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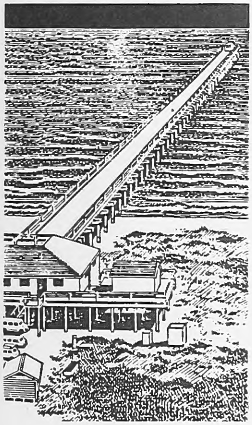

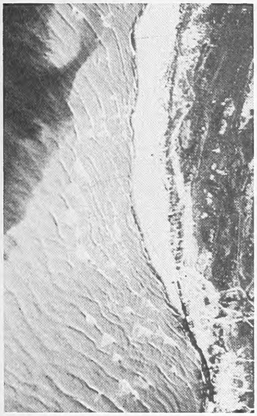

TECHNICAL REPORT CERC-86-4

# REGIONAL COASTAL PROCESSES NUMERICAL MODELING SYSTEM

## Report 1

## RCPWAVE—A LINEAR WAVE PROPAGATION MODEL FOR ENGINEERING USE

by

Bruce A. Ebersole, Mary A. Cialone, Mark D. Prater

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March 1986
Report 1 of a Series

Approved For Public Release; Distribution Unlimited

Prepared for

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>Technical Report CERC-86-4 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>REGIONAL COASTAL PROCESSES NUMERICAL MODELING SYSTEM; Report 1: RCPWAVE--A LINEAR WAVE PROPAGATION MODEL FOR ENGINEERING USE | | 5. TYPE OF REPORT & PERIOD COVERED<br>Report 1 of a series<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>Bruce A. Ebersole<br>Mary A. Cialone<br>Mark D. Prater | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>US Army Engineer Waterways Experiment Station<br>Coastal Engineering Research Center<br>PO Box 631, Vicksburg, Mississippi 39180-0631 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>DEPARTMENT OF THE ARMY<br>US Army Corps of Engineers<br>Washington, DC 20314-1000 | | 12. REPORT DATE<br>March 1986<br>13. NUMBER OF PAGES<br>160 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>Unclassified<br>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

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer model
Diffraction
Refraction
Water waves

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The numerical model documented here, RCPWAVE, can be used to solve wave propagation problems over arbitrary bathymetry. The governing equations solved in the model are the "mild slope" equation for linear, monochromatic waves, and the equation specifying irrotationality of the wave phase function gradient. Finite difference approximations of these equations are solved to predict wave propagation outside the surf zone. Inside the breaker zone, an

(Continued)

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20. ABSTRACT (Continued).

empirical method is used to predict wave transformation. This method is based on a hydraulic jump representation of the entire surf zone. The model is verified using laboratory and field data.

A user's manual section is provided to aid potential users. This documentation contains two examples illustrating application of the model. These examples describe job control language files, job submission procedures, sample input and output files, and execution costs.

# PREFACE

The model development documented here was authorized as part of the Civil Works Research and Development Program of the Office, Chief of Engineers (OCE), US Army. The research work unit funding this work, Regional Coastal Processes Numerical Modeling System, is part of the Shore Protection and Restoration Program. Messrs. John H. Lockhart and John G. Housley were the OCE Technical Monitors during preparation and publication of this report.

The study was conducted under the direction of Dr. James R. Houston, Chief, Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES); Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and Mr. H. Lee Butler, Chief, Research Division. The report was prepared by Mr. Bruce A. Ebersole, Research Hydraulic Engineer; Mrs. Mary A. Cialone, Hydraulic Engineer; and Mr. Mark D. Prater, Research Hydraulic Engineer. The prototype data used in the model verification procedure were supplied by members of the staff of CERC's Field Research Facility, particularly Messrs. William A. Birkemeier and H. Carl Miller. This report was edited by Ms. Shirley A. J. Hanshaw, Publications and Graphic Arts Division, WES.

Director of WES during publication of this report was COL Allen F. Grum, USA. Technical Director was Dr. Robert W. Whalin.

# CONTENTS

# REGIONAL COASTAL PROCESSES NUMERICAL MODELING SYSTEM

## RCPWAVE--A LINEAR WAVE PROPAGATION MODEL FOR ENGINEERING USE

## PART I: INTRODUCTION

1. The "Regional Coastal Processes Numerical Modeling System" research work unit is part of the US Army Corps of Engineers (Corps) Shore Protection and Restoration research program. Its goal is the development of a modeling system that can predict coastal processes on a regional scale so that coastal changes resulting from natural forces and man-made structures and modifications can be determined on a regional basis. All important physical processes that determine coastal changes over a region will be considered in the system's development. Long-wave (e.g. tide and storm surge) hydrodynamics, short-wave (e.g. swell and wind sea) propagation, and associated currents and setup/setdown will be addressed. These wave phenomena will be used as forcing functions to drive models which calculate alongshore and on- offshore sediment transport. Sediment sources and sinks such as sediment discharge from rivers, dredging gains or losses, and dune erosion will be considered in the sediment models. The modeling system will provide a tool for predicting coastal erosion and deposition, paths of sediment movement, and ultimate fates of coastal sediments.

2. All component models comprising the system must be capable of performing regional scale simulations in a cost-effective manner. Regional scale implies an area of interest with horizontal length scales of up to tens of miles and simulation times ranging from days to years. These requirements impose severe restrictions on candidate models. Individual models must also be compatible so that they can interface with one another in an efficient manner. Some examples of compatibility are (a) solutions from different models computed at identical spatial locations and (b) input/output information common to different models retrieved/stored using identical formats.

