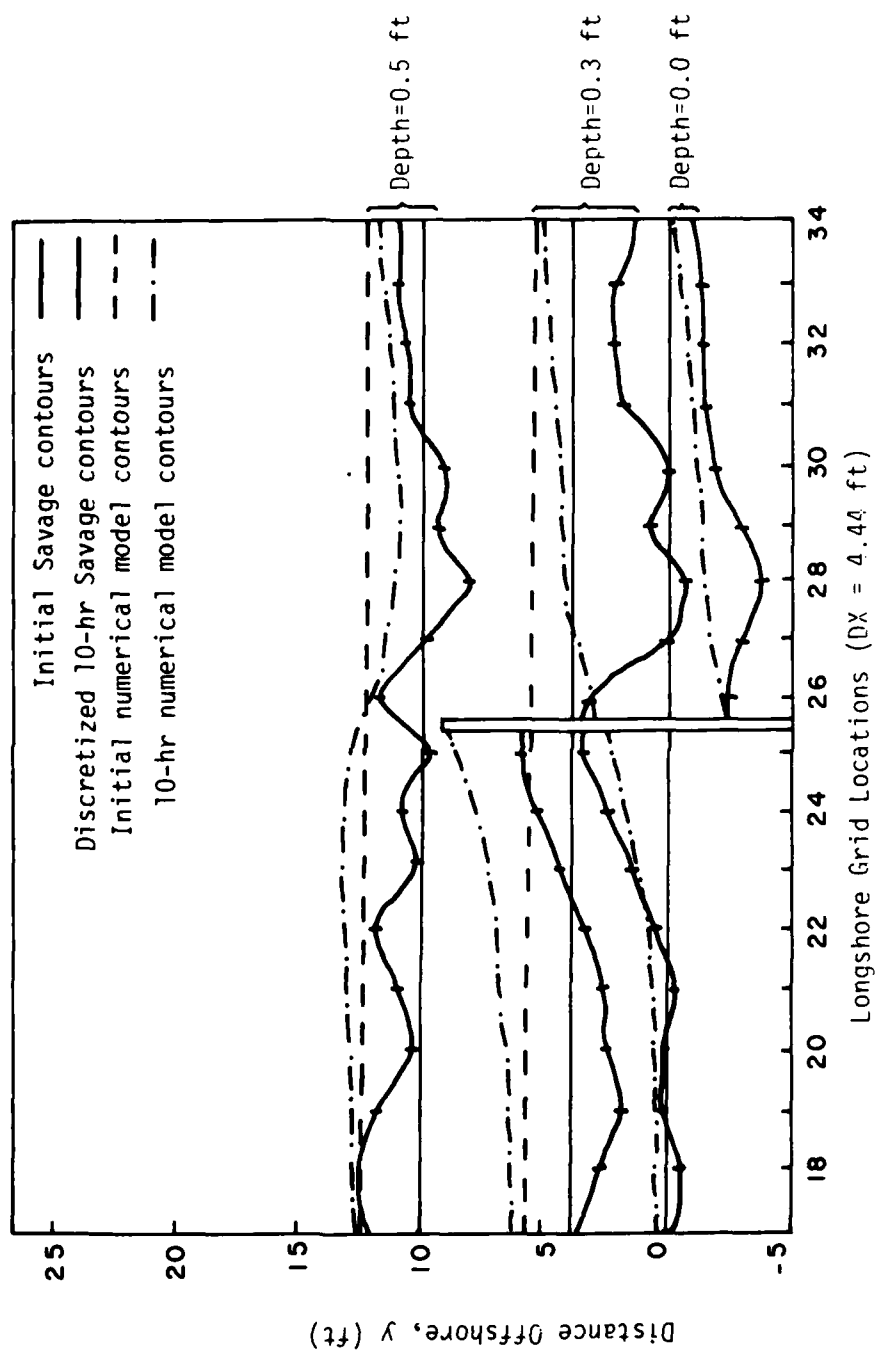


Figure 6. Simulation of the physical model of Savage (1959).

of 60°) was used as input for all four cases. Case 4.2a used an equilibrium shape factor A of 0.0899 and one groin. Case 4.2b was similar to 4.2a with the only modification being, that the A value was changed to 0.1486. In this way, a direct comparison was made based only on the shape of the equilibrium profile. Cases 4.2c and 4.2d used A-values of 0.0899 and 0.1486, respectively, but this time three shore-perpendicular, evenly spaced structures were simulated.

a. Comparison of Cases 4.2a and 4.2b. The most obvious difference between Figures 7 and 8 is the volume of sand impounded updrift and eroded downdrift. This is due to blockage of more of the active transport zone in the second case (i.e., a shorter groin is required for an equivalent performance on a steeper beach). The next obvious difference is the size of the perturbation which exists in the offshore contours. Clearly, case 4.2b is more perturbed and this is expected because larger offshore transports occur due to the steepening on the updrift side. Conversely, this means less sediment is initially bypassed (and along with the downdrift requirement for larger volumes of sand) causes larger erosional features in case 4.2b. Another interesting feature is the downdrift fillet which occurs in the third, fourth, and fifth contours. The fillet is due to the shape of the sixth contour which occurs because of the inability of the wave to transport more sediment (due to the reduction in wave height and angle in the diffraction shadow zone). The remaining difference is also due to the volume of sediment being impounded; i.e., the distance and extent of change the presence of the groin causes upcoast and downcoast.

b. Comparison of Cases 4.2c and 4.2d. The variations between cases 4.2c and 4.2d are very similar to the differences between cases 4.2a and 4.2b as would be expected with a groin field (here, three groins) as compared with a single groin (see Figs. 9 and 10). There is, however, one additional feature which can be attributed to the additional groins. Note that in the direction of littoral drift, the size of the fillet is decreasing. This is due to the updrift beach having an uninterrupted supply of sediment while the downdrift groin compartments are supplied sand at a rate determined by the bypassing. Part of this feature may also be due to the system not having attained complete equilibrium.

The effects of the fixed boundary conditions are evident on all cases run. In these example cases, the boundaries are clearly too close to the structure to provide a proper representation of the fillet contours.

3. Simulations of Sediment Transport of Dredge Disposal in the Vicinity of Oregon Inlet.

Hypothetical dredge disposal movement in the nearshore but beyond what is normally the surf zone at Oregon Inlet's adjacent beach to the south was modeled. In order to do these simulations, the program was altered such that for every n^{th} iteration (time periods), the contours were shifted seaward to simulate the addition of dredged sediment disposal. The program presented in Appendix B does require slight modification to simulate this situation.

In general, the fifth and sixth contours were shifted seaward on a monthly basis to simulate the disposal of 121,000 cubic yards of sediment.

Note: J=7 and 8 contours not shown

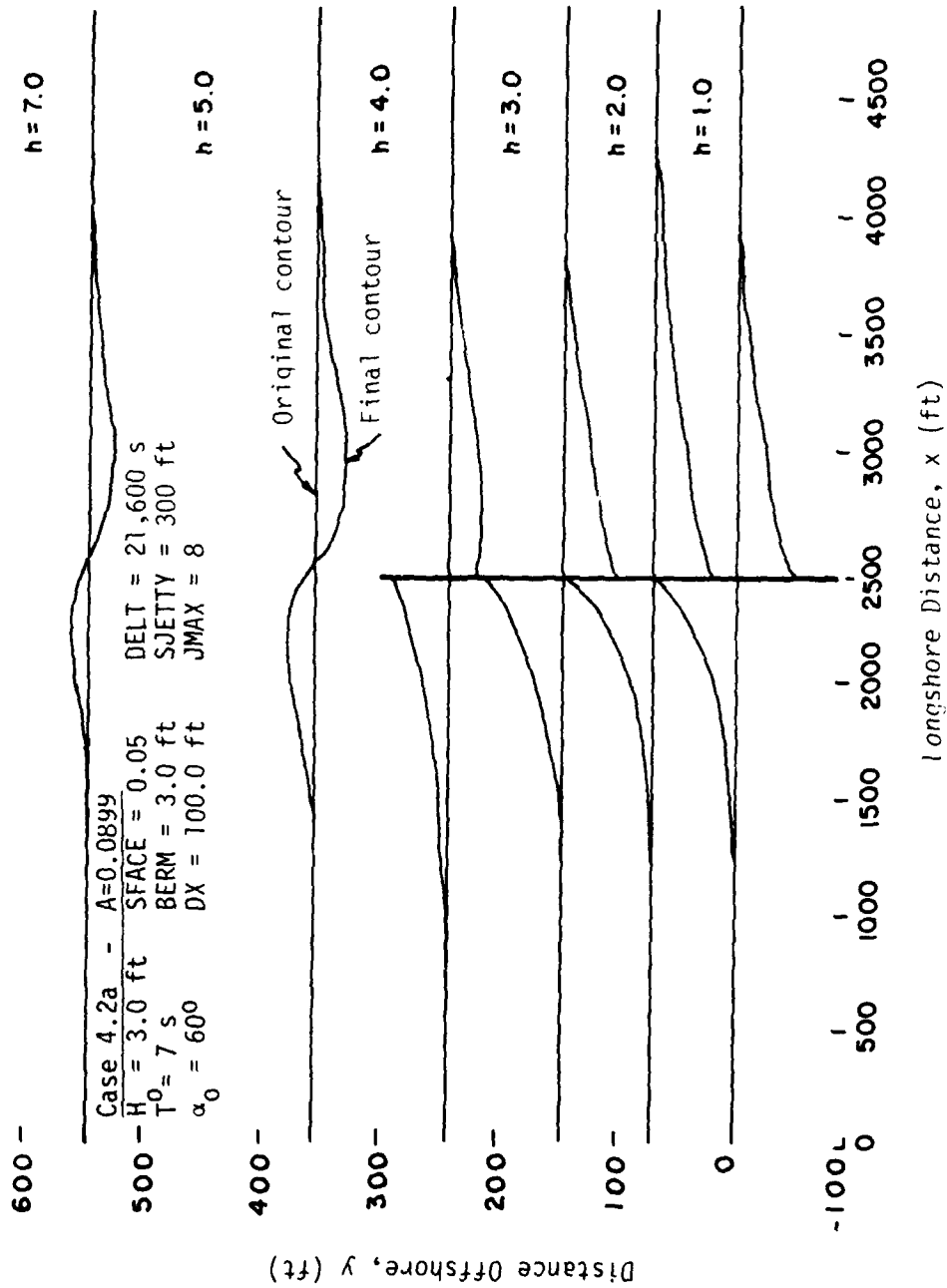


Figure 7. Equilibrium planform, case 4.2a.

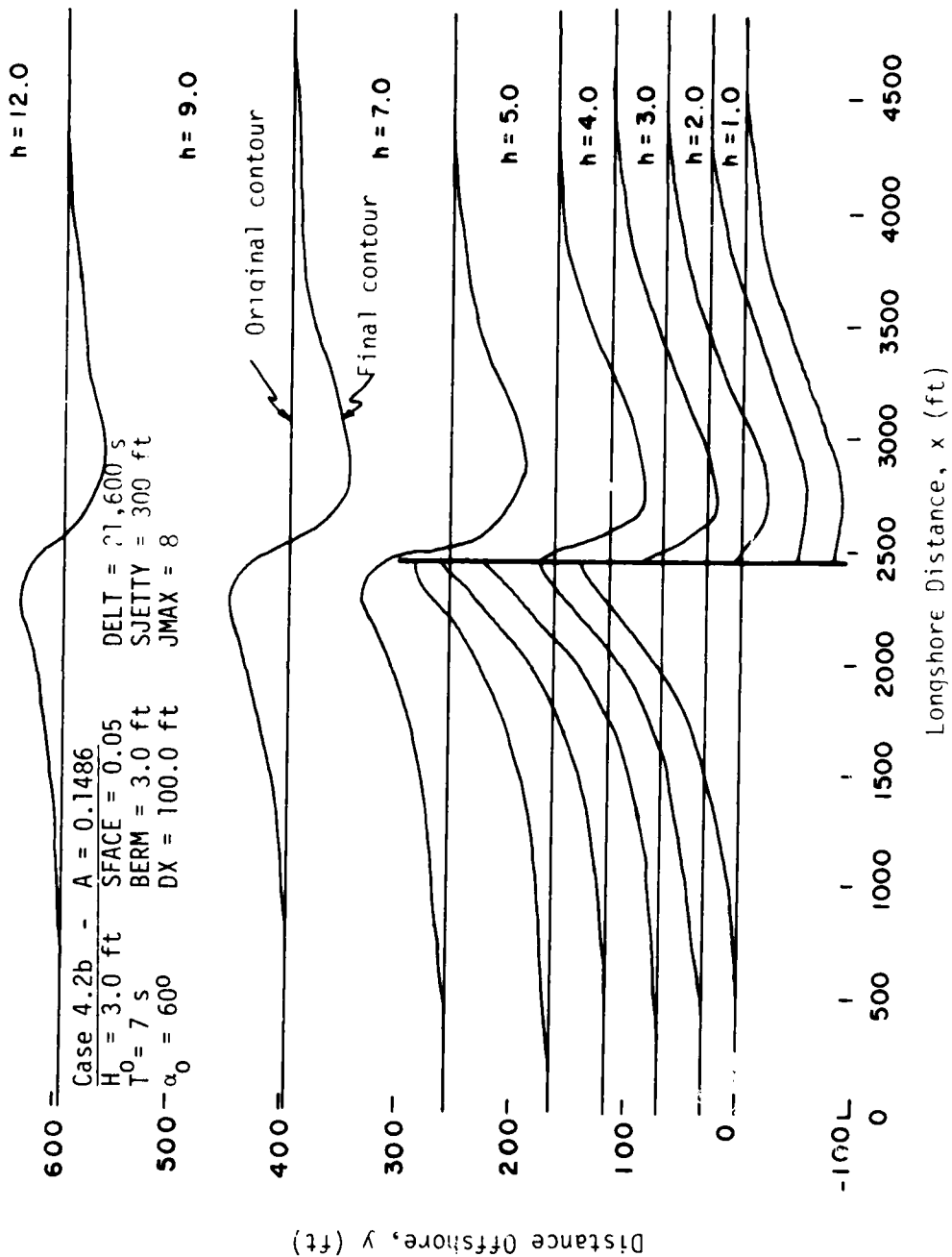


Figure 8. Equilibrium planform, case 4.2b.

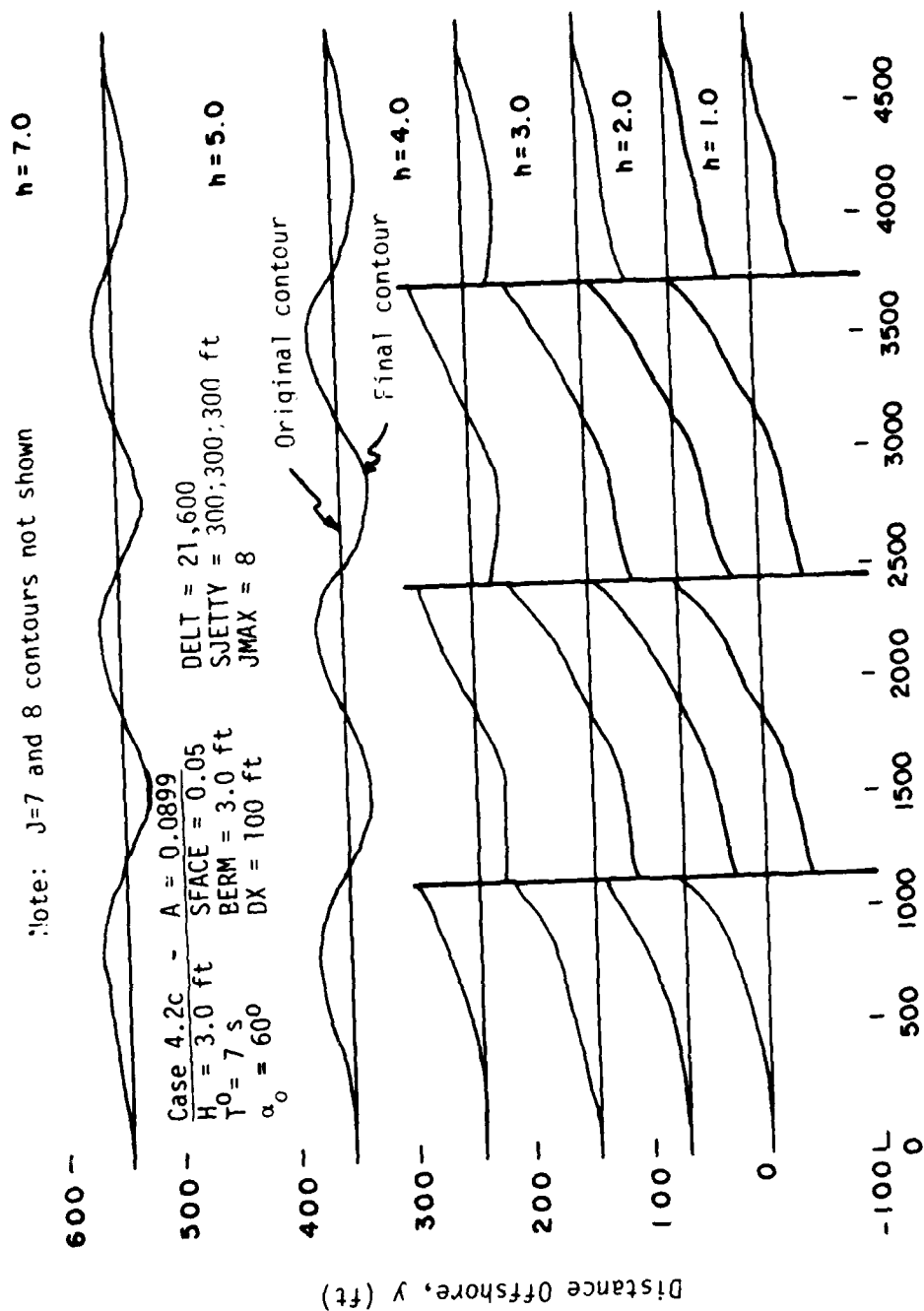


Figure 9. Equilibrium planform, case 4.2c.

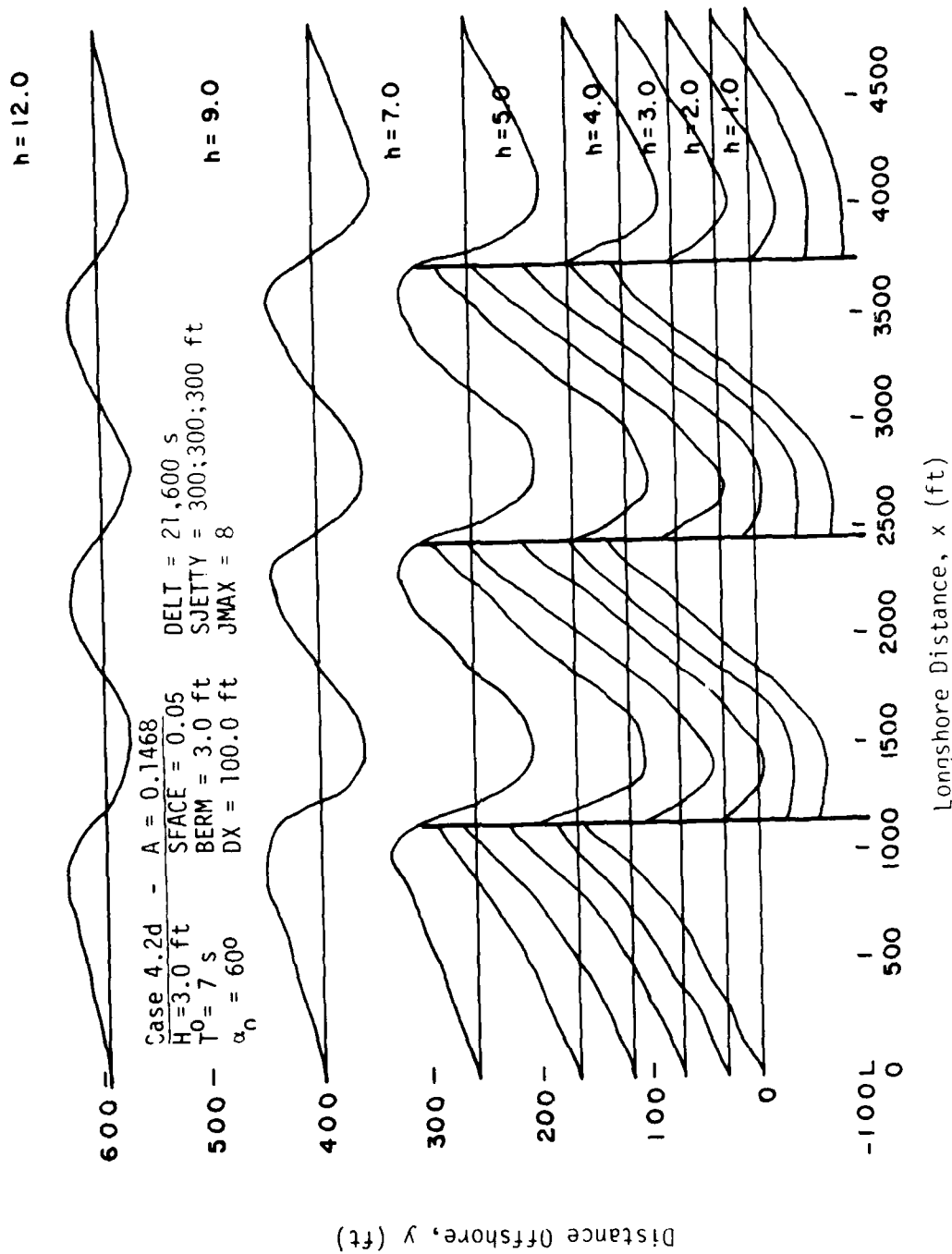


Figure 10. Equilibrium planform, case 4.2d.

In all these simulations, the following variables were held constant: (a) a time-step of 3 hours, (b) a shoreline length of 10,000 feet, (c) a longshore space-step of 200 feet, (d) an A value of $0.15 \text{ foot}^{1/3}$ for the equilibrium profile (see Fig. 11), (e) a berm height of 5.3 feet with a beach face slope of 0.05, and (f) a duration of 1 year. The wave climate was provided by the U.S. Army Engineer Waterways Experiment Station Wave Information Study (WIS) 1975 data and was initiated at different times of the year as indicated in the specific cases below. All simulations, prior to any addition of sediment, used the bathymetry shown in Figure 12. The shoreline (relative to mean low water, MLW) was scaled from a bathymetry-topography survey provided by the U. S. Army Engineer District, Wilmington. The initial offshore bathymetry was computed according to the equilibrium profile and the 0-foot contour; i.e., the profile was shifted seaward or landward, accordingly, (see App. C.) The boundary profiles were fixed throughout the simulations. The variation of COFF outside the surf zone was used because of the importance of the time rate of change in this simulation. Table 1 presents the percentage of sediment which moves out of the control volume (i.e., imaginary boundaries around the area where sediment was added) directly onshore and the percentage of sediment remaining in the control volume at the conclusion of the simulation for each of the cases. In addition, a seventh (case 3) and eighth (case 4) were modeled. In Case 3, the only difference was that sediment was placed at the 11- and 14-foot contours. Case 4, however, was quite different and will be described in detail later. It has a 20,000-foot shoreline, a longshore space-step of 400 feet, and sediment was added on a weekly basis. Also, the resolution in the profile was better.

a. Specific Cases.

(1) Case 2.a. In order to provide insight for the interpretation of the other modeling efforts, a simulation of the shoreline evolution using the January to December WIS time series, with no addition of sediment, was carried out. As expected, the contours almost attain an equilibrium planform shape (i.e., straight and parallel between the fixed end profiles; they do not, however, become aligned parallel to the base line because of the end conditions). Because of the scales involved, alongshore versus onshore-offshore, plotting the contours without distortion does not yield much information. Appendix C provides a listing of the final contours for all the cases modeled.

(2) Case 2.b. The only difference between cases 2.a and 2.b is the suppression of the WIS wave angle which was set equal to zero (i.e., wave crest approach is shore-parallel at the offshore boundary of the model). This does not cause the longshore sediment transport to vanish completely. There are still local gradients in the contours which cause refraction and relative angles between wave crest and contour, thereby driving the longshore sediment transport (even if refraction was not considered, the local angle between the wave crest and contour would cause sediment transport). Note the larger onshore transport (Table 1) for this case compared with Case 2.a. This is due to the reduction in longshore transport caused by the wave angle of 0° . The model still tries to smooth the contour lines; however, more of the smoothing for the present case must be done by onshore-offshore transport.

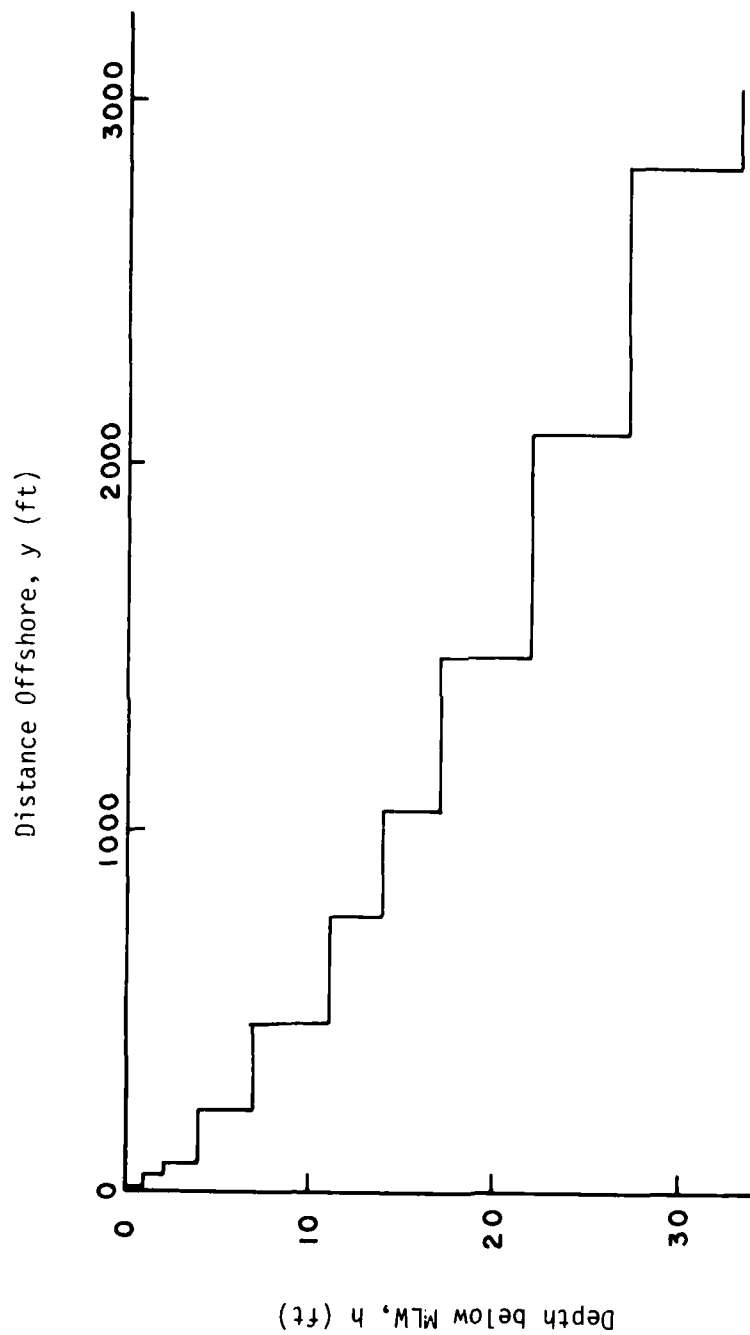


Figure 11. Stepped version of equilibrium profile used in the Oregon Inlet modeling,
 $h = Ay^2/3$ ($A = 0.15 \text{ feet}^{1/3}$).

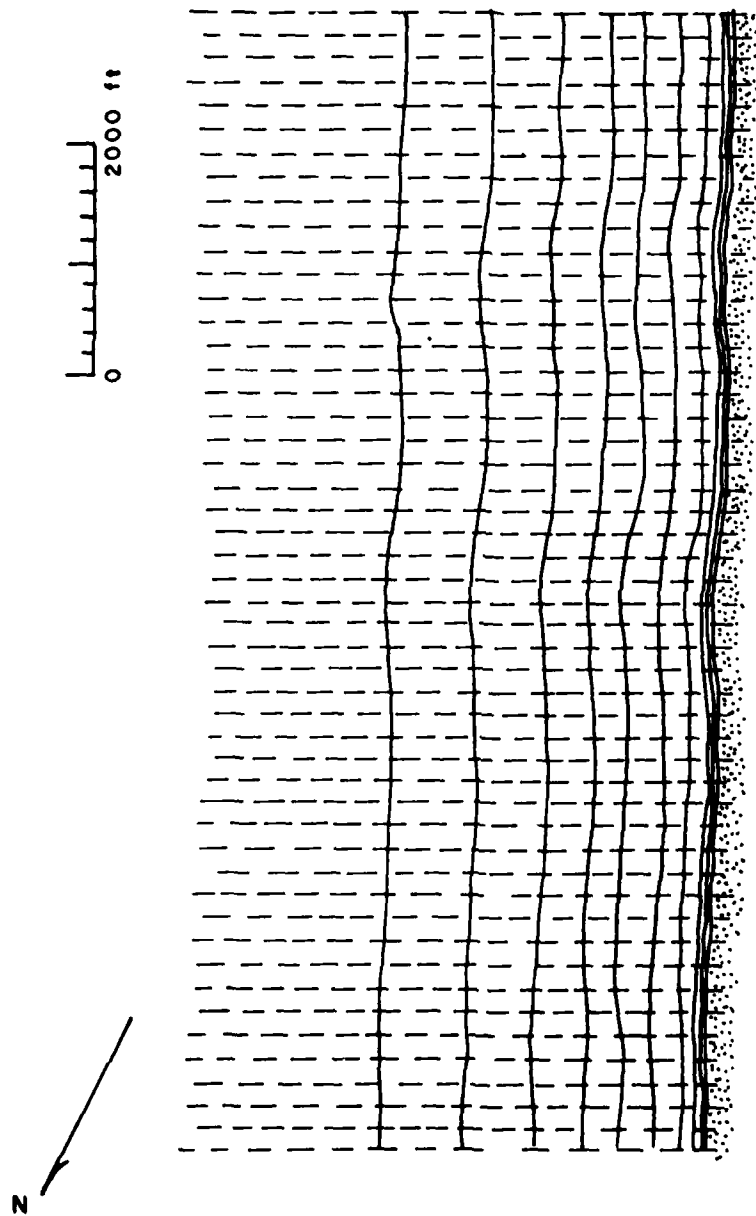


Figure 12. Initial contours used in the numerical model for all the Oregon Inlet simulations. (The scale for case 4 was twice the scale shown.)

Table 1. Summary of results at Oregon Inlet.

Case No.	Description	Pct Onshore out of control volume	Pct Remaining in control volume
2.a	No sediment added, WIS waves Jan. - Dec.	Onshore Movement (992 yd ³)	Increase (14,148 yd ³)
2.b	No sediment added, WIS waves ($\alpha = 0^\circ$) Jan. - Dec.	Onshore Movement (1624 yd ³)	Increase (9,356 yd ³)
2.c1	121,000 yd ³ added monthly, WIS waves Jan - Dec.	31.7 (460,264 yd ³)	38.6 (559,984 yd ³)
2.c2	121,000 yd ³ added monthly, WIS waves Apr. - Mar.	32.1 (466,160 yd ³)	36.9 (535,392 yd ³)
2.c3	121,000 yd ³ added monthly, WIS waves July - June.	28.6 (415,784 yd ³)	47.0 (682,088 yd ³)
2.c4	121,000 yd ³ added monthly, WIS waves Oct. - Sept.	27.2 (395,556 yd ³)	46.8 (670,848 yd ³)
3	121,000 yd ³ added monthly at the 11- and 14-foot contours WIS waves, Jan. - Dec.	8.9 * (32,164 yd ³)	78.0 (283,016 yd ³)
4	27,923 yd ³ added weekly on the 7-8-, 9-, and 10-foot contours, WIS waves Jan. - Dec.	19.0 (275,796 yd ³)	47.4 (687,525 yd ³)

* After 17 weeks, the addition of sand caused contours to cross. Prior sediment added was 363,000 yd³. Problem was rectified; however, case was not rerun.

(3) Case 2.c1. In this simulation, sediment is added to the system each month. It was simulated by advancing the 7- and 11-foot contours on a monthly basis to represent 121,000 cubic yards per month. Specifically, the sand volumes were "tapered" starting at the center of the nourished area over a distance of + 2,700 feet from the center. Table 2 presents the monthly Δy values for the blocks between the 7- to 11-foot contours and the 11- to 14 foot contours. Figure 13 shows the planform Δy values added monthly. WIS waves were used with the sequence being the normal calendar year, January through December.

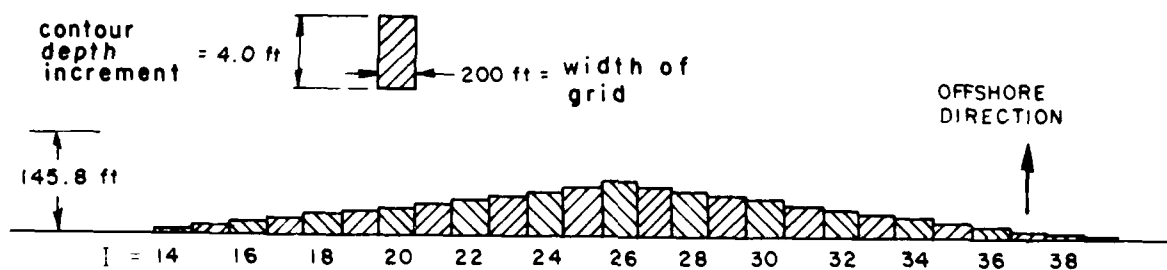


Figure 13. Monthly incremental values of Δy due to dredge disposal illustrated for the block between 7- and 11-foot contours.

The initial and final fifth and sixth contours have been plotted in Figures 14 and 15. The first figure has no distortion; the second is distorted 10 to 1. The simulation predicts that 31.7 percent of the dredge disposal will move shoreward out of the control volume. An additional 29.7 percent efflux occurs in the offshore and longshore directions, leaving only 38.6 percent of the total amount of sediment added remaining in the control volume. It is not clear what quantity of the sediment leaving in the longshore direction would reach shore. It is conceivable that most of this sediment would eventually reach the surf zone. The rate at which this material would move ashore would be expected to be slower than the rate at which the large mounds would move ashore because the deviation of the profile from equilibrium is much less.

(4) Cases 2.c2, 2.c3, and 2.c4. The next three simulations were the same as 2.c1 except the time series of wave events has been seasonally altered. Cases 2.c2, 2.c3 and 2.c4 use the 1975 wave climate from April through March, July through June, and October through September, respectively. The maximum variation is about 5 percent for the sediment volume moving onshore, and about 10 percent for the volume remaining. The variation in the

Table 2. Monthly values of Δy for the steps located between the 7- to 10-foot contours and the 11- to 14-foot contours.