3. A philosophy for development of the modeling system has been adopted which provides direction to the work unit research. The aim is to develop (and/or obtain) and link a series of models so that all important physical processes are simulated to a predetermined level of sophistication. This

milestone will occur approximately 2 years before the scheduled conclusion of the work unit. Component models comprising the initial system are determined by: (a) available models within the Coastal Engineering Research Center (CERC) addressing the important physical processes, (b) other (outside CERC) state-of-the-art methods for modeling these processes on a regional scale, and (c) the need for having a field oriented product in the near future. The framework designed for linking these models into a usable system will allow for integration of more sophisticated models when they become available. Research addressing perceived weaknesses in the system models will be conducted concurrently with work done to bring the system to its initial level of sophistication.

4. Any technology created as an interim product, which can immediately aid Corps field engineers and can be easily transferred to them, will be made available. This report documents such a product. The Regional Coastal Processes Wave (RCPWAVE) Propagation Model can be used to predict linear, plane wave propagation over a "regional" area of arbitrary bathymetry. This model currently forms the initial level of sophistication for the short-wave modeling component of the regional system.

# PART II: REGIONAL COASTAL PROCESSES WAVE PROPAGATION MODEL (RCPWAVE)

## Background Information

5. Linear wave theory was chosen as the initial level of sophistication for the short-wave modeling component because, historically, it has been shown to yield fairly accurate first order solutions to wave propagation problems. Considering both accuracy and cost, it is currently the most feasible way to model waves on a regional scale. Modeling short-wave processes using either a fully two-dimensional nonlinear wave theory or a two-dimensional spectral representation of irregular waves is presently impractical for the types of applications anticipated for this modeling system.

6. Much of the early work addressing the problem of linear, monochromatic wave propagation was based on wave ray methods and the manual construction of refraction diagrams (see Johnson, O'Brien, and Issacs (1948); Dunham (1951); and Pierson, Neumann, and James (1952) for examples). During the 1960's and early 1970's the refraction problem was solved in a more efficient way through the use of the computer (for examples see Harrison and Wilson (1964), Dobson (1967), Noda et al. (1974), and Rabe (1975). Refraction theory fails in regions of complex bathymetry where waves are strongly convergent or divergent. Crossing wave rays results in the computation of erroneously large wave height estimates. Strongly divergent wave fields manifest themselves in regions of unusually small wave heights. Laboratory and prototype observations show that refraction theory is inadequate under these conditions (Whalin 1971 and 1972).

7. Inclusion of diffractive effects into the equations governing wave propagation allows wave energy to be diffused from regions of convergence to regions of divergence. Berkhoff (1972 and 1976) derived an elliptic equation approximating the complete wave transformation process for linear waves over an arbitrary bathymetry constrained only to have mild bottom slopes (hence the designation "mild slope equation" (Smith and Sprinks 1975)). The mild slope equation can be expressed in the form

$$\frac{\partial}{\partial x}\left(cc_g \frac{\partial \phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(cc_g \frac{\partial \phi}{\partial y}\right) + \sigma^2 \frac{c_g}{c} \phi = 0 \qquad (1)$$

where

$x$ and $y$ = two orthogonal horizontal coordinate directions

$c(x,y)$ = the wave celerity ($= \sigma/k$)

$\sigma$ = angular wave frequency (defined to be $2\pi/T$)

$k(x,y)$ = wave number given by the dispersion relation, $\sigma^2 = gk \tanh (kh)$

$T$ = wave period

$c_g(x,y)$ = group velocity ($= \partial\sigma/\partial k$)

$\phi(x,y)$ = complex velocity potential

$g$ = acceleration due to gravity

$h(x,y)$ = still-water depth

8. Numerical solution of this equation for the velocity potential field is an effective means for solving the complete wave propagation problem. The equation can be solved using either finite element (Berkhoff 1972 and Houston 1981) or finite difference methods (William, Darbyshire, and Holmes 1980). Since transmission and reflection boundary conditions are easily implemented into these solution schemes, this approach is a popular one for modeling tsunami propagation and for solving problems involving the response of harbors to short and long waves. This method becomes computationally infeasible for large scale, open coast, short-wave problems because of its great expense. Numerical solutions of Equation 1 are only practical, as a rough rule of thumb, when the dimensions of the spatial area of interest are no more than 10 times the length scale of the wave lengths being considered (Berkhoff, Booy, and Radder 1982).

9. An alternative method based upon a simplification of this equation has recently been developed. This method alleviates the computational burden imposed by a direct solution of Equation 1. The velocity potential can be separated into a forward scattered and a reflected component. By neglecting the reflected part and assuming that diffractive effects in the direction of propagation are much less than those perpendicular to the direction of wave advance, the following equation for the forward scattered wave can be derived:

$$\frac{\partial\phi}{\partial x} = \left[ik - \frac{1}{2kcc_g}\frac{\partial}{\partial x}(kcc_g)\right]\phi + \frac{1}{2kcc_g}\frac{\partial}{\partial y}\left(cc_g\frac{\partial\phi}{\partial y}\right) \qquad (2)$$

where $i = \sqrt{-1}$ and $x$ is now defined as the principal direction of propagation. Here, the velocity potential describes only the forward scattered wave field. The assumption made above, concerning the relative magnitude of the diffractive effects, changes the character of the governing equation from elliptic to parabolic. Very efficient computational techniques exist for solving this type of equation. Candel (1979), Radder (1979), Lozano and Liu (1980), Tsay and Liu (1982), Berkhoff, Booy, and Radder (1982), Booij (1981), and Kirby (1983) all applied this approach to study the problem of wave propagation over complex bathymetries using finite difference solution techniques.

10. The "parabolic approximation" method, as it is called, has the following disadvantage. It requires that one grid coordinate be approximately parallel to the predominant wave direction. This requirement can conceivably result in erroneous solutions to problems involving complex bathymetries where a dominant wave direction may not be clearly defined. Booij (1981) examined errors associated with the application of different parabolic approximations to solve the problem of oblique wave incidence over a horizontal bottom. To date, nothing has been documented concerning errors which may result from using this method to model wave incidence over arbitrary bathymetry. This directional restriction also implies that more than one grid system may be required in order to simulate a wide range of incident wave directions. The parabolic approximation method is a powerful tool for predicting linear wave transformations, but, it does have some deficiencies. These unaddressed problems currently preclude its incorporation into the regional modeling system, as it is envisioned.

11. The model presented in this report, RCPWAVE, is an alternative approach for solving the open coast wave propagation problem. It addresses both processes, refraction and diffraction, and can be applied on a regional basis quite economically. The model also contains an algorithm which estimates wave conditions inside the surf zone. This wave breaking model is an extension of the work of Dally, Dean, and Dalrymple (1984) to two horizontal dimensions. Kirby (1983) implemented their one-dimensional breaking model into his parabolic approximation model. Any short-wave propagation model integrated into the regional system must address the problem of wave transformation within the surf zone where many of the physical processes interact and move sediment.

## Wave Transformation Outside the Surf Zone

### Theoretical Basis

12. The velocity potential function for linear, monochromatic, plane waves can be represented by the expression

$$\phi = ae^{is} \tag{3}$$

where

$a(x,y)$ = wave amplitude function equal to $gH(x,y)/2\sigma$
$H(x,y)$ = wave height
$s(x,y)$ = wave phase function

Here again, the velocity potential function only describes the forward scattered wave field. No considerations are given to wave reflections. By substituting this expression for the velocity potential into Equation 1 and solving the real and imaginary parts separately, two equations can be derived (Berkhoff 1976), namely,

$$\frac{1}{a}\left\{\frac{\partial^2 a}{\partial x^2} + \frac{\partial^2 a}{\partial y^2} + \frac{1}{cc_g}\left[\nabla a \cdot \nabla (cc_g)\right]\right\} + k^2 - |\nabla s|^2 = 0 \tag{4}$$

$$\nabla \cdot (a^2 cc_g \nabla s) = 0 \tag{5}$$

where the symbol $\nabla$ denotes the denotes the horizontal gradient operation.

13. Together, these equations describe the combined refraction and diffraction process. Diffraction is often erroneously described as the propagation of energy along wave crests which are defined to be perpendicular to the wave phase function gradient $\nabla s$. Equation 5 shows energy is still propagated in a direction perpendicular to the wave crest. Diffractive effects do change the phase function as a result of significant wave height gradients and curvatures. These changes cause the local wave direction to vary. If diffractive effects are neglected, Equations 4 and 5 reduce to those describing pure refraction in which the wave number represents the magnitude of the phase function gradient.

14. Linear wave theory assumes irrotationality of the wave phase function gradient. This property can be expressed mathematically as

$$\nabla x(\nabla s) = 0 \tag{6}$$

The phase function gradient can be written in vector notation as

$$\nabla s = |\nabla s| \cos\theta \vec{i} + |\nabla s| \sin\theta \vec{j} \tag{7}$$

where $\vec{i}$ and $\vec{j}$ are unit vectors in the x- and y-directions, respectively, and $\theta(x,y)$ is the local wave direction. Equations 6 and 7 can be combined to yield the following expression:

$$\frac{\partial}{\partial x}\left(|\nabla s| \sin\theta\right) - \frac{\partial}{\partial y}\left(|\nabla s| \cos\theta\right) = 0 \tag{8}$$

If the magnitude of the wave phase gradient is known, local wave angles can be calculated from Equation 8. Similarly, Equation 7 can be substituted into Equation 5 to yield

$$\frac{\partial}{\partial x}\left(a^2 cc_g |\nabla s| \cos\theta\right) + \frac{\partial}{\partial y}\left(a^2 cc_g |\nabla s| \sin\theta\right) = 0 \tag{9}$$

This form of the energy equation can be solved for the wave amplitude function $a$ once the wave phase characteristics $\nabla s$ and $\theta$ are known. The wave height can be determined and is proportional to the amplitude function, since wave frequency is constant.

15. Equations 4, 8, and 9, along with the dispersion relation, describe the combined refraction and diffraction process for linear plane waves subject to the restrictions that the bottom slopes are small, wave reflections are negligible, and any energy losses are very small and can be neglected. The numerical solution scheme used to solve these equations is presented in the next section. These equations are assumed to be valid outside the surf zone. The method used to determine wave characteristics inside the surf zone is described later.

### Numerical solution

16. The three governing equations (Equations 4, 8, and 9) are solved using numerical methods. Partial derivatives within the equations are approximated using finite difference operators. Finite difference solution methods require the construction of a computational grid system or mesh. Solution accuracy is directly related to resolution within the grid system. Discussion

throughout the text will refer only to grid systems comprised of constant sized, rectangular cells. RCPWAVE is capable of computing solutions on variably sized, rectilinear grid systems. Technology for creating variably sized grids, which are compatible with the wave model, exists at CERC.

17. Figure 1 shows nine rectangular cells which make up a small part of a larger mesh. Each cell has a length equal to $\Delta x$ in the x-direction and $\Delta y$ in the y-direction. The maximum values of $i$ and $j$ are $M$ and $N$, respectively.