Value of I	Monthly Δy value (ft) for steps between	
	7- and 11-foot contours	11- and 14-foot contours
26	145.8	194.4
25,27	135.4	180.5
24,28	125.0	166.6
23,29	114.6	152.7
22,30	104.1	138.9
21,31	93.7	125.0
20,32	83.3	111.1
19,33	72.9	97.2
18,34	62.5	83.3
17,35	52.1	69.4
16,36	41.7	55.5
15,37	31.2	41.7
14,38	20.8	27.8
13,39	10.4	13.9
All Others	0	0

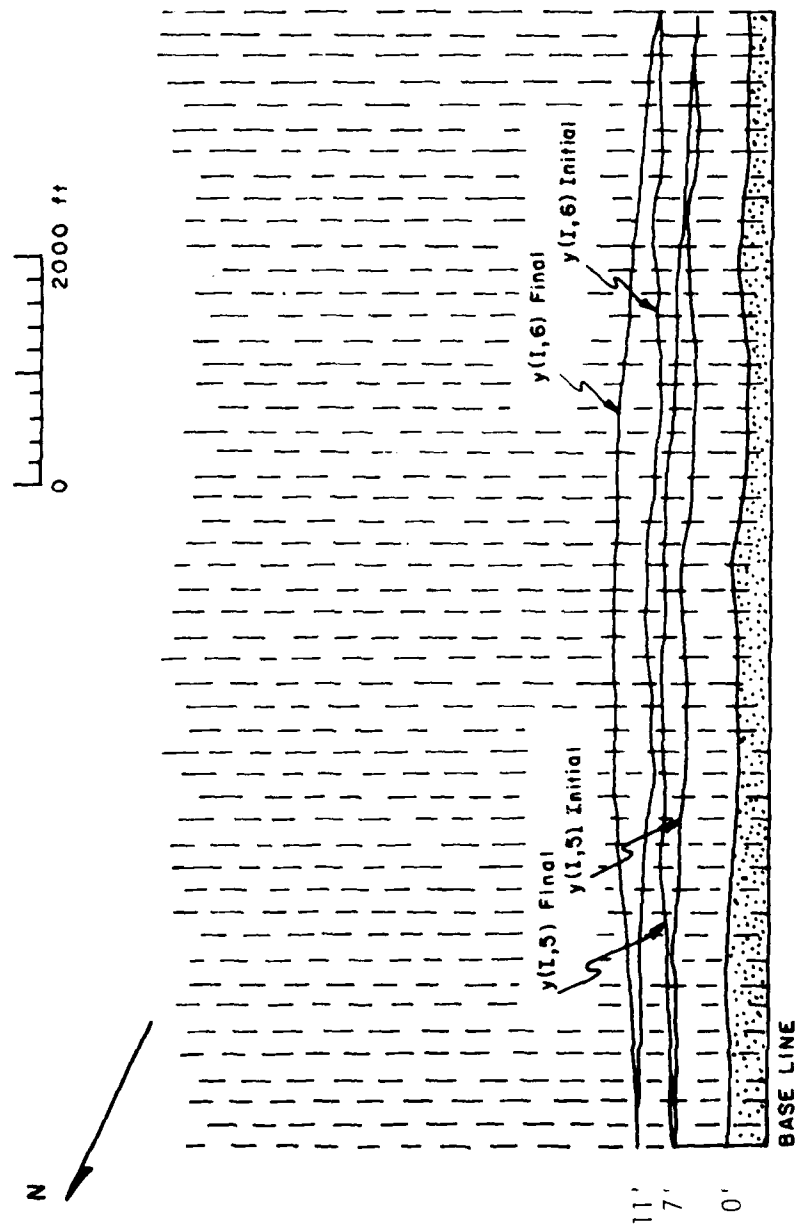


Figure 14. Initial and final 7- and 11-foot contours (no distortion).

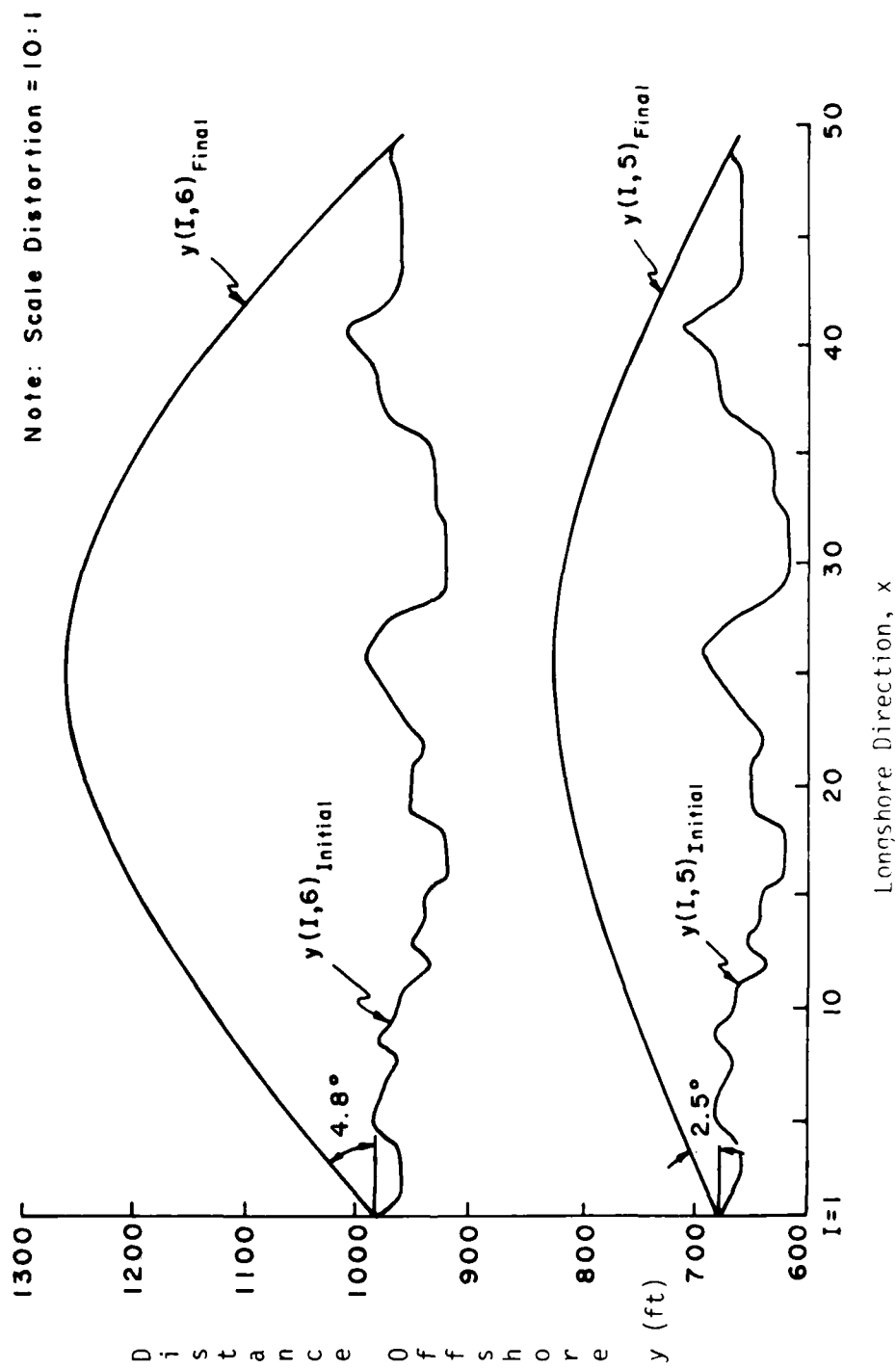


Figure 15. Initial and final contours for case 2.c1 [$y(I,5)$ and $y(I,6)$].

quantity moving onshore could be caused by waves that first tend to move more sediment longshore; then, the waves that transport more sediment onshore have a less out-of-equilibrium profile to cause movement upon. The variation in percentage remaining is due to the variation of the time series of the wave climate, with the last month in the simulation being especially important.

(5) Case 3. Instead of extending the 7- and 11-foot contours monthly to simulate the disposal of dredged sediments, the 11- and 14-foot contours were extended (194.4 feet each at the center of the disposal area). This case was modeled because the larger available dredge could not dump in more shallow water. The reduction and increase in the percent of onshore volume and the percent volume remaining (8.9 percent and 78.0 percent, respectively) demonstrate the sensitivity of the depths investigated. Qualitatively, these depths are the depths to which offshore bars occur along the Atlantic U.S. coast.

(6) Case 4. Further investigation of the disposal process demonstrated the need for an 11,000-foot shore-parallel disposal length with the sediment placed at the 11-foot contour building to about 7 feet. It was decided to model this physical situation also. The total shoreline length was changed to 20,000 feet, and the space step to 400 feet; the length of the disposal area in the longshore direction was increased to 10,800 feet. The resolution in the vicinity of the depths of the dump was improved by adding the additional contours and the profile is shown in Figure 16. As in the other seven cases, 1,452,000 cubic yards was added annually to the system; however, the addition was accomplished on a weekly basis (27,923 cubic yards per week). Sediment was still added by extending the contours seaward, but rather than placing one-fourth of the sediment at each of the four contours, the volumes were determined based on the trapezoidal cross section shown in Figure 17. This cross section more closely resembles the disposal mound formed by hopper dredging. The incremental values Figure 18 show, in planform, the extension of the contours to simulate the weekly sediment addition at the 8-foot contour.

A schematic illustration of the sediment transported from the nourished region is presented in Appendix C. Nineteen percent of the sediment added moved directly onshore out of the control volume.

b. Conclusions for the Movement of Disposed Sediment in the Vicinity of Oregon Inlet. The computer simulations, tempered with engineering judgment, demonstrate that between 15 and 35 percent of the material added to the 7- and 11-foot contours, or to the 7- 8- 9-, and 10-foot contours would be transported into the nearshore transport system during the first year. If the disposal process was continued, the system would approach steady state in terms of the volume of deposited material residing offshore.

For the case of sediment addition at the 11- and 14-foot contours, the computer simulations, tempered with engineering judgment, show that between 5 and 25 percent of the material added would be transported into the nearshore transport system during the first year.

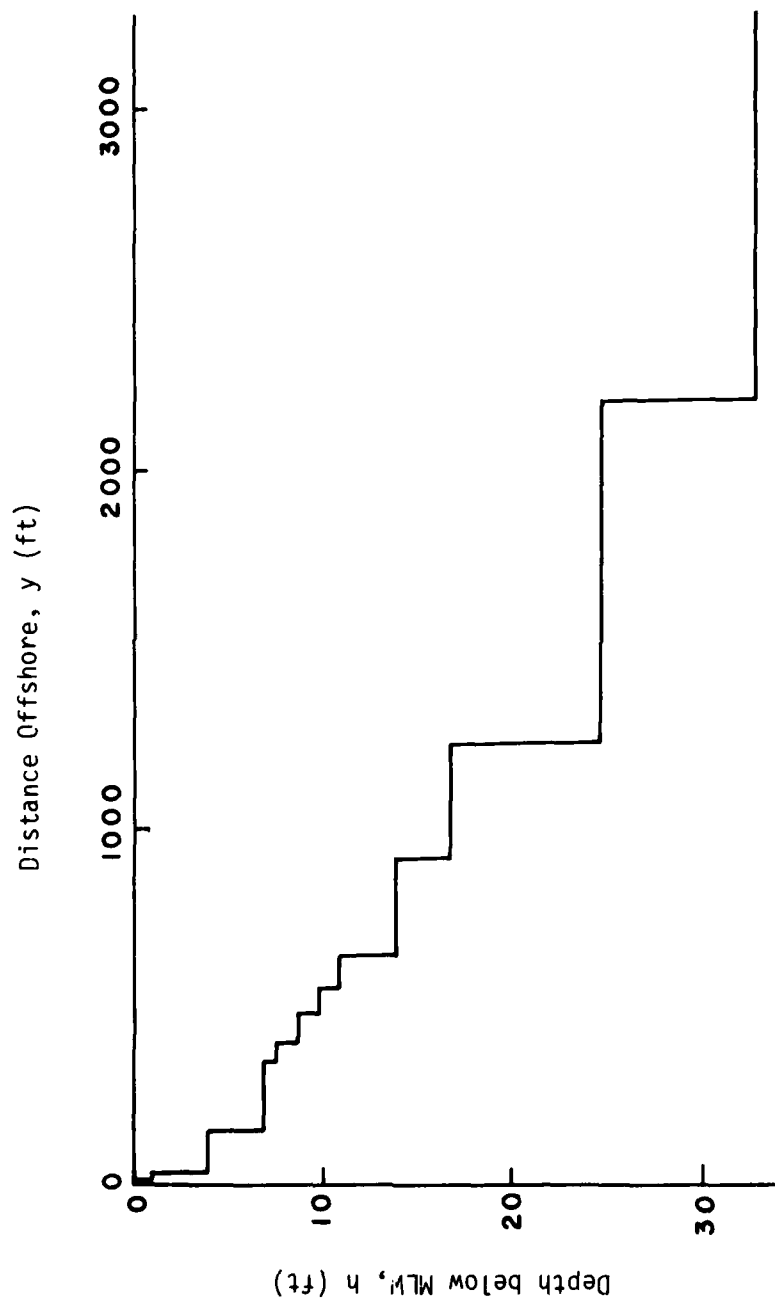


Figure 16. Stepped version of equilibrium profile used in the Oregon Inlet modeling, $h=Ay^{2/3}$ ($A=0.15 \text{ feet}^{1/3}$), case 4. Note the resolution at 7, 8, 9, and 10 feet.

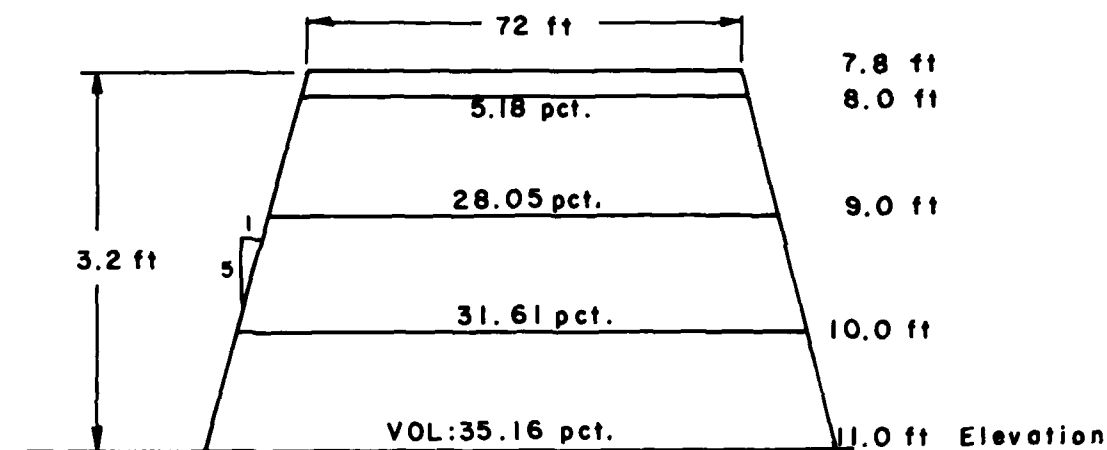


Figure 17. Shore-perpendicular cross section of disposal mound. The volumes represent the volume percentage of the trapezoidal section between contours and therefore, the quantity of sediment added to the 7-, 8-, 9-, and 10- foot contours.

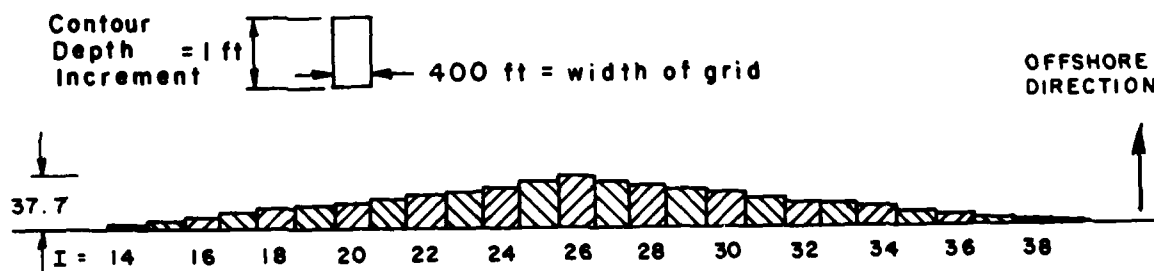


Figure 18. Incremental values of Δy due to dredge disposal, illustrated for the block between 8- and 9-foot contours (case 4).

4. Simulation of the Longshore Sand Transport Study at Channel Islands Harbor, California.

The CIH Longshore Sand Transport Study (Bruno, et al., 1981) was the only field study found suitable for verification purposes. Wave data collected included the LEO data and a two pressure-sensor gage array. Although the pressure gages were not in operation throughout the study, it was expected that the data they produced would be superior to that of the LEO data. However, these data were not available in a reduced form, so the LEO data were used. An adjustment of 11° was made to the breaker angle to orient the angle with respect to the base line, rather than to the local shoreline orientation angle. Observations had been taken twice daily at three locations; the middle location was used (observer No. 5714). Waves which approached the shoreline at angles too large to have originated in a depth of 10 meters, according to Snell's law, were set equal to 90° at that depth (crest of wave perpendicular to the baseline). The 10-meter depth was chosen because it is the approximate depth at the tip of the offshore breakwater (for this reason, it was also chosen as the depth of the step beyond the $y(I, J_{MAX} + 2)^{th}$ contour). It was assumed that each of the two daily observations occurred for 12 hours and using a time-step of 6 hours, this meant two time-steps per wave. In cases where parts of the wave data (H_b , a_b , or T) were missed by the observer or were equal to zero, the data were ignored (no computations were made), but the time was included. Because the time rate of change is important for this simulation, the variation of C_{OFF} outside the break point was used.

The period chosen to model was 20 April through 1 December 1976. The initial survey was taken after dredging of the sediment trap and for this reason was known to be out of equilibrium. The bathymetric surveys were conducted using several methods, the most advanced being a Lighter Amphibious Resupply Cargo vessel (LARC) proceeding along shore-perpendicular lines (approximately in the vicinity of each survey station) taking fathometer readings every 10 seconds, with positioning systems trilaterating the vessel's position concurrently. These data were recorded on tape. The beach-face data were taken using standard surveying methods. Because the data fluctuated randomly about the stations, depending on the speed of the craft, the (x, y) coordinate positions had to be altered to fixed changes in x and y . This was accomplished using an interpolation routine. The x values were made to coincide with the stations used in the surveys, and the y values were determined at 100-foot intervals beginning from the base line. Stations 100+00 and 118+00 were located at the north jetty and termination of the detached breakwater, respectively (these correspond to I values of 16.5 and 34.5 in the model). See Figure 19.

Monotonic profiles of the form $h = A(y - y_{del})^{2/3}$ were fit to the data along each station line. " y_{del} " represents the zero location of the fitted shoreline, the value of which was unknown. Because dredging had been done in the lee of the breakwater, there was no reason to expect the A value to correspond to the value upcoast where the influence of the structure and the dredging was negligible. For this reason, the profiles of Stations 122+00 through 134+00 were evaluated separately to determine an A value for the equilibrium profile to be used in the numerical model. For the detailed method used (LaGrange Multipliers and Newton-Raphson Method for nonlinear

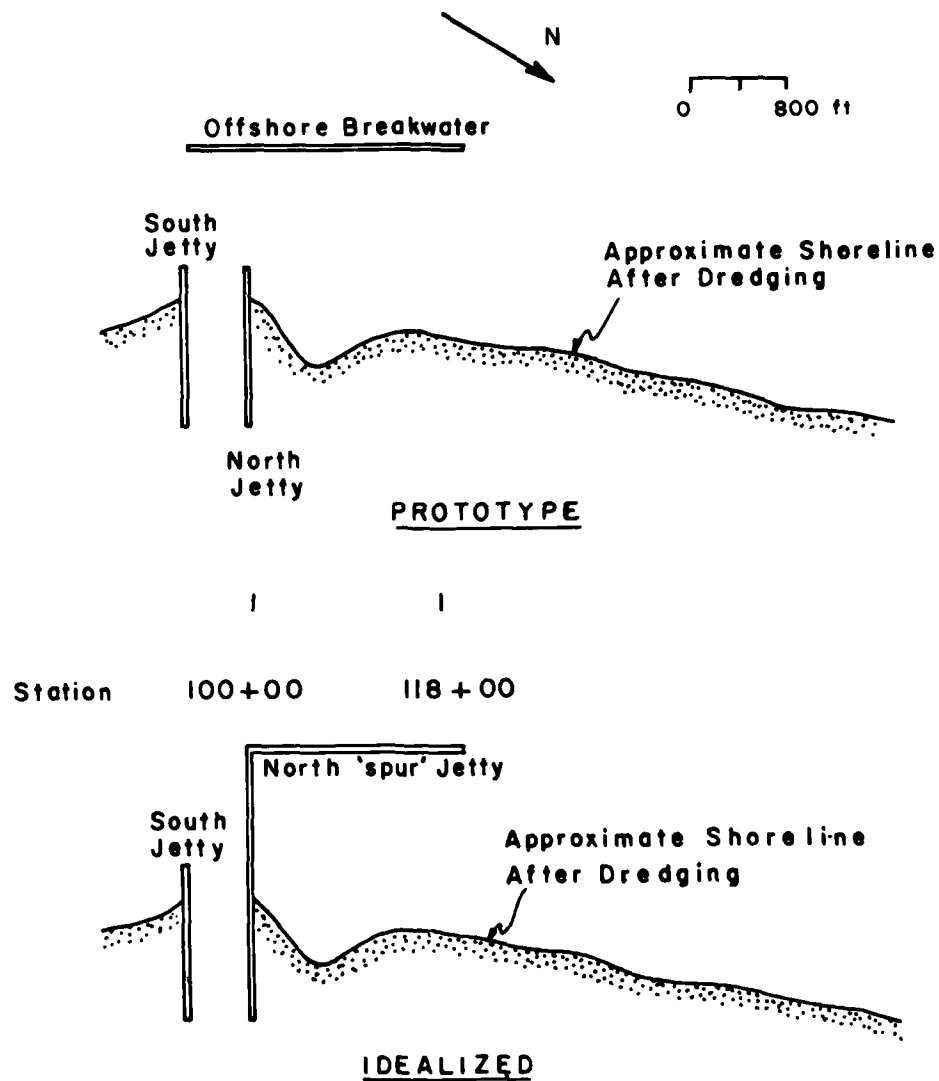


Figure 19. Idealized numerical model representation of offshore breakwater at Channel Islands Harbor, California.

equations) and the computer programs see Appendix D. The two values obtained for the surveys of 20 April and 1 December 1976 were averaged to obtain the value used in the model, $A = 0.2606$. Stations 101+00 through 121+00 were treated separately for the purpose of obtaining values with which to initialize those parts of the contours in the model and for comparison of the model predictions with the prototype values. Note that although the breakwater extends only to about Station 118+00, the influence of the structure and dredging extends beyond that location and so, although arbitrary, the 121+00 station was chosen as the dividing line. The initial and final values of the scaling parameter A for the profiles were 0.3233 and 0.3528, respectively. Because the initial shoreline is so irregular, a discontinuity between 121+00 and 122+00 is not evident.

One further idealization was made. The jetty-breakwater system was idealized as shown in Figure 19. This was required to simplify the physical situation, and although waves, currents, and sediment do pass through the opening in the prototype, it is hoped that they are of secondary importance.

The results of the numerical modeling of Channel Islands Harbor are presented in Figures 20 and 21. The first figure presents the shoreline contour (depth = 0); the second figure presents the farthest offshore, modeled contour. In both cases, the initial shoreline represents the model and prototype (after fitting of the profiles). The initial shoreline contour is further offshore along the section of beach beyond the end of the breakwater, while in the lee of the breakwater, as would be expected after dredging, the shoreline is closer to the base line. The final prototype contour has undergone erosion along the reach beyond the tip of the structure, and accretion in the lee.

The model's shoreline contour has undergone similar changes, and on the average, represents the final prototype contour quite well. The $JMAX^{th}$ contour has been displaced quite similarly to the shoreline contour with shoreward movement (erosion) along the reach beyond the tip of the breakwater and seaward movement (accretion) within. It appears that the final model's shoreline has predicted too much erosion and not enough accretion. Several parameters could be incorrect, with the onshore-offshore sediment transport rate coefficient, C_{OFF} , perhaps the most likely. Overall, the model seemed to predict reasonable values on the contours.

V. SUMMARY AND RECOMMENDATIONS

Some of the parameters that the model does not include are important and should be mentioned. As stated previously, the model does not include bar formation. This is precluded by an n -line system. There are no provisions for water level fluctuations or currents. Improvement to the model could also be facilitated with better longshore and cross-shore sediment transport relationships. A more reliable equation for distribution of sediment transport across the surf zone would also be helpful (or further testing and calibration of the equation proposed herein). Finally, combining refraction and diffraction using equations to predict their combined effect would improve the wave field. The program was constructed such that improvement

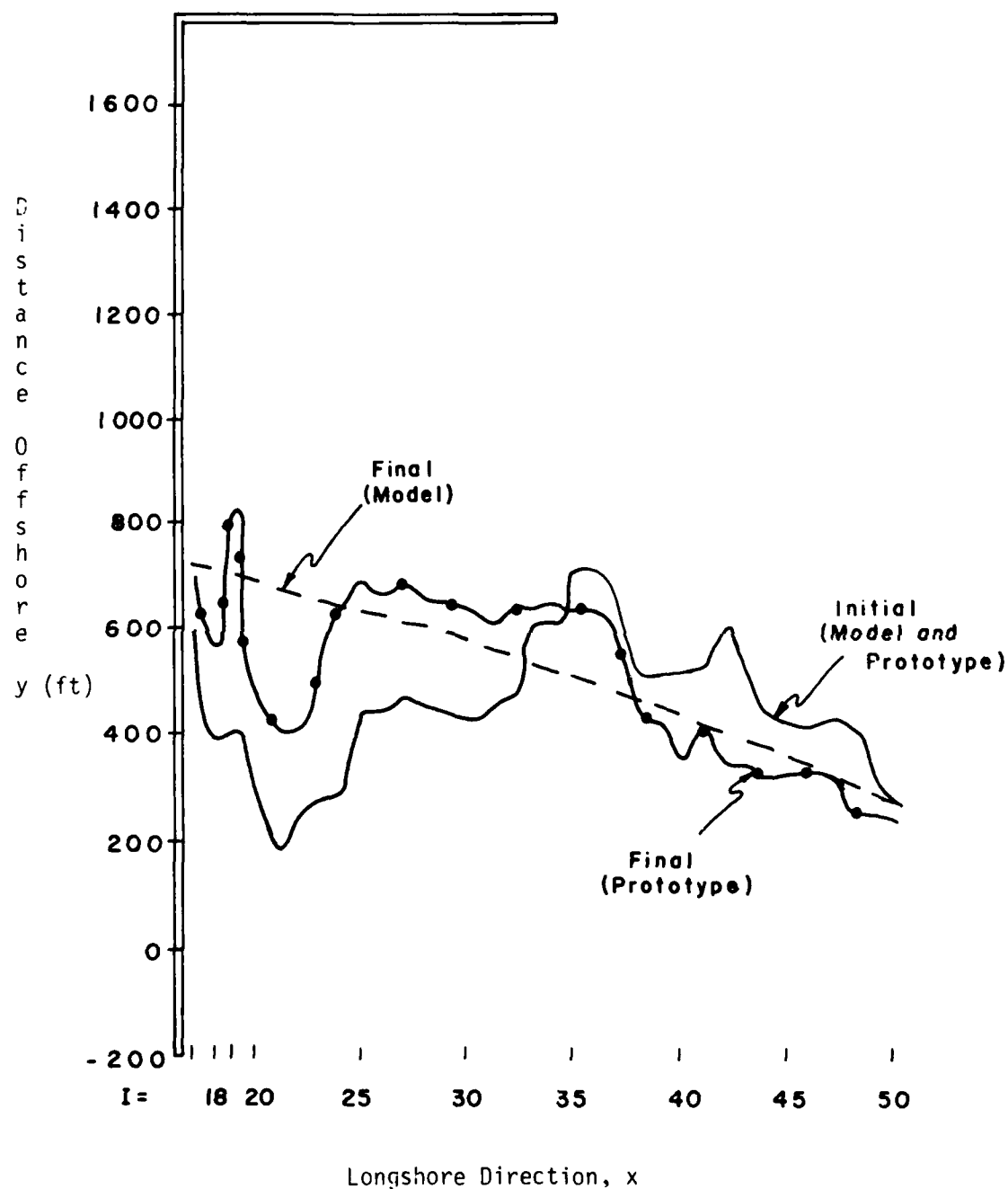


Figure 20. CIH simulation of shoreline contour, 20 April - 1 December 1976 (from LEO data).

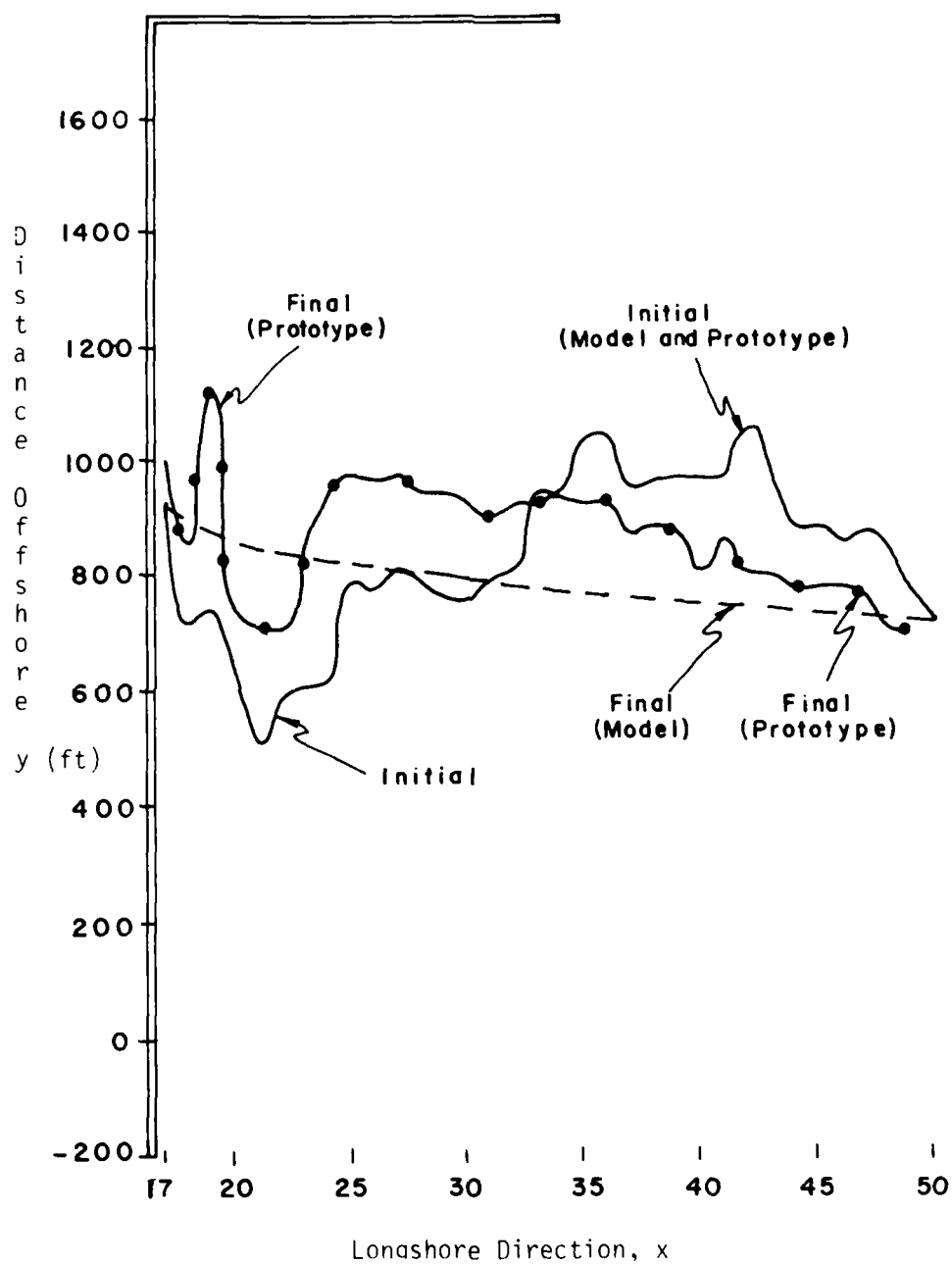


Figure 21. CIH simulation of (JMAX)th contour, 20 April - 1 December 1976 (from LEO data).

could be accomplished with minimum effort. Therefore, if a more suitable equation becomes available, the change of a subroutine should be sufficient for implementation of the equation.

Although the model is limited by the omission of the aforementioned parameters, it is reasonably correct. The ability to simulate various physical situations (shore-perpendicular structures, beach fills, breakwater and shore-perpendicular structures) has been demonstrated. In the CIH simulation where the data were first transformed to monotonically decreasing contours and LEO wave data were used, the model still predicts the prototype shoreline changes in a reasonable fashion.

Further research and model development should include exercising the model in a number of different situations. Several theoretical cases should be simulated, which if analyzed properly, would provide a tool for the coastal engineer. Combined refraction and diffraction should be included, if possible, along with any of the aforementioned parameters which have been omitted and for which relationships exist. Perhaps the most difficult problem to researchers working on modeling sediment transport in the vicinity of structures is the availability of field data. High-quality concurrent wave and bathymetric change data in the vicinity of coastal structures do not exist. One suggested field experiment is to monitor changes both updrift and downdrift of a jettied inlet which has a bypassing plant. Monitoring should begin immediately after bypassing, when the profiles are out of equilibrium. The recorded bathymetric and wave data would then provide data with which to calibrate, verify, and evaluate the existing models.

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APPENDIX A

DISCUSSION OF CONSTANTS AND SOME OF THE VARIABLES REQUIRED BY THE MODEL

Establishing the grid-contour system requires several variables. IMAX represents the number of cross-shore grid lines desired and JMAX the number of contours simulated. DX represents the spacing between the IMAX grid lines and DY the spacing between the contours. DX is a value which must be chosen along with IMAX and JMAX such that sufficient detail is obtained where necessary (e.g., in the shadow zone, if diffraction effects are believed to be very important, DX must be assigned a sufficiently small value so that at least some points lie within the shadow zone for the larger wave angles). DY is not a constant, but a dimensional array which is computed by the model according to the contour location. Once the depths of contours to be modeled are chosen, the initialization of DY and the y values are computed with the following equation after Dean, 1977

$$h = A y^{2/3} \quad (A-1)$$

where h is the depth, y is the offshore distance and A is the scaling parameter Dean gives values for A for several diameter sediments; however, if long-term beach profiles are available for the site being modeled, the modeler may want to choose a slightly different A value to more closely match the site-specific beach profile. Figure A-1 presents values of A versus diameter (after Moore, 1982). The model is programmed to input the h(I,J) values (depths as shown in Figure 1, called DEEP (I,J) in the program) read in the value of A (called ADEAN in program) and it then computes the y values. Also shown in Figure 1 is the height of the berm (BERM) and this value, along with the beach-face slope (SFACE), is required as program input and can be obtained from beach profile site data. Because the model does not include water level fluctuations such as tides, all values are to be referenced to a chosen datum. Other geometrical constants depending on the site include SJETTY (the length of the jetty), MMAX (the number of structures to be input), and IJET (M), M = 1,2,...MMAX (the smaller I value adjacent to the Mth structure's location). If no structure is required, as in a beach fill, the value of SJETTY must be entered as 0.0, with MMAX and IJET (M) entered as 1 and (IMAX/2), respectively. As set up presently, the groin locations must be equally spaced.

One constant used throughout the program is the breaking wave criteria (CAPPA in the program) equal to 0.78. It is required in several different computations and always governs the maximum wave height allowed according to the depth.

Another group of variables assigned values within the program is the sediment and fluid properties. These include fluid mass density, sediment mass density, porosity, and the angle of repose (e.g., RHO = 1.99, RHOS = 5.14, POROS = 0.40, and REPOSE = 32°, respectively). The values can easily be changed to reflect site conditions.