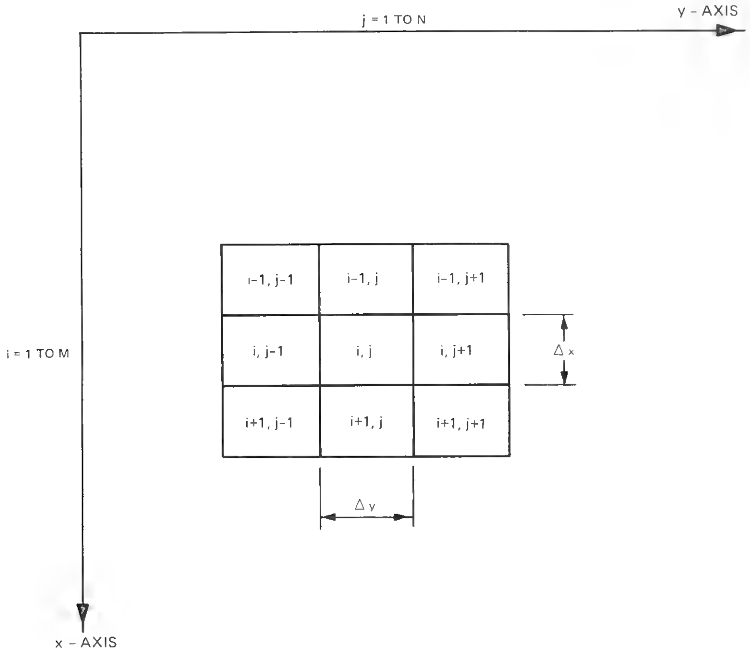

Figure 1. Definition of coordinate system and grid cell conventions used in the model

18. All variables which vary as a function of space are defined at the cell centers. For any dependent variable $F$, the following finite difference operators are used to approximate certain partial derivatives of $F$ at the position $(i,j)$:

$$\frac{\partial^2 F}{\partial x^2} \simeq \frac{2F_{i,j} - 5F_{i+1,j} + 4F_{i+2,j} - F_{i+3,j}}{(\Delta x)^2} \tag{10}$$

$$\frac{\partial^2 F}{\partial y^2} \simeq \frac{F_{i,j+1} - 2F_{i,j} + F_{i,j-1}}{(\Delta y)^2} \tag{11}$$

$$\frac{\partial F}{\partial x} \simeq \frac{-3F_{i,j} + 4F_{i+1,j} - F_{i+2,j}}{2\Delta x} \tag{12}$$

$$\frac{\partial F}{\partial y} \simeq \frac{F_{i,j+1} - F_{i,j-1}}{2\Delta y} \tag{13}$$

Equations 11 and 13 are central differences, and Equations 10 and 12 are backward differences. All four expressions have the same order of accuracy.

19. The magnitude of the wave phase function gradient at any point (i,j) is computed from the following expression,

$$\begin{aligned} |\nabla s|^2_{i,j} = k^2_{i,j} + \frac{1}{a_{i,j}} \Bigg\{ & \left[\frac{2a_{i,j} - 5a_{i+1,j} + 4a_{i+2,j} - a_{i+3,j}}{(\Delta x)^2}\right] \\ & + \left[\frac{a_{i,j+1} - 2a_{i,j} + a_{i,j-1}}{(\Delta y)^2}\right] + \frac{1}{cc_{g_{i,j}}} \\ & \times \Bigg[\left(\frac{-3a_{i,j} + 4a_{i+1,j} - a_{i+2,j}}{2\Delta x}\right)\left(\frac{-3cc_{g_{i,j}} + 4cc_{g_{i+1,j}} - cc_{g_{i+2,j}}}{2\Delta x}\right) \\ & + \left(\frac{a_{i,j+1} - a_{i,j-1}}{2\Delta y}\right)\left(\frac{cc_{g_{i,j+1}} - cc_{g_{i,j-1}}}{2\Delta y}\right)\Bigg]\Bigg\} \end{aligned} \tag{14}$$

This equation was derived by approximating the partial derivatives in Equation 4 using the finite difference operators given in Equations 10 through 13. The reason for selecting backward finite differences to approximate the x-derivatives, specifically the curvature, will be discussed later in this section.

20. Equations 8 and 9 can both be expressed in the following general form:

$$\frac{\partial F}{\partial x} + \frac{\partial G}{\partial y} = 0 \qquad (15)$$

If partial derivatives in both the x- and y-directions are estimated using central differences about the point $i\text{-}1/2,j$ , then an approximate form of Equation 15 can be written as

$$\frac{F_{i,j} - F_{i-1,j}}{\Delta x} + W\left(\frac{G_{i-1,j+1} - G_{i-1,j-1}}{2\Delta y}\right) + (1 - W)\left(\frac{G_{i,j+1} - G_{i,j-1}}{2\Delta y}\right) = 0 \qquad (16)$$

The partial derivative $\partial G/\partial y$ at position $i\text{-}1/2,j$ has been represented as a weighted average of its values at locations $i,j$ and $i\text{-}1,j$ . The value of the weighting factor $W$ used in RCPWAVE is 1.0. This choice implies that an implicit solution of the equation is required. One additional approximation is made by using the following weighted sum:

$$F_{i,j} = \alpha F_{i,j+1} + (1 - 2\alpha)F_{i,j} + \alpha F_{i,j-1} \qquad (17)$$

to represent the variable $F$ at position $i,j$ . Here $\alpha$ is another weighting parameter. The value of $\alpha$ is set to 0.167 in RCPWAVE. This "dissipative interface" (Abbott 1975) is used to enhance the stability of the numerical scheme. Substitution of Equation 17 into Equation 16 results in the following expression:

$$F_{i-1,j} = \alpha F_{i,j+1} + (1 - 2\alpha)F_{i,j} + \alpha F_{i,j-1}$$

$$+ \Delta x\left[W\left(\frac{G_{i-1,j+1} - G_{i-1,j-1}}{2\Delta y}\right) + (1 - W)\left(\frac{G_{i,j+1} - G_{i,j-1}}{2\Delta y}\right)\right] \qquad (18)$$

The finite difference formulation of Equations 8 and 9, which will be described next, is identical to that used by Perlin and Dean (1983). Their choices for $W$ and $\alpha$ were 1.0 and 0.25, respectively.

21. The finite difference form of Equation 8 is derived by substituting the following expressions for $F$ and $G$ into Equation 18:

$$F = |\nabla s| \sin\theta \qquad (19)$$

$$G = -|\nabla s| \cos \theta \tag{20}$$

These substitutions result in the following equation in which the sine of the local wave angle at the location $i-1,j$ is the quantity to be determined, thus

$$\begin{aligned}
\sin \theta_{i-1,j} = \frac{1}{|\nabla s|_{i-1,j}} \Bigg[ \Big( & \alpha |\nabla s|_{i,j+1} \sin \theta_{i,j+1} + (1 - 2\alpha) |\nabla s|_{i,j} \sin \theta_{i,j} \\
& + \alpha |\nabla s|_{i,j-1} \sin \theta_{i,j-1} \Big) - \frac{W \Delta x}{2 \Delta y} \Big( |\nabla s|_{i-1,j+1} \cos \theta_{i-1,j+1} \\
& - |\nabla s|_{i-1,j-1} \cos \theta_{i-1,j-1} \Big) - \frac{(1 - W) \Delta x}{2 \Delta y} \Big( |\nabla s|_{i,j+1} \cos \theta_{i,j+1} \\
& - |\nabla s|_{i,j-1} \cos \theta_{i,j-1} \Big) \Bigg]
\end{aligned} \tag{21}$$

22. Similarly, using the substitutions

$$F = a^2 A \tag{22}$$

$$G = a^2 B \tag{23}$$

where

$$A = c c_g |\nabla s| \cos \theta \tag{24}$$

$$B = c c_g |\nabla s| \sin \theta \tag{25}$$

the finite difference form of Equation 9 becomes

$$a^2_{i-1,j} = \frac{1}{A_{i-1,j}} \Bigg[\left(\alpha a^2_{i,j+1} A_{i,j+1} + (1 - 2\alpha) a^2_{i,j} A_{i,j} + \alpha a^2_{i,j-1} A_{i,j-1}\right) + \frac{W\Delta x}{2\Delta y}\left(a^2_{i-1,j+1} B_{i-1,j+1} - a^2_{i-1,j-1} B_{i-1,j-1}\right) + \frac{(1-W)\Delta x}{2\Delta y}\left(a^2_{i,j+1} B_{i,j+1} - a^2_{i,j-1} B_{i,j-1}\right)\Bigg] \qquad (26)$$

This equation can be solved for the wave amplitude function, and subsequently the wave height, at the location $i-1,j$. The remainder of this section describes the procedure used to solve the set of approximate Equations 14, 21, and 26.

23. Model input (described in detail in Part IV) includes values of the deepwater height $H_o$, direction $\theta_o$, and period $T$ of waves to be simulated. It also includes specification of the bottom bathymetry throughout the grid. The wave number, which is related to the wave period and the local water depth through the dispersion relation, is computed at every cell. Wave number is used as an initial guess for the magnitude of the wave phase function gradient. The wave celerity $c$ and the group velocity $c_g$ are functions of the wave period and wave number. Therefore these variables can be calculated at each cell.

24. From Snell's law,

$$\frac{\sin\theta}{c} = \frac{\sin\theta_o}{c_o} \qquad (27)$$

where $c_o$ is the deepwater wave celerity (defined to be $gT/2\pi$), an estimate of the local wave angle is calculated everywhere. This estimate assumes that the bottom contours are parallel with the y-axis. If the bottom bathymetric contours make a known nonzero angle with the y-axis, a better first guess for the wave angles can be computed. The new approximation is

$$\theta = \pi - \sin^{-1}\left(\frac{\sin(\theta_o - \theta_c)}{\frac{c_o}{c}}\right) + \theta_c \qquad (28)$$

where $\theta_c$ defines the contour angle. The local wave angle, deepwater wave angle, and contour angle follow the angle convention shown in Figure 2. The contour angle is an input parameter into RCPWAVE.

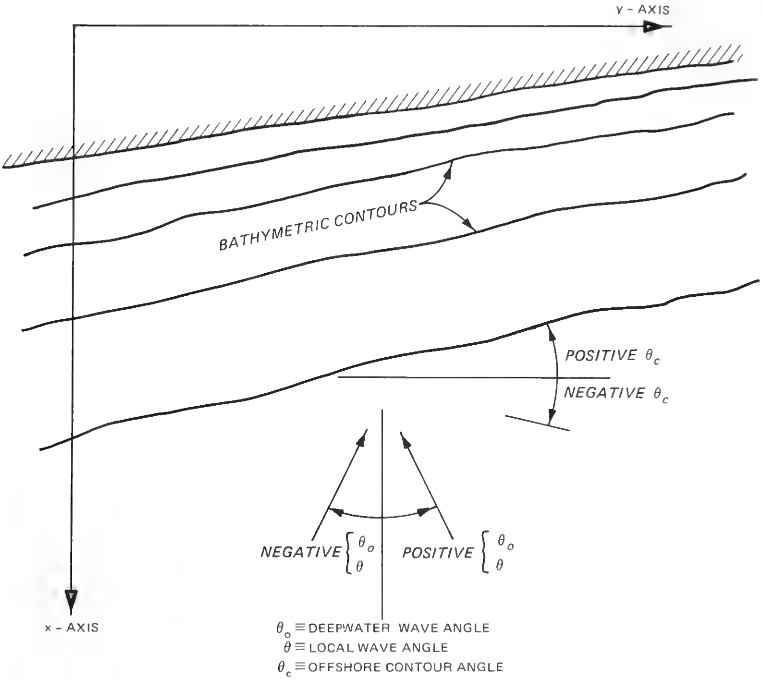

Figure 2. Definition of angle conventions used in the model

25. Wave heights at each cell are estimated as the product of the deepwater wave height, a shoaling coefficient $\kappa_s$, and a refraction coefficient $\kappa_r$, thus

$$H = H_o \kappa_r \kappa_s \tag{29}$$

where

$$\kappa_r = \left( \frac{\cos \theta_o}{\cos \theta} \right)^{1/2} \tag{30}$$

and

$$\kappa_s = \left[ \frac{1}{\left(1 + \frac{2kh}{\sinh\,(2kh)}\right) \tanh\,(kh)} \right]^{1/2} \tag{31}$$

The dispersion relation, Snell's law, and this simple estimator of the wave height allow an initial guess to be made for the variables of interest throughout the grid system.