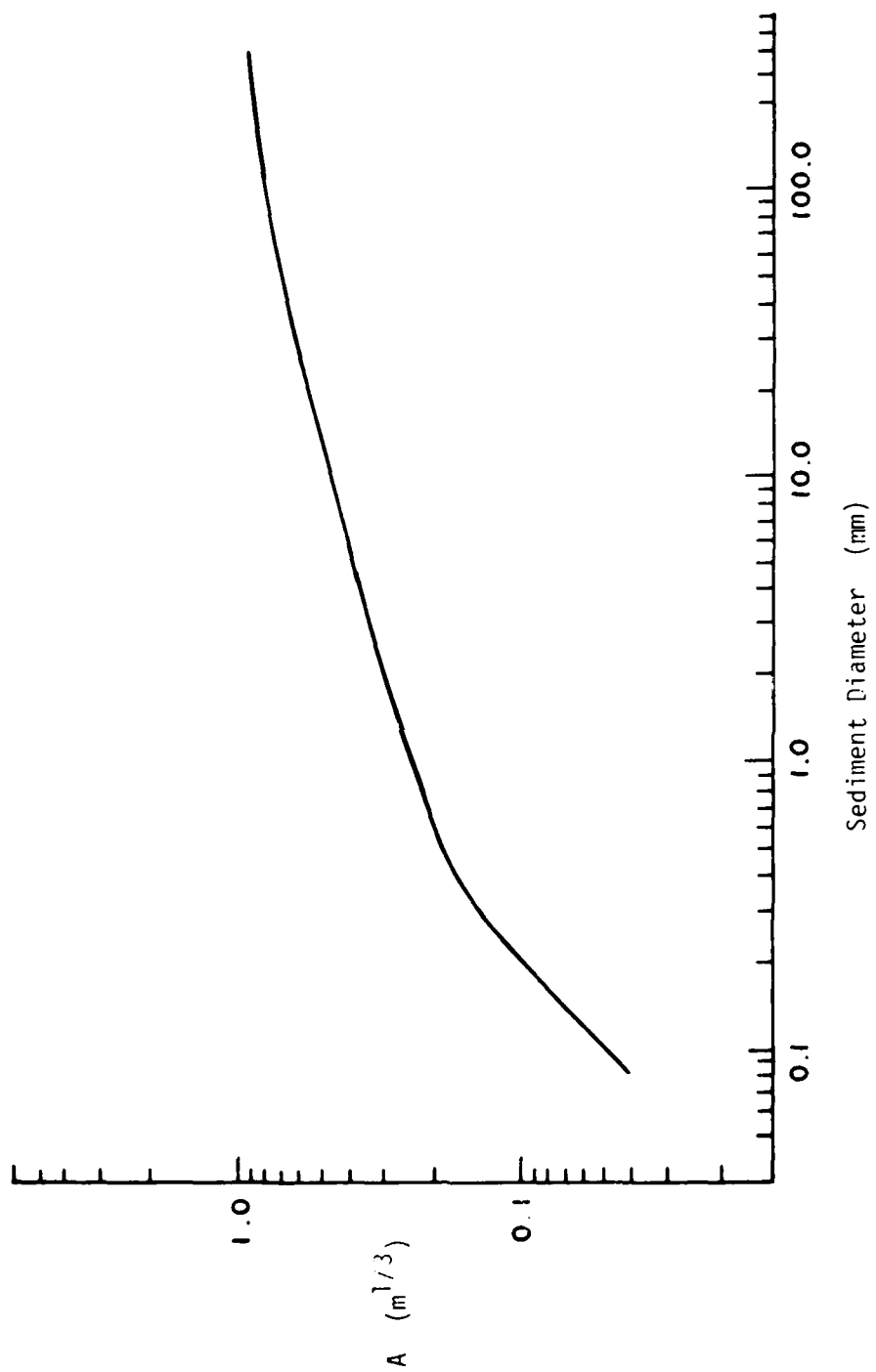


Figure A-1. A versus sediment diameter (after Moore, 1982).

Another very important set of constants is the constant chosen for the longshore and cross-shore components of sediment transport. Equation (27), the total longshore transport equation, contains the constant C' equal to

$$C' = \frac{K \rho (g)^{1/2}}{(\rho_s - \rho) (1 - p) (16) (\kappa)^{1/2}} \quad (A-2)$$

where

$K = 0.77$ (Komar and Inman, 1970)

g is the acceleration of gravity (32.17 ft/sec²)

ρ_s and ρ are the mass densities of the sediment and the seawater (5.14 and 1.99 slugs per cubic feet, respectively)

p is the porosity (0.40), and

κ is taken as 0.78.

Using these values to compute C' (TKSI in the program), a value of 0.325 is obtained. It is stressed that if any of these values are different for the site to be modeled, they should be changed and the program will compute another value for C' .

The parameter C_{OFF} is an "activity factor" which, based on earlier work primarily within the surf zone, was found to be

$$C_{OFF} = 10^{-5} \text{ ft/s,} \quad h < h_b$$

To generalize this concept for transport seaward of the surf zone, the wave energy dissipation per unit volume was utilized as a measure of mobilization of the bottom sediment. Inside the surf zone, the dominant wave energy dissipation is caused by wave breaking; outside the surf zone, the dominant mode of wave energy dissipation is due to bottom friction. These two components will be denoted by D_1 and D_2 , respectively.

(a) Energy Dissipation by Wave Breaking. The wave energy dissipation per unit volume by wave breaking, D_1 , is

$$D_1 = \frac{1}{h} \frac{\partial}{\partial y} (E C_G) \quad (A-3)$$

which, employing the spilling breaker assumption ($H = \kappa h$) within the surf zone, can be shown to be

$$D_1 = \frac{5}{16} \rho g^{3/2} \kappa^{2/3} h^{1/2} \frac{\partial h}{\partial y} \quad (A-4)$$

or

$$D_1 = \frac{5}{24} \rho g^{3/2} \kappa^{2/3} A^{3/2} \quad (A-5)$$

in which A is the scale parameter in the equilibrium beach profile

$$h(y) = Ay^{2/3} \quad (A-6)$$

(b) Energy Dissipation by Bottom Friction. The wave energy dissipation per unit volume due to bottom friction, D_2 , is

$$D_2 = \frac{1}{h} \tau u_b = \frac{1}{h} \rho C_f \overline{|u_b|^2} \quad (A-7)$$

in which C_f is a bottom friction coefficient, u_b is the bottom water particle velocity and the overbar indicates a time average. For linear waves, equation (A-7) can be reduced to

$$D_2 = \frac{1}{6\pi} \frac{\rho}{h} C_f \frac{H_c^3}{\sinh^3 kh} \quad (A-8)$$

The activity coefficient C_{OFF} , outside the surf zone, is expressed as

$$C_{OFF} = \frac{1}{\Gamma} \frac{D_2}{D_1} \times 10^{-5} \text{ ft/s}, \quad h > h_b \quad (A-9)$$

$$C_{OFF} = \frac{4}{5\Gamma} \frac{C_f^3}{g^{3/2} \kappa^{2/3} A^{3/2} h} \left(\frac{H}{\sinh kh} \right)^3 \times 10^{-5} \quad (A-10)$$

in which Γ is a parameter relating the efficiency with which breaking wave energy (which occurs primarily near the water surface) mobilizes the sediment bottom ($0 < \Gamma \leq 1$). Herein, Γ is taken to be one.

Figure A-2 presents an example of the variation of the activity coefficient versus relative depth for a particular wave period and deep water wave height. It is seen that the activity coefficient reduces rapidly with increasing depth.

The value of C_{OFF} for the physical modeling of Savage's (1959) data was taken as 10^{-4} feet per second. Perlin (1978) presents some rationale for choosing a value of C_{OFF} ; however, very little testing has been done and none is based on actual field measurement.

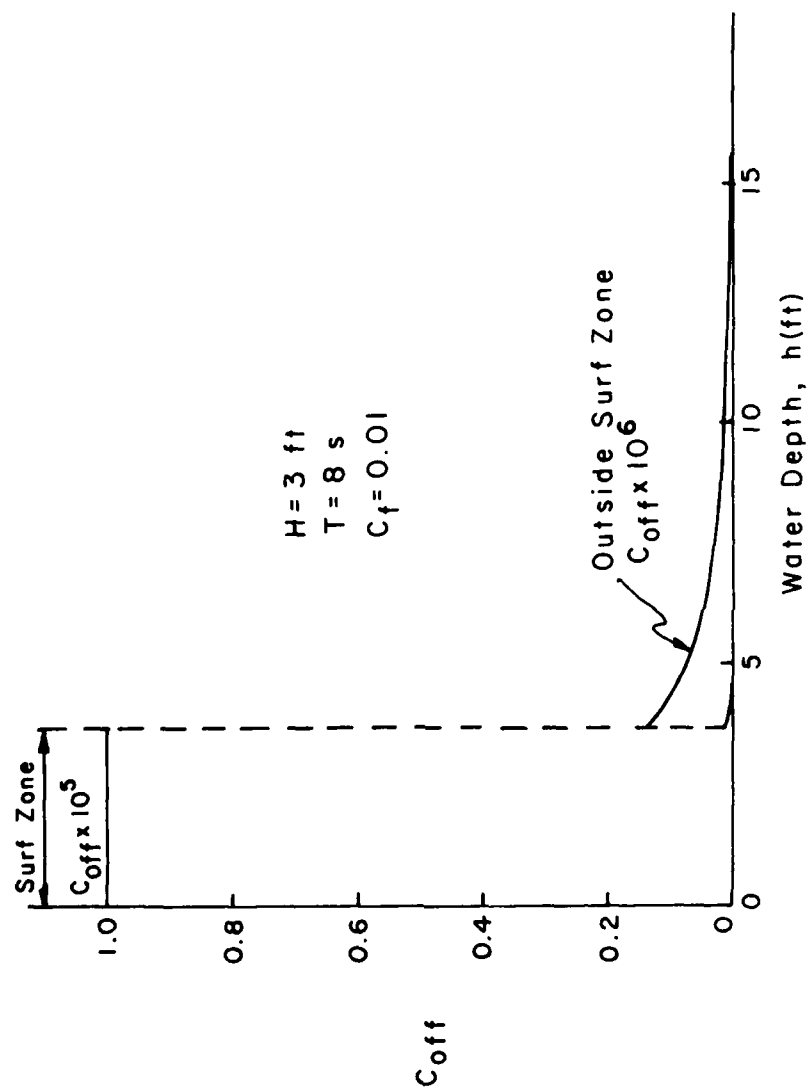


Figure A-2. Example of activity coefficient, C_{off} versus water depth, h , for particular wave conditions.

Finally, wave data are read into the program and the simulation begins. (For information regarding "Read Formats" for the various constants and variables, see Appendix E). Wave data required are wave height, wave period, wave angle relative to the x-axis of the model at a depth, WDEPTH and the duration of the wave climate (HS, T, ALPWIS, and a combination of NTIMES x DELT, respectively, in the model). As is always the case with numerical models, the time step and space steps are very important to both stability and accuracy. Time steps on the order of 3 to 6 hours (10,800 to 21,600 seconds) or less are recommended. However, the complexity of the bathymetry, variation and time series of the wave data, constants used (especially C_{OFF}) along with several other factors, greatly influences the stability and accuracy of the results.

Table A-1 lists several of the important variables in the computer program.

Table A-1. List of important variables in the program

ABAND	The input banded matrix which stores the values from equation (37)
ADEAN	The value of the scaling parameter in the equilibrium beach profile
ALPHAS	The angle a contour makes with the x-direction base line (counter-clockwise is positive)
ALPWIS	The angle (-90° to +90°) the wave crest makes with the x-direction (counter-clockwise is positive)
AMP	The amplitude of the diffracted wave in the shadow zone
ANGGEN	The wave angle at a depth, WDEPTH
ANGLOC	The local contour orientation angle
AWARE	See equations (36) and (37)
BERM	The height of the berm above water level
BMATRX	The matrix which, upon solution of the banded matrix problem yields the new y values
C	The wave celerity
CAPPA	The breaking wave index
CC	Constant which establishes the width of the distribution of sediment transport across the surf zone
CG	The group velocity throughout the wave field
CGEN	The linear wave theory celerity at a depth, WDEPTH

CGGEN	The linear wave theory group velocity at a depth, WDEPTH
CO	The deepwater, linear wave theory wave celerity
COFF	The onshore-offshore transport rate coefficient within the surf zone
CONST	The constant in the longshore sediment transport relationship (0.77)
CONST6	The space step, DX, multiplied by the activity coefficient
DEEP	The water depth at any grid location
DEEPB	The initial breaking depth along each profile (between adjacent profiles)
DEEBI	The initial breaking depth along each profile (at each profile, rather than between them)
DELT	The time-step in seconds (DELT x NTIMES = wave condition duration)
DIAM	The mean diameter of the sediment particles
DISTR	See equations (36) and (37)
DX	The alongshore space-step in the x-direction (distance between I values)
DY	The onshore-offshore space-step in the y-direction as defined by the stepped profile
ELO	The deepwater, linear wave theory wavelength
ELTIP	The wavelength at the tip of the structure
EPS	The change in the wave number which is acceptably small
G	The acceleration of gravity (32.17 feet/second ²)
GAMMA	The specific weight of seawater
H	The wave height throughout the wave field
HB	The maximum wave height which could exist throughout the wave field (where $H = 0.78 * h$)
HBI	The initial breaking wave height along any profile at the y values rather than between them
HBQ	The initial breaking wave height along any profile, between adjacent profiles

HGEN	Average wave height at a depth, WDEPTH
HS	The significant wave height input
I	The longshore grid location
IBREAK	The leeward side of the initial breaker location J value
IJET	Represents the lesser I value adjacent to the structure (these must be evenly spaced alongshore)
IMAX	The total number of grid points in the x-direction (alongshore)
J	The offshore contour location
JMAX	The value of the seawardmost contour simulated
JUSE	(JMAX + 2) the seawardmost contour at which the wave field is calculated
J1	Landward contour of refraction zone
J2	Seaward contour of refraction zone
J1REF	Landward J values of boundary of refraction zone
J2REF	Seaward J values of boundary of refraction zone
MMAX	The number of shore-perpendicular structures to be simulated (present maximum of 16)
NITER	The counterindex in the refraction routine
NTIME	The counterindex in the time simulation "DO" loop
NTIMES	The number of iterations of time-step, DELT, for which a particular wave is simulated
NUNIV	The total number of time-steps simulated at any time
PI	The value of $\pi = 3.141592654$
POROS	The porosity of the sediment
QX	The longshore sediment transport rate at a specific location
QXTOT	The total alongshore sediment transport rate due to the height and angle of the initial breaking wave
QY	The onshore-offshore sediment transport rate at a specific location
R	See equations (36) and (37)

REPOSE	The angle of repose of the sediment
RHO	The mass density of seawater
RHOND	The dimensionless distance from the tip of structure where diffraction is initiated
RHOS	The mass density of sediment
RK	The wave number
S3	See equations (36) and (37)
SFACE	The slope of the shoreface
SJETTY	The length of the shore-perpendicular structure (from the base line)
SIGMA	The wave radian frequency
T	The wave period
TAU	The dissipative interface parameter
THETA	The wave angle throughout the wave field
THEATO	The wave angle at the tip of the structure
TKSI	The longshore sediment transport rate coefficient
TWOPI	Twice the value of π
U	See equations (36) and (37)
UCRIT	The critical velocity required to move the sediment according to the Sheid's diagram
V	See equations (36) and (37)
WDEPTH	The depth of water in meters to which the input wave conditions are to be transformed
WEQ	The equilibrium profile distance between contours as defined by the stepped profile
XCOOR	The x-coordinate where the wave field is to be calculated. Together with YCOOR, they determine whether the position is within or beyond the diffraction shadow zone
XDISTN	The location of the structure along the shoreline in feet
Y	The distance offshore to the contours

YCOOR	The y-coordinate where the wave field is to be calculated. Together with XCOOR, they determine whether the position is within or beyond the diffraction shadow zone
YDISS	The value of y after the use of the dissipative interface
YOLD	The previous value of y
YZERO	The berm contour location
Z1	See equation (37)
Z2	See equation (37)

APPENDIX B
PROGRAM LISTING

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100 C* ***** PROGRAM IMPLICIT SEDTRAN
200 C*THIS PROGRAM IS SET-UP TO HANDLE MULTIPLE GROINS(M<=10)
300 COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
400 COMMON/AA/YZERO(60)
500 COMMON/BB/WEQ(60,20)
600 COMMON/B/ THETA(60,20),QXTOT(60), OLDANG(60,20), DY(60,20)
700 COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)
800 COMMON/N USED/JUSE,T,CD,CGEN,CGGEN,ANGGEN,DX,BERM,THETA0(10),MMAX
900 COMMON/D/SIGMA,G,ELO,JMAX,IMAX,PI,TWOPI,PIO2,HGEN,IJET(10),SJETTY
1000 COMMON/F/ADEAN,REPOSE,DIAM
1100 COMMON/AAA/DELT,NTIMES
1200 COMMON/COUNT/NUNIV
1300 COMMON/EXPL/QYEXP(60,20),YIMP(60,20)
1400 DIMENSION CHANGE(20),HC(10),TC(10)
1500 DIMENSION YORIG(60,20),YZERO0(60),SANGLE(20)
1600 NUNIV=0
1700 JMAX=8
1800 JUSE=JMAX+2
1900 IMAX=50
2000 PI=3.141592654
2100 TWOPI=PI*2.
2200 PIO2=PI/2.0
2300 REPOSE=32.*TWOPI/360.
2400 WRITE(6,732)
2500 732 FORMAT('*****')
2600 WRITE(6,733)
2700 733 FORMAT(2X,'TO WHAT DEPTH ARE THE WAVES TO BE TRANSFORMED')
2800 C*WDEPTH MUST BE A DEPTH BEYOND THE END OF THE STRUCT, PREFERABLY AT
2900 C**DEEP(JMAX) OR GREATER(OR ELSE SNELL'S LAW OR SHOAL COULD BLOWUP IN
3000 C***DEEPER WATER. IT'S IN METERS HERE!
3100 READ(5,770) WDEPTH
3200 770 FORMAT(10X,F10.3)
3300 WDEPTH=WDEPTH*3.28084
3400 WRITE(6,762) WDEPTH
3500 762 FORMAT(2X,'THE DEPTH (IN FT) WAVES TRANSFORMED TO, WDEPTH= '
3600 * F10.3)
3700 WRITE(6,732)
3800 WRITE(6,777)
3900 777 FORMAT(2X,'ITS TIME FOR SJETTY, BERM, SFACE, AND DIAM'.//)
4000 C*SJETTY MUST BE MUCH LESS THAN Y(I,JMAX)
4100 READ(5,776) SJETTY,BERM,SFACE,DIAM
4200 776 FORMAT(2F10.3,F10.4,F10.3)
4300 WRITE(6,761) SJETTY
4400 761 FORMAT(2X,'THE LENGTH OF THE STRUCTURE, SJETTY= ',F10.3)
4500 WRITE(6,740) BERM
4600 740 FORMAT(2X,'THE HEIGHT OF THE BERM, BERM= ',F10.3)
4700 WRITE(6,739)SFACE
4800 739 FORMAT(2X,'THE SLOPE OF THE BEACH FACE, SFACE= ',F10.4)
4900 WRITE(6,738) DIAM
5000 738 FORMAT(2X,'THE SEDIMENT DIAMETER, DIAM= ',F10.3)
5100 WRITE(6,732)
5200 780 FORMAT(2X,'SUPPLY MMAX( THE NO. OF GROINS) AND THEIR I-LOC'.//)
5300 UCRIT=16.3*SQRT(DIAM*0.00328)
5400 C*THE NO. OF MULTIPLE GROINS,MMAX MUST BE GIVEN THEIR X LOCATIONS.
5500 READ(5,779) MMAX
5600 779 FORMAT(I3)
5700 DO 760 M=1,MMAX
5800 C*IJET REPS LESSER I-VALUE ADJACENT TO STRUCTURE.
5900 760 READ(5,779) IJET(M)
6000 WRITE(6,759) (M,IJET(M),M=1,MMAX)
6100 759 FORMAT(2X,'THE NUMBER',I5,' GROIN IS LOCATED AT GRID',I5)
6200 WRITE(6,732)
6300 C*CONVERT TO RADIANS
6400 C*FIRST MUST GIVE Y COORS POSITIONS AND DEPTHS
6500 C*FIRST, MUST SET UP ALL OF THE DEEP-VALUES
6600 WRITE(6,773)
6700 773 FORMAT(2X,'NOW ENTER THE VALUE OF ADEAN')
6800 READ(5,774)ADEAN
6900 774 FORMAT(F10.4)
7000 WRITE(6,749) ADEAN
7100 749 FORMAT(2X,'THE VALUE OF ADEAN= ',F10.4,' IN THE EQ. H=AY**2/3')
7200 WRITE(6,732)

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7300      WRITE(6,772)
7400      772 FORMAT(2X,"READ IN THE SPACE STEP, Timestep",/)
7500      READ(5,775)  DX, DELT
7600      775 FORMAT(2(F10.3))
7700      WRITE(6,737)  DX
7800      737 FORMAT(2X,"THE VALUE OF THE LONGSHORE SPACE-STEP, DX= ",F10.3)
7900      WRITE(6,736)  DELT
8000      736 FORMAT(2X,"THE TIME-STEP IN SECONDS, DELT= ",F10.3)
8100      DATA CHANGE/1.,2.,3.,5.,7.,11.,14.,17.,25.,32.,808.,10*0.0/
8200      DO 220 J=1,JMAX+2
8300      DO 220 I=1,IMAX
8400      220 DEEP(I,J)=CHANGE(J)
8500      DATA(HC(I),I=1,8)/1.87,0.5,0.35.,25.,21.,20.,19.,19/
8600      DATA(TC(I),I=1,8)/2.,3.,4.,6.,8.,10.,12.,14./
8700      DO 200 J=1,JMAX+2
8800      DO 200 I=1,IMAX
8900      200 Y(I,J+1)=(0.5*(DEEP(I,J+1)+DEEP(I,J))/ADEAN)**1.5+Y(I,1)
9000      WRITE(6,732)
9100      C*****
9200      C*WE WILL ALWAYS REQUIRE Y(I,JMAX+2) TO COMPUTE DY AND YBAR.
9300      C*WE WILL ALWAYS REQUIRE DEEP(I,JMAX+2) TO COMP SEDIMENT TRANSPORT
9400      C*****
9500      WRITE(6,734)
9600      734 FORMAT(2X,"THE BOUNDARY Y-VALUES, I=1,IMAX ARE AS FOLLOWS",/)
9700      WRITE(6,801)  (Y(1,J),J=1,JMAX+2)
9800      WRITE(6,801)  (Y(IMAX,J),J=1,JMAX+2)
9900      WRITE(6,732)
10000     WRITE(6,735)
10100     735 FORMAT(/,2X,"THE DEPTHS BETWEEN CONTOURS ARE AS FOLLOWS",/)
10200     WRITE(6,801)  (DEEP(1,J),J=1,JMAX+2)
10300     WRITE(6,732)
10400     801 FORMAT(2X,10(F8.2))
10500     DO 2 I=1,IMAX
10600     2 YZERO(I)=Y(I,1)-(BERM/SPACE)
10700     C*WILL COMPUTE THE EQUIL WIDTH BETWEEN CONTOURS, HERE.
10800     DO 1 I=1,IMAX
10900     WEQ(I,1)=Y(I,1)-YZERO(I)
11000     DO 1 J=1,JMAX
11100     IF(J NE.1) GO TO 32
11200     YTEMP1=0.0
11300     GO TO 33
11400     32 YTEMP1=((0.5*(DEEP(I,J-1)+DEEP(I,J)))/ADEAN)**1.5
11500     33 YTEMP2=((0.5*(DEEP(I,J)+DEEP(I,J+1)))/ADEAN)**1.5
11600     WEQ(I,J+1)=YTEMP2-YTEMP1
11700     1 CONTINUE
11800     C*LET'S STORE THE ORIG VALUES TO COMPUTE VOL CHANGES OVER CONTOURS, LATER
11900     DO 796 I=1,IMAX+1
12000     YZERO0(I)=YZERO(I)
12100     DO 796 J=1,JMAX+2
12200     796 YORIG(I,J)=Y(I,J)
12300     C*****
12400     C*READ THE DISK FILE AND TRANSFORM PARAMETERS INTO MY UNITS.
12500     C*****!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
12600     C*ALL ADJUSTMENTS TO WAVE ANGLE, HEIGHT, CELERITY, GROUP VEL, WILL BE MADE
12700     C*HERE, AND THRUOUT THE REST OF THE PROG, THEY WILL BE AS IF OCCURRED
12800     C***AT WDEPTH!
12900     798 READ(5,799,END=1000)  HS,T,ALPWIS
13000     799 FORMAT(10X,3F6.1)
13100     NTIMES=1
13200     NCHECK=NUNIV+NTIMES
13300     HGEN=0.707107*HS
13400     SIGMA=TWOPI/T
13500     G=32.17
13600     CO=G*T/TWOPI
13700     ELO=CO*T
13800     IF(T.LE.2.0) GO TO 797
13900     HCC=0.23
14000     DO 444 I=2,7
14100     T2=TC(I)
14200     IF(T.GT.T2) GO TO 444
14300     T1=TC(I-1)
14400     DELTAT=T2-T1

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14500      DT=(T-T1)/DELTAT
14600      DTT=(T2-T)/DELT
14700      HCC=HC(I)*DT+HC(I-1)*DTT
14800      GO TO 446
14900      444 CONTINUE
15000      446 CONTINUE
15100      IF(HGEN.LT.HCC) GO TO 797
15200      ANGEN=ALPWIS*TWOPI/360
15300      C*****
15400      CALL WVNUM(WDEPTH,T,DUMKKK)
15500      C*ANGGEN,HGEN,CGEN,CGGEN REPRESENT THE WAVE ANGLE,HEIGHT,CELERITY AND
15600      C**GROUP VEL(RESPECT.) OF THE SPECIFIED WAVE INPUT AT A DEPTH. WDEPTH
15700      CALL WVNUM(11.0,T,DUMKKK)
15800      C11=TWOPI/(T*DUMKKK)
15900      CG11=0.5*C11*(1.+(2.*DUMKKK*11.0/SINH(2.*DUMKKK*11.0)))
16000      CGEN=TWOPI/(T*DUMKKK)
16100      CGGEN=0.5*CGEN*(1.+(2.*DUMKKK*WDEPTH/SINH(2.*DUMKKK*WDEPTH)))
16200      CALL TRANS
16300      797 IF(NCHECK.NE.NUNIV) NUNIV=NCHECK
16400      709 GO TO 798
16500      1000 CONTINUE
16600      STOP
16700      END
16800      C*****
16900      SUBROUTINE TRANS
17000      C*THIS SUBROUTINE WILL COMPUTE SEDIMENT TRANSPORT
17100      COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
17200      COMMON/AA/YZERO(60)
17300      COMMON/BB/WEQ(60,20)
17400      COMMON/B/ THETA(60,20),QXTOT(60),OLDANG(60,20),DY(60,20)
17500      COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)
17600      COMMON/N USED/JUSE,T.CO,CGEN,CGGEN,ANGGEN,DX,BERM,THETA0(10),MMAX
17700      COMMON/D/SIGMA,G,ELO,UMAX,IMAX,PI,TWOPI,PIO2,HGEN,IJET(10),SJETTY
17800      COMMON/E/RHO,RHOS,POROS,CONST,TKSI
17900      COMMON/F/ADEAN,REPOSE,DIAM
18000      COMMON/G/IBREAK(60),HNONBR(20)
18100      COMMON/P/HBQ(60),DEEPB(60)
18200      COMMON/ZZZ/NTIME
18300      COMMON/AAA/DELT,NTIMES
18400      COMMON/COUNT/NUNIV
18500      DIMENSION YOLD(60,20),R(60,20),S(60,20),HC(60,20),QY(60,20),YDISS(
18600      * 60,20)
18700      DIMENSION RHS1(60,20),S3(60,20),THETAB(60,20),ANGLOC(60,20)
18800      DIMENSION DISTR(60,20),AWARE(60,20)
18900      C*****
19000      C*****
19100      C***** NOTE : SIZE OF ABAND AND XL HAVE TO BE CHANGED
19200      C***** ACCORDING TO JMAX+1+JMAX AND JMAX+1,RESPECT
19300      C***** CHANGE REQ'D AT 7040 AND 18650
19400      C*****
19500      * ),BMatrix(432),ABAND(432,19),QX(60,20),XL(432,10),CONST6(60,20)
19600      COMMON/MP/ RKB(60),HBI(60),DEEPBI(60)
19700      COMMON/EXPL/QYEXP(60,20),YIMP(60,20)
19800      DIMENSION SANGLE(20)
19900      C*LET'S ZERO-OUT ALL OF THE DIMENSIONED MATRICES.
20000      DO 1000 J=1,JMAX+2
20100      SANGLE(J)=0.0
20200      DO 1000 I=1,IMAX+2
20300      YOLD(I,J)=0.0
20400      R(I,J)=0.0
20500      S(I,J)=0.0
20600      HC(I,J)=0.0
20700      QY(I,J)=0.0
20800      YDISS(I,J)=0.0
20900      RHS1(I,J)=0.0
21000      S3(I,J)=0.0
21100      THETAB(I,J)=0.0
21200      ANGLOC(I,J)=0.0
21300      DISTR(I,J)=0.0
21400      AWARE(I,J)=0.0
21500      QX(I,J)=0.0
21600      CONST6(I,J)=0.0

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21700      1000 CONTINUE
21800      RHO=1.99
21900      RHOS=5.14
22000      POROS=0.40
22100      CONST=0.77
22200      CAPPA=0.78
22300      TAU=0.25
22400      TKS1=(CONST*RHO*SQRT(G))/((RHOS-RHO)*(1.0-POROS)*16.0*SQRT(CAPPA))
22500      C* QX(I,J) IS THE TRANSPORT BETWEEN THE (I,J+1) AND (I,J) CONTOURS.
22600      C*THE 'DO 1 LOOP' SIMULATES TIME---TIME=DELT*NTIMES.
22700      COFF=0.00001
22800      GAMMA=RHO*G
22900      DO 1 NTIME=1,NTIMES
23000      NUNIV=NUNIV+1
23100      C*THE MATRICES ABAND AND BMATRX MUST BE "ZEROED OUT"
23200      K=0
23300      DO 26 I=2,IMAX-1
23400      DO 26 J=1,JMAX
23500      K=K+1
23600      BMATRX(K)=0.0
23700      DO 26 L=1,JMAX+1+JMAX
23800      26 ABAND(K,L)=0.0
23900      XNTIME=1.0*(NTIME)
24000      CALL PREDIF
24100      C*SMOOTHING OF THE WAVE ANGLE,THETA, IS RE'D TO ACCT FOR DIFF EFFECTS.
24200      CALL SMOOTH(THETA,IMAX,JMAX,IJET,SJETTY,MMAX,Y)
24300      CALL QTRAN
24400      C*FIRST THE LONGSHORE SEDIMENT TRANSPORT WILL BE DISTRIBUTED
24500      C****ACROSS THE SURF ZONE....
24600      CC=1.25
24700      C***QX(I,J) WILL BE DETERMINED BY SUBTRACTING FROM THE INTEGRAL
24800      C**OF QX FROM DEEP(I,J-1) TO INFINITY, THE INTEGRAL OF QX FROM DEEP(I,J)
24900      C**TO INFINITY. IN THIS WAY THE SEDIMENT TRANS FROM JMAX OUT GETS
25000      C***INCLUDED IN QX(I,JMAX). TO INCLUDE THE SWASH TRANS. WHEN J=1
25100      C*WE WILL SUBTRACT FROM 2 TO INFINITY FROM 1.0
25200      C*LOOP FOR VALUES WHICH ARE HELD CONST AND STORED.
25300      THETAB(1,1)=0.5*(THETA(1,1)+0.0)
25400      R(1,1)=0.5/(DX*(DEEP(1,1)+BERM/2.))
25500      DO 290 I=2,IMAX
25600      R(I,1)=0.5/(DX*(DEEP(I,1)+BERM/2.))
25700      C* THETAB(I,1)=0.25*(THETA(I,1)+THETA(I-1,1)+0.0)
25800      THETAB(I,1)=0.5*(THETA(I,1)+THETA(I-1,1))
25900      C*NO NEED TO COMPUTE PROP ANGLE AT STRUCTS BECAUSE QX =0.0 AT IJET(M)+1
26000      ANGLOC(I,1)=ATAN((Y(I,1)-Y(I-1,1))/DX)
26100      C*HBQ(IJET(M)+1) IS PROPERLY SET IN THE SUBROUTINE QTRAN.
26200      DISTR(I,1)=1.0-EXP(-((DEEP(I,1)**1.5+HBQ(I)*ADEAN**1.5)/(CC*DEEPB(I)**1.5)))**3)
26300      * (CC*DEEPB(I)**1.5))**3)
26400      DISTR(I,1)=DISTR(I,1)*TKS1*HBQ(I)**2.5
26500      DO 290 J=2,JMAX
26600      R(I,J)=0.5/(DX*(DEEP(I,J)-DEEP(I,J-1)))
26700      THETAB(I,J)=0.5*(THETA(I,J)+THETA(I-1,J))
26800      ANGLOC(I,J)=ATAN((Y(I,J)-Y(I-1,J))/DX)
26900      DISTR(I,J)=EXP(-((DEEP(I,J-1)**1.5+HBQ(I)*ADEAN**1.5)/(CC*DEEPB(I)**1.5)))**3)-EXP(-((DEEP(I,J)**1.5+HBQ(I)*ADEAN**1.5)/(CC*DEEPB(I)**1.5)))**3)
27000      * DEEPB(I)**1.5))**3)
27100      DISTR(I,J)=DISTR(I,J)*TKS1*HBQ(I)**2.5
27200      290 CONTINUE
27300      DO 301 J=1,JMAX
27400      DO 301 I=2,IMAX
27500      AWARE(I,J)=DELT*R(I,J)*(QX(I,J)-QX(I+1,J)+QY(I,J)-QY(I,J+1))+Y(I,J)
27600      * )
27700      S1=2.*SIN(THETAB(I,J))*COS(THETAB(I,J))*(-1.+2.*(COS(
27800      * ANGLOC(I,J)))**2)
27900      S2=COS(2.*THETAB(I,J))*COS(ANGLOC(I,J))/(SQRT(DX**2+
28000      * (Y(I,J)-Y(I-1,J))**2))
28100      S3(I,J)=S2*DISTR(I,J)
28200      IF(SJETTY EQ 0.0) GO TO 302
28300      DO 325 M=1,MMAX
28400      IF(I NE IJET(M)+1) GO TO 325
28500      IF(THETA(M) GE 0.0) ISIDE=IJET(M)
28600      IF(THETA(M) LT 0.0) ISIDE=IJET(M)+1
28700      YSEA=0.5*(Y(ISIDE,J)+Y(ISIDE,J+1))
28800      YSHORE=0.5*(Y(ISIDE,J)+Y(ISIDE,J-1))
28900