26. The solution scheme implements the following marching procedure once initial guesses for the variables of interest have been made. Starting at the offshore row designated by $i=M-3$ , Equations 21 and 26 are used to compute wave angles and then heights along the entire row (from $j=2$ to $j=N-1$). Wave height is used interchangeably with amplitude function since one is directly proportional to the other.

27. Wave angle and height solutions along a given row are solved iteratively because of the implicit differencing formulation used. Calculations of the wave angle (actually the sine of the wave angle) and the wave amplitude function are reiterated until the average change (along a row) in each variable from one iteration to the next is less than some tolerance. These convergence criteria, 0.0005 for wave sines and 0.001 ft* (or a metric equivalent) for wave heights, are suggested values for prototype applications. They can be easily changed by modifying the source code using the method outlined in Part IV.

28. This solution considers only refraction since the wave number $k$ is used as an estimate of the magnitude of the phase function gradient. Equation 14 is then used to compute the true magnitude of the wave phase gradient. This new wave number accounts for the effects of diffraction. Backwards differences are used to approximate the x-derivatives because they require only information which has already been computed. Next, Equations 21 and 26 are again solved in order to compute the wave angles and heights using these new wave numbers. This procedure is repeated along the row under consideration until the change in new wave number, from one iteration to the next, is less than 0.5 percent of the newly computed value. This condition must be met at each cell along the row. As a row of new wave numbers is computed, the values are filtered in the y-direction using the method of Sheng, Segur, and Lewellen

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* To convert feet to metres use a conversion factor of 0.3048.

(1978). This filter removes cell-to-cell oscillations introduced as a result of the differencing scheme used to compute the new wave numbers. Row-by-row marching proceeds until solutions are computed along row i=2.

29. Lateral boundary conditions for a row are specified at the conclusion of calculations for that row. The value of all variables at cells $j=N$ and $j=1$ are set equal to their values at cells $j=N-1$ and $j=2$, respectively. This boundary condition implies that the change in the variable in the y-direction is zero. The condition is most valid when the bathymetric contours are nearly straight and parallel to the y-axis. For this reason it is recommended that users orient their grid system so that the y-axis is nearly parallel to bottom contours along the lateral boundaries.

30. Boundary conditions along the seaward extent of the grid are used to initiate the shoreward marching algorithm. They are computed from deep-water wave input supplied by the user along with the following assumption. Bottom contours extending from the offshore grid row $i=M$ out to deep water are assumed to be straight and parallel to a line making an angle of $\theta_c$ with the y-axis. In other words, Snell's law is assumed to be valid from deep water to the outer boundary of the grid system. No inshore boundary conditions (along row i=1) are required because of the foreward marching solution scheme.

## Wave Transformation Inside the Surf Zone

### Theoretical basis

31. Waves approaching the very nearshore zone tend to steepen and eventually break because of decreasing water depths. Shoreward of this breaking point dissipative energy losses due to turbulence strongly influence the wave height. Linear theory does not allow for prediction of the breaker location nor for wave transformation across the surf zone. Instead, empirical and approximate methods must be used to describe the breaking process.

32. The first aspect to consider in surf zone transformation of waves is incipient wave breaking. Iwata and Sawaragi (1982) reviewed many criteria for determining wave characteristics at the breaking point. One which is appealing because of its basis on wave physics defines breaking as the point when the particle velocity at the wave crest exceeds the wave celerity. The following formulas:

$$H_b = 0.78h_b \tag{32}$$

and

$$H_b = 0.142L_b \tanh\left(\frac{2\pi h_b}{L_b}\right) \tag{33}$$

where

$H_b$ = breaking wave height
$h_b$ = water depth at breaking
$L_b$ = wave length at breaking

by McCowan (1891) and Miche (1944), respectively, are based on this criterion. Equations 32 and 33 were derived for solitary and periodic shallow-water waves, respectively, in water of uniform depth (Iwata and Sawaragi 1982). A breaking height predictor based on wave energy flux was developed by Komar and Gaughan (1972) and is given by

$$H_b = \kappa^*(g)^{1/5}\left(TH_o^2\right) \tag{34}$$

where $\kappa^*$ is a dimensional coefficient equal to 0.39. Field and laboratory data have shown this predictor to be quite accurate. Other incipient breaking criteria have been developed by fitting empirical relationships to breaking wave data. These methods are not derived from any theoretical considerations of wave physics, yet results derived using them agree very well with observed data. The most widely used of these criteria are those developed in Equations 35, 36, and 37 by Le Méhauté and Koh (1967), Goda (1970), and Weggel (1972), respectively. These criteria are as follows:

$$H_b = 0.76\, H_o\left(\frac{H_o}{L_o}\right)^{-1/4} m^{1/7} \tag{35}$$

where

$L_o$ = deepwater wave length
$m$ = bottom slope

$$H_b = 0.17L_o\left\{1 - \exp\left[-1.5\pi\,\frac{h_b}{L_o}(1 + 15(m))^{4/3}\right]\right\} \tag{36}$$

and

$$H_b = \frac{\bar{b}h_b}{1 + \frac{\bar{b}\bar{a}}{gT^2}} \qquad (37)$$

where

$$\bar{a} = 43.75\left[1 - e^{(-19m)}\right]$$

$$\bar{b} = 1.56/\left[1 + e^{(-19.5m)}\right]$$

33. All of these empirical methods give reasonable approximations of the incipient breaking wave height. In choosing a criterion for inclusion into RCPWAVE, the following factors were considered. The criterion should account for bottom slope and wave period since field and laboratory tests show these parameters to be important (Iwata and Sawaragi 1982). It should not depend on deepwater parameters alone because the transformation algorithm must be capable of modeling multiple breaking and reformation. The Weggel (1972) and Goda (1970) criteria satisfy both requirements. The former was selected for inclusion into RCPWAVE.

34. Once the incipient breaking point is defined, a mechanism is needed to transform the breaking wave across the surf zone. Historically the wave height has been assumed to be proportional to the local water depth throughout the surf zone. The constant of proportionality was assumed to be about 0.8. Field and laboratory data have shown that this approximation consistently overestimates actual wave heights within the surf zone (Dally 1980 and Thornton and Guza 1982). Other formulations have been developed and applied successfully by researchers to calculate surf zone wave heights. Most are of the following form:

$$\frac{\partial(Ec_g)}{\partial x} = -\delta \qquad (38)$$

where $Ec_g$ is the energy flux associated with the breaking wave and $\delta$ is a term representing the rate of energy lost due to bottom friction, turbulence, and other dissipative processes.

35. Divoky, Le Méhauté, and Lin (1970) considered the dissipation in a breaking wave to resemble that in a hydraulic jump. They assumed that the change in energy flux could be approximated by

$$\frac{\partial(Ec_g)}{\partial x} = \rho g Q \left[\frac{\left(Y_1 - Y_2\right)^3}{4Y_1Y_2}\right] \tag{39}$$

where

$\rho$ = water density

$Q$ = flow across the jump

$Y_1$ = water depth on the high end of the jump

$Y_2$ = water depth on the low end of the jump

For water of uniform depth, they assumed that $Y_2 = h + H$ and $Y_1 = h + \beta H$ where $\beta$ is a coefficient related to the percentage of the wave height covered by foam. Battjes and Janssen (1978) also used a hydraulic jump representation of wave breaking. They used the following expression:

$$\frac{\partial(Ec_g)}{\partial x} = \alpha^* \rho g \; Q \, \frac{H^2}{4T} \tag{40}$$

where $\alpha^*$ is a coefficient of order one. Mizuguchi (1980) modeled surf zone energy loss as,

$$\frac{\partial(Ec_g)}{\partial x} = 2\rho g \; \nu_e \left(\frac{kH}{2}\right)^2 \tag{41}$$

where $\nu_e$ is a coefficient of turbulent eddy viscosity. Results derived from this model compared quite well with experimental data, but any physical reasoning behind the use of the eddy viscosity formulation is, as Mizuguchi (1980) states, obscure. Horikawa and Kuo (1966) developed an analytical scheme using second order solitary wave theory and theoretical expressions for dissipation due to bottom friction and turbulence. Their governing equation contained two coefficients, one for each dissipative mechanism.

36. The transformation algorithm selected for use in RCPWAVE (Dally, Dean, and Dalrymple 1984) uses the same energy flux basis as the models mentioned above. However, instead of using a hydraulic jump to represent energy loss in a single breaking wave, the form of the hydraulic jump energy loss is used to approximate losses across the entire surf zone. Through analogy with energy flux in a channel, the following equation is postulated:

$$\frac{\partial(Ec_g)}{\partial x} = \frac{-\kappa}{h}\left[Ec_g - \left(Ec_g\right)_s\right] \tag{42}$$

where

$\kappa$ = rate of energy dissipation coefficient (set equal to 0.2 in RCPWAVE)

$\left(Ec_g\right)_s$ = stable level of energy flux that the transformation process seeks to attain

The right-hand side of Equation 42 is simply a dissipation term. The subscript s is used to denote the stable level of some quantity. Substituting the linear wave theory estimate for E ($E = 0.125\ \rho g H^2$) into Equation 42 results in the following expression:

$$\frac{\partial(H^2 c_g)}{\partial x} = \frac{-\kappa}{h}\left(H^2 c_g\right)_s \qquad (43)$$

37. Various field (Thornton and Guza 1982) and laboratory (Horikawa and Kuo 1966) experiments have shown that, well into the surf zone, the wave height tends toward a stable value which is proportional to the local water depth. This relationship can be expressed as

$$H_s = \gamma h$$

where

$H_s$ = stable wave height

$\gamma$ = proportionality coefficient (set equal to 0.4 in RCPWAVE)

Equation 43 can now be rewritten as

$$\frac{\partial\left(H^2 c_g\right)}{\partial x} = \frac{-\kappa}{h}\left[H^2 c_g - \left(\gamma^2 h^2 c_g\right)_s\right] = D \qquad (45)$$

38. This surf zone wave transformation model can be incorporated into the conservation of wave energy equation (Equation 5) by simply adding the dissipation term D to the right-hand side. The function D must now represent dissipation in the direction of wave propagation. Also for dimensional consistency, the term D must be multiplied by the wave celerity and the magnitude of the wave phase gradient, and the wave height must be replaced by the wave amplitude function. In vector notation, the energy equation becomes

$$\nabla\cdot\left(a^2 c c_g \nabla s\right) = \frac{-\kappa}{h}\left\{a^2 c c_g\left|\nabla s\right| - \left[\left(\frac{g}{2\sigma}\right)^2 \gamma^2 h^2 c c_g \left|\nabla s\right|\right]_s\right\} \qquad (46)$$

This equation can be thought of as being valid both inside and outside the surf zone. Outside, the coefficient $\kappa$ is zero, and the equation reduces to Equation 5.