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29000      IF(YSEA GT SJETTY AND YSHORE GT SJETTY) GO TO 302
29100      IF(YSEA GT SJETTY AND YSHORE LE SJETTY) GO TO 298
29200      C*BECAUSE A NO FLOW B C IS USED ALONG THE STRUCT, NO ATTN WAS PAID
29300      C**TO GETTING PROPER VALUES OF ANGLOC, THETAB,DISTR,ETC.
29400      S3(I,J)=0.0
29500      DISTR(I,J)=0.0
29600      GO TO 302
29700      325 CONTINUE
29800      GO TO 302
29900      C***ABOVE, ALL PARAMETERS(I E .S1,S2,S3,THETAB,DISTR,ANGLOC)
30000      C***ARE COMPUTED AS IF THE STRUCT IS NOT THERE THE B C AT THE
30100      C***STRUCT TIP ASSUMES QX COMPUTED AS IF NO STRUCT PRESENT AND THEN
30200      C***BYPASSES ACCORDING TO "RATIO"
30300      298 RATIO=(YSEA-SJETTY)/(YSEA-YSHORE)
30400      S3(I,J)=S3(I,J)*RATIO
30500      DISTR(I,J)=DISTR(I,J)*RATIO
30600      302 RHS1(I,J)=DISTR(I,J)*S1-S3(I,J)*(Y(I,J)-Y(I-1,J))
30700      301 CONTINUE
30800      CALL BREAK(IMAX,JMAX)
30900      C*TO DETERMINE DECAY OF CONST6(I,J),NEED WAVE NO. AT BREAKING.
31000      DO 754 I=1,IMAX+1
31100      754 CALL WNUM(DEEPBI(I),T,RKB(I))
31200      C*USING SHIELD'S DIAG.Y AXIS=0.05 & (TAUO=RHO*C*U**2).GET UCRIT(FT/SEC)
31300      UCRIT=16.3*SQRT(DIAM*.00328)
31400      DO 750 I=1,IMAX+1
31500      CONST6(I,1)=COFF*DX
31600      DO 750 J=2,JMAX+2
31700      C*CONST6(I,J) GOES W/ QY(I,J) WHICH IS ASSOC W/ DEEP(I,J-1)
31800      IF(DEEP(I,J-1) LE DEEPBI(I)) GO TO 751
31900      C*HERE MUST CAUSE COFF TO DECAY (WE'RE BEYOND SURF ZONE)
32000      UMAXB=HBI(I)*G*T*RKB(I)/(2.*TWOPI*COSH(RKB(I)*DEEPBI(I)))
32100      UMAX=H(I,J-1)*G*T*RK(I,J-1)/(2.*TWOPI*COSH(RK(I,J-1)*DEEP(I,J-1)))
32200      IF(UCRIT LT UMAX AND UCRIT LT UMAXB) GO TO 749
32300      CONST6(I,J)=0.0
32400      GO TO 750
32500      749 TOP=0.01*H(I,J-1)**3*SIGMA**3/(SINH(RK(I,J-1)*DEEP(I,J-1))**3)
32600      BOT=DEEP(I,J-1)*(0.625*TWOPI*G**1.5*0.78**2*ADEAN**1.5+
32700      *(0.01*HBI(I)**3*SIGMA**3/(DEEPBI(I)*(SINH(RKB(I)*DEEPBI(I))**3)))
32800      CONST6(I,J)=DX*COFF*TOP/BOT
32900      GO TO 750
33000      751 CONST6(I,J)=COFF*DX
33100      750 CONTINUE
33200      K=0
33300      C**PUT INTO BANDED FORM USING THE ALGORITHM A(M,N)->B(M,NN) WHERE
33400      C***NN=KB+1.M*N(KB IS THE NUMBER OF LOWER CODIAGONALS(=JMAX,HERE)).
33500      DO 304 I=2,IMAX+1
33600      DO 304 J=1,JMAX
33700      K=K+1
33800      AWARE(I,J)=AWARE(I,J)+DELT*RHS1(I,J)*R(I,J)-DELT*R(I,J)*RHS1(I+1,J
33900      * )+DELT*R(I,J)*CONST6(I,J)*WEQ(I,J)-DELT*R(I,J)*CONST6(I,J+1)*
34000      * WEQ(I,J+1)
34100      YDUM=YZERO(I)
34200      IF(J NE 1) YDUM=Y(I,J-1)
34300      AWARE(I,J)=AWARE(I,J)+DELT*R(I,J)*CONST6(I,J)*0.5*(YDUM-Y(I,J))
34400      * -DELT*R(I,J)*CONST6(I,J+1)*0.5*(Y(I,J)-Y(I,J+1))
34500      U=DELT*R(I,J)*S3(I,J)
34600      V=DELT*R(I,J)*S3(I+1,J)
34700      Z1=DELT*R(I,J)*CONST6(I,J)*0.5
34800      Z2=DELT*R(I,J)*CONST6(I,J+1)*0.5
34900      C*NOW WILL SET UP THE MATRICES ABAND AND BMATRX.
35000      ABAND(K,JMAX+1)=1.0+U+V+Z1+Z2
35100      IF(I NE 2) GO TO 305
35200      AWARE(I,J)=AWARE(I,J)+U*Y(I-1,J)
35300      GO TO 310
35400      305 ABAND(K,1)=-U
35500      310 IF(I NE IMAX+1) GO TO 306
35600      AWARE(I,J)=AWARE(I,J)+V*Y(IMAX,J)
35700      GO TO 311
35800      306 ABAND(K,JMAX+1+JMAX)=-V
35900      311 IF(J NE 1) GO TO 307
36000      ABAND(K,JMAX+1)=ABAND(K,JMAX+1)-Z1
36100      AWARE(I,1)=AWARE(I,1)+Z1*(YZERO(I)-Y(I,1))
36200      GO TO 312

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36300      307 ABAND(K,JMAX)--Z1
36400      312 IF(J NE JMAX) GO TO 308
36500          AWARE(I,J)=AWARE(I,J)+Z2*Y(I,JMAX+1)
36600          GO TO 309
36700      308 ABAND(K,JMAX+2)=-Z2
36800      309 BMATRX(K)=AWARE(I,J)
36900      304 CONTINUE
37000          KMAX=K
37100      C**CALL IMSL ROUTINE LEQT1B TO SOLVE THE BANDED MATRIX.
37200          CALL LEQT1B(ABAND,KMAX,JMAX,JMAX,432,BMATRX,1,432,0,XL,IER)
37300      C*NOW, GIVE Y'S THEIR NEW VALUES STORING OLD VALUES IN YOLD.
37400          K=0
37500          DO 315 I=2,IMAX-1
37600              YOLD(I,JMAX+1)=Y(I,JMAX+1)
37700          DO 315 J=1,JMAX
37800              K=K+1
37900              YOLD(I,J)=Y(I,J)
38000              Y(I,J)=BMATRX(K)
38100      315 CONTINUE
38200          DO 320 J=1,JMAX+3
38300              YOLD(1,J)=Y(1,J)
38400      320 YOLD(IMAX,J)=Y(IMAX,J)
38500      C*WILL USE ABBOTT'S DISSIPATIVE INTERFACE TO RID HIGH FREQ OSCILLATIONS
38600          DO 650 J=1,JMAX
38700          DO 650 I=2,IMAX-1
38800              YDISS(I,J)=TAU*Y(I-1,J)+(1.-2.*TAU)*Y(I,J)+TAU*Y(I+1,J)
38900              IF(SJETTY.EQ.0.0) GO TO 650
39000          DO 649 M=1,MMAX
39100              IF(I NE IJET(M).AND.I NE IJET(M)+1) GO TO 649
39200              IF(Y(IJET(M),J).GT.SJETTY.OR.Y(IJET(M)+1,J).GT.SJETTY)GO TO 649
39300              IF(I.EQ.IJET(M))YDISS(I,J)=TAU*Y(I-1,J)+(1.-TAU)*Y(I,J)
39400              IF(I.EQ.(IJET(M)+1))YDISS(I,J)=TAU*Y(I+1,J)+(1.-TAU)*Y(I,J)
39500      649 CONTINUE
39600      650 CONTINUE
39700          DO 651 J=1,JMAX
39800          DO 651 I=2,IMAX-1
39900              651 Y(I,J)=YDISS(I,J)
40000      C*THIS LOOP WILL STORE THE IMPLICIT Y VALUES REQ'D TO COMP QY&QX
40100          DO 40 I=1,IMAX+1
40200          DO 40 J=1,JMAX+3
40300      40 YIMP(I,J)=Y(I,J)
40400      C*THIS LOOP WILL EXPLICITLY MOVE CONTOURS SEAWARD IF REPOSE EXCEEDED.
40500          KOUNT=0
40600          SLOPEM=TAN(0.9*REPOSE)
40700          DO 48 I=1,IMAX
40800      43 KOUNT=KOUNT+1
40900          IF(KOUNT GT.50000) GO TO 41
41000      C*LET US COMPUTE ALL THE SLOPES(PSLOP) FOR EACH CHANGE IN DEPTH.
41100          DO 47 J=1,JMAX+1
41200              DUM=-BERM/2.0
41300              IF(J NE 1) DUM=DEEP(I,J-1)
41400              DELH=0.5*(DEEP(I,J+1)+DEEP(I,J))-0.5*(DEEP(I,J)+DUM)
41500              PSLOP=DELH/(Y(I,J+1)-Y(I,J))
41600      47 SANGLE(J)=ATAN(PSLOP)
41700      C*FIND THE MIN NEG SLOPE ANGLE OR THEN THE POS SLOPE>REPOSE OR FORGET IT
41800          ASLOPM=-1.0E50
41900          ASLOPP=0.0
42000          DO 46 J=1,JMAX+1
42100              IF(SANGLE(J) GT 0.0) GO TO 45
42200              IF(SANGLE(J) GT ASLOPM)ASLOPM=SANGLE(J)
42300              IF(ASLOPM.EQ.SANGLE(J)) JM=J
42400          GO TO 46
42500      45 IF(SANGLE(J).GT.REPOSE.AND.SANGLE(J) GT ASLOPP)ASLOPP=SANGLE(J)
42600              IF(ASLOPP.EQ.SANGLE(J)) JP=J
42700      46 CONTINUE
42800              IF(ASLOPM.EQ.-1.0E50.AND.ASLOPP.EQ.0.0) GO TO 42
42900              IF(ASLOPM.EQ.-1.0E50) GO TO 44
43000              DUM=-BERM/2.
43100              IF(JM NE 1) DUM=DEEP(I,JM-1)
43200              ALTER=((0.5/SLOPEM*(DEEP(I,JM+1)-DUM))-(Y(I,JM+1)-Y(I,JM)))/
43300              * (1.0+((DEEP(I,JM+1)-DEEP(I,JM))/(DEEP(I,JM)-DUM)))
43400              Y(I,JM+1)=Y(I,JM+1)+ALTER

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43500      Y(I,JM)=Y(I,JM)-(ALTER*(DEEP(I,JM+1)-DEEP(I,JM))/(DEEP(I,JM)-DUM))
43600      QYEXP(I,JM+1)=QYEXP(I,JM+1)+DX/DELT*ALTER*(DEEP(I,JM+1)-DEEP(I,JM)
43700      *
43800      GO TO 43
43900      44 CONTINUE
44000      DUM=-BERM/2.
44100      IF(JP.NE.1) DUM=DEEP(I,JP-1)
44200      ALTER=((0.5/SLOPEM*(DEEP(I,JP+1)-DUM))-(Y(I,JP+1)-Y(I,JP)))/
44300      * (1.0+((DEEP(I,JP+1)-DEEP(I,JP))/(DEEP(I,JP)-DUM)))
44400      Y(I,JP+1)=Y(I,JP+1)+ALTER
44500      Y(I,JP)=Y(I,JP)-(ALTER*(DEEP(I,JP+1)-DEEP(I,JP))/(DEEP(I,JP)-DUM))
44600      QYEXP(I,JP+1)=QYEXP(I,JP+1)+DX/DELT*ALTER*(DEEP(I,JP+1)-DEEP(I,JP)
44700      *
44800      GO TO 43
44900      42 WEQ(I,JMAX+1)=Y(I,JMAX+1)-Y(I,JMAX)
45000      48 CONTINUE
45100      C*IF WE GET SENT HERE, LOOP 444 WILL CATCH THE CROSSED CONTOURS.
45200      41 CONTINUE
45300      C*NOW WE CAN COMPUTE QX'S AND QY'S!
45400      DO 318 I=2,IMAX
45500      C*ALL IMPLIC AND EXPLIC MOVEMENT OF YZERO WILL BE TAKEN CARE OF HERE
45600      QY(I,1)=-BERM*DX*(Y(I,1)-YOLD(I,1))/DELT
45700      YZERO(I)=YZERO(I)+(Y(I,1)-YOLD(I,1))
45800      319 DO 318 J=1,JMAX
45900      QX(I,J)=RHS1(I,J)-S3(I,J)*YIMP(I,J)+S3(I,J)*YIMP(I-1,J)
46000      318 QY(I,J+1)=CONST6(I,J+1)*(0.5*(YIMP(I,J)+YOLD(I,J)-YIMP(I,J+1)
46100      * -YOLD(I,J+1))+WEQ(I,J+1))
46200      DO 323 J=1,JMAX
46300      QX(1,J)=QX(2,J)
46400      323 QX(IMAX+1,J)=QX(IMAX,J)
46500      C*TOTAL QYS WILL BE COMP FROM IMPLIC AND EXPLIC VALUES.THEN ZERO QYEXP
46600      DO 39 I=1,IMAX+1
46700      DO 39 J=1,JMAX+3
46800      QY(I,J)=QY(I,J)+QYEXP(I,J)
46900      39 QYEXP(I,J)=0.0
47000      C*THIS CHECK WILL BOMB THINGS OUT IF CONTOURS HAVE CROSSED.
47100      DO 444 II=1,IMAX
47200      DO 444 JJ=1,JMAX
47300      C*IF CONTOURS CROSS AT ANY TIME WANT PROGRAM TO STOP!
47400      IF(Y(II,JJ).LT.Y(II,JJ+1)) GO TO 444
47500      WRITE(6,103)
47600      WRITE(6,*/ ) NUNIV
47700      DO 150 J=1,JMAX
47800      150 WRITE(6,100) (QX(I,J),I=1,IMAX)
47900      DO 151 J=1,JMAX
48000      151 WRITE(6,101) (QY(I,J),I=1,IMAX)
48100      DO 152 J=1,JMAX
48200      152 WRITE(6,100) (Y(I,J),I=1,IMAX)
48300      103 FORMAT(2X,'THE CONTOURS HAVE CROSSED AND SOMETHING IS WRONG',/)
48400      DO 19 J=1,JMAX
48500      19 WRITE(6,100) (YOLD(I,J),I=1,IMAX)
48600      GO TO 445
48700      444 CONTINUE
48800      WRITE(6,*/ ) NUNIV
48900      C*THE FOLLOWING STATEMENT DETERMINES AT WHAT FREQ EVERYTHING IS WRITTEN'
49000      IF(MOD(NUNIV,10).NE.0) GO TO 1
49100      C*LET'S WRITE ALL OF IT OUT.
49200      WRITE(6,926) NUNIV
49300      926 FORMAT(2X,'THE TOTAL ELAPSED NUMBER OF TIME-STEPS. NUNIV= ',15,/)
49400      800 FORMAT(2X,14(F8.4))
49500      C*
49600      C*900 WRITE(6,800) (THETA(I,J),J=1,JMAX)
49700      C* DO 903 J=1,JMAX+1
49800      C*903 WRITE(6,801) DEEP(1,J)
49900      C* DO 906 I=1,IMAX
50000      C*906 WRITE(6,800) (H(I,J),J=1,JMAX)
50100      C* DO 755 J=1,JMAX
50200      C*755 WRITE(6,800) (CONST6(I,J),I=1,IMAX)
50300      801 FORMAT(2X,14(F8.2))
50400      WRITE(6,107)
50500      107 FORMAT(/,2X,'THE LONGSHORE TRANSPORTS,QX, FOLLOW')
50600      DO 15 J=1,JMAX
50700      15 WRITE(6,100) (QX(I,J),I=1,IMAX)

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010000 WRITE(100)
010001 100 FORMAT(2X THE ON OFFSHORE TRANSPORTS OF FOLLOW 1
010002 DO 10 J=1, JMAX
010003 10 WRITE(100) (Q(I), J=1, JMAX)
010004 WRITE(100)
010005 100 FORMAT(2X THE NEW CONTINU VALUES OF FOLLOW 1
010006 DO 10 J=1, JMAX
010007 10 WRITE(100) (V(I), J=1, JMAX)
010008 100 FORMAT(2X 111111 11)
010009 101 FORMAT(2X 111111 11)
010010 1 CONTINUE
010011 RETURN
010012 GO TO 440
020000 440 STOP
020001 440 CONTINUE
020002 END
020003
020004 .....
020005 SUBROUTINE QTRAN
020006 C THIS SUBROUTINE CALC THE BREAKER HEIGHT FOR EACH
020007 C OF THE 1 GRID LINES METHOD FINIS V LOCATIONS BEFORE AND AFTER
020008 C BREAKING HAS OCCURRED BY REFRACTION THEN USES SIMILATING TO GET THE
020009 C CORRU SNEEL S LAW IS USED FOR REFRACTION OVER THE SHORT DIST TO BREAKING
020010 C Q(I), J) IS THE TRANS BETWEEN(1, J) AND (1, J) AT THE BREAKING
020011 COMMON/AA/ ZER0(60)
020012 COMMON/BB/ THE1(60, 20), QN0(60), D1DANG(60, 20), D(60, 20)
020013 COMMON/CC/ H(60, 20), C(60, 20), D0(60, 20), D0(60, 20), V(60)
020014 COMMON/NN/ USED, JUSE, J(60), GEN, CGEN, ANGEN, BY, BERM, THE1A(100, JMAX)
020015 COMMON/SS/ SIGMA, G, FLD, JMAX, JMAX, PI, TWOT, PI02, THIN, L0(100), SURF1
020016 COMMON/G/ BREAK(60), THIN(60, 20)
020017 COMMON/E/ H(60), W(60), P(60), (ONST, INST)
020018 COMMON/P/ H(60), D(60)
020019 CAPPA=0.70
020020 DO 1 J=1, JMAX
020021 DO 2 J=1, JMAX
020022 J=JMAX+J+1
020023 H(0)=H(1, J)
020024 H(0)=H(0, J)
020025 C CAN ONLY USE COMB ON ONE SIDE OF STRUCT CAN I AVG HERE?
020026 IF(SURF1 EQ 0.0) GO TO 4
020027 DO 4 M=1, JMAX
020028 IF(NE J(ITEM)+1) GO TO 4
020029 IF(ITEM) OF 0.0) SIDE=J(ITEM)
020030 IF(ITEM) OF 1.0) SIDE=J(ITEM)+1
020031 C AT STRUCT TIP ASSUMES Q0 (IMP AS IF NO STRUCT IS PRESENT)
020032 VSEA=0.01*V(SIDE, J)
020033 IF(VSEA GT SURF1) GO TO 3
020034 H(0)=H(SIDE, J)
020035 H(0)=H(SIDE, J)
020036 GO TO 3
020037 4 CONTINUE
020038 3 IF(H(0) LT H(0)) GO TO 1
020039 DEPR(1)=((H(0)-H(0)) / H(0)) * 100.0
020040 DEPR(1)=DEPR(1) / 20.0
020041 CAPPA=0.0
020042 H(0)=CAPPA*DEPR(1)
020043 C H(0) AND DEPR(1) WILL BE COMPUTED ACCORDING TO THE WAVE DIR
020044 C AT THE STRUCTURE TIP THE1A
020045 IF(SURF1 EQ 0.0) GO TO 1
020046 DO 6 M=1, JMAX
020047 IF(NE J(ITEM)+1) GO TO 6
020048 C THE TRANSPORTING WAVES WILL BE COMPUTED USING THE WAVE TO PROP SIDE
020049 IF(ITEM) OF 0.0) GO TO 11
020050 DEPR(1)=((H(0)-H(0)) / H(0)) * 100.0
020051 DEPR(1)=DEPR(1) / 20.0
020052 CAPPA=0.0
020053 H(0)=CAPPA*DEPR(1)
020054 GO TO 1
020055 6 CONTINUE
020056 GO TO 1
020057 2 CONTINUE
020058 1 CONTINUE

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58100 C*IF THE OFFSHORE WAVE HT IS ZERO, NEVER GET TO HERE
58200 C*HOWEVER IF THE H IS SUCH THAT IT WOULD BREAK INSHORE OF Y(I,2)
58300 C*DEEPB(I) WOULD STILL BE ZERO AND DISTR(I,J) WOULD BLOW-UP.
58400 DO 20 I=1,IMAX
58500 IF(DEEPB(I).GT.0.0) GO TO 20
58600 DEEPB(I)=(H(I,1)*DEEP(I,1)**0.25/CAPPA)**0.8
58700 HBQ(I)=CAPPA*DEEPB(I)
58800 20 CONTINUE
58900 HBQ(1)=HBQ(2)
59000 HBQ(IMAX+1)=HBQ(IMAX)
59100 DEEPB(1)=DEEPB(2)
59200 DEEPB(IMAX+1)=DEEPB(IMAX)
59300 RETURN
59400 END
59500 C*****
59600 SUBROUTINE BREAK(IMAX,JMAX)
59700 C*ROUTINE WILL DETERMINE HB AND DEEPB ON THE GRID LINES RATHER
59800 C* THAN BETWEEN THEM. REQ'D FOR COFF BEYOND SURF ZONE.
59900 COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
60000 COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)
60100 COMMON/MP/ RKB(60),HBI(60),DEEPBI(60)
60200 CAPPA=0.78
60300 DO 1 I=2,IMAX
60400 DO 2 JJ=1,JMAX
60500 J=JMAX-JJ+1
60600 IF(H(I,J).LT.HB(I,J)) GO TO 2
60700 DEEPBI(I)=((H(I,J+1)*DEEP(I,J+1)**0.25)/CAPPA)**0.8
60800 HBI(I)=CAPPA*DEEPBI(I)
60900 C***ONCE THE HEIGHT & DEPTH AT BREAKING ARE FOUND, GO TO NEXT GRID-LINE.
61000 GO TO 1
61100 2 CONTINUE
61200 1 CONTINUE
61300 DO 20 I=1,IMAX
61400 IF(DEEPBI(I).GT.0.0) GO TO 20
61500 DEEPBI(I)=(H(I,1)*DEEP(I,1)**0.25/CAPPA)**0.8
61600 HBI(I)=CAPPA*DEEPBI(I)
61700 20 CONTINUE
61800 DEEPBI(1)=DEEPBI(2)
61900 DEEPBI(IMAX+1)=DEEPBI(IMAX)
62000 HBI(1)=HBI(2)
62100 HBI(IMAX+1)=HBI(IMAX)
62200 RETURN
62300 END
62400 C*****
62500 SUBROUTINE REFRAC(JBEGIN,JEND,NPTS,IBEGIN,IEND,ISTART,M)
62600 COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
62700 COMMON/AA/ YZERO(60)
62800 COMMON/B/ THETA(60,20),QXTOT(60),OLDANG(60,20),DY(60,20)
62900 COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)
63000 COMMON/N USED/JUSE,T,CD,CGEN,CGGEN,AIIGGEN,DX,BERM,THETA0(10),MMAX
63100 COMMON/D/ SIGMA,G,ELO,JMAX,IMAX,PI,TWJPI,PIO2,HGEN,IJET(10),SJETTY
63200 COMMON/G/ IBREAK(60),HNONBR(20)
63300 COMMON/ZZZ/ NTIME
63400 DIMENSION JBEGIN(60),JEND(60)
63500 C***** THIS SUBROUTINE WILL DETERMINE H AND
63600 C***** THETA AT THE MID PT OF Y VALUES.
63700 C***TAU IS THE FACTOR WHICH RECOUPLES THE REFRACTION EQS.SEE ABBOTT
63800 TAU=0.25
63900 C*MUST PRESCRIBE THE WAVE ANGLE AT THE OUTERMOST CONTOUR BOX
64000 C*SNELL'S LAW WILL BE USED TO START THINGS OFF.
64100 C*THETA(I,J) WILL BE AT AREA'S CENTER AND WILL USE Y(I,J) IN NEG Y-DIR
64200 C*WILL INITIALIZE ALL THETA'S USING SNELL'S LAW.
64300 DO 206 I=IBEGIN,IEND
64400 C*INITIALIZE TWO J-VALUES BEYOND JMAX,IF IN REGION 1.
64500 IF(JEND(I).EQ.JMAX) JINIT=2
64600 IF(JEND(I).NE.JMAX) JINIT=0
64700 DO 206 J=JBEGIN(I),JEND(I)+JINIT
64800 C*MUST CORRECT FOR THE CONTOUR ORIENTATION, ALPHAS.
64900 IF(I.NE.IBEGIN) GO TO 960
65000 ALPHAS(I,J)=ATAN((0.5*(Y(I+1,J)+Y(I+1,J+1))-0.5*(Y(I,J)
65100 * +Y(I,J+1))))/DX)
65200 GO TO 962

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65300      960 IF(I.NE.IEND) GO TO 961
65400      ALPHAS(I,J)=ATAN((0.5*(Y(I,J)+Y(I,J+1))-0.5*(Y(I-1,J)
65500      *   +Y(I-1,J+1)))/DX)
65600      GO TO 962
65700      961 ALPHAS(I,J)=ATAN((0.5*(Y(I+1,J)+Y(I+1,J+1))-0.5*
65800      *   (Y(I-1,J)+Y(I-1,J+1)))/(2.*DX))
65900      962 DALPHA=ANGGEN-ALPHAS(I,J)
66000      THETA(I,J)=ARSIN((C(I,J)/CGEN)*SIN(DALPHA))
66100      C*MUST GET THETA WRT THE X-AXIS.
66200      THETA(I,J)=THETA(I,J)+ALPHAS(I,J)
66300      206 CONTINUE
66400      C*NOW, WE MUST COMP THE BOUN WAVE HTS SO THE HTS CAN BE COMPUTED.
66500      C*WILL USE THE EQ. ***** DEL DOT (E*CG)=0.0
66600      C*NOW WE WILL CORRECT THE HT FOR SHOALING AND REFRACTION TO THE B.C.
66700      C*WILL ALSO INITIALIZE H'S WITH THESE EQUATIONS FOR ENTIRE ARRAY.
66800      DO 500 I=IBEGIN,IEND
66900      C*INITIALIZE TWO J-VALUES BEYOND JMAX IF IN REGION 1.
67000      IF(JEND(I) EQ.JMAX) JINIT=2
67100      IF(JEND(I).NE.JMAX) JINIT=0
67200      DO 500 J=JBEGIN(I),JEND(I)+JINIT
67300      H(I,J)=HGEN*SQRT(CGGEN/CG(I,J))*SQRT(COS(ANGGEN)/COS(THETA(I,
67400      *   J)))
67500      IF(HB(I,J).LT.H(I,J)) H(I,J)=HB(I,J)
67600      500 CONTINUE
67700      C*-----
67800      C*****
67900      C*LET'S FILL THE DY ARRAY.
68000      C*DY WILL BE INDEXED AS THE THETA TO WHICH WE ARE GOING.
68100      DO 209 I=IBEGIN,IEND
68200      DO 209 J=JBEGIN(I)+1,JEND(I)
68300      DY(I,J-1)=0.5*(Y(I,J-1)+Y(I,J))-0.5*(Y(I,J)+Y(I,J+1))
68400      209 CONTINUE
68500      NITERS=100
68600      DO 100 NITER=1,NITERS
68700      SUMANG=0.0
68800      C*DO "60 LOOP" GOES FROM 2 TO IMAX IF ISTART =IBEGIN
68900      C*DO "60 LOOP" GOES FROM IMAX-1 TO 1 IF ISTART=IEND
69000      DO 60 II=IBEGIN,IEND
69100      C*MUST HAVE IT SET UP SO THAT THE KNOWN BOUNDARIES ANGLES AREN'T RECOMP
69200      IF(ISTART.EQ.IBEGIN) I=II
69300      IF(ISTART.EQ.IBEGIN .AND. I.EQ.IBEGIN) GO TO 60
69400      IF(ISTART.EQ.IEND) I=IEND-II+IBEGIN
69500      IF(ISTART.EQ.IEND .AND. I.EQ.IEND) GO TO 60
69600      C*ADX EQUALS ACTUAL DELTA X ACROSS SPACE STEP.
69700      C*ONLY ON BOUNDARIES WHERE FORWARD OR BACKWARD DIFFERENCING.
69800      IF(I.NE.IBEGIN) GO TO 6
69900      ADX=DX
70000      IP=I+1
70100      IM=I
70200      GO TO 12
70300      6 IF(I.NE.IEND) GO TO 10
70400      ADX=DX
70500      IP=I
70600      IM=I-1
70700      GO TO 12
70800      10 ADX=2.0*DX
70900      IP=I+1
71000      IM=I-1
71100      12 CONTINUE
71200      DO 40 J=JBEGIN(I),JEND(I)-1
71300      C*WILL GO FROM (JMAX-1) TO 1 BECAUSE THAT'S THE DIR WAVE COMES IN FROM.
71400      JJ=JEND(I)-1-J+JBEGIN(I)
71500      OLDANG(I,JJ)=THETA(I,JJ)
71600      C*LOCATE MIDPOINT BETWEEN TWO ADJACENT BLOCK CENTERS
71700      C*BECAUSE THETA'S JJ-VALUE IS THE SAME AS THE FIRST SHOREWARD Y VALUE
71800      C*MUST USE JJ, JJ+1, AND JJ+2 TO COMPUTE YBAR.
71900      YBAR=0.25*(Y(I,JJ)+2.0*Y(I,JJ+1)+Y(I,JJ+2))
72000      C*LOCATE APPROPRIATE INDICES ON IP AND IM GRID LINES.
72100      IMINUS=-1
72200      IPLUS=+1
72300      CALL LOC(IM,JJ,JOIM,USIM,YBAR,IMINUS)
72400      CALL LOC(IP,JJ,JOIP,USIP,YBAR,IPLUS)
72500      C*NOW USE THE CONSERVATION OF WAVES EQUATION.

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72600      PART1C=RK(I,JJ+1)*SIN(THETA(I,JJ+1))
72700      PART2=-DY(I,JJ)/ADX
72800      C*WILL LINEARLY INTERPOLATE TO DETERMINE RK*COS(THETA) AT I+1 AND I-1.
72900      C*IF NO ADJ SHOREWARD PT EXISTS, PUT IN ZERO FOR TERMS IN GOV. EQ.
73000      IF(JSIM.NE.O) GO TO 301
73100      PART3B=0.0
73200      GO TO 302
73300      301 TOPIM=RK(IM,JOIM-1)*COS(THETA(IM,JOIM-1))
73400      BOTIM=RK(IM,JSIM)*COS(THETA(IM,JSIM))
73500      TOTALB=0.5*(Y(IM,JOIM)+Y(IM,JOIM-1))-0.5*(Y(IM,JSIM+1)+Y(IM,JSIM))
73600      DUMB=0.5*(Y(IM,JOIM)+Y(IM,JOIM-1))-YBAR
73700      PART3B=((TOTALB-DUMB)*(TOPIM-BOTIM)/TOTALB)+BOTIM
73800      302 IF(JSIP.NE.O) GO TO 303
73900      PART3A=0.0
74000      GO TO 304
74100      303 TOPIP=RK(IP,JOIP-1)*COS(THETA(IP,JOIP-1))
74200      BOTIP=RK(IP,JSIP)*COS(THETA(IP,JSIP))
74300      TOTALA=0.5*(Y(IP,JOIP)+Y(IP,JOIP-1))-0.5*(Y(IP,JSIP+1)+Y(IP,JSIP))
74400      DUMA=0.5*(Y(IP,JOIP)+Y(IP,JOIP-1))-YBAR
74500      PART3A=((TOTALA-DUMA)*(TOPIP-BOTIP)/TOTALA)+BOTIP
74600      304 PART3=PART3A-PART3B
74700      C*NOW MUST FIND RK*SIN(THETA) FOR I+1 AND I-1 AT J+1
74800      YBARP=0.25*(Y(I,JJ+1)+2.*Y(I,JJ+2)+Y(I,JJ+3))
74900      CALL LOC(IM,JJ+1,JPOIM,JPSIM,YBARP,IMINUS)
75000      CALL LOC(IP,JJ+1,JPOIP,JPSIP,YBARP,IPLUS)
75100      IF(JPSIM.NE.O) GO TO 305
75200      PART1B=0.0
75300      GO TO 306
75400      305 TOPM=RK(IM,JPOIM-1)*SIN(THETA(IM,JPOIM-1))
75500      BOTM=RK(IM,JPSIM)*SIN(THETA(IM,JPSIM))
75600      TOTB=0.5*(Y(IM,JPOIM)+Y(IM,JPOIM-1))-0.5*(Y(IM,JPSIM+1)+
75700      * Y(IM,JPSIM))
75800      DUMPB=0.5*(Y(IM,JPOIM)+Y(IM,JPOIM-1))-YBARP
75900      PART1B=((TOTB-DUMPB)*(TOPM-BOTM)/TOTB)+BOTM
76000      306 IF(JPSIP.NE.O) GO TO 307
76100      PART1A=0.0
76200      GO TO 308
76300      307 TOPP=RK(IP,JPOIP-1)*SIN(THETA(IP,JPOIP-1))
76400      BOTP=RK(IP,JPSIP)*SIN(THETA(IP,JPSIP))
76500      TOTA=0.5*(Y(IP,JPOIP)+Y(IP,JPOIP-1))-0.5*(Y(IP,JPSIP+1)+Y(IP,JPSIP
76600      * ))
76700      DUMPA=0.5*(Y(IP,JPOIP)+Y(IP,JPOIP-1))-YBARP
76800      PART1A=((TOTA-DUMPA)*(TOPP-BOTP)/TOTA)+BOTP
76900      308 PART1=TAU*PART1B+(1.-2.*TAU)*PART1C+TAU*PART1A
77000      IF(JPSIM.EQ.O)PART1=(1.-TAU)*PART1C+TAU*PART1A
77100      IF(JPSIP.EQ.O)PART1=TAU*PART1B+(1.-TAU)*PART1C
77200      ARG=((PART1+PART2*PART3)/RK(I,JJ))
77300      C*IF THE ROUTINE IS TO BLOWUP,USE SNELLS LAW.
77400      IF(ABS(ARG).LE.1.O) GO TO 41
77500      ARG=(C(I,JJ)/C(I,JJ+1))*SIN(THETA(I,JJ+1))
77600      IF(ARG.GT.1.O) ARG=1.O
77700      THETA(I,JJ)=ARSIN(ARG)
77800      GO TO 42
77900      41 THETA(I,JJ)=ARSIN(ARG)
78000      42 THETA(I,JJ)=0.5*(THETA(I,JJ)+OLDANG(I,JJ))
78100      SUMANG=SUMANG+(ABS(THETA(I,JJ)-OLDANG(I,JJ)))
78200      40 CONTINUE
78300      60 CONTINUE
78400      C*MUST EJECT IF WE HAVE REACHED AN ACCEPTABLE ITERATION ERROR
78500      C*IF THE SUM OF THE ABSOLUTE VALUE OF ANGLE CHANGES DURING AN ITERATION
78600      C* AVERAGES LESS THAN 0.02 DEGREES PER GRID ITS CLOSE ENOUGH.
78700      IF(SUMANG.LT.(NPTS*0.0035)) GO TO 215
78800      IF(NITER.GE.50) GO TO 215
78900      100 CONTINUE
79000      WRITE(6,803)
79100      215 CONTINUE
79200      C*ITERATION LOOP FOR THE WAVE HEIGHT.
79300      DO 501 NITER=1,NITERS
79400      SUMH=0.0
79500      DO 510 II=IBEGIN,IEND
79600      C*MUST HAVE IT SET UP SO THAT THE KNOWN BOUNDARIES HTS. AREN'T RECOMP
79700      IF(ISTART.EQ.IBEGIN) I=II
79800      IF(ISTART.EQ.IBEGIN .AND. I.EQ.IBEGIN) GO TO 510

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79900      IF(ISTART.EQ.IEND) I=IEND-II+IBEGIN
80000      IF(ISTART.EQ.IEND .AND. I.EQ.IEND) GO TO 510
80100      C*ADX EQUALS ACTUAL DELTA X ACROSS SPACE STEP.
80200      C*ONLY ON BOUNDARIES WHERE FORWARD OR BACKWARD DIFFERENCING.
80300      IF(I.NE.IBEGIN) GO TO 503
80400      ADX=DX
80500      IP=I+1
80600      IM=I
80700      GO TO 505
80800      503 IF(I.NE.IEND) GO TO 504
80900      ADX=DX
81000      IP=I
81100      IM=I-1
81200      GO TO 505
81300      504 ADX=2.0*DX
81400      IP=I+1
81500      IM=I-1
81600      505 CONTINUE
81700      DO 502 J=JBEGIN(I),JEND(I)-1
81800      JJ=JEND(I)-1-J+JBEGIN(I)
81900      HOLD(I,JJ)=H(I,JJ)
82000      YBAR=0.25*(Y(I,JJ)+2.0*Y(I,JJ+1)+Y(I,JJ+2))
82100      CALL LOC(IM,JJ,JOIM,JSIM,YBAR,IMINUS)
82200      CALL LOC(IP,JJ,JOIP,JSIP,YBAR,IPLUS)
82300      PART13=(H(I,JJ+1)**2.)*CG(I,JJ+1)*COS(THETA(I,JJ+1))
82400      PART2=DY(I,JJ)/ADX
82500      IF(JSIM.NE.O) GO TO 311
82600      PART4B=0.0
82700      GO TO 312
82800      311 TOPIMH=(H(IM,JOIM-1)**2.)*CG(IM,JOIM-1)*(SIN(THETA(IM,JOIM-1)))
82900      BOTIMH=(H(IM,JSIM)**2.)*CG(IM,JSIM)*SIN(THETA(IM,JSIM))
83000      TOTALB=0.5*(Y(IM,JOIM)+Y(IM,JOIM-1))-0.5*(Y(IM,JSIM+1)+Y(IM,JSIM))
83100      DUMB=0.5*(Y(IM,JOIM)+Y(IM,JOIM-1))-YBAR
83200      PART4B=((TOTALB-DUMB)*(TOPIMH-BOTIMH)/TOTALB)+BOTIMH
83300      312 IF(JSIP.NE.O) GO TO 313
83400      PART4A=0.0
83500      GO TO 314
83600      313 TOPIPH=(H(IP,JOIP-1)**2.)*CG(IP,JOIP-1)*SIN(THETA(IP,JOIP-1))
83700      BOTIPH=(H(IP,JSIP)**2.)*CG(IP,JSIP)*SIN(THETA(IP,JSIP))
83800      TOTALA=0.5*(Y(IP,JOIP)+Y(IP,JOIP-1))-0.5*(Y(IP,JSIP+1)+Y(IP,JSIP))
83900      DUMA=0.5*(Y(IP,JOIP)+Y(IP,JOIP-1))-YBAR
84000      PART4A=((TOTALA-DUMA)*(TOPIPH-BOTIPH)/TOTALA)+BOTIPH
84100      314 PART4=PART4A-PART4B
84200      YBARP=0.25*(Y(I,JJ+1)+2.0*Y(I,JJ+2)+Y(I,JJ+3))
84300      CALL LOC(IM,JJ+1,JPOIM,JPSIM,YBARP,IMINUS)
84400      CALL LOC(IP,JJ+1,JPOIP,JPSIP,YBARP,IPLUS)
84500      IF(JPSIM.NE.O) GO TO 315
84600      PART12=0.0
84700      GO TO 316
84800      315 TOPMH=(H(IM,JPOIM-1)**2.)*CG(IM,JPOIM-1)*COS(THETA(IM,JPOIM-1))
84900      BOTMH=(H(IM,JPSIM)**2.)*CG(IM,JPSIM)*COS(THETA(IM,JPSIM))
85000      TOTB=0.5*(Y(IM,JPOIM)+Y(IM,JPOIM-1))-0.5*(Y(IM,JPSIM+1)+Y(IM,JPSIM))
85100      DUMPB=0.5*(Y(IM,JPOIM)+Y(IM,JPOIM-1))-YBARP
85200      PART12=((TOTB-DUMPB)*(TOPMH-BOTMH)/TOTB)+BOTMH
85300      316 IF(JPSIP.NE.O) GO TO 317
85400      PART11=0.0
85500      GO TO 318
85600      317 TOPPH=(H(IP,JPOIP-1)**2.)*CG(IP,JPOIP-1)*COS(THETA(IP,JPOIP-1))
85700      BOTPH=(H(IP,JPSIP)**2.)*CG(IP,JPSIP)*COS(THETA(IP,JPSIP))
85800      TOTA=0.5*(Y(IP,JPOIP)+Y(IP,JPOIP-1))-0.5*(Y(IP,JPSIP+1)+Y(IP,JPSIP))
85900      DUMPA=0.5*(Y(IP,JPOIP)+Y(IP,JPOIP-1))-YBARP
86000      PART11=((TOTA-DUMPA)*(TOPPH-BOTPH)/TOTA)+BOTPH
86100      318 PART1H=TAU*PART12+(1.-2.*TAU)*PART13+TAU*PART11
86200      IF(JPSIM.EQ.O)PART1H=(1.-TAU)*PART13+TAU*PART11
86300      IF(JPSIP.EQ.O)PART1H=TAU*PART12+(1.-TAU)*PART13
86400      ARG=((PART1H+PART2*PART4)/(CG(I,JJ)*COS(THETA(I,JJ))))
86500      C*IF THERE IS TO BE AN INVALID SQRT,USE LINEAR SHOALING.
86600      IF(ARG.GE.O.) GO TO 44
86700      ARG=(CG(I,JJ+1)*COS(THETA(I,JJ+1)))/(CG(I,JJ)*COS(THETA(I,JJ)))
86800      IF(ARG.LT.O.O) ARG=0.0
86900      H(I,JJ)=H(I,JJ+1)*SQRT(ARG)
87000      GO TO 45

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87100      44 H(I,JJ)=SQRT(ARG)
87200      45 H(I,JJ)=0.5*(H(I,JJ)+HOLD(I,JJ))
87300      HNONBR(JJ)=H(I,JJ)
87400 C*IBREAK(I)=JJ, THEREFORE JJ WILL BE LEEWARD SIDE OF GRID AT INIT BREAK
87500      IF(HB(I,JJ).LT. H(I,JJ) .AND. HB(I,JJ+1).GE.HNONBR(JJ+1))
87600      *      IBREAK(I)=JJ
87700      IF(HB(I,JJ).LT.H(I,JJ)) H(I,JJ)=HB(I,JJ)
87800      SUMH=SUMH+ABS(H(I,JJ)-HOLD(I,JJ))
87900      502 CONTINUE
88000      510 CONTINUE
88100      IBREAK(IEND)=IBREAK(IEND-1)
88200      IBREAK(IBEGIN)=IBREAK(IBEGIN+1)
88300      IF(SUMH.LT.(NPTS*0.01)) GO TO 507
88400      IF(NITER.GE.50) GO TO 507
88500      501 CONTINUE
88600      WRITE(6,803)
88700      507 CONTINUE
88800      802 FORMAT(2X,4(F15.5),////)
88900      803 FORMAT(2X,"AFTER NITERS ITERATIONS, CONVERGENCE WAS NOT REACHED")
89000      804 FORMAT(2X,"THE WAVE HT. ROUTINE CONVERGED IN, NITER= ",I5,/)
89100      805 FORMAT(2X,"THIS IS MY CHECKING WRITE STATEMENT")
89200      806 FORMAT(2X,"THE WAVE ANGLE ROUTINE CONVERGED IN, NITER= ",I5,/)
89300      RETURN
89400      END
89500 C*****
89600      SUBROUTINE DIFF(RHOND,THETAO,ANGLE,AMP)
89700 C****DIFFRACTION ABOUT SEMI INFINITE BREAKWATER (PENNEY-PRICE)
89800      PI=3.14159265
89900      ABSS=SIN(0.5*(ANGLE-THETAO))
90000      ABSP=SIN(0.5*(ANGLE+THETAO))
90100      ABC=COS(ANGLE-THETAO)
90200      ABC1=COS(ANGLE+THETAO)
90300      XX=RHOND*ABC
90400      XXC=COS(XX)
90500      XXS=SIN(XX)
90600      XX1=RHOND*ABC1
90700      XXC1=COS(XX1)
90800      XXS1=SIN(XX1)
90900      AL=SQRT(RHOND/PI)
91000      SIG=2.0*AL*ABSS
91100      SIGP=-2.0*AL*ABSP
91200      CALL FRES(SIG,C,S,FR,FI)
91300      CALL FRES(SIGP,CP,SP,FRP,FIP)
91400      SUM1=XXC*FR+XXS*FI+XXC1*FRP+XXS1*FIP
91500      SUM2=XXC*FI-XXS*FR+XXC1*FIP-XXS1*FRP
91600      AMP=SQRT(SUM1**2+SUM2**2)
91700      RETURN
91800      END
91900 C*****
92000      SUBROUTINE FRES(A,C,S,FR,FI)
92100 C*FRESNEL INTEGRAL SUBROUTINE****AFTER ABROMOWITZ AND STEGUN.
92200      Z=ABS(A)
92300      P02=1.5707963
92400      FZ=(1.0+0.926*Z)/(2.0+1.792*Z+3.104*Z*Z)
92500      GZ=1.0/(2.0+4.142*Z+3.492*Z*Z+6.670*Z*Z*Z)
92600      XX=P02*Z*Z
92700      CZ=COS(XX)
92800      SZ=SIN(XX)
92900      C=0.5-GZ*CZ+FZ*SZ
93000      S=0.5-FZ*CZ-GZ*SZ
93100      IF(A.GT.0.0) GO TO 50
93200      C=-C
93300      S=-S
93400      50 FR=0.5*(1.0+C+S)
93500      FI=-0.5*(S-C)
93600      RETURN
93700      END
93800 C*****
93900      SUBROUTINE PREDIF
94000      COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
94100      COMMON/AA/YZERO(60)
94200      COMMON/B/ THETA(60,20),QXTOT(60),OLDANG(60,20),DY(60,20)
94300      COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)

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94400      COMMON/N USED/JUSE,T.CO,CGEN,CGGEN,ANGGEN,DX,BERM,THETA0(10),MMAX
94500      COMMON/D/SIGMA,G,ELO,JMAX,IMAX,PI,TWOPI,PI02,HGEN,IJET(10),SJETTY
94600      COMMON/G/IBREAK(60),HNONBR(20)
94700      DIMENSION J1(60),J2(60),J1REF(60),J3REF(60)
94800      C*THIS SUB CALCS WHERE DIFFRACTION GOVERNS AND WHERE REFRACT GOVERNS.
94900      C*IT WILL CALL REFRAC FOR OFFSHORE AREA(OFF TIP OF STRUCTURE).
95000      C*THEN IT WILL DO THE SHADOW ZONE USING DIFF(IF THETA0.NE.0.0)
95100      C* IT WILL THEN FINISH THE OTHERS USING REFRACT AGAIN.
95200      C*LET'S ZERO-OUT THE DIMENSIONED ARRAYS.
95300          DO 1000 I=1,IMAX+2
95400              J1(I)=0.0
95500              J2(I)=0.0
95600              J1REF(I)=0.0
95700          1000 J3REF(I)=0.0
95800      C*NOW, LETS FIND C,CG,RK,HB, AND WVNUM.
95900          DO 202 I=1,IMAX
96000          DO 202 J=1,JMAX+2
96100              DEPTH=DEEP(I,J)
96200              CALL WVNUM(DEPTH,T,DUMK)
96300              RK(I,J)=DUMK
96400              C(I,J)=CO*TANH(RK(I,J)*DEEP(I,J))
96500              EN=0.5*(1.0+((2.*RK(I,J)*DEEP(I,J))/SINH(2.*RK(I,J)*DEEP(I,J))))
96600              CG(I,J)=EN*C(I,J)
96700              HB(I,J)=0.78*DEEP(I,J)
96800          202 CONTINUE
96900      C*WILL ATTRIB AN EQUAL REACH TO EACH SIDE OF EACH M-GROIN.
97000          DO 200 M=1,MMAX
97100              IDUML=1
97200              IF(M.NE.1) IDUML=(IJET(M)+IJET(M-1))/2
97300              IDUMR=IMAX
97400              IF(M.NE.MMAX) IDUMR=(IJET(M)+IJET(M+1))/2
97500              NPTS=0
97600              DO 1 I=IDUML,IDUMR
97700              DO 2 J=1,JMAX
97800                  IF(Y(I,J).LT.SJETTY) GO TO 14
97900                  J1(I)=J
98000                  J2(I)=JMAX
98100                  GO TO 15
98200          14 CONTINUE
98300          2 CONTINUE
98400          15 CONTINUE
98500      C*IF NO STRUCT IS PRESENT(SJETTY=0.0), DO REFRACT THRUOUT GRID SYSTEM
98600          IF(SJETTY.EQ.0.0) J1(I)=1
98700          1 CONTINUE
98800          DO 16 I=IDUML,IDUMR
98900      C* 'REFRACT' STARTS ON THE NEXT TO LAST J-CONTOUR,NOT THE LAST!
99000          DO 16 J=J1(I),J2(I)-1
99100          16 NPTS=NPTS+1
99200      C*WILL NOW DO THE REFRACT FOR THE REGION 1 AREA.
99300      C*ISTART REPRESENTS THE DIRECTION THE SWEEPS WILL BEGIN FROM
99400      C*WILL USE DUMMY IMAX,IJET,IJET+1 IN CALL STTS SO IBEGIN,IEND, AND
99500      C***ISTART WON'T CHANGE THEM MUST RESET AFTER EACH CALL REFRAC
99600          IMAXT=IDUMR
99700          IJETT=IJET(M)
99800          IJETP1=IJET(M)+1
99900          IDUMLL=IDUML
100000      IF(ANGGEN.GE.0.0) CALL REFRAC(J1,J2,NPTS,IDUMLL,IMAXT,IDUMLL,M)
100100      IF(ANGGEN.LT.0.0) CALL REFRAC(J1,J2,NPTS,IDUMLL,IMAXT,IMAXT,M)
100200          IMAXT=IDUMR
100300          IJETT=IJET(M)
100400          IJETP1=IJET(M)+1
100500          IDUMLL=IDUML
100600          JDUMN=J1(IJET(M))
100700          JDUMS=J1(IJET(M)+1)
100800          XDISTN=(IJET(M)-1.0)*DX+DX/2
100900          ELTIP=T*0.5*(C(IJET(M),JDUMN)+C(IJET(M)+1,JDUMS))
101000      C*NOW MUST CHECK THE ANGLE AT THE STRUCTURE'S TIP TO SEE WHERE SHAD ZONE
101100      C*IF NO STRUCT PRESENT(SJETTY=0.0), FUTHUR REFRACT/DIFF UNNECESSARY
101200          IF(SJETTY.EQ.0.0) GO TO 13
101300          THETA0(M)=0.5*(THETA(IJET(M),JDUMN)+THETA(IJET(M)+1,JDUMS))
101400          HINC=0.5*(H(IJET(M),JDUMN)+H(IJET(M)+1,JDUMS))
101500          IF(THETA0(M))10,11,12
101600      C*THIS SECTION HANDLES REFRACT/DIFF IF THETA0<0.0

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101700      10 CONTINUE
101800      C*FIRST ALL OF REGION 2 WILL GET REFRACTED.
101900      NPTS=0
102000      DO 100 I=IJET(M)+1, IDUMR
102100      J2(I)=J1(I)
102200      100 J1(I)=1
102300      DO 101 I=IJET(M)+1, IDUMR
102400      DO 101 J=J1(I), J2(I)-1
102500      101 NPTS=NPTS+1
102600      IMAXT=IDUMR
102700      IDUMLL=IDUML
102800      IJETT=IJET(M)
102900      IJETP1=IJET(M)+1
103000      CALL REFRAC(J1, J2, NPTS, IJETP1, IMAXT, IMAXT, M)
103100      IMAXT=IDUMR
103200      IJETT=IJET(M)
103300      IJETP1=IJET(M)+1
103400      IDUMLL=IDUML
103500      C*NOW MUST DO REGION 3 OF NEG THETA0 CASE-SHADOW ZONE.
103600      DO 102 I=IDUML, IJET(M)
103700      J2(I)=J1(I)
103800      102 J1(I)=1
103900      DO 103 I=IDUML, IJET(M)
104000      J1REF(I)=1
104100      DO 104 J=J1(I), J2(I)+1
104200      XCOORD=(I-1.0)*DX
104300      YCOORD=0.5*(Y(I, J)+Y(I, J+1))
104400      ANGLE=ATAN((XDISTN-XCOORD)/(SJETTY-YCOORD))
104500      IF(YCOORD.GT.SJETTY) ANGLE=PI+ANGLE
104600      C*IF MOST SHOREWARD PT OUT OF SHAD ZONE, SO ARE THE OTHERS FOR THAT I.
104700      IF(ABS(ANGLE).GT.ABS(THETA0(M))) GO TO 105
104800      RAD=SQRT((XDISTN-XCOORD)**2+(SJETTY-YCOORD)**2)
104900      RHOND=RAD*TWOPI/ELTIP
105000      C*DIFFRACTION TREATS THE POS THETA0 CASE.
105100      THE=ABS(THETA0(M))
105200      CALL DIFF(RHOND, THE, ANGLE, AMP)
105300      H(I, J)=AMP*HINC
105400      ANGRAD=-ANGLE
105500      C*WILL NOW REFRACT DIFF WAVES IN THE SHAD ZONE USING SNELL'S.
105600      CTIP=ELTIP/T
105700      ALPHAS(I, J)=ATAN((0.5*(Y(I+1, J)+Y(I+1, J+1))-0.5*
105800      * (Y(I-1, J)+Y(I-1, J+1)))/(2.*DX))
105900      IF(I.EQ.IJET(M))ALPHAS(I, J)=ATAN((0.5*(Y(I, J)+Y(I, J+1))-0.5*(Y(I-1
106000      * (J)+Y(I-1, J+1)))/DX)
106100      DALPHA=ANGRAD-ALPHAS(I, J)
106200      THETA(I, J)=ARSIN((C(I, J)/CTIP)*SIN(DALPHA))
106300      THETA(I, J)=THETA(I, J)+ALPHAS(I, J)
106400      C*MUST CHECK TO SEE IF WAVE WOULD HAVE BROKEN.
106500      IF(HB(I, J) LE H(I, J) AND HB(I, J+1).GT.H(I, J+1))IBREAK(I)=J
106600      IF(HB(I, J) LT H(I, J)) H(I, J)=HB(I, J)
106700      104 CONTINUE
106800      GO TO 103
106900      105 J1REF(I)=J
107000      103 CONTINUE
107100      C*NOW MUST DO REFRACTION FOR REGION 4.
107200      NPTS=0
107300      DO 106 I=IDUML, IJET(M)
107400      DO 106 J=J1REF(I), J2(I)-1
107500      106 NPTS=NPTS+1
107600      IDUMLL=IDUML
107700      IMAXT=IDUMR
107800      IJETT=IJET(M)
107900      IJETP1=IJET(M)+1
108000      CALL REFRAC(J1REF, J2, NPTS, IDUMLL, IJETT, IDUMLL, M)
108100      IDUMLL=IDUML
108200      IMAXT=IDUMR
108300      IJETT=IJET(M)
108400      IJETP1=IJET(M)+1
108500      GO TO 13
108600      C*THIS HANDLES REFRAC/DIFF IF THETA0 IS 0.0.
108700      C*FOR THIS CASE, ONLY THREE REGIONS EXIST
108800      11 CONTINUE
108900      NPTS=0

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109000      DO 120 I=IDUML,IJET(M)
109100      J2(I)=J1(I)
109200      120 J1(I)=1
109300      DO 121 I=IDUML,IJET(M)
109400      DO 121 J=J1(I),J2(I) 1
109500      121 NPTS=NPTS+1
109600      IMAXT=IDUMR
109700      IDUMLL=IDUML
109800      IJETT=IJET(M)
109900      IJETP1=IJET(M)+1
110000      CALL REFRAC(J1,J2,NPTS,IDUMLL,IJETT,IDUMLL,M)
110100      IMAXT=IDUMR
110200      IJETT=IJET(M)
110300      IJETP1=IJET(M)+1
110400      IDUMLL=IDUML
110500      DO 122 I=IJET(M)+1,IDUMR
110600      J2(I)=J1(I)
110700      122 J1(I)=1
110800      NPTS=0
110900      DO 123 I=IJET(M)+1,IDUMR
111000      DO 123 J=J1(I),J2(I)-1
111100      123 NPTS=NPTS+1
111200      IMAXT=IDUMR
111300      IDUMLL=IDUML
111400      IJETT=IJET(M)
111500      IJETP1=IJET(M)+1
111600      CALL REFRAC(J1,J2,NPTS,IJETP1,IMAXT,IMAXT,M)
111700      IMAXT=IDUMR
111800      IJETT=IJET(M)
111900      IJETP1=IJET(M)+1
112000      IDUMLL=IDUML
112100      GO TO 13
112200      C*THIS SECTION HANDLES REFRACT/DIFF IF THETA0>0.0
112300      12 CONTINUE
112400      C*FIRST, REGION 2- ALL REFRACTION.
112500      NPTS=0
112600      DO 110 I=IDUML,IJET(M)
112700      J2(I)=J1(I)
112800      110 J1(I)=1
112900      DO 111 I=IDUML,IJET(M)
113000      DO 111 J=J1(I),J2(I)-1
113100      111 NPTS=NPTS+1
113200      IMAXT=IDUMR
113300      IDUMLL=IDUML
113400      IJETT=IJET(M)
113500      IJETP1=IJET(M)+1
113600      CALL REFRAC(J1,J2,NPTS,IDUMLL,IJETT,IDUMLL,M)
113700      IMAXT=IDUMR
113800      IJETT=IJET(M)
113900      IJETP1=IJET(M)+1
114000      IDUMLL=IDUML
114100      C*NOW WILL DO REGION 3 OF THE POS THETA0 CASE.
114200      DO 112 I=IJET(M)+1,IDUMR
114300      J2(I)=J1(I)
114400      112 J1(I)=1
114500      DO 113 I=IJET(M)+1,IDUMR
114600      J1REF(I)=1
114700      C*WILL GO ONE PT. BEYOND J2(I) TO MAKE SURE OUTOF DIFF ZONE.
114800      DO 114 J=J1(I),J2(I)+1
114900      XCOORD=(I-1.0)*DX
115000      YCOORD=0.5*(Y(I,J)+Y(I,J+1))
115100      ANGLE=ATAN((XCOORD-XDISTN)/(SJETTY-YCOORD))
115200      IF(YCOORD.GT.SJETTY) ANGLE=PI+ANGLE
115300      C*IF LEAST J-VALUE IS OUT OF SHAD ZONE,SO ARE OTHER J'S (FOR EACH I)
115400      IF(ANGLE.GT.ABS(THETA0(M))) GO TO 115
115500      RAD=SQRT((XCOORD-XDISTN)**2+(SJETTY-YCOORD)**2)
115600      RHOND=RAD*TWOPI/ELTIP
115700      THE=THETA0(M)
115800      CALL DIFF(RHOND,THE,ANGLE,AMP)
115900      ANGRAD=ANGLE
116000      C*WILL NOW REFRACT DIFFRACTED WAVES IN SHAD ZONE USING SNELL'S
116100      CTIP=ELTIP/T
116200      ALPHAS(I,J)=ATAN((0.5*(Y(I+1,J)+Y(I+1,J+1))-0.5*

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116300      * (Y(I-1,J)+Y(I+1,J+1))/(2 *DX)
116400      IF(I EQ IJET(M)+1)ALPHAS(I,J)=ATAN((0.5*(Y(I-1,J)+Y(I+1,J+1))-5*
116500      * (Y(I,J)+Y(I,J+1)))/DX)
116600      DALPHA=ANGRAD-ALPHAS(I,J)
116700      THETA(I,J)=ARSIN((C(I,J)/CTIP)*SIN(DALPHA))
116800      THETA(I,J)=THETA(I,J)+ALPHAS(I,J)
116900      H(I,J)=HINC*AMP
117000      C*MUST CHECK TO SEE IF WAVE WOULD HAVE BROKEN
117100      IF(HB(I,J) LE H(I,J) AND HB(I,J+1) GT H(I,J+1))BREAK(1)=1
117200      IF(HB(I,J) LT H(I,J)) H(I,J)=HB(I,J)
117300      114 CONTINUE
117400      GO TO 113
117500      115 JIREF(I)=J
117600      113 CONTINUE
117700      C*NOW MUST DO REFRACTION FOR REGION 4
117800      NPTS=0
117900      DO 116 I=IJET(M)+1, IDUMR
118000      DO 116 J=JIREF(I), J2(I)+1
118100      116 NPTS=NPTS+1
118200      IMAXT=IDUMR
118300      IDUMLL=IDUML
118400      IJETT=IJET(M)
118500      IJETP1=IJET(M)+1
118600      CALL REFRACTION(JIREF,J2,NPTS,IJETP1,IMAXT,IMAXT,M)
118700      IMAXT=IDUMR
118800      IJETT=IJET(M)
118900      IJETP1=IJET(M)+1
119000      IDUMLL=IDUML
119100      13 CONTINUE
119200      200 CONTINUE
119300      RETURN
119400      END
119500      C*-----
119600      SUBROUTINE LOC(IM,JJ,JOIM,JSIM,YBAR,IDUM)
119700      COMMON/A/ C(60,20),RK(60,20),Y(60,20),DEEP(60,20),ALPHAS(60,20)
119800      COMMON/AA/YZERO(60)
119900      COMMON/B/ THETA(60,20),Q*10T(60),OLDANG(60,20),D*(60,20)
120000      COMMON/C/ H(60,20),CG(60,20),HOLD(60,20),HB(60,20),YB(60)
120100      COMMON/N USED/JUSE,T,CO,CGEN,CGGEN,ANGGEN,DX,BERM,THETA0(10),MMA*
120200      COMMON/D/SIGMA,G,ELO,JMAX,IMAX,PI,TWOPI,PIO2,HGEN,IJET(10),SLE*
120300      C*SUBROUTINE LOC FINDS J-VALUES WHICH ARE GREATER AND LESS THAN YBAR
120400      JOIM=2
120500      2 AA=0.5*(Y(IM,JOIM)+Y(IM,JOIM-1))
120600      IF(AA GT YBAR) GO TO 4
120700      JOIM=JOIM+1
120800      C*THE FOLLOWING IS REQ'D SO THAT DY/DX>0.5
120900      C*WILL DETERMINE K SIN THETA ON IM-LINE AT A DIST YBAR
121000      C*WILL CALL THIS POINT JUSE+1
121100      IF(JOIM LE JUSE) GO TO 2
121200      JOIM=JUSE+1
121300      Y(IM,JOIM)=YBAR
121400      C* DEPTH AT THIS POINT WILL BE COMP ASSUMING CONST BEACH SLOPE ON I=IM
121500      DEL=.5*(Y(IM,JOIM-1)+Y(IM,JOIM-2))-5*(Y(IM,JOIM-2)+Y(IM,JOIM-3))
121600      BSLOPE=(DEEP(IM,JOIM-2)-DEEP(IM,JOIM-3))/DEL
121700      DEEP(IM,JOIM-1)=DEEP(IM,JOIM-2)+BSLOPE*(Y(IM,JOIM)-Y(IM,JOIM-1))
121800      DEPTH=DEEP(IM,JOIM-1)
121900      CALL WNUM(DEPTH,T,DUMK)
122000      RK(IM,JOIM-1)=DUMK
122100      C(IM,JOIM-1)=CO*TANH(RK(IM,JOIM-1)*DEEP(IM,JOIM-1))
122200      EN=0.5*(1.0+((2.0*RK(IM,JOIM-1)*DEEP(IM,JOIM-1))/SINH(
122300      * 2.0*RK(IM,JOIM-1)*DEEP(IM,JOIM-1))))
122400      CG(IM,JOIM-1)=C(IM,JOIM-1)*EN
122500      C*WILL USE SNELL'S LAW TO DETERMINE THE WAVE ANGLE HERE
122600      C*ANGLE OF CONTOUR WILL BE ASSUME TO BE THE SAME AS THE JMAX+1 CONTOUR
122700      IF(IDUM EQ 1)ALPH=ATAN((Y(IM,JOIM-1)-Y(IM-1,JOIM-1))/DX)
122800      IF(IDUM EQ -1)ALPH=ATAN((Y(IM+1,JOIM-1)-Y(IM,JOIM-1))/DX)
122900      DALPHA=ANGGEN-ALPH
123000      THETA(IM,JOIM-1)=ARSIN((C(IM,JOIM-1)/CGEN)*SIN(DALPHA))
123100      THETA(IM,JOIM-1)=THETA(IM,JOIM-1)+ALPH
123200      4 JSIM=JMAX-1
123300      6 AA=0.5*(Y(IM,JSIM)+Y(IM,JSIM+1))
123400      IF(AA LT YBAR) GO TO 8
123500      JSIM=JSIM+1

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123600 C*IF JSIM=0,THERE IS NO ADJ PT. SUB REFRAC CAN HANDLE IT
123700 IF(JSIM.EQ.0) GO TO 8
123800 GO TO 6
123900 8 RETURN
124000 END
124100 C*****
124200 SUBROUTINE WVNUM(DEPTH,T,RK)
124300 G=32.17
124400 EPS=0.001
124500 TWOPI=6.283185307
124600 SIGMA=TWOPI/T
124700 RK=TWOPI/((T*SQRT(G*DEPTH))
124800 DO 100 IT=1,20
124900 ARG=RK*DEPTH
125000 EK=(G*RK*TANH(ARG))-(SIGMA**2)
125100 EKPR=G*(ARG*((SECH(ARG))**2)+TANH(ARG))
125200 RKNEW=RK-EK/EKPR
125300 IF(ABS(RKNEW-RK).LE.ABS(EPS*RKNEW)) GO TO 120
125400 RK=RKNEW
125500 100 CONTINUE
125600 WRITE(6,1000) IT,DEPTH,RK
125700 1000 FORMAT(///,10X,"ITERATION FOR K FAILED TO CONVERGE AFTER"
125800 * ,3X,13,"ITERATION",/, "OUTPUT DEPTH, RK",3X,2F13.5)
125900 CALL EXIT
126000 120 RK=RKNEW
126100 IF(RK.GT.0.0) GO TO 140
126200 WRITE(6,1020) DEPTH,RK
126300 1020 FORMAT(///,10X," RK IS NEG",/, " OUTPUT DEPTH,RK",3X,2F13.5)
126400 CALL EXIT
126500 140 RETURN
126600 END
126700 C*****
126800 SUBROUTINE SMOOTH(THETA,IMAX,UMAX,IJET,SJETTY,MMAX,Y)
126900 C*THIS WILL SMOOTH THE WAVE ANGLE FIELD TO ACCT FOR DIFF(ARTIFICIALLY)
127000 DIMENSION TEMP(60,20),Y(60,20),THETA(60,20),IJET(10)
127100 C*(MMAX+1) IS REQ'D BECAUSE M-GROINS HAVE M+1 REACHES OF SHORELINE
127200 DO 10 M=1,MMAX+1
127300 IF(M.NE.1) GO TO 3
127400 ILEFT=2
127500 IRIGHT=IJET(1)
127600 GO TO 5
127700 3 IF(M.NE.MMAX+1) GO TO 4
127800 ILEFT=IJET(MMAX)+1
127900 IRIGHT=IMAX-1
128000 GO TO 5
128100 4 ILEFT=IJET(M-1)+1
128200 IRIGHT=IJET(M)
128300 5 CONTINUE
128400 DO 1 J=1,UMAX-1
128500 DO 1 I=ILEFT,IRIGHT
128600 IF(I.NE.ILEFT AND I.NE.IRIGHT) GO TO 15
128700 C*TO GET HERE, MUST BE ON BOUN OR ADJ TO A STRUCTURE
128800 IF(I.EQ.2.OR.I.EQ.IMAX-1) GO TO 15
128900 C*TO GET HERE,ADJ TO A STRUCT AND CAN BE ILEFT OR IRIGHT
129000 IF(Y(I,J) GE. SJETTY) GO TO 15
129100 C*IF HERE, WITHIN JETTY AND ADJ TO EITHER SIDE
129200 IF(I.EQ.ILEFT)TEMP(I,J)=0.5*(THETA(I,J)+THETA(I+1,J))
129300 IF(I.EQ.IRIGHT)TEMP(I,J)=0.5*(THETA(I,J)+THETA(I-1,J))
129400 GO TO 1
129500 15 TEMP(I,J)=0.25*THETA(I-1,J)+0.50*THETA(I,J)+0.25*THETA(I+1,J)
129600 1 CONTINUE
129700 10 CONTINUE
129800 DO 2 J=1,UMAX-1
129900 DO 2 I=2,IMAX-1
130000 2 THETA(I,J)=TEMP(I,J)
130100 RETURN
130200 END
130300 C*****
130400 FUNCTION SECH(A)
130500 SECH=1/O/COSH(A)
130600 RETURN
130700 END
130800 C****HERE IS WHERE THE IMSL ROUTINES MUST GO!

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APPENDIX C

CONTOURS AND SCHEMATIC ILLUSTRATIONS

This appendix presents tables of the original contours at Oregon Inlet and the final contours for the eight numerical simulations (Tables C-1 to C-9). Also included are schematic illustrations of sediment volumes transported from the nourished region (Figs. C-1 to C-8).

Table C-1. Initial bathymetry for all simulations (prior to any sediment addition).

Increasing I →																
I=	220.000	200.000	200.000	200.000	220.000	220.000	220.000	210.000	200.000	200.000	220.000	200.000	200.000	200.000	200.000	200.000
1	180.000	180.000	160.000	160.000	160.000	190.000	190.000	190.000	180.000	180.000	180.000	180.000	210.000	220.000	230.000	190.000
2	220.000	200.000	160.000	160.000	160.000	160.000	170.000	170.000	170.000	170.000	180.000	180.000	210.000	220.000	230.000	220.000
3	230.000	250.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	210.000	200.000	200.000	200.000
4	251.623	231.623	231.623	231.623	251.623	251.623	251.623	241.623	231.623	231.623	251.623	231.623	231.623	231.623	231.623	231.623
5	211.623	211.623	191.623	191.623	191.623	221.623	221.623	221.623	221.623	221.623	221.623	221.623	241.623	241.623	251.623	251.623
6	251.623	231.623	191.623	191.623	191.623	191.623	201.623	201.623	201.623	201.623	201.623	211.623	211.623	211.623	241.623	251.623
7	281.623	281.623	251.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623	231.623
8	309.443	289.443	289.443	289.443	289.443	309.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443
9	269.443	269.443	249.443	249.443	249.443	279.443	279.443	279.443	279.443	279.443	279.443	279.443	279.443	279.443	279.443	279.443
10	309.443	289.443	249.443	249.443	249.443	249.443	259.443	259.443	259.443	259.443	259.443	259.443	259.443	259.443	259.443	259.443
11	319.443	339.443	309.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443	289.443
12	442.028	422.028	422.028	422.028	422.028	442.028	442.028	442.028	442.028	442.028	442.028	442.028	442.028	442.028	442.028	442.028
13	402.028	402.028	382.028	382.028	382.028	412.028	412.028	412.028	412.028	412.028	412.028	412.028	412.028	412.028	412.028	412.028
14	442.028	422.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028	382.028
15	452.028	472.028	442.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028	422.028
16	684.758	684.758	664.758	664.758	664.758	684.758	684.758	684.758	684.758	684.758	684.758	684.758	684.758	684.758	684.758	684.758
17	644.758	644.758	624.758	624.758	624.758	654.758	654.758	654.758	654.758	654.758	654.758	654.758	654.758	654.758	654.758	654.758
18	684.758	684.758	624.758	624.758	624.758	624.758	634.758	634.758	634.758	634.758	634.758	634.758	634.758	634.758	634.758	634.758
19	694.758	714.758	684.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758	664.758
20	980.726	980.726	960.726	960.726	960.726	980.726	980.726	980.726	980.726	980.726	980.726	980.726	980.726	980.726	980.726	980.726
21	940.726	940.726	920.726	920.726	920.726	950.726	950.726	950.726	950.726	950.726	950.726	950.726	950.726	950.726	950.726	950.726
22	980.726	960.726	920.726	920.726	920.726	920.726	930.726	930.726	930.726	930.726	930.726	930.726	930.726	930.726	930.726	930.726
23	980.726	1010.726	980.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726	960.726
24	1270.414	1250.414	1250.414	1250.414	1270.414	1270.414	1270.414	1260.414	1250.414	1250.414	1270.414	1270.414	1250.414	1250.414	1250.414	1250.414
25	1230.414	1230.414	1210.414	1210.414	1210.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414	1240.414
26	1270.414	1250.414	1210.414	1210.414	1210.414	1210.414	1210.414	1220.414	1220.414	1220.414	1220.414	1230.414	1230.414	1230.414	1230.414	1230.414
27	1280.414	1300.414	1270.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414	1250.414
28	1702.228	1682.228	1682.228	1682.228	1702.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228
29	1662.228	1662.228	1642.228	1642.228	1642.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228	1672.228
30	1702.228	1682.228	1642.228	1642.228	1642.228	1642.228	1642.228	1652.228	1652.228	1652.228	1652.228	1652.228	1652.228	1652.228	1652.228	1652.228
31	1712.228	1732.228	1702.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228	1682.228

Table C-2. Final contours, case 2.a.

THE NEW CONTOUR VALUES, V, FOLLOW														
220.000	219.421	218.883	218.266	217.691	217.119	216.550	215.985	215.425	214.871	214.322	213.779	213.248	212.716	212.187
212.187	211.687	211.186	210.694	210.213	209.748	209.285	208.836	208.390	207.969	207.551	207.148	206.748	206.362	205.987
205.987	205.621	205.266	204.922	204.588	204.264	203.950	203.645	203.348	203.050	202.757	202.469	202.186	201.907	201.632
201.632	201.363	201.097	200.835	200.577	200.324	200.076	199.833	199.594	199.359	199.128	198.900	198.676	198.455	198.237
198.237	198.019	197.804	197.591	197.381	197.174	196.970	196.769	196.571	196.376	196.184	195.995	195.808	195.624	195.442
195.442	195.261	195.082	194.905	194.730	194.557	194.386	194.217	194.050	193.885	193.722	193.561	193.402	193.245	193.090
193.090	192.936	192.783	192.631	192.481	192.332	192.184	192.038	191.893	191.750	191.608	191.468	191.329	191.191	191.055
191.055	190.919	190.784	190.650	190.517	190.385	190.254	190.124	190.000	189.877	189.755	189.634	189.514	189.395	189.277
189.277	189.159	189.042	188.926	188.811	188.696	188.582	188.469	188.357	188.246	188.136	188.026	187.917	187.808	187.700
187.700	187.592	187.485	187.379	187.274	187.169	187.065	186.961	186.858	186.755	186.653	186.551	186.450	186.349	186.248
186.248	186.147	186.046	185.945	185.845	185.745	185.645	185.545	185.445	185.345	185.245	185.145	185.045	184.945	184.845
184.845	184.745	184.645	184.545	184.445	184.345	184.245	184.145	184.045	183.945	183.845	183.745	183.645	183.545	183.445
183.445	183.345	183.245	183.145	183.045	182.945	182.845	182.745	182.645	182.545	182.445	182.345	182.245	182.145	182.045
182.045	181.945	181.845	181.745	181.645	181.545	181.445	181.345	181.245	181.145	181.045	180.945	180.845	180.745	180.645
180.645	180.545	180.445	180.345	180.245	180.145	180.045	179.945	179.845	179.745	179.645	179.545	179.445	179.345	179.245
179.245	179.145	179.045	178.945	178.845	178.745	178.645	178.545	178.445	178.345	178.245	178.145	178.045	177.945	177.845
177.845	177.745	177.645	177.545	177.445	177.345	177.245	177.145	177.045	176.945	176.845	176.745	176.645	176.545	176.445
176.445	176.345	176.245	176.145	176.045	175.945	175.845	175.745	175.645	175.545	175.445	175.345	175.245	175.145	175.045
175.045	174.945	174.845	174.745	174.645	174.545	174.445	174.345	174.245	174.145	174.045	173.945	173.845	173.745	173.645
173.645	173.545	173.445	173.345	173.245	173.145	173.045	172.945	172.845	172.745	172.645	172.545	172.445	172.345	172.245
172.245	172.145	172.045	171.945	171.845	171.745	171.645	171.545	171.445	171.345	171.245	171.145	171.045	170.945	170.845
170.845	170.745	170.645	170.545	170.445	170.345	170.245	170.145	170.045	169.945	169.845	169.745	169.645	169.545	169.445
169.445	169.345	169.245	169.145	169.045	168.945	168.845	168.745	168.645	168.545	168.445	168.345	168.245	168.145	168.045
168.045	167.945	167.845	167.745	167.645	167.545	167.445	167.345	167.245	167.145	167.045	166.945	166.845	166.745	166.645
166.645	166.545	166.445	166.345	166.245	166.145	166.045	165.945	165.845	165.745	165.645	165.545	165.445	165.345	165.245
165.245	165.145	165.045	164.945	164.845	164.745	164.645	164.545	164.445	164.345	164.245	164.145	164.045	163.945	163.845
163.845	163.745	163.645	163.545	163.445	163.345	163.245	163.145	163.045	162.945	162.845	162.745	162.645	162.545	162.445
162.445	162.345	162.245	162.145	162.045	161.945	161.845	161.745	161.645	161.545	161.445	161.345	161.245	161.145	161.045
161.045	160.945	160.845	160.745	160.645	160.545	160.445	160.345	160.245	160.145	160.045	159.945	159.845	159.745	159.645
159.645	159.545	159.445	159.345	159.245	159.145	159.045	158.945	158.845	158.745	158.645	158.545	158.445	158.345	158.245
158.245	158.145	158.045	157.945	157.845	157.745	157.645	157.545	157.445	157.345	157.245	157.145	157.045	156.945	156.845
156.845	156.745	156.645	156.545	156.445	156.345	156.245	156.145	156.045	155.945	155.845	155.745	155.645	155.545	155.445
155.445	155.345	155.245	155.145	155.045	154.945	154.845	154.745	154.645	154.545	154.445	154.345	154.245	154.145	154.045
154.045	153.945	153.845	153.745	153.645	153.545	153.445	153.345	153.245	153.145	153.045	152.945	152.845	152.745	152.645
152.645	152.545	152.445	152.345	152.245	152.145	152.045	151.945	151.845	151.745	151.645	151.545	151.445	151.345	151.245
151.245	151.145	151.045	150.945	150.845	150.745	150.645	150.545	150.445	150.345	150.245	150.145	150.045	149.945	149.845
149.845	149.745	149.645	149.545	149.445	149.345	149.245	149.145	149.045	148.945	148.845	148.745	148.645	148.545	148.445
148.445	148.345	148.245	148.145	148.045	147.945	147.845	147.745	147.645	147.545	147.445	147.345	147.245	147.145	147.045
147.045	146.945	146.845	146.745	146.645	146.545	146.445	146.345	146.245	146.145	146.045	145.945	145.845	145.745	145.645
145.645	145.545	145.445	145.345	145.245	145.145	145.045	144.945	144.845	144.745	144.645	144.545	144.445	144.345	144.245
144.245	144.145	144.045	143.945	143.845	143.745	143.645	143.545	143.445	143.345	143.245	143.145	143.045	142.945	142.845
142.845	142.745	142.645	142.545	142.445	142.345	142.245	142.145	142.045	141.945	141.845	141.745	141.645	141.545	141.445
141.445	141.345	141.245	141.145	141.045	140.945	140.845	140.745	140.645	140.545	140.445	140.345	140.245	140.145	140.045
140.045	139.945	139.845	139.745	139.645	139.545	139.445	139.345	139.245	139.145	139.045	138.945	138.845	138.745	138.645
138.645	138.545	138.445	138.345	138.245	138.145	138.045	137.945	137.845	137.745	137.645	137.545	137.445	137.345	137.245
137.245	137.145	137.045	136.945	136.845	136.745	136.645	136.545	136.445	136.345	136.245	136.145	136.045	135.945	135.845
135.845	135.745	135.645	135.545	135.445	135.345	135.245	135.145	135.045	134.945	134.845	134.745	134.645	134.545	134.445
134.445	134.345	134.245	134.145	134.045	133.945	133.845	133.745	133.645	133.545	133.445	133.345	133.245	133.145	133.045
133.045	132.945	132.845	132.745	132.645	132.545	132.445	132.345	132.245	132.145	132.045	131.945	131.845	131.745	131.645
131.645	131.545	131.445	131.345	131.245	131.145	131.045	130.945	130.845	130.745	130.645	130.545	130.445	130.345	130.245
130.245	130.145	130.045	129.945	129.845	129.745	129.645	129.545	129.445	129.345	129.245	129.145	129.045	128.945	128.845
128.845	128.745	128.645	128.545	128.445	128.345	128.245	128.145	128.045	127.945	127.845	127.745	127.645	127.545	127.445
127.445	127.345	127.245	127.145	127.045	126.945	126.845	126.745	126.645	126.545	126.445	126.345	126.245	126.145	126.045
126.045	125.945	125.845	125.745	125.645	125.545	125.445	125.345	125.245	125.145	125.045	124.945	124.845	124.745	124.645
124.645	124.545	124.445	124.345	124.245	124.145	124.045	123.945	123.845	123.745	123.645	123.545	123.445	123.345	123.245
123.245	123.145	123.045	122.945	122.845	122.745	122.645	122.545	122.445	122.345	122.245	122.145	122.045	121.945	121.845
121.845	121.745	121.645	121.545	121.445	121.345	121.245	121.145	121.045	120.945	120.845	120.745	120.645	120.545	120.445
120.445	120.345	120.245	120.145	120.045	119.945	119.845	119.745	119.645	119.545	119.445	119.345	119.245	119.145	119.045
119.045	118.945	118.845	118.745	118.645	118.545	118.445	118.345	118.245	118.145	118.045	117.945	117.845	117.745	117.645
117.645	117.545	117.445	117.345	117.245	117.145	117.045	116.945	116.845	116.745	116.645	116.545	116.445	116.345	116.245
116.245	116.145	116.045	115.945	115.845	115.745	115.645	115.545	115.445	115.345	115.245	115.145	115.045	114.945	114.845
114.845	114.745	114.645	114.545	114.445	114.345	114.245	114.145	114.045	113.945	113.845	113.745	113.645	113.545	113.445
113.445	113.345	113.245	113.145	113.045	112.945	112.845	112.745	112.645	112.545	112.445	112.345	112.245	112.145	112.045
112.045	111.945	111.845	111.745	111.645	111.545	111.445	111.345	111.245	111.145	111.045	110.945	110.845	110.745	110.645
110.645	110.545	110.445	110.345	110.245	110.145	110.045	109.945	109.845	109.745	109.645	109.545	109.445	109.345	109.245
109.245	109.145	109.045	108.945	108.845	108.745	108.645	108.545	108.445	108.345	108.245				

Table C-3. Final contours, case 2.b.

THE NEW CONTOUR VALUES, Y, FOLLOW														
220.000	212.432	210.880	210.321	217.705	217.210	216.659	216.112	215.568	215.024	214.495	213.967	213.400		
218.931	212.428	211.925	211.414	210.902	210.479	210.016	209.561	209.115	208.680	208.254	207.837	207.430		
207.932	206.403	205.261	205.533	205.102	204.640	204.508	204.508	204.144	203.868	203.561	203.260	202.966		
202.677	202.328	202.116	201.842	201.571	201.304	201.040	200.778	200.518	200.259	200.000				
201.623	201.065	200.508	200.954	200.401	200.850	200.307	200.757	200.210	200.679	200.148	200.621	200.101		
200.508	200.002	200.584	200.095	200.615	200.144	200.681	200.211	200.789	200.355	200.930	200.514	200.107		
210.108	210.317	210.936	210.563	210.200	210.847	210.504	210.170	210.846	210.530	210.222	210.921	210.626		
210.337	210.052	210.771	210.494	210.219	210.948	210.674	210.415	210.144	210.885	210.621				
309.443	308.891	308.341	307.791	307.246	306.702	306.160	305.620	305.084	304.551	304.022	303.498	302.980		
302.562	301.966	301.471	300.985	300.504	300.043	299.586	299.140	298.701	298.271	297.849	297.435	297.028		
296.628	296.214	295.848	295.470	295.102	294.745	294.394	294.063	293.738	293.421	293.114	292.813	292.516		
292.226	291.938	291.653	291.369	291.087	290.807	290.531	290.257	289.985	289.713	289.443				
432.828	431.890	430.954	430.018	429.084	428.150	427.219	426.290	425.364	424.441	423.522	422.607	421.697		
435.163	434.668	434.174	433.694	433.226	432.760	432.303	431.847	431.454	431.038	430.623	430.212	429.803		
429.398	428.997	428.601	428.213	427.835	427.469	427.117	426.774	426.453	426.139	425.834	425.535	425.240		
428.947	428.653	428.359	428.064	427.768	427.474	427.181	426.890	426.601	426.314	426.028				
608.758	608.237	607.717	607.197	606.676	606.156	605.635	605.114	604.591	604.069	603.548	603.029	602.510		
678.011	677.515	677.032	676.561	676.104	675.660	675.228	674.806	674.392	673.982	673.574	673.166	672.756		
672.344	671.933	671.524	671.124	670.735	670.361	670.004	669.665	669.343	669.034	668.735	668.441	668.146		
667.852	667.553	667.248	666.948	666.653	666.361	666.074	665.794	665.517	665.245	664.978				
989.7	989.191	988.657	988.122	987.587	987.050	986.513	985.975	985.436	984.899	984.363	983.827	983.291		
923.795	923.292	922.803	922.324	921.868	921.422	920.989	920.564	920.146	920.734	920.322	920.911	920.509		
968.087	967.678	967.275	966.882	966.502	966.140	965.794	965.468	965.157	964.859	964.571	964.287	964.003		
963.718	963.428	963.133	962.835	962.533	962.230	961.927	961.624	961.324	961.024	960.726				
1278.414	1269.827	1260.234	1250.653	1240.069	1230.487	1220.907	1210.332	1200.760	1200.194	1200.634	1200.071	1200.510		
1263.000	1262.478	1261.954	1261.456	1260.964	1260.485	1260.018	1259.562	1259.117	1258.683	1258.254	1257.828	1257.400		
1257.045	1256.601	1256.208	1255.827	1255.471	1255.140	1254.825	1254.524	1254.234	1254.013	1253.731	1253.455	1253.186		
1252.921	1252.600	1252.401	1252.146	1251.903	1251.642	1251.393	1251.147	1250.901	1250.658	1250.414				
1702.228	1701.600	1700.973	1700.348	1699.726	1699.104	1698.484	1697.864	1697.244	1696.629	1696.013	1695.395	1694.780		
1694.390	1693.851	1693.315	1692.791	1692.279	1691.780	1691.293	1690.820	1690.361	1689.915	1689.483	1689.065	1688.660		
1689.270	1688.893	1688.530	1688.180	1687.844	1687.520	1687.204	1686.895	1686.593	1686.296	1685.995	1685.700	1685.403		
1684.316	1684.108	1683.876	1683.659	1683.445	1683.236	1683.030	1682.827	1682.626	1682.427	1682.228				

Table C-4. Final contours, case 2.c1.

THE NEW CONTOUR VALUES, Y. FOLLOW															
200.000	222.832	225.655	228.459	231.234	233.970	236.655	239.278	241.828	244.294	246.665	248.929	251.075			
233.000	254.944	256.685	258.239	259.618	260.810	261.805	262.594	263.168	263.520	263.643	263.533	263.184			
262.000	261.791	260.740	259.459	257.953	256.229	254.295	252.160	249.834	247.327	244.651	241.817	238.837			
235.725	232.492	229.151	225.714	222.193	218.602	214.951	211.253	207.519	203.764	200.000					
251.623	254.652	257.687	260.718	263.712	266.652	269.545	272.386	275.145	277.797	280.346	282.804	285.152			
207.389	209.369	291.215	292.907	294.439	295.772	296.865	297.705	298.308	298.694	298.868	298.818	298.515			
207.935	207.079	295.972	294.634	293.068	291.265	289.216	286.935	284.449	281.778	278.928	275.925	272.796			
209.535	206.119	262.565	258.909	255.172	251.353	247.456	243.493	239.492	235.520	231.623					
309.443	311.514	317.553	321.665	325.688	329.646	333.542	337.363	341.075	344.657	348.113	351.445	354.628			
357.610	360.396	362.951	365.314	367.461	369.345	370.917	372.171	373.126	373.798	374.180	374.249	373.912			
373.330	372.334	371.011	369.385	367.455	365.207	362.637	359.769	356.641	353.273	349.677	345.882	341.915			
337.768	333.404	326.673	324.214	319.450	314.581	309.623	304.600	299.541	294.483						
482.028	487.543	453.038	456.495	463.895	469.219	474.449	479.566	484.553	489.390	494.060	498.542	502.816			
506.862	510.658	514.183	517.414	520.328	522.901	525.111	526.937	528.362	529.371	529.958	530.118	529.884			
529.149	528.819	526.458	524.470	522.061	519.242	516.025	512.428	508.470	504.176	499.571	494.685	489.563			
484.171	478.590	472.817	466.868	460.760	454.511	448.146	441.690	435.170	428.608	422.028					
684.757	693.500	702.203	710.828	719.341	727.712	735.913	743.920	751.708	759.253	766.528	773.507	780.161			
786.463	792.381	797.887	802.950	807.539	811.626	815.180	818.172	820.578	822.373	823.591	824.065	823.934			
823.139	821.676	819.544	816.751	813.310	809.242	804.571	799.327	793.544	787.256	780.500	773.310	765.723			
757.770	749.480	740.882	732.003	722.872	713.521	703.986	694.304	684.514	674.654	664.758					
980.726	987.388	1014.001	1020.517	1046.898	1063.067	1079.004	1094.650	1109.953	1124.857	1139.303	1153.231	1166.576			
1179.271	1191.249	1202.442	1212.781	1222.200	1230.635	1238.024	1244.309	1249.436	1253.359	1256.035	1257.430	1257.518			
1256.205	1253.726	1249.849	1244.675	1238.238	1230.584	1221.770	1211.859	1200.921	1189.030	1176.260	1162.684	1148.372			
1133.393	1117.612	1101.693	1085.097	1068.088	1050.725	1033.071	1015.185	997.127	978.954	960.726					
1270.414	1275.696	1280.964	1286.207	1291.410	1296.559	1301.640	1306.637	1311.533	1316.308	1320.943	1325.417	1329.706			
1333.766	1337.633	1341.221	1344.522	1347.511	1350.162	1352.451	1354.354	1355.850	1356.922	1357.553	1357.733	1357.453			
1336.712	1335.509	1333.852	1331.750	1329.218	1326.273	1322.938	1319.236	1315.172	1310.832	1306.184	1301.275	1296.130			
1310.775	1305.236	1299.529	1293.683	1287.717	1281.649	1275.498	1269.283	1263.020	1256.725	1250.414					
1702.228	1701.697	1701.166	1700.636	1700.109	1699.584	1699.062	1698.544	1698.030	1697.521	1697.017	1696.519	1696.026			
1695.541	1695.061	1694.589	1694.123	1693.664	1693.213	1692.764	1692.331	1691.901	1691.478	1691.062	1690.652	1690.250			
1689.854	1689.464	1689.082	1688.705	1688.335	1687.972	1687.614	1687.263	1686.917	1686.577	1686.243	1685.913	1685.584			
1685.260	1684.952	1684.640	1684.331	1684.025	1683.722	1683.420	1683.121	1682.822	1682.525	1682.228					

Table C-5. Final contours, case 2.c2.

THE NEW CONTOUR VALUES, Y, FOLLOW														
220.000	222.574	225.142	227.698	230.232	232.735	235.198	237.610	239.962	242.243	244.443	246.550	248.594		
250.442	252.202	253.822	255.290	256.593	257.720	258.660	259.402	259.937	260.256	260.355	260.227	259.869		
259.200	258.461	257.414	256.145	254.659	252.965	251.073	248.994	246.739	244.321	241.751	239.043	236.200		
233.260	230.209	227.060	223.848	220.560	217.215	213.824	210.390	206.946	203.477	200.000				
251.623	254.307	257.181	259.990	262.707	265.552	268.275	270.949	273.563	276.104	278.562	280.926	283.187		
205.327	207.332	209.187	210.877	212.388	213.708	214.821	215.716	216.382	216.811	217.095	217.224	217.299		
205.985	205.117	203.992	202.618	201.000	209.148	207.075	204.796	202.327	279.882	276.875	273.917	270.824		
207.614	204.301	200.896	207.407	253.846	250.224	246.555	242.849	239.119	235.374	231.623				
309.443	312.369	315.475	318.666	321.824	324.931	327.987	330.992	333.933	336.779	339.523	342.195	344.810		
347.324	349.679	351.847	353.825	355.606	357.172	358.504	359.591	360.427	361.022	361.390	361.498	361.247		
360.580	359.554	358.265	356.739	354.956	352.905	350.596	348.053	345.302	342.360	339.231	335.913	332.433		
328.855	325.224	321.524	317.726	313.833	309.864	305.835	301.762	297.660	293.549	289.443				
442.020	445.538	449.186	452.859	456.485	460.091	463.669	467.192	470.631	473.936	477.076	480.140	483.249		
404.354	409.283	414.944	420.342	426.498	432.422	438.102	443.566	448.893	454.093	459.166	464.110	468.930		
503.870	502.557	500.893	499.043	496.955	494.569	491.946	489.038	485.882	482.495	478.844	475.030	470.940		
464.773	462.654	460.508	458.299	455.989	453.601	451.133	448.596	445.993	443.337	440.626	437.866	435.056		
664.758	663.580	702.347	711.058	719.730	728.360	736.919	745.379	753.715	761.903	769.943	778.355	785.635		
413.210	430.484	447.316	463.718	479.584	494.889	509.591	523.639	536.984	549.588	561.432	572.431	577.454		
971.427	959.166	946.416	932.695	918.235	903.074	887.251	870.809	853.788	836.240	818.222	799.793	781.024		
764.526	752.893	743.835	734.202	724.578	714.904	704.920	694.953	684.921	674.849	664.758				
980.726	966.141	1011.526	1026.850	1042.081	1057.184	1072.120	1086.848	1101.319	1115.484	1129.283	1146.126	1169.417		
1195.11	1221.161	1245.989	1270.014	1293.157	1315.340	1329.771	1340.535	1350.556	1359.797	1368.228	1375.828	1379.114		
1374.609	1365.793	1356.149	1345.701	1334.479	1322.518	1305.427	1281.833	1257.273	1231.821	1205.553	1178.548	1150.882		
1126.103	1107.752	1092.429	1076.727	1060.706	1044.422	1027.926	1011.265	994.484	977.624	960.726				
1270.414	1273.892	1277.367	1280.834	1284.289	1287.728	1291.146	1294.535	1297.888	1301.196	1304.445	1307.622	1310.710		
1313.680	1316.535	1319.224	1321.730	1324.022	1326.073	1327.821	1329.271	1330.421	1331.271	1331.821	1332.029	1332.915		
1379.410	1370.594	1360.950	1350.502	1339.280	1327.319	1314.094	1300.089	1285.382	1269.906	1253.641	1236.654	1218.913		
1293.050	1289.694	1285.465	1281.177	1276.844	1272.478	1268.089	1263.682	1259.265	1254.841	1250.414				
1702.228	1701.684	1701.140	1700.596	1700.054	1699.513	1698.974	1698.438	1697.906	1697.377	1696.854	1696.336	1695.825		
1695.321	1694.824	1694.336	1693.856	1693.385	1692.923	1692.469	1692.023	1691.586	1691.156	1690.734	1690.319	1689.912		
1689.513	1689.122	1688.718	1688.364	1687.997	1687.640	1687.291	1686.950	1686.617	1686.292	1685.974	1685.662	1685.356		
1685.055	1684.754	1684.467	1684.178	1683.893	1683.611	1683.331	1683.053	1682.777	1682.502	1682.228				

Table C-6. Final contours, case 2.c3.

THE NEW CONTOUR VALUES, Y, FOLLOW																								
220.000	221.005	223.603	225.509	227.313	229.089	230.828	232.523	234.167	235.753	237.272	238.716	240.077	241.348	242.519	243.583	244.530	245.353	246.044	246.595	246.999	247.250	247.344	247.277	247.047
246.101	245.308	244.519	243.498	242.328	241.012	239.554	237.957	236.227	234.369	232.393	230.308	228.125	225.855	223.507	221.089	218.609	216.071	213.480	210.843	208.168	205.462	202.736	200.000	
251.623	253.498	255.392	257.293	259.177	261.030	262.846	264.621	266.350	268.025	269.639	271.186	272.660	274.050	275.345	276.533	277.605	278.550	279.355	280.008	280.498	280.816	280.956	280.915	280.693
279.700	278.935	278.004	276.914	275.671	274.278	272.735	271.046	269.215	267.249	265.161	262.964	260.672	258.303	255.866	253.369	250.814	248.203	245.537	242.819	240.057	237.263	234.447	231.623	
309.443	311.420	313.526	315.697	317.843	319.940	321.993	324.009	325.987	327.907	329.763	331.568	333.333	335.036	336.684	338.135	339.505	340.744	341.834	342.746	343.458	343.962	344.255	344.343	344.224
343.258	342.373	341.268	339.974	338.519	336.896	335.104	333.146	331.029	328.772	326.388	323.885	321.286	318.625	315.921	313.167	310.354	307.487	304.568	301.600	298.590	295.551	292.498	289.443	
442.028	445.418	448.880	452.348	455.784	459.206	462.618	466.027	469.418	472.725	475.932	479.175	482.583	486.080	489.479	492.681	495.692	498.535	501.184	503.567	505.609	507.274	508.581	509.611	510.362
509.876	508.291	506.130	503.646	500.898	497.879	494.580	491.005	487.184	483.176	479.013	474.675	470.194	465.732	461.411	457.184	452.802	448.382	443.943	439.518	435.114	430.730	426.368	422.028	
684.758	696.120	706.490	716.309	726.334	736.809	747.685	758.088	770.505	782.855	796.988	813.373	831.732	852.453	870.788	897.290	919.475	941.203	962.353	982.669	1001.785	1019.385	1035.244	1048.952	1058.086
1057.956	1048.151	1033.429	1018.170	997.242	977.029	955.720	933.448	910.379	886.753	862.903	839.272	816.819	796.596	779.055	764.002	750.342	737.126	724.257	711.804	699.726	687.912	676.278	664.758	
986.726	986.702	1015.781	1032.198	1048.818	1066.111	1083.912	1101.890	1120.103	1139.021	1159.681	1183.592	1210.260	1238.961	1271.244	1302.237	1329.025	1346.090	1362.660	1378.627	1393.615	1407.198	1419.140	1429.286	1438.352
1438.553	1428.600	1417.146	1403.576	1388.502	1372.372	1355.413	1337.697	1319.213	1299.330	1256.251	1223.058	1190.661	1161.109	1136.338	1115.349	1095.497	1075.419	1055.283	1035.610	1016.477	997.673	979.099	960.726	
1270.414	1273.743	1276.935	1279.784	1282.576	1285.699	1289.080	1292.438	1295.774	1299.326	1303.099	1306.958	1311.005	1315.456	1320.326	1325.416	1333.826	1350.891	1367.441	1383.428	1398.416	1411.999	1423.941	1434.087	1441.399
1441.354	1433.401	1421.947	1408.377	1393.303	1377.173	1360.214	1342.498	1324.014	1315.513	1309.511	1303.873	1298.513	1293.316	1288.477	1284.093	1279.828	1275.396	1270.916	1266.612	1262.487	1258.424	1254.393	1250.414	
1762.228	1701.607	1701.066	1700.441	1699.896	1699.317	1698.746	1698.179	1697.615	1697.057	1696.506	1695.961	1695.423	1694.894	1694.377	1693.869	1693.366	1692.875	1692.393	1691.923	1691.467	1691.019	1690.579	1690.149	1689.733
1688.934	1688.549	1688.173	1687.806	1687.449	1687.104	1686.769	1686.446	1686.131	1685.825	1685.527	1685.238	1684.958	1684.684	1684.414	1684.161	1683.910	1683.660	1683.413	1683.170	1682.932	1682.696	1682.461	1682.228	

Table C-7. Final contours, case 2.c4.

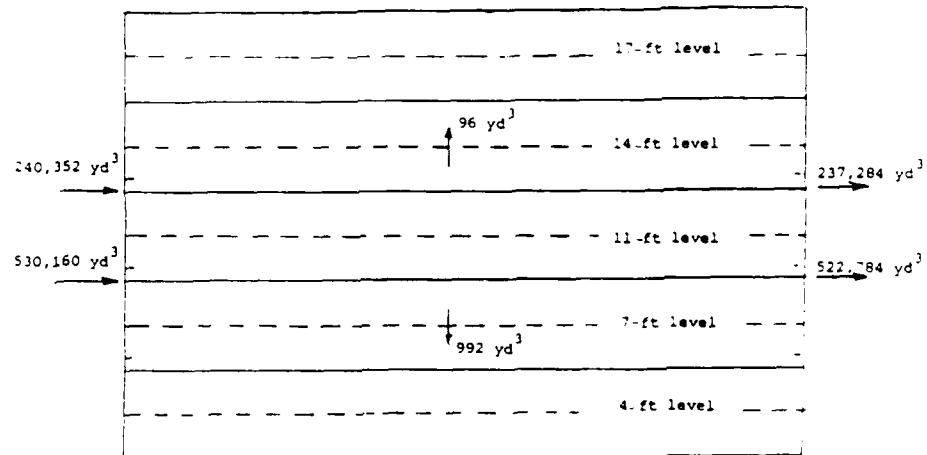
THE NEW CONTOUR VALUES, Y, FOLLOW															
220.000	221.000	223.000	225.532	227.357	229.164	230.947	232.699	234.414	236.083	237.699	239.254	240.734			
242.133	243.488	244.642	245.728	246.688	247.511	248.186	248.704	249.057	249.239	249.244	249.067	248.708			
248.163	247.434	246.522	245.433	244.170	242.740	241.153	239.418	237.545	235.545	233.430	231.211	228.899			
224.504	224.036	221.504	218.918	216.286	213.617	210.920	208.203	205.473	202.737	200.000					
251.623	253.492	255.355	257.214	259.064	260.901	262.716	264.502	266.251	267.956	269.609	271.205	272.731			
274.176	275.526	276.771	277.898	278.906	279.753	280.459	281.004	281.381	281.583	281.605	281.437	281.075			
280.520	279.777	278.847	277.734	276.443	274.982	273.359	271.585	269.671	267.629	265.471	263.208	260.853			
258.420	255.916	253.349	250.728	248.061	245.356	242.622	239.864	237.096	234.344	231.623					
309.443	311.824	314.207	316.594	318.982	321.367	323.741	326.099	328.431	330.730	332.986	335.188	337.320			
339.366	341.307	343.125	344.802	346.317	347.652	348.789	349.712	350.405	350.858	351.058	350.994	350.662			
350.062	349.197	348.071	346.688	345.061	343.202	341.126	338.853	336.401	333.790	331.036	328.166	325.192			
322.133	319.003	315.814	312.579	309.309	306.014	302.702	299.380	296.058	292.744	289.443					
402.028	405.709	409.391	413.072	416.753	420.429	424.098	427.751	431.380	434.973	438.514	441.986	445.364			
480.632	491.756	494.710	497.464	499.986	502.246	504.214	505.862	507.163	508.095	508.641	508.786	508.522			
507.847	506.762	505.276	503.402	501.157	498.564	495.646	492.432	488.951	485.234	481.309	477.208	472.958			
468.585	464.11	459.566	454.960	450.309	445.628	440.926	436.211	431.487	426.758	422.011					
684.758	699.616	714.513	729.483	744.557	759.753	775.078	790.525	806.069	821.667	837.259	852.857	868.494			
903.921	928.912	953.321	976.995	999.774	1021.498	1042.010	1061.164	1078.824	1094.873	1109.216	1121.782	1127.320			
1120.607	1106.894	1091.341	1074.105	1055.249	1034.889	1013.156	990.193	966.154	941.196	915.473	889.135	862.324			
837.770	818.198	801.075	783.899	766.720	749.579	732.498	715.486	698.536	681.634	664.758					
980.726	1000.366	1020.022	1039.705	1059.422	1079.168	1098.927	1118.668	1138.343	1157.890	1177.226	1196.724	1220.739			
1260.672	1291.908	1322.296	1351.684	1373.324	1389.434	1404.547	1418.545	1431.322	1442.782	1452.850	1461.448	1465.130			
1460.350	1450.611	1439.418	1426.623	1412.903	1397.747	1381.461	1364.160	1339.492	1308.613	1276.890	1243.878	1210.323			
1179.637	1155.419	1130.309	1112.934	1091.375	1069.696	1047.945	1026.156	1004.350	982.538	960.726					
1270.414	1275.657	1280.936	1286.205	1291.736	1297.314	1303.040	1308.927	1314.976	1321.182	1327.523	1333.970	1340.476			
1346.987	1353.432	1359.733	1365.801	1371.825	1378.125	1384.235	1390.348	1396.123	1401.563	1407.651	1413.269	1419.931			
1405.151	1405.912	1404.219	1431.624	1417.704	1402.548	1386.262	1368.961	1357.242	1350.198	1342.912	1335.469	1327.947			
1320.413	1312.922	1305.514	1298.220	1291.055	1284.025	1277.123	1270.336	1263.641	1257.011	1250.414					
1702.228	1701.648	1701.068	1700.491	1699.917	1699.347	1698.782	1698.223	1697.671	1697.127	1696.591	1696.063	1695.545			
1695.036	1694.536	1694.047	1693.567	1693.096	1692.636	1692.185	1691.743	1691.310	1690.886	1690.471	1690.064	1689.665			
1689.275	1688.892	1688.517	1688.151	1687.792	1687.441	1687.097	1686.762	1686.433	1686.113	1685.800	1685.494	1685.195			
1680.902	1684.616	1684.335	1684.060	1683.789	1683.523	1683.260	1682.999	1682.741	1682.484	1682.228					

Table C-8. Final contours, case 3 (17 weeks plus sediment addition).

220.000	219.071	210.148	217.236	216.342	215.470	214.625	213.812	213.033	212.291	211.589	210.926	210.303
209.719	209.172	208.660	208.180	207.729	207.305	206.903	206.522	206.158	205.809	205.473	205.147	204.829
204.516	204.207	203.901	203.596	203.292	202.992	202.695	202.406	202.125	201.857	201.603	201.367	201.149
200.950	200.773	200.616	200.480	200.363	200.265	200.185	200.121	200.071	200.033	200.000		
251.623	250.708	249.802	248.909	248.035	247.187	246.370	245.589	244.848	244.150	243.495	242.884	242.317
241.792	241.367	240.957	240.560	240.179	239.812	239.459	239.121	238.798	238.489	238.193	237.909	237.636
237.069	236.767	236.437	236.101	235.758	235.412	235.066	234.722	234.384	234.056	233.741	233.443	233.165
232.909	232.676	232.467	232.282	232.119	231.978	231.860	231.766	231.696	231.651	231.623		
309.443	308.558	307.680	306.817	305.980	305.175	304.411	303.694	303.027	302.414	301.855	301.349	300.896
308.492	300.131	299.808	299.517	299.249	298.999	298.757	298.516	298.286	298.067	297.850	297.634	297.418
296.781	295.423	296.042	295.640	295.220	294.784	294.336	293.883	293.429	292.979	292.541	292.120	291.723
291.353	291.013	290.703	290.422	290.167	289.936	289.735	289.578	289.478	289.440	289.443		
182.028	181.318	180.621	179.951	179.321	178.745	178.232	177.789	177.421	177.129	176.913	176.770	176.696
436.683	436.722	436.798	436.899	437.013	437.127	437.225	437.289	437.302	437.252	437.136	436.952	436.699
416.373	415.968	415.482	414.916	414.278	413.576	412.822	412.026	411.198	410.354	409.508	408.679	407.882
427.128	426.722	425.764	425.148	424.568	424.020	423.508	423.043	422.643	422.312	422.020		
604.750	604.608	604.472	604.368	604.297	604.283	604.331	604.448	604.639	604.907	605.250	605.665	606.145
686.682	687.249	687.876	688.502	689.122	689.717	690.266	690.747	691.140	691.424	691.581	691.597	691.459
691.160	690.696	690.088	689.284	688.352	687.289	686.110	684.837	683.490	682.091	680.661	679.221	677.788
676.378	675.004	673.675	672.398	671.175	670.006	668.887	667.813	666.774	665.760	664.758		
980.726	981.842	1002.983	1014.100	1025.389	1036.678	1048.028	1059.430	1070.864	1082.300	1093.693	1105.458	1129.498
1154.760	1179.183	1203.166	1226.603	1249.386	1271.492	1292.545	1312.709	1331.801	1349.737	1366.447	1381.880	1396.056
1381.020	1364.718	1347.118	1328.266	1308.222	1287.085	1264.885	1241.782	1217.863	1193.239	1168.019	1142.310	1116.214
1093.293	1077.103	1064.242	1051.298	1038.315	1025.327	1012.356	999.412	986.497	973.605	960.726		
1270.414	1267.593	1264.812	1307.106	1319.506	1332.036	1344.706	1357.516	1370.450	1383.476	1396.543	1413.054	1436.496
1483.017	1449.303	1515.137	1540.383	1564.697	1588.535	1611.156	1632.924	1652.616	1671.623	1683.044	1690.753	1694.217
1689.950	1681.451	1668.760	1648.974	1627.783	1605.291	1581.617	1556.892	1531.254	1504.845	1477.803	1450.263	1422.548
1397.648	1379.716	1365.183	1350.630	1336.109	1321.650	1307.270	1292.970	1278.740	1264.563	1250.414		
1702.228	1701.147	1700.070	1699.001	1697.943	1696.900	1695.876	1694.874	1693.897	1692.948	1692.029	1691.143	1690.292
1689.476	1688.742	1687.966	1687.269	1686.613	1685.998	1685.424	1684.891	1684.399	1683.946	1683.530	1683.164	1682.828
1680.821	1685.049	1682.010	1681.807	1681.635	1681.491	1681.376	1681.287	1681.223	1681.183	1681.164	1681.166	1681.167
1681.226	1681.240	1681.349	1681.431	1681.523	1681.626	1681.737	1681.854	1681.976	1682.101	1682.228		
2180.943	2179.761	2178.582	2177.412	2176.254	2175.111	2173.988	2172.898	2171.815	2170.771	2169.760	2168.784	2167.844
2166.949	2166.094	2165.262	2164.516	2163.797	2163.125	2162.501	2161.925	2161.398	2160.919	2160.487	2160.102	2159.763
2159.468	2159.217	2159.008	2158.840	2158.710	2158.617	2158.559	2158.533	2158.539	2158.573	2158.634	2158.719	2158.828
2158.954	2159.103	2159.267	2159.445	2159.636	2159.836	2160.048	2160.266	2160.488	2160.715	2160.943		

Table C-9. Final contours, case 4.

THE NEW CONTOUR VALUES, Y, FOLLOW									
220.000	236.361	252.720	269.079	285.438	301.797	318.156	334.515	350.874	367.233
230.500	246.861	263.220	279.579	295.938	312.297	328.656	345.015	361.374	377.733
240.000	257.361	273.720	290.079	306.438	322.797	339.156	355.515	371.874	388.233
250.500	267.861	284.220	300.579	316.938	333.297	349.656	365.015	381.374	398.733
260.000	278.361	294.720	310.079	326.438	343.797	360.156	375.515	391.874	409.233
270.500	288.861	305.220	319.579	336.938	353.297	370.656	385.015	401.374	419.733
280.000	299.361	315.720	328.079	346.438	363.797	380.156	395.515	411.874	430.233
290.500	309.861	326.220	337.579	356.938	373.297	390.656	405.015	421.374	440.733
300.000	320.361	336.720	346.079	366.438	383.797	400.156	415.515	431.874	451.233
310.500	330.861	346.220	355.579	376.938	393.297	410.656	425.015	441.374	461.733
320.000	341.361	356.720	365.079	386.438	403.797	420.156	435.515	451.874	472.233
330.500	351.861	367.220	374.579	396.938	413.297	430.656	445.015	461.374	482.733
340.000	362.361	377.720	384.079	406.438	423.797	440.156	455.515	471.874	493.233
350.500	372.861	388.220	393.579	416.938	433.297	450.656	465.015	481.374	503.733
360.000	383.361	398.720	403.079	426.438	443.797	460.156	475.515	491.874	514.233
370.500	393.861	409.220	412.579	436.938	453.297	470.656	485.015	501.374	524.733
380.000	404.361	419.720	422.079	446.438	463.797	480.156	495.515	511.874	535.233
390.500	414.861	430.220	431.579	456.938	473.297	490.656	505.015	521.374	545.733
400.000	425.361	440.720	441.079	466.438	483.797	500.156	515.515	531.874	556.233
410.500	435.861	451.220	450.579	476.938	493.297	510.656	525.015	541.374	566.733
420.000	446.361	461.720	460.079	486.438	503.797	520.156	535.515	551.874	577.233
430.500	456.861	472.220	469.579	496.938	513.297	530.656	545.015	561.374	587.733
440.000	467.361	482.720	479.079	506.438	523.797	540.156	555.515	571.874	598.233
450.500	477.861	493.220	488.579	516.938	533.297	550.656	565.015	581.374	608.733
460.000	488.361	503.720	498.079	526.438	543.797	560.156	575.515	591.874	619.233
470.500	498.861	514.220	507.579	536.938	553.297	570.656	585.015	601.374	629.733
480.000	509.361	524.720	517.079	546.438	563.797	580.156	595.515	611.874	640.233
490.500	519.861	535.220	526.579	556.938	573.297	590.656	605.015	621.374	650.733
500.000	530.361	545.720	536.079	566.438	583.797	600.156	615.515	631.874	661.233
510.500	540.861	556.220	545.579	576.938	593.297	610.656	625.015	641.374	671.733
520.000	551.361	566.720	555.079	586.438	603.797	620.156	635.515	651.874	682.233
530.500	561.861	577.220	564.579	596.938	613.297	630.656	645.015	661.374	692.733
540.000	572.361	587.720	574.079	606.438	623.797	640.156	655.515	671.874	703.233
550.500	582.861	598.220	583.579	616.938	633.297	650.656	665.015	681.374	713.733
560.000	593.361	608.720	593.079	626.438	643.797	660.156	675.515	691.874	724.233
570.500	603.861	619.220	602.579	636.938	653.297	670.656	685.015	701.374	734.733
580.000	614.361	629.720	612.079	646.438	663.797	680.156	695.515	711.874	745.233
590.500	624.861	640.220	621.579	656.938	673.297	690.656	705.015	721.374	755.733
600.000	635.361	650.720	631.079	666.438	683.797	700.156	715.515	731.874	766.233
610.500	645.861	661.220	640.579	676.938	693.297	710.656	725.015	741.374	776.733
620.000	656.361	671.720	650.079	686.438	703.797	720.156	735.515	751.874	787.233
630.500	666.861	682.220	659.579	696.938	713.297	730.656	745.015	761.374	797.733
640.000	677.361	692.720	669.079	706.438	723.797	740.156	755.515	771.874	808.233
650.500	687.861	703.220	678.579	716.938	733.297	750.656	765.015	781.374	818.733
660.000	698.361	713.720	688.079	726.438	743.797	760.156	775.515	791.874	829.233
670.500	708.861	724.220	697.579	736.938	753.297	770.656	785.015	801.374	839.733
680.000	719.361	734.720	707.079	746.438	763.797	780.156	795.515	811.874	850.233
690.500	729.861	745.220	716.579	756.938	773.297	790.656	805.015	821.374	860.733
700.000	740.361	755.720	726.079	766.438	783.797	800.156	815.515	831.874	871.233
710.500	750.861	766.220	735.579	776.938	793.297	810.656	825.015	841.374	881.733
720.000	761.361	776.720	745.079	786.438	803.797	820.156	835.515	851.874	892.233
730.500	771.861	787.220	754.579	796.938	813.297	830.656	845.015	861.374	902.733
740.000	782.361	797.720	764.079	806.438	823.797	840.156	855.515	871.874	913.233
750.500	792.861	808.220	773.579	816.938	833.297	850.656	865.015	881.374	923.733
760.000	803.361	818.720	783.079	826.438	843.797	860.156	875.515	891.874	934.233
770.500	813.861	829.220	792.579	836.938	853.297	870.656	885.015	901.374	944.733
780.000	824.361	839.720	802.079	846.438	863.797	880.156	895.515	911.874	955.233
790.500	834.861	850.220	811.579	856.938	873.297	890.656	905.015	921.374	965.733
800.000	845.361	860.720	821.079	866.438	883.797	900.156	915.515	931.874	976.233
810.500	855.861	871.220	830.579	876.938	893.297	910.656	925.015	941.374	986.733
820.000	866.361	881.720	840.079	886.438	903.797	920.156	935.515	951.874	997.233
830.500	876.861	892.220	849.579	896.938	913.297	930.656	945.015	961.374	1007.733
840.000	887.361	902.720	859.079	906.438	923.797	940.156	955.515	971.874	1018.233
850.500	897.861	913.220	868.579	916.938	933.297	950.656	965.015	981.374	1028.733
860.000	908.361	923.720	878.079	926.438	943.797	960.156	975.515	991.874	1039.233
870.500	918.861	934.220	887.579	936.938	953.297	970.656	985.015	1001.374	1049.733
880.000	929.361	944.720	897.079	946.438	963.797	980.156	995.515	1011.874	1060.233
890.500	939.861	955.220	906.579	956.938	973.297	990.656	1005.015	1021.374	1070.733
900.000	950.361	965.720	916.079	966.438	983.797	1000.156	1015.515	1031.874	1081.233
910.500	960.861	976.220	925.579	976.938	993.297	1010.656	1025.015	1041.374	1091.733
920.000	971.361	986.720	935.079	986.438	1003.797	1020.156	1035.515	1051.874	1102.233
930.500	981.861	997.220	944.579	996.938	1013.297	1030.656	1045.015	1061.374	1112.733
940.000	992.361	1007.720	954.079	1006.438	1023.797	1040.156	1055.515	1071.874	1123.233
950.500	1002.861	1018.220	963.579	1016.938	1033.297	1050.656	1065.015	1081.374	1133.733
960.000	1013.361	1028.720	973.079	1026.438	1043.797	1060.156	1075.515	1091.874	1144.233
970.500	1023.861	1039.220	982.579	1036.938	1053.297	1070.656	1085.015	1101.374	1154.733
980.000	1034.361	1049.720	992.079	1046.438	1063.797	1080.156	1095.515	1111.874	1165.233
990.500	1044.861	1060.220	1001.579	1056.938	1073.297	1090.656	1105.015	1121.374	1175.733
1000.000	1055.361	1070.720	1011.079	1066.438	1083.797	1100.156	1115.515	1131.874	1186.233
1010.500	1065.861	1081.220	1020.579	1076.938	1093.297	1110.656	1125.015	1141.374	1196.733
1020.000	1076.361	1091.720	1030.079	1086.438	1103.797	1120.156	1135.515	1151.874	1207.233
1030.500	1086.861	1102.220	1039.579	1096.938	1113.297	1130.656	1145.015	1161.374	1217.733
1040.000	1097.361	1112.720	1049.079	1106.438	1123.797	1140.156	1155.515	1171.874	1228.233
1050.500	1107.861	1123.220	1058.579	1116.938	1133.297	1150.656	1165.015	1181.374	1238.733
1060.000	1118.361	1133.720	1068.079	1126.438	1143.797	1160.156	1175.515	1191.874	1249.233
1070.500	1128.861	1144.220	1077.579	1136.938	1153.297	1170.656	1185.015	1201.374	1259.733
1080.000	1139.361	1154.720	1087.079	1146.438	1163.797	1180.156	1195.515	1211.874	1270.233
1090.500	1149.861	1165.220	1096.579	1156.938	1173.297	1190.656	1205.015	1221.374	1280.733
1100.000	1160.361	1175.720	1106.079	1166.438	1183.797	1200.156	1215.515	1231.874	1291.233
1110.500	1170.861	1186.220	1115.579	1176.938	1193.297	1210.656	1225.015	1241.374	1301.733
1120.000	1181.361	1196.720	1125.079	1186.438	1203.797	1220.156	1235.515	1251.874	1312.233
1130.500	1191.861	1207.220	1134.579	1196.938	1213.297	1230.656	1245.015	1261.374	1322.733
1140.000	1202.361	1217.720	1144.079	1206.438	1223.797	1240.156	1255.515	1271.874	1333.233
1150.500	1212.861	1228.220	1153.579	1216.938	1233.297	1250.656	1265.015	1281.374	1343.733
1160.000	1223.361	1238.720	1163.079	1226.438	1243.797	1260.156	1275.515	1291.874	



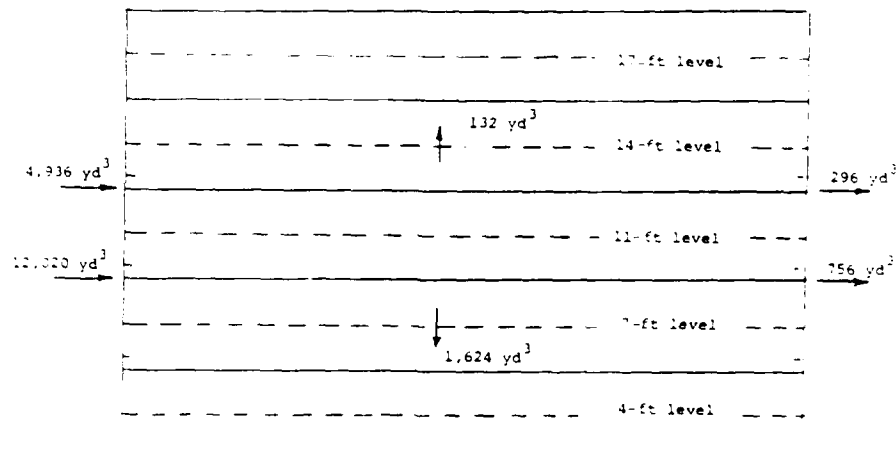
Case 2.a.

Period Considered: Twelve months, January through December, using 1970
WIS wave hindcasts

Sediment Budget Summary:

Amount of sediment added:	None
Amount of sediment transported shoreward from nourished region:	992 yd ³
Amount of sediment transported seaward from nourished region:	96 yd ³
Net amount of sediment transported alongshore from nourished region:	10,444 yd ³
Total amount of sediment transported from nourished region:	9,156 yd ³

Figure C-1. Schematic illustration of sediment volumes transported from region, case 2.a.



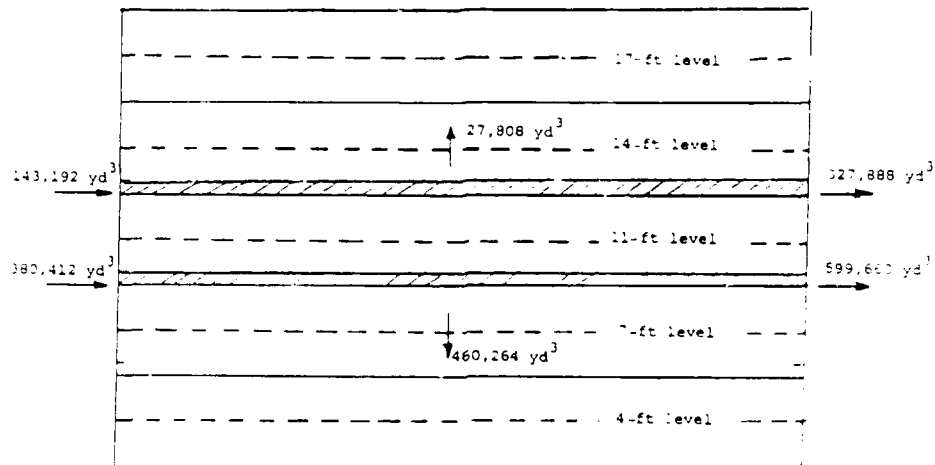
Case No. 2b.

Period considered: Twelve months, January through December, using 1970
 410 wave hindcasts, but wave angle always set equal
 to 0°

Sediment Budget Summary:

Amount of sediment added:	None
Amount of sediment transported shoreward from nourished region:	1,624 yd ³
Amount of sediment transported seaward from nourished region:	132 yd ³
Net amount of sediment transported alongshore from nourished region:	-15,904 yd ³
Total amount of sediment transported from nourished region:	-14,148 yd ³

Figure C-2. Schematic illustration of sediment volumes transported from region, case 2.b.



Use 2.c1.

Period considered: levels months, from 10/1/82 to 10/1/83, using 1978-81 wave climatology.

Sediment Budget Summary:

Amount of sediment added: 1,431,912 yd³ on 7- and 11-ft contours

Amount of sediment transported seaward from nourished region: 460,264 yd³ (31.7%)

Amount of sediment transported seaward from nourished region: 27,808 yd³ (1.9%)

Net amount of sediment transported alongshore from nourished region: 403,944 yd³ (27.8%)

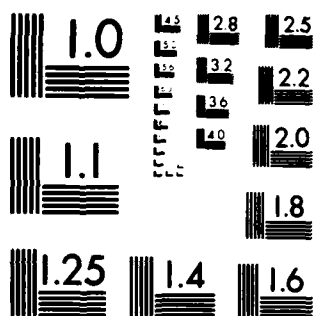
Total amount of sediment transported from nourished region: 592,016 yd³ (41.4%)

Figure C-3. Schematic illustration of sediment volumes transported from nourished region, case 2.c1.

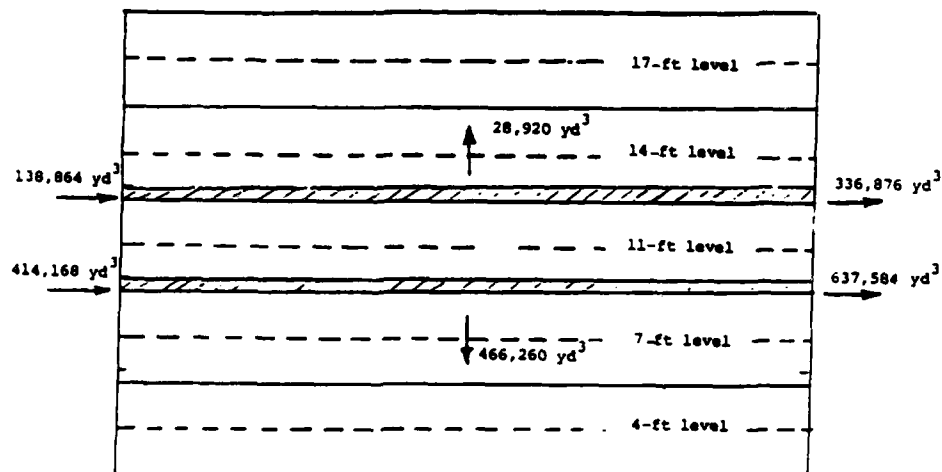
AD-A130 197 A NUMERICAL MODEL TO SIMULATE SEDIMENT TRANSPORT IN THE VICINITY OF COAST..(U) COASTAL AND OFFSHORE ENGINEERING
AND RESEARCH INC NEWARK DE M PERLIN ET AL. MAY 83
UNCLASSIFIED CERC-MR-83-10 DACW72-80-C-0030 F/G 8/3 NL

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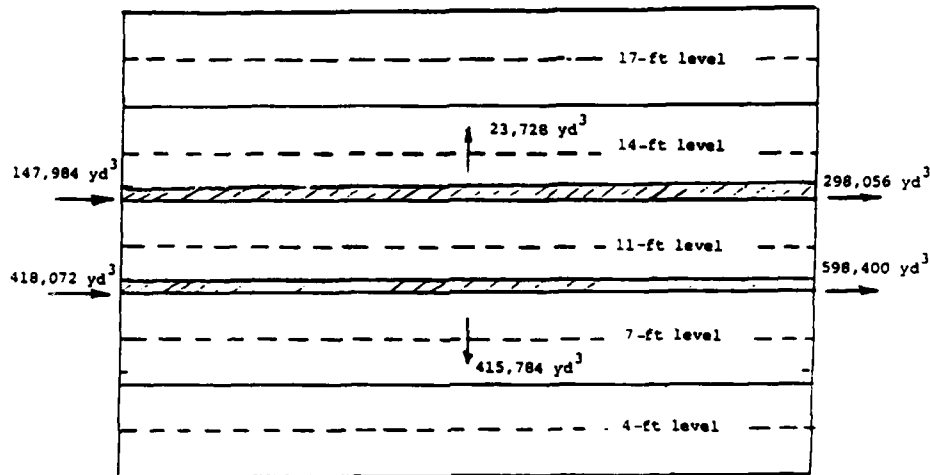
Case 2.c2.

Period considered: Twelve months, April through March, using 1975
WIS wave hindcasts.

Sediment Budget Summary:

Amount of sediment added:	1,452,000 yd ³ (on 7- and 11-ft contours)
Amount of sediment transported shoreward from nourished region:	466,260 yd ³ (32.1pct)
Amount of sediment transported seaward from nourished region:	28,920 yd ³ (2.0 pct)
Net amount of sediment transported alongshore from nourished region:	421,428 yd ³ (29.0pct)
Total amount of sediment transported from nourished region:	916,608 yd ³ (63.1pct)

Figure C-4. Schematic illustration of sediment volumes transported from nourished region, case 2.c2.



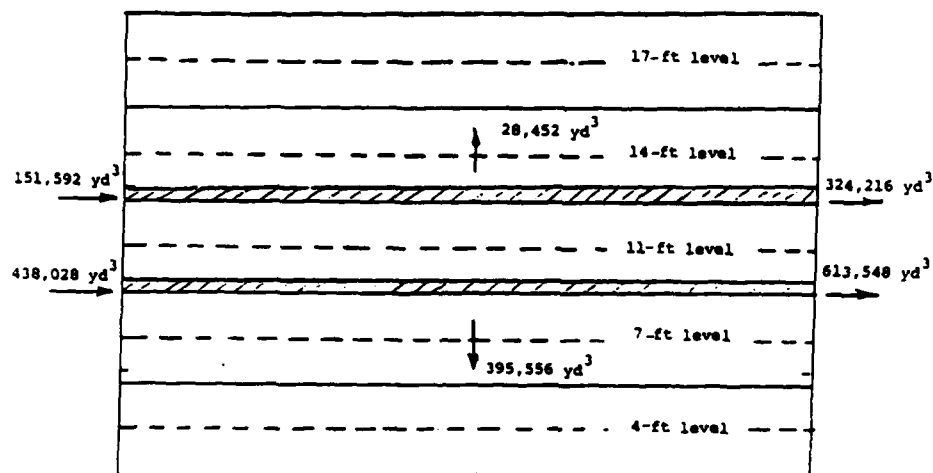
Case 2.c3.

Period considered: Twelve months, July through June, using 1975
WIS wave hindcasts.

Sediment Budget Summary

Amount of sediment added:	1,452,000 yd ³ (on 7- and 11-ft contour)
Amount of sediment transported shoreward from nourished region:	415,784 yd ³ (28.6 pct)
Amount of sediment transported seaward from nourished region:	23,728 yd ³ (1.6 pct)
Net amount of sediment transported alongshore from nourished region:	392,056 yd ³ (27.0 pct)
Total amount of sediment transported from nourished region:	415,784 yd ³ (28.6 pct)

Figure C-5. Schematic illustration of sediment volumes transported from nourished region, case 2.c3.



Case 2.c4.

Period considered: Twelve months, October through September, using 1975 WIS wave hindcasts.

Sediment Budget Summary:

Amount of sediment added: 1,452,000 yd³ (on 7- and 11-ft contours).

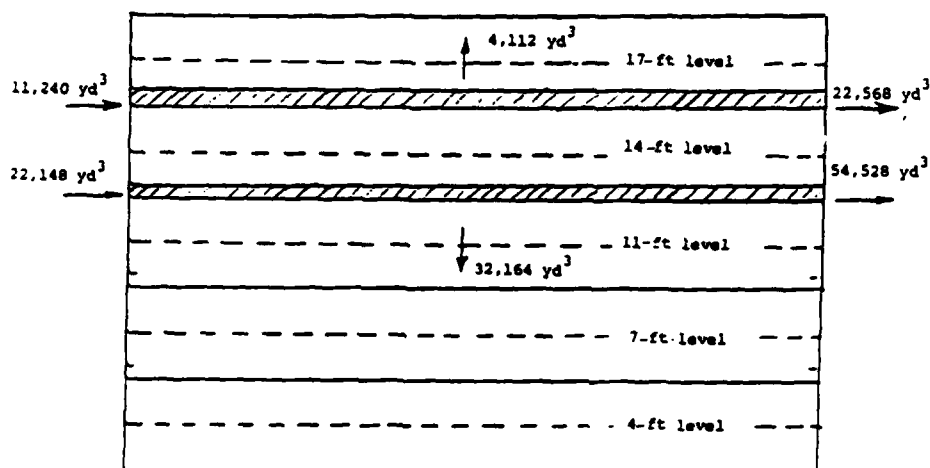
Amount of sediment transported shoreward from nourished region: 395,556 yd³ (27.2 pct)

Amount of sediment transported seaward from nourished region: 28,452 yd³ (2.0 pct)

Net amount of sediment transported alongshore from nourished region: 368,144 yd³ (24.0 pct)

Total amount of sediment transported from nourished region: 772,152 yd³ (53.2 pct)

Figure C-6. Schematic illustration of sediment volumes transported from nourished region, case 2.c4.



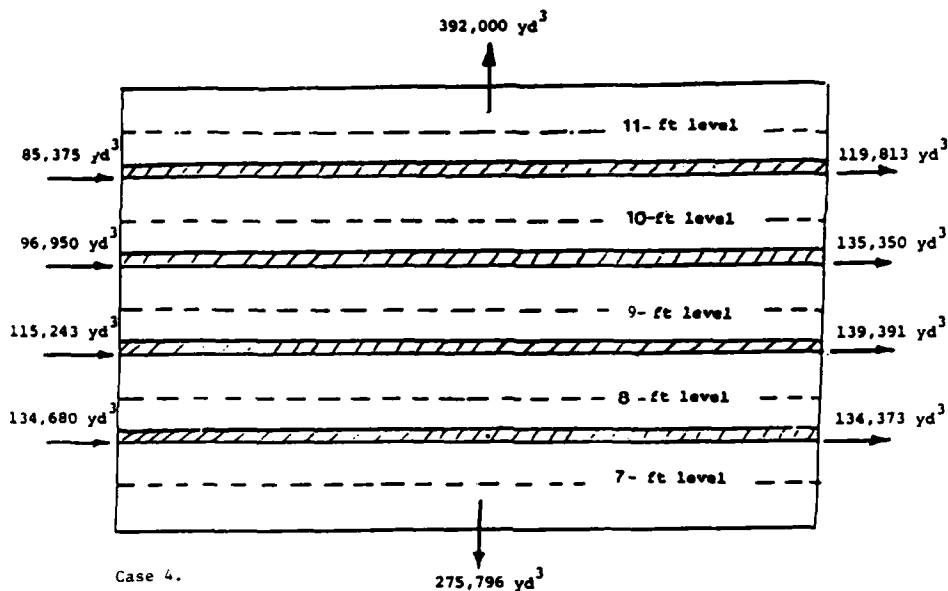
Case 3.

Period considered: Four months, January through April, using 1975 WIS wave hindcasts.

Sediment Budget Summary:

Amount of sediment added 363,000 yd³ (on 11- and 14-ft contours).
 Amount of sediment transported shoreward from nourished region: 32,164 yd³ (8.9pct)
 Amount of sediment transported seaward from nourished region: 4,112 yd³ (1.1pct)
 Net amount of sediment transported alongshore from nourished region: 43,708 yd³ (12.0pct)
 Total amount of sediment transported from nourished region: 79,984 yd³ (22.0pct)

Figure C-7. Schematic illustration of sediment volumes transported from nourished region, case 3.



Period considered: Twelve months, January through December, using 1975
WIS wave hindcasts.

Sediment Budget Summary:

Amount of sediment added: 1,452,000 yd³ (on 7-, 8-, 9-, and 10-ft contours).
 Amount of sediment transported shoreward from nourished region: 275,796 yd³ (19.0pct)
 Amount of sediment transported seaward from nourished region: 392,000 yd³ (27.0pct)
 Net amount of sediment transported alongshore from nourished region: 96,679 yd³ (6.7pct)
 Total amount of sediment transported from nourished region: 764,475 yd³ (52.6pct)

Figure C-8. Schematic illustration of sediment volumes transported from nourished region, case 4.

APPENDIX D

METHODOLOGY AND PROGRAM LISTING OF COMPUTER PROGRAM WHICH CONVERTS BATHYMETRIC DATA INTO MONOTONICALLY DECREASING DEPTH CONTOURS

In order to simulate prototype shorelines (and in this case to help verify the numerical model via Channel Islands Harbor data), the (x, y, z) data points must be transformed into a form suitable for use in the model (i.e., bars can not be present). First, the bathymetric data have to be put into a form with fixed longshore and offshore spacings (i.e., Δx and Δy equal constants). This can be accomplished using one of the many available canned programs which do the interpolation. The problem is then one of finding the most suitable value of the constant, A, in the equation $h = Ay^{2/3}$. However, as is usually the case, the exact location of the shoreline ($h = 0$) is unknown. In addition, one requires the added constraint is required that the volumes of sediment (or conversely, the water above the profiles) balance. The problem is solved using LaGrange Multipliers and the Newton Raphson technique for non linear equations.

The equation to be minimized is

$$F(A, y_{del1}, y_{del2}, \dots, y_{del_{IMAX}}) = \sum_{i=1}^{IMAX} \sum_{j=1}^{IMAX} (h_{meas_{i,j}} - h_{pred_{i,j}})^2 \quad (D-1)$$

where A is the scale parameter in the equilibrium beach profile, y_{del_i} are the locations of the shoreline for the IMAX profiles, h_{meas} is the interpolated depth from the survey, and h_{pred} is the depth predicted by the equation

$$h_{pred_{i,j}} = A(y_{i,j} - y_{del_i})^{2/3} \quad (D-2)$$

The constraint equation is as follows

$$\begin{aligned} g(A, y_{del1}, \dots, y_{del_{IMAX}}) &= V_{pred} = \sum_{i=1}^{IMAX} \Delta x \left\{ \int_{y_{del_i}}^y A(y - y_{del_i})^{2/3} dy \right\} \\ &= \sum_{i=1}^{IMAX} \frac{3}{5} \Delta x A(y_f - y_{del_i})^{5/3} = V_{meas} \end{aligned} \quad (D-3)$$

where V_{pred} is the predicted volume of water above the profile to the reference datum, V_{meas} is the measured volume computed from the survey, Δx is the longshore distance between onshore-offshore profiles, and y_f is the distance offshore to the last point on each of the measured profiles (it was a constant after the interpolation routine was used).

LaGrange Multipliers procedure says to form the quantify F^* as

$$F^* = F - \lambda g \quad (D-4)$$

take the total differential of equation (D-4)

$$dF^* = dF - \lambda dg = \left(\frac{dF}{dA} dA + \frac{dF}{d(ydel_1)} d(ydel_1) + \dots \frac{dF}{d(ydel_{IMAX})} d(ydel_{IMAX}) \right) - \lambda \left(\frac{dg}{dA} dA + \frac{dg}{d(ydel_1)} d(ydel_1) + \dots \frac{dg}{d(ydel_{IMAX})} d(ydel_{IMAX}) \right) \quad (D-5)$$

Rearranging

$$0 = dF^* = \left(\frac{dF}{dA} - \lambda \frac{dg}{dA} \right) dA + \left(\frac{dF}{d(ydel_1)} - \lambda \frac{dg}{d(ydel_1)} \right) d(ydel_1) + \dots \quad (D-6)$$

It is clear that the terms in brackets in equation (D-6) must individually equal zero, however this leaves $(IMAX + 2)$ unknown ($ydel_i =$ to $IMAX$, A , and λ) and only $(IMAX + 1)$ Equations. The $(IMAX + 2)$ th equation is taken as equation (D-3). The following system of equation then results:

$$0 = \frac{dF}{dA} - \lambda \frac{dg}{dA} = \sum_{i=1}^{IMAX} \sum_{j=1}^{JMAX} [-2(h_{meas_{i,j}} - A(y_{i,j} - ydel_i)^{2/3})(y_{i,j} - ydel_i)^{2/3}] - \lambda \sum_{i=1}^{IMAX} \frac{3}{5} \Delta x (y_f - ydel_i)^{5/3} \quad (D-7-1)$$

$$0 = \frac{dF}{d(y_{del1})} - \lambda \frac{dg}{d(y_{del1})} = \sum_{j=1}^{JMAX} [2(h_{meas1,j} - A(y_{1,j} - y_{del1})^{2/3})$$

$$* (2/3 A(y_{1,j} - y_{del1})^{-1/3} + \lambda \Delta x A(y_f - y_{del1})^{2/3}$$

(D-7-2)

$$0 = \frac{dF}{d(y_{delIMAX})} - \lambda \frac{dg}{d(y_{delIMAX})} = \sum_{j=1}^{JMAX} [2(h_{measIMAX,j} - A(y_{IMAX,j} - y_{delIMAX})^{2/3})$$

$$* (2/3 A(y_{IMAX,j} - y_{delIMAX})^{-1/3}] + \lambda \Delta x A(y_f - y_{delIMAX})^{2/3}$$

(D-7-(IMAX+1))

$$V_{meas} = \sum_{i=1}^{IMAX} (3/5 \Delta x A(y_f - y_{del1})^{5/3})$$

(D-7-(IMAX+2))

Because Equations (D-7) is a system of nonlinear equations, it can not be written in matrix form as a $[D] [x] = [E]$ system of equations (the brackets denote matrices). To solve the equations, a Newton-Raphson Iteration technique for nonlinear equations was used. This is done by differentiating each of the $(IMAX + 2)$ equations with respect to each of the unknowns, the resulting equations are then linear in terms of Δa , Δy_{del1} , . . . $\Delta y_{delIMAX}$, $\Delta \lambda$. The resulting matrix is inverted to obtain the Δ (unknown) and the quantities are added to the original estimates to produce a better estimate. This iterative procedure is continued until the changes become acceptably small. The solution converged rapidly. Generally, the first row of the matrix to be inverted is (a_{11} represents the k^{th} row and the 1^{th} column of the matrix).

$$a_{11} = \sum_{i=1}^{IMAX} \sum_{j=1}^{JMAX} 2(y_{i,j} - y_{del1})^{4/3}$$

$$a_{1,2} = \sum_{j=1}^{JMAX} \frac{4}{3} (y_{1,j} - y_{del1})^{-1/3} (h_{meas1,j} - 2A(y_{1,j} - y_{del1})^{2/3})$$

$$a_{1,IMAX+1} = \sum_{j=1}^{JMAX} \left[\frac{4}{3} (y_{IMAX,j} - y_{del_{IMAX}})^{-1/3} (h_{meas_{IMAX,j}} - 2A(y_{IMAX,j} - y_{del_{IMAX}})^{2/3}) \right]$$

$$a_{1,IMAX+2} = \sum_{i=1}^{IMAX} \left[\frac{3}{5} \Delta x (y_f - y_{del_1})^{5/3} \right] \quad (D-8)$$

The second row of the matrix is as follows:

$$a_{2,1} = \sum_{j=1}^{JMAX} \left[\frac{4}{3} h_{meas_{1,j}} (y_{1,j} - y_{del_1})^{-1/3} - \frac{8}{3} A (y_{1,j} - y_{del_1})^{1/3} \right] + \lambda \Delta x (y_f - y_{del_1})^{2/3}$$

$$a_{2,2} = \sum_{j=1}^{JMAX} \left[\frac{4}{9} A h_{meas_{1,j}} (y_{1,j} - y_{del_1})^{-4/3} + \frac{4}{9} A^2 (y_{1,j} - y_{del_1})^{-2/3} \right] - \lambda (2/3) \Delta x A (y_f - y_{del_1})^{-1/3}$$

$$a_{2,3} = 0$$

$$\vdots$$

$$a_{2,IMAX+1} = 0$$

$$a_{2,IMAX+2} = \Delta x A (y_f - y_{del_1})^{2/3} \quad (D-9)$$

The third row is simply these elements repeated except that the ones on the right-hand side of the first and last elements are changed to twos, and the $a_{3,3}$ element is similar to the $a_{2,2}$ except the ones on the right hand side become twos. The remaining column elements (i.e., those when the $k = 1$) are zeroes. This process is continued to fill the array, except for the last row.

The $(IMAX+2)^{th}$ row is as follows:

$$a_{IMAX+2,1} = \sum_{i=1}^{IMAX} \frac{3}{5} \Delta x (y_f - y_{del_i})^{5/3}$$

$$a_{IMAX+2,2} = -\Delta x A (y_f - y_{del_1})^{2/3}$$

$$\vdots$$

$$a_{IMAX+2, IMAX+1} = -\Delta x A (y_f - y_{del_{IMAX}})^{2/3}$$

$$a_{IMAX+2, IMAX+2} = 0 \quad (D-10)$$

The E matrix in the [D] [x] = [E] system of equations is

$$E_1 = - \sum_{i=1}^{IMAX} \sum_{j=1}^{JMAX} 2(h_{meas_{i,j}} - A(y_{i,j} - y_{del_i})^{2/3})(y_{i,j} - y_{del_i})^{2/3} \\ - \lambda \sum_{i=1}^{IMAX} \left(\frac{3}{5} \right) \Delta x (y_f - y_{del_i})^{5/3}]$$

$$E_2 = - \left[\sum_{j=1}^{JMAX} 2(h_{meas_{1,j}} - A(y_{1,j} - y_{del_1})^{2/3}) \left(\frac{2}{3} \right) A (y_{1,j} - y_{del_1})^{-1/3} \right. \\ \left. + \lambda (\Delta x A (y_f - y_{del_1})^{2/3}) \right]$$

$$E_{IMAX+1} = - \left[\sum_{j=1}^{JMAX} 2(h_{meas_{IMAX,j}} - A(y_{IMAX,j} - y_{del_{IMAX}})^{2/3}) \right. \\ \left. * \left(\frac{2}{3} \right) A (y_{1,j} - y_{del_1})^{-1/3} \right] + \lambda (\Delta x A (y_f - y_{del_1})^{2/3})]$$

$$E_{IMAX+2} = - \left[\sum_{i=1}^{IMAX} \left(\frac{3}{5} \right) \Delta x A (y_f - y_{del_i})^{5/3} - v_{meas} \right] \quad (D-11)$$

The $[D] [x] = [E]$ system of equations was then solved, as explained previously, by solving the x column vector (which represents the changes in the unknowns, $\Delta A, \Delta y_{del1} \dots \Delta y_{delMAX}, \Delta \lambda$), adding these changes to the respective variables and iterating until a final solution is obtained.

The computer program which did these calculations for the Channel Island Harbor simulation follows. A user-supplied matrix inversion routine is required (Line 37,200).

```

100  $RESET FREE
200  C*****PROGRAM  CIH/BVALUE1
300  FILE 5(KIND=PACK,TITLE="CIH42076A",FILETYPE=7)
400  FILE 6(KIND=REMOTE)
500  C*THIS PROGRAM USES THE INTERPOLATED PROFILES OF CIH.
600  C*IT FINDS THE LOCATION OF THE SHORELINE, YDEL AND THE BEST
700  C*FIT LEAST SQUARES "B" VALUE FOR H=BY**2/3
800  C*USES LAGRANGE MULTIPLIERS TO CONSTRAIN THE VOLUMES(SO THEY ARE EQUAL)
900  C*THEN IT USES NEWTON-RAPHSON ITER FOR NON-LIN EQS
1000  DIMENSION X(40)
1100  DIMENSION WKAREA(600),AMATRX(23,23),BMATRX(23,1)
1200  DIMENSION Y(40,20),Z(40,20),YDEL(40),JBEGIN(40),YDELI(40)
1300  DIMENSION DYTWO(40,20),DYONE(40,20),DYMTWO(40,20),DYMONE(40,20)
1400  DIMENSION DYMFOR(40,20),DYFOR(40,20),YDONE(40,20),YDMTWO(40,20)
1500  DIMENSION YDMONE(40,20),YETWO(40),YEONE(40),YEMONE(40)
1600  DIMENSION YEMTWO(40),YEMFOR(40),YEFIVE(40)
1700  EXPON=2./3.
1800  THIRD=0.3333333333333333
1900  C*FIRST READ IN THE PROFILES FROM DISKPACK.
2000  DO 1 I=1,34
2100  DO 1 J=1,15
2200  1 READ(5,100) X(I),Y(I,J),Z(I,J)
2300  100 FORMAT(14X,F6.0,F5.0,F5.0)
2400  C*NOW WE MUST GET A FIRST APPROX FOR YDEL
2500  C*WE WILL USE LINEAR INTERPOLATION TO DETERMINE IT.
2600  IBEGIN=1
2700  IMAX=21
2800  JMAX=15
2900  C*CHANGE PROFILE TO SPAN 1 TO IMAX(IF ALREADY DONE,WON'T HARM THINGS)
3000  ITEMP1=1
3100  ITEMP2=IMAX-IBEGIN+1
3200  K=-1
3300  DO 777 I=1,ITEMP2
3400  K=K+1
3500  DO 777 J=1,JMAX
3600  Y(I,J)=Y(IBEGIN+K,J)
3700  777 Z(I,J)=Z(IBEGIN+K,J)
3800  IMAX=ITEMP2
3900  DX=100.00
4000  DO 2 I=1,IMAX
4100  DO 3 J=1,JMAX
4200  IF(Z(I,J).GE.0.0) GO TO 3
4300  C*FIRST NEG POINT ON THE PROFILE IS SEAWARD OF Z=0.0
4400  C* WE MUST ALSO REMEMBER THIS LOCATION.
4500  C*IF Z(I,1)<0.,CHOOSE ARBITRARY PT. ROUTINE ITERATES TO SOLN.
4600  ZDUM=1.0
4700  IF(J.NE.1) ZDUM=Z(I,J-1)
4800  YDUM=Y(I,J)-50.0
4900  IF(J.NE.1) YDUM=Y(I,J-1)
5000  DELY=ZDUM/((ZDUM-Z(I,J))/(Y(I,J)-YDUM))
5100  YDEL(I)=YDUM+DELY
5200  JBEGIN(I)=J
5300  GO TO 2
5400  3 CONTINUE
5500  2 CONTINUE
5600  C*THE VALUES FOR Z ARE NEG ON FILE, MUST NOW MAKE POS.
5700  C*THE Z VALUES ARE ALSO *10.
5800  DO 35 I=1,IMAX
5900  DO 35 J=JBEGIN(I),JMAX
6000  35 Z(I,J)=-Z(I,J)/10.0
6100  C*MUST INITIALIZE "B" SO WILL MAKE A FIRST GUESS.
6200  C*MUST ALSO GUESS LAMBDA (XLAMB)
6300  B=0.30
6400  XLAMB=-2.0
6500  DO 10 ITER=1,100
6600  C*LET'S CALCULATE THE VOL OF WATER ABOVE THE PROFILE,VMEAS.
6700  C*ITS OUR CONSTRAINT,BUT SINCE YDEL IS NOT KNOWN,A PRIORI,IT WILL CHANGE
6800  VMEAS=0.0
6900  DO 200 I=1,IMAX
7000  DO 200 J=JBEGIN(I),JMAX
7100  IF(J.NE.JBEGIN(I)) GO TO 201

```

```

7200      VMEAS=VMEAS+DX*Z(I,J)*(0.5*(Y(I,J)+Y(I,J+1))-YDEL(I))
7300      GO TO 200
7400      201 IF(J.EQ.JMAX) GO TO 202
7500      VMEAS=VMEAS+DX*0.5*(Y(I,J+1)-Y(I,J-1))*Z(I,J)
7600      GO TO 200
7700      202 VMEAS=VMEAS+DX*Z(I,J)*(Y(I,J)-0.5*(Y(I,J)+Y(I,J+1)))
7800      200 CONTINUE
7900      C*PRIOR TO EQS.COMPUTE AND STORE SEVERAL VALUES WE NEED OVER AND OVER
8000      C*BECAUSE COMPUTER CAN'T RAISE A NEG VALUE TO AN EXPONENT
8100      C*MUST PRESERVE THE SIGN.
8200      DO 400 II=1,IMAX
8300      DO 401 JJ=JBEGIN(II),JMAX
8400      ARG1=Y(II,JJ)-YDEL(II)
8500      DYSIGN=SIGN(1.,ARG1)
8600      DY=ABS(Y(II,JJ)-YDEL(II))
8700      DYTWO(II,JJ)=DY**EXPON
8800      DYONE(II,JJ)=DYSIGN*DY**THIRD
8900      DYMTWO(II,JJ)=DY**(-EXPON)
9000      DYMONE(II,JJ)=DYSIGN*DY**(-THIRD)
9100      DYMFOR(II,JJ)=DY**(-2.*EXPON)
9200      DYFOR(II,JJ)=DY**(2.*EXPON)
9300      401 CONTINUE
9400      ARG2=1400.-YDEL(II)
9500      DSIGN=SIGN(1.,ARG2)
9600      DYE=ABS(ARG2)
9700      YETWO(II)=DYE**EXPON
9800      YEONE(II)=DSIGN*DYE**THIRD
9900      YEMONE(II)=DSIGN*DYE**(-THIRD)
10000     YEMTWO(II)=DYE**(-EXPON)
10100     YEMFOR(II)=DYE**(-2.*EXPON)
10200     YEFIVE(II)=DSIGN*DYE**(5.*THIRD)
10300     400 CONTINUE
10400     C*LET'S INPUT THE FIRST ROW OF THE MATRIX, A
10500     SUM1B=0.0
10600     DO 300 II=1,IMAX
10700     DO 300 JJ=JBEGIN(II),JMAX
10800     300 SUM1B=SUM1B+2.*DYFOR(II,JJ)
10900     AMATRX(1,1)=SUM1B
11000     SUMLAM=0.0
11100     DO 305 K=1,IMAX
11200     SUM1K=0.0
11300     DO 306 JJ=JBEGIN(K),JMAX
11400     306 SUM1K=SUM1K+2.*EXPON*DYMONE(K,JJ)*(Z(K,JJ)-2.*B*
11500     * DYTWO(K,JJ))
11600     SUMLAM=SUMLAM-0.6*DX*YEFIVE(K)
11700     305 AMATRX(1,K+1)=SUM1K
11800     AMATRX(1,IMAX+2)=SUMLAM
11900     C*NOW THE MIDDLE ROWS OF THE AMATRX.
12000     DO 410 LROW=2,IMAX+1
12100     SUM2B=0.0
12200     II=LROW-1
12300     DO 415 JJ=JBEGIN(II),JMAX
12400     415 SUM2B=SUM2B+2.*EXPON*Z(II,JJ)*DYMONE(II,JJ)-4.*EXPON*
12500     * B*DYONE(II,JJ)
12600     AMATRX(LROW,1)=SUM2B+XLAMB*DX*YETWO(II)
12700     DO 430 II=1,IMAX
12800     SUM2Y=0.0
12900     DO 425 JJ=JBEGIN(II),JMAX
13000     425 SUM2Y=SUM2Y+2.*EXPON*THIRD*B*Z(II,JJ)*DYMFOR(II,JJ)+THIRD*EXPON
13100     * 2.*B*B*DYMTWO(II,JJ)
13200     IF((II+1).EQ.LROW) GO TO 431
13300     AMATRX(LROW,II+1)=0.0
13400     GO TO 430
13500     431 AMATRX(LROW,II+1)=SUM2Y-XLAMB*EXPON*DX*B*YEMONE(II)
13600     430 CONTINUE
13700     410 AMATRX(LROW,IMAX+2)=DX*B*YETWO(LROW-1)
13800     C*NOW THE LAST ROW OF THE MATRIX A
13900     SUMFB=0.0
14000     DO 450 II=1,IMAX
14100     450 SUMFB=SUMFB+0.6*DX*YEFIVE(II)
14200     AMATRX(IMAX+2,1)=SUMFB

```

```

14300      DO 453  II=1,IMAX
14400      453  AMATRX(IMAX+2,II+1)=-DX*B*YETWO(II)
14500      AMATRX(IMAX+2,IMAX+2)=0.0
14600      C*NOW MUST INPUT THE BMATRX.
14700      SUMF1A=0.0
14800      SUMF1B=0.0
14900      DO 455  II=1,IMAX
15000      SUMF1B=SUMF1B+XLAMB*0.6*DX*YEFIVE(II)
15100      DO 455  JJ=JBEGIN(II),JMAX
15200      455  SUMF1A=SUMF1A-2.*(Z(II,JJ)-B*DYTWO(II,JJ))*DYTWO(II,JJ)
15300      BMATRX(1,1)=-(SUMF1A-SUMF1B)
15400      DO 460  II=1,IMAX
15500      SUMFII=0.0
15600      DO 462  JJ=JBEGIN(II),JMAX
15700      462  SUMFII=SUMFII+2.*(Z(II,JJ)-B*DYTWO(II,JJ))*EXPON*B*DYMONE(II,JJ)
15800      SUMFII=SUMFII+XLAMB*DX*B*YETWO(II)
15900      460  BMATRX(II+1,1)=SUMFII
16000      SUMV=0.0
16100      DO 465  II=1,IMAX
16200      465  SUMV=SUMV+0.6*DX*B*YEFIVE(II)
16300      BMATRX(IMAX+2,1)=-(SUMV-VMEAS)
16400      C*NEXT LET'S CALL THE MATRIX INVERSION ROUTINE VIA IMSL
16500      CALL LEQT2F(AMATRX,1,IMAX+2,23,BMATRX,3,WKAREA,IER)
16600      C*THE SOLN IS RETURNED IN THE VECTOR BMATRX
16700      C*FINALLY, WE MUST UPDATE THE X VECTOR IN AX=B.
16800      B=B+BMATRX(1,1)
16900      XLAMB=XLAMB+BMATRX(IMAX+2,1)
17000      DO 470  II=1,IMAX
17100      470  YDEL(II)=YDEL(II)+BMATRX(II+1,1)
17200      C*CHECK THE CRITERION FOR COMPLETION
17300      SUMVEC=0.0
17400      DO 475  II=1,IMAX
17500      475  SUMVEC=SUMVEC+ABS(BMATRX(II,1))
17600      IF(SUMVEC.LT.(0.1*(IMAX+2))) GO TO 11
17700      WRITE(6,*) B,ITER,(I,YDEL(I),I=1,IMAX),XLAMB
17800      10  CONTINUE
17900      11  CONTINUE
18000      C*LET'S WRITE IT ALL OUT.
18100      WRITE(6,*) ITER,B,(I,YDEL(I),I=1,IMAX)
18200      STOP
18300      END

```

APPENDIX E

USER DOCUMENTATION AND INPUT AND OUTPUT FOR PROGRAM VERIFICATION

The computer program presented in Appendix B was run on a Burroughs B-7700 computer. The B7000/B6000 series FORTRAN language was designed so several existing programs written in FORTRAN would be compatible with minimal changes. It was designed to be compatible with Fortram IV, H level and to contain ANSI X3.9-1966 Standard FORTRAN as a subset.

Line 37,200 of the coding (see App. B) requires a subroutine from the IMSL subroutine package, LEQT1B and its associated subroutines. If the user's computing center has access to this package of subroutine programs they need only bind them to the program (note: copyright laws prohibited the inclusion of the IMSL coding). If not, a substitute subroutine must be user supplied. It must facilitate the solution of a banded storage mode matrix.

The program input will be described here using a card deck set-up, however, the use of diskpack or magnetic tape input follows directly. Lines 3100, 4100, 5500, 5900, 6800, 7500, and 12,900 are read statements. The cards used for the simulation presented in this appendix are shown in Figure E-1. The first card contains the value of WDEPTH, the depth of water (in meters) to which the input wave conditions are to be transformed (a partial list of variables used in the program is presented beginning on page A-8 of Appendix A). The format statements are obviously in the program coding.

The second data input card is read by line 4100 where the variables SJETTY, BERM, SFACE, and DIAM are required (length of the structure, berm height, shore face slope, and sediment diameter, respectively).

Lines 5500 reads MMAX, the number of structures to be simulated (as set-up here, a maximum of 10 structures can be modeled, however, appropriate changes in array dimensions would allow additions (structures). Line 5900, which is in a "DO" loop reads the lesser I grid value adjacent to where the structure is desired. The number of structures, MMAX, determines the number of data cards required here; 3 structures require 3 cards with the 3 I grid locations (note, the present configuration of the refraction and diffraction subroutines requires evenly spaced structures, however this can be altered if necessary).

The parameter ADEAN, which represents the value of A in the equilibrium profile used is the next value input (line 6800). As mentioned previously, whenever possible a site-specific value should be used. The space-step and time-step (DX and DELT in the coding) are input next (line 7500).

The last input values are the wave data, HS, T, ALPWIS read by line 12,900. This statement is in a loop made by the unconditional GO TO statement (line 16,400) and the read statement. There is an action specifier included in the read statement to transfer the program to statement 1000, thereby stopping execution of the program once all the wave climate data have been used. The number of data cards required for this read statement is dictated by the length of the simulation and the time-step used.

The input file and output for program verification follow.

INPUT: FILE DUM

100					
200					
300	1	300.000	10.000	0.0500	0.220
400	25				
500		0.1500			
600		100.00	21600.00		
700			5.0	8.0	3.0
800			5.0	8.0	3.0
900			5.0	8.0	3.0
1000			5.0	8.0	3.0
1100			5.0	8.0	3.0
1200			5.0	8.0	3.0
1300			5.0	8.0	3.0
1400			5.0	8.0	3.0
1500			5.0	8.0	3.0
1600			5.0	8.0	3.0
1700			5.0	8.0	3.0
1800			5.0	8.0	3.0
1900			5.0	8.0	3.0
2000			5.0	8.0	3.0
2100			5.0	8.0	3.0
2200			5.0	8.0	3.0
2300			5.0	8.0	3.0
2400			5.0	8.0	3.0
2500			5.0	8.0	3.0
2600			5.0	8.0	3.0
2700			5.0	8.0	3.0
2800			5.0	8.0	3.0
2900			5.0	8.0	3.0
3000			5.0	8.0	3.0
3100			5.0	8.0	3.0
3200			5.0	8.0	3.0
3300			5.0	8.0	3.0
3400			5.0	8.0	3.0
3500			5.0	8.0	3.0
3600			5.0	8.0	3.0

.....
 TO WHAT DEPTH ARE THE WAVES TO BE TRANSFORMED
 THE DEPTH (IN FT) WAVES TRANSFORMED TO DEPTH= 32 808
 ITS TIME FOR SURF, BEHM, SPACE, AND DIAM
 THE LENGTH OF THE STRUCTURE, SURF= 300 000
 THE HEIGHT OF THE BEHM BEHM= 5 000
 THE SLOPE OF THE BEACH FACE, SPACE= 0 0500
 THE SEDIMENT DIAMETER, DIAM= 0 220
 THE NUMBER 1 GROIN IS LOCATED AT GRID 25
 NOW ENTER THE VALUE OF AHEAD
 THE VALUE OF AHEAD= 0 1500 IN THE EQ H=AV*2/3
 READ IN THE SPACE STEP TIME STEP
 THE VALUE OF THE COASTLINE SPACE STEP, DX= 100 000
 THE TIME STEP IN SECONDS, DELT= 21600 000
 THE RUNNARY Y VALUES, Y=1, MAX ARE AS FOLLOWS

0 00 31 62 68 01 137 71 252 98 464 76 760 73 1050 41 1656 50 2674 85
 0 00 31 62 68 01 137 71 252 98 464 76 760 73 1050 41 1656 50 2674 85

THE DEPTHS BETWEEN CONTOURS ARE AS FOLLOWS

1 00 2 00 3 00 5 00 7 00 11 00 14 00 17 00 25 00 32 81

MINIV-1.

MINIV-2.

MINIV-3.

MINIV-4.

MINIV-5.

MINIV-6.

MINIV-7.

MINIV-8.

MINIV-9.

MINIV-10.

THE TOTAL ELAPSED NUMBER OF TIME STEPS, MINIV= 10

THE LOW-WATER TRANSPORTS OF FOLLOWS

0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000
 0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000
 0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000 0 000

[illegible]

THE NEW (CONTOUR VALUES, Y, FOLLOW

0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.006	0.008	0.011	0.015	0.021	0.029
0.040	0.056	0.078	0.109	0.152	0.212	0.294	0.401	0.534	0.685	0.831	0.928	-0.929
0.832	0.686	0.515	0.401	0.294	0.212	0.151	0.108	0.078	0.056	0.040	0.029	-0.021
0.015	0.011	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000
31.621	31.626	31.631	31.636	31.643	31.650	31.661	31.674	31.692	31.714	31.744	31.784	31.835
31.902	31.988	32.101	32.248	32.438	32.683	32.997	33.396	33.893	34.491	35.191	35.766	27.425
28.051	28.751	29.351	29.849	30.248	30.563	30.809	30.999	31.145	31.258	31.345	31.412	31.463
31.502	31.532	31.555	31.572	31.585	31.595	31.603	31.610	31.615	31.619	31.623	31.627	31.630
68.011	68.058	68.076	68.096	68.119	68.147	68.182	68.226	68.281	68.351	68.439	68.550	68.690
68.864	69.083	69.306	69.605	70.115	70.834	71.774	72.957	75.413	79.157	84.275	90.848	98.915
60.527	61.920	63.064	64.024	64.809	65.449	65.963	66.390	66.729	67.002	67.221	67.395	67.535
67.645	67.733	67.813	67.888	67.962	68.036	68.110	68.184	68.258	68.332	68.406	68.480	68.554
117.706	137.763	137.811	137.858	137.905	137.952	138.000	138.047	138.094	138.141	138.188	138.235	138.282
139.568	139.873	140.457	141.032	141.714	142.521	143.471	144.566	145.895	147.468	149.231	150.840	124.560
126.171	127.957	129.512	130.822	131.939	132.891	133.698	134.381	134.957	135.441	135.847	136.185	136.468
136.702	136.896	137.057	137.190	137.300	137.392	137.468	137.536	137.594	137.650	137.706	137.762	137.818
252.987	253.067	253.150	253.234	253.321	253.411	253.507	253.608	253.716	253.831	253.952	254.081	254.217
254.358	254.805	255.405	256.143	257.017	258.025	259.165	260.437	261.851	263.417	265.135	266.905	268.727
250.559	250.535	250.569	250.643	250.747	250.872	251.011	251.158	251.308	251.458	251.605	251.747	251.883
252.012	252.134	252.249	252.357	252.458	252.554	252.645	252.731	252.815	252.898	252.982	253.066	253.150
464.758	464.759	464.761	464.761	464.763	464.764	464.765	464.766	464.767	464.768	464.770	464.771	464.772
464.773	464.774	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775
464.752	464.748	464.744	464.742	464.741	464.740	464.739	464.740	464.740	464.741	464.741	464.742	464.745
464.746	464.748	464.749	464.750	464.751	464.752	464.753	464.754	464.755	464.756	464.757	464.758	464.759
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414

MINIV 21.

MINIV 22.

MINIV 23.

MINIV 24.

MINIV 25.

MINIV 26.

MINIV 27.

MINIV 28.

MINIV 29.

MINIV 30.

THE TOTAL ELAPSED MINIMUM OF TIME STEPS. MINIV= 30

THE LONGEST TRANSPIRITS OF FOLLOW

0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.006	0.008	0.011	0.015	0.021	0.029
0.040	0.056	0.078	0.109	0.152	0.212	0.294	0.401	0.534	0.685	0.831	0.928	-0.929
0.832	0.686	0.515	0.401	0.294	0.212	0.151	0.108	0.078	0.056	0.040	0.029	-0.021
0.015	0.011	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000
31.621	31.626	31.631	31.636	31.643	31.650	31.661	31.674	31.692	31.714	31.744	31.784	31.835
31.902	31.988	32.101	32.248	32.438	32.683	32.997	33.396	33.893	34.491	35.191	35.766	27.425
28.051	28.751	29.351	29.849	30.248	30.563	30.809	30.999	31.145	31.258	31.345	31.412	31.463
31.502	31.532	31.555	31.572	31.585	31.595	31.603	31.610	31.615	31.619	31.623	31.627	31.630
68.011	68.058	68.076	68.096	68.119	68.147	68.182	68.226	68.281	68.351	68.439	68.550	68.690
68.864	69.083	69.306	69.605	70.115	70.834	71.774	72.957	75.413	79.157	84.275	90.848	98.915
60.527	61.920	63.064	64.024	64.809	65.449	65.963	66.390	66.729	67.002	67.221	67.395	67.535
67.645	67.733	67.813	67.888	67.962	68.036	68.110	68.184	68.258	68.332	68.406	68.480	68.554
117.706	137.763	137.811	137.858	137.905	137.952	138.000	138.047	138.094	138.141	138.188	138.235	138.282
139.568	139.873	140.457	141.032	141.714	142.521	143.471	144.566	145.895	147.468	149.231	150.840	124.560
126.171	127.957	129.512	130.822	131.939	132.891	133.698	134.381	134.957	135.441	135.847	136.185	136.468
136.702	136.896	137.057	137.190	137.300	137.392	137.468	137.536	137.594	137.650	137.706	137.762	137.818
252.987	253.067	253.150	253.234	253.321	253.411	253.507	253.608	253.716	253.831	253.952	254.081	254.217
254.358	254.805	255.405	256.143	257.017	258.025	259.165	260.437	261.851	263.417	265.135	266.905	268.727
250.559	250.535	250.569	250.643	250.747	250.872	251.011	251.158	251.308	251.458	251.605	251.747	251.883
252.012	252.134	252.249	252.357	252.458	252.554	252.645	252.731	252.815	252.898	252.982	253.066	253.150
464.758	464.759	464.761	464.761	464.763	464.764	464.765	464.766	464.767	464.768	464.770	464.771	464.772
464.773	464.774	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775	464.775
464.752	464.748	464.744	464.742	464.741	464.740	464.739	464.740	464.740	464.741	464.741	464.742	464.745
464.746	464.748	464.749	464.750	464.751	464.752	464.753	464.754	464.755	464.756	464.757	464.758	464.759
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726	760.726
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414
1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414	1050.414

MINIV 21.

MINIV 22.

MINIV 23.

MINIV 24.

MINIV 25.

MINIV 26.

MINIV 27.

MINIV 28.

MINIV 29.

MINIV 30.

THE TOTAL ELAPSED MINIMUM OF TIME STEPS. MINIV= 30

THE NEW CONTOUR VALUES, V, FOLLOW

0.000	0.003	0.007	0.011	0.016	0.022	0.029	0.038	0.050	0.064	0.083	0.107	0.137
0.177	0.227	0.293	0.377	0.484	0.618	0.783	0.977	1.196	1.471	1.823	2.150	2.451
-1.624	-1.422	-1.196	-0.978	-0.783	-0.618	-0.484	-0.377	-0.293	-0.227	-0.177	-0.137	-0.106
-0.083	-0.064	-0.050	-0.038	-0.029	-0.022	-0.016	-0.011	-0.007	-0.003	0.000	0.003	0.006
31.623	31.642	31.667	31.685	31.710	31.738	31.771	31.817	31.860	31.918	31.990	32.077	32.184
32.314	32.474	32.659	32.908	33.198	33.551	33.975	34.480	35.075	35.754	36.512	37.318	26.122
26.729	27.487	28.168	28.764	29.270	29.695	30.048	30.339	30.577	30.773	30.933	31.063	31.170
31.257	31.328	31.387	31.435	31.475	31.508	31.537	31.561	31.584	31.604	31.623	31.638	31.648
68.011	68.095	68.150	68.208	68.270	68.340	68.421	68.516	68.626	68.757	68.913	69.098	69.318
69.580	69.872	70.264	70.706	71.211	71.854	72.592	73.466	74.498	75.700	77.129	78.737	80.514
82.445	84.376	86.414	88.549	90.789	93.132	95.570	98.108	100.746	103.484	106.322	109.260	112.298
115.436	118.574	121.812	125.150	128.588	132.126	135.764	139.502	143.340	147.178	151.016	154.854	158.692
162.530	166.470	170.410	174.350	178.290	182.230	186.170	190.110	194.050	197.990	201.930	205.870	209.810
213.706	217.828	221.950	226.072	230.194	234.316	238.438	242.560	246.682	250.804	254.926	259.048	263.170
267.292	271.414	275.536	279.658	283.780	287.902	292.024	296.146	300.268	304.390	308.512	312.634	316.756
320.878	324.999	329.121	333.243	337.365	341.487	345.609	349.731	353.853	357.975	362.097	366.219	370.341
374.463	378.585	382.707	386.829	390.951	395.073	399.195	403.317	407.439	411.561	415.683	419.805	423.927
428.049	432.171	436.293	440.415	444.537	448.659	452.781	456.903	461.025	465.147	469.269	473.391	477.513
481.639	485.761	489.883	493.905	498.027	502.149	506.271	510.393	514.515	518.637	522.759	526.881	530.903
535.025	539.147	543.269	547.391	551.513	555.635	559.757	563.879	567.901	572.023	576.145	580.267	584.389
588.511	592.633	596.755	600.877	604.999	609.121	613.243	617.365	621.487	625.609	629.731	633.853	637.975
642.097	646.219	650.341	654.463	658.585	662.707	666.829	670.951	675.073	679.195	683.317	687.439	691.561
695.683	699.805	703.927	708.049	712.171	716.293	720.415	724.537	728.659	732.781	736.903	741.025	745.147
749.269	753.391	757.513	761.635	765.757	769.879	773.901	778.023	782.145	786.267	790.389	794.511	798.633
802.755	806.877	810.999	815.121	819.243	823.365	827.487	831.609	835.731	839.853	843.975	848.097	852.219
856.341	860.463	864.585	868.707	872.829	876.951	881.073	885.195	889.317	893.439	897.561	901.683	905.805
909.927	914.049	918.171	922.293	926.415	930.537	934.659	938.781	942.903	947.025	951.147	955.269	959.391
963.513	967.635	971.757	975.879	979.901	984.023	988.145	992.267	996.389	1000.511	1004.633	1008.755	1012.877
1016.999	1021.121	1025.243	1029.365	1033.487	1037.609	1041.731	1045.853	1049.975	1054.097	1058.219	1062.341	1066.463
1070.585	1074.707	1078.829	1082.951	1087.073	1091.195	1095.317	1099.439	1103.561	1107.683	1111.805	1115.927	1120.049
1124.171	1128.293	1132.415	1136.537	1140.659	1144.781	1148.903	1153.025	1157.147	1161.269	1165.391	1169.513	1173.635
1177.757	1181.879	1185.901	1190.023	1194.145	1198.267	1202.389	1206.511	1210.633	1214.755	1218.877	1222.999	1227.121
1231.243	1235.365	1239.487	1243.609	1247.731	1251.853	1255.975	1260.097	1264.219	1268.341	1272.463	1276.585	1280.707
1284.829	1288.951	1293.073	1297.195	1301.317	1305.439	1309.561	1313.683	1317.805	1321.927	1326.049	1330.171	1334.293
1338.415	1342.537	1346.659	1350.781	1354.903	1359.025	1363.147	1367.269	1371.391	1375.513	1379.635	1383.757	1387.879
1391.901	1396.023	1400.145	1404.267	1408.389	1412.511	1416.633	1420.755	1424.877	1428.999	1433.121	1437.243	1441.365
1445.487	1449.609	1453.731	1457.853	1461.975	1466.097	1470.219	1474.341	1478.463	1482.585	1486.707	1490.829	1494.951
1499.073	1503.195	1507.317	1511.439	1515.561	1519.683	1523.805	1527.927	1532.049	1536.171	1540.293	1544.415	1548.537
1552.659	1556.781	1560.903	1565.025	1569.147	1573.269	1577.391	1581.513	1585.635	1589.757	1593.879	1597.901	1602.023
1606.145	1610.267	1614.389	1618.511	1622.633	1626.755	1630.877	1634.999	1639.121	1643.243	1647.365	1651.487	1655.609
1659.731	1663.853	1667.975	1672.097	1676.219	1680.341	1684.463	1688.585	1692.707	1696.829	1700.951	1705.073	1709.195
1713.317	1717.439	1721.561	1725.683	1729.805	1733.927	1738.049	1742.171	1746.293	1750.415	1754.537	1758.659	1762.781
1766.903	1771.025	1775.147	1779.269	1783.391	1787.513	1791.635	1795.757	1799.879	1803.901	1808.023	1812.145	1816.267
1820.389	1824.511	1828.633	1832.755	1836.877	1840.999	1845.121	1849.243	1853.365	1857.487	1861.609	1865.731	1869.853
1873.975	1878.097	1882.219	1886.341	1890.463	1894.585	1898.707	1902.829	1906.951	1911.073	1915.195	1919.317	1923.439
1927.561	1931.683	1935.805	1939.927	1944.049	1948.171	1952.293	1956.415	1960.537	1964.659	1968.781	1972.903	1977.025
1981.145	1985.267	1989.389	1993.511	1997.633	2001.755	2005.877	2009.999	2014.121	2018.243	2022.365	2026.487	2030.609
2034.731	2038.853	2042.975	2047.097	2051.219	2055.341	2059.463	2063.585	2067.707	2071.829	2075.951	2080.073	2084.195
2088.317	2092.439	2096.561	2100.683	2104.805	2108.927	2113.049	2117.171	2121.293	2125.415	2129.537	2133.659	2137.781
2141.903	2146.025	2150.147	2154.269	2158.391	2162.513	2166.635	2170.757	2174.879	2178.901	2183.023	2187.145	2191.267
2195.389	2199.511	2203.633	2207.755	2211.877	2215.999	2220.121	2224.243	2228.365	2232.487	2236.609	2240.731	2244.853
2248.975	2253.097	2257.219	2261.341	2265.463	2269.585	2273.707	2277.829	2281.951	2286.073	2290.195	2294.317	2298.439
2302.561	2306.683	2310.805	2314.927	2319.049	2323.171	2327.293	2331.415	2335.537	2339.659	2343.781	2347.903	2352.025
2356.145	2360.267	2364.389	2368.511	2372.633	2376.755	2380.877	2384.999	2389.121	2393.243	2397.365	2401.487	2405.609
2409.731	2413.853	2417.975	2422.097	2426.219	2430.341	2434.463	2438.585	2442.707	2446.829	2450.951	2455.073	2459.195
2463.317	2467.439	2471.561	2475.683	2479.805	2483.927	2488.049	2492.171	2496.293	2500.415	2504.537	2508.659	2512.781
2516.903	2521.025	2525.147	2529.269	2533.391	2537.513	2541.635	2545.757	2549.879	2553.901	2558.023	2562.145	2566.267
2570.389	2574.511	2578.633	2582.755	2586.877	2590.999	2595.121	2599.243	2603.365	2607.487	2611.609	2615.731	2619.853
2623.975	2628.097	2632.219	2636.341	2640.463	2644.585	2648.707	2652.829	2656.951	2661.073	2665.195	2669.317	2673.439
2677.561	2681.683	2685.805	2689.927	2694.049	2698.171	2702.293	2706.415	2710.537	2714.659	2718.781	2722.903	2727.025
2731.145	2735.267	2739.389	2743.511	2747.633	2751.755	2755.877	2759.999	2764.121	2768.243	2772.365	2776.487	2780.609
2784.731	2788.853	2792.975	2797.097	2801.219	2805.341	2809.463	2813.585	2817.707	2821.829	2825.951	2830.073	2834.195
2838.317	2842.439	2846.561	2850.683	2854.805	2858.927	2863.049	2867.171	2871.293	2875.415	2879.537	2883.659	2887.781
2891.903	2896.025	2900.147	2904.269	2908.391	2912.513	2916.635	2920.757	2924.879	2928.901	2933.023	2937.145	2941.267
2945.389	2949.511	2953.633	2957.755	2961.877	2965.999	2970.121	2974.243	2978.365	2982.487	2986.609	2990.731	2994.853
2998.975	3003.097	3007.219	3011.341	3015.463	3019.585	3023.707	3027.829	3031.951	3036.073	3040.195	3044.317	3048.439
3052.561	3056.683	3060.805	3064.927	3069.049	3073.171	3077.293	3081.415	3085.537	3089.659	3093.781	3097.903	3102.025
3106.145	3110.267	3114.389	3118.511	3122.633	3126.755	3130.877	3134.999	3139.121	3143.243	3147.365	3151.487	3155.609
3159.731	3163.853	3167.975	3172.097	3176.219	3180.341	3184.463	3188.585	3192.707	3196.829	3200.951	3205.073	3209.195
3213.317	3217.439	3221.561	3225.683	3229.805	3233.927	3238.049	3242.171	3246.293	3250.415	3254.537	3258.659	3262.781
3266.903	3271.025	3275.147	3279.269	3283.391	3287.513	3291.635	3295.757	3299.879	3303.901	3308.023	3312.145	3316.267
3320.389	3324.511	3328.633	3332.755	3336.877	3340.999	3345.121	3349.243	3353.365	3357.487	3361.609	3365.731	3369.853
3373.975	3378.097	3382.219	3386.341	3390.463	3394.585	3398.707	3402.829	3406.951	3411.073	3415.195	3419.317	3423.439
3427.561	3431.683	3435.805	3439.927	3444.049	3448.171	3452.293	3456.415	3460.537	3464.659	3468.781	3472.90	

Perlin, Marc A numerical model to simulate sediment transport in the vicinity of coastal structures / by Marc Perlin and Robert G. Dean.--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [119] p. : ill. ; 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-10). Cover title. "May 1983." Report provides an implicit finite-difference, n-line numerical model which predicts sediment transport and the resulting bathymetry in the vicinity of coastal structures. The wave field transformation includes refraction, shoaling, and diffraction. 1. Numerical model. 2. Shoreline evolution. 3. Sediment transport. 4. Wave transformation. 5. Littoral barrier. I. Title. II. Dean, Robert G. III. Coastal Engineering Research Center (U.S.). IV. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)). TC203 .U581mr no. 83-10 627	Perlin, Marc A numerical model to simulate sediment transport in the vicinity of coastal structures / by Marc Perlin and Robert G. Dean.--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [119] p. : ill. ; 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-10). Cover title. "May 1983." Report provides an implicit finite-difference, n-line numerical model which predicts sediment transport and the resulting bathymetry in the vicinity of coastal structures. The wave field transformation includes refraction, shoaling, and diffraction. 1. Numerical model. 2. Shoreline evolution. 3. Sediment transport. 4. Wave transformation. 5. Littoral barrier. I. Title. II. Dean, Robert G. III. Coastal Engineering Research Center (U.S.). IV. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)). TC203 .U581mr no. 83-10 627
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