39. Discussion relating to wave transformation within the surf zone has addressed the problem of determining wave heights. The problem of wave phase must be addressed also. Diffraction effects are assumed to be negligible inside the surf zone. Therefore, the wave number $k$ is assumed to accurately represent the magnitude of the wave phase function gradient. The linear wave theory assumption that the waves are irrotational also will be assumed to remain valid inside the surf zone. Consequently, wave angles inside the surf zone are computed in the same manner that was used outside the surf zone.

<u>Numerical solution</u>

40. The numerical procedure for computing wave angles inside and outside the surf zone is the same. This section documents only the solution scheme used to determine breaking wave heights. The finite difference form of the wave energy equation outside the surf zone (Equation 26) can be expressed in the following form:

$$a^2_{i-1,j} = \frac{\bar{F} + \Delta x \, \bar{G}}{A_{i-1,j}} \tag{47}$$

where

$$\bar{F} = \alpha a^2_{i,j+1} A_{i,j+1} + (1 - 2\alpha) a^2_{i,j} A_{i,j} + \alpha a^2_{i,j-1} A_{i,j-1}$$

$$\bar{G} = (1 - W)\left(\frac{a^2_{i,j+1} B_{i,j+1} - a^2_{i,j-1} B_{i,j-1}}{2\Delta y}\right)$$

$$+ W\left(\frac{a^2_{i-1,j+1} B_{i-1,j+1} - a^2_{i-1,j-1} B_{i-1,j-1}}{2\Delta y}\right)$$

$$B = cc_g \, |\nabla s| \sin \theta$$

$$A = cc_g |\nabla s| \cos \theta$$

With the inclusion of the dissipative term, Equation 47 becomes

$$a^2_{i-1,j} = \frac{\bar{F} + \Delta x\ \bar{G}}{A_{i-1,j}} + \frac{\Delta x\ D^*}{A_{i-1,j}} \qquad (48)$$

where D* represents the finite difference form of the dissipation term on the right-hand side of Equation 46. Reiterating, the dissipation term is an average value along the wave path. The wave path is determined by the local wave angle at the position i-1,j which has already been computed. Therefore, the average along the path is an average of information at cell i-1,j and another cell whose position is denoted by ikey,jkey . The procedure used for determining the location of this cell will be presented later.

41. The term D can be written in finite difference form as

$$D^* = \frac{\kappa}{\bar{h}}\left\{\left[\frac{\left(a^2cc_g|\nabla s|\right)_{ikey,jkey} + \left(a^2cc_g|\nabla s|\right)_{i-1,j}}{2}\right] - \left(\frac{g}{2\sigma}\right)^2\left(\frac{\gamma^2h^2cc_g|\nabla s|_{ikey,jkey} + \gamma^2h^2cc_g|\nabla s|_{i-1,j}}{2}\right)\right\} \qquad (49)$$

where

$$\bar{h} = \frac{h_{i-1,j} + h_{ikey,jkey}}{2}$$

With some algebra, Equation 48 can be reorganized so that the amplitude function at the position i-1,j only appears on the left-hand side of the equation. Therefore, the energy equation inside the surf zone can be numerically solved using the same procedure which was used to solve it outside the surf zone.

42. The location of the cell denoted ikey,jkey is found using the following procedure. "Areas of influence" are determined by extending lines from the center of the cell i-1,j to the midpoints between the surrounding cell centers (Figure 3). Angles are computed from the x-axis to these radial lines. The local wave angle calculated at cell i-1,j is compared to each of these angles in order to determine the nearest, prior cell along the wave path. For example (refer to Figure 3), if the local wave angle is greater than $\theta_2$ but less than $\theta_1$ , then cell i,j+1 is the cell of influence and ikey = i and jkey = j+1.

43. A flow chart describing the wave height computation is shown in

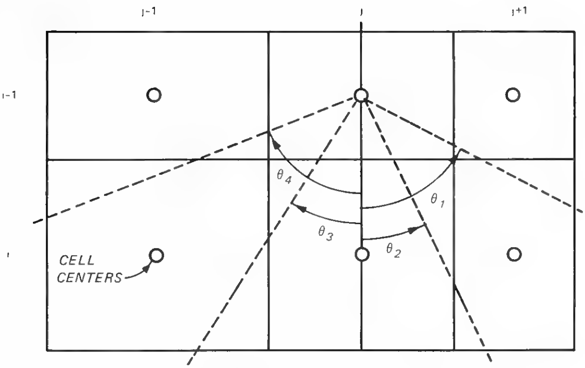


Figure 3. Schematic drawing showing cell of influence conventions used in the wave breaking scheme

Figure 4. The wave amplitude function is computed from the energy equation assuming no dissipation. The amplitude function is converted to wave height and compared to the stable wave height $\gamma h$ . If the wave is less than or equal to this stable level, the wave is either inside the surf zone, having been transformed to a state below the stable level, or it is outside the surf zone. In either case, no further transformation is needed. If the wave height is greater than $\gamma h$ , then additional wave transformation may occur. The cell of influence is located and tested to determine whether or not the wave has experienced prior breaking. If the wave is undergoing transformation in the cell of influence, it continues to be transformed. If the wave in the cell of influence is not being transformed, the local wave height is checked against the incipient breaking height criterion. If the height exceeds the allowable value, wave dissipation begins. The accuracy of the surf zone wave transformation model has been verified using laboratory data of Horikawa and Kuo (1966) and Izumiya (1984). Comparisons between model results and these data are described in Part III.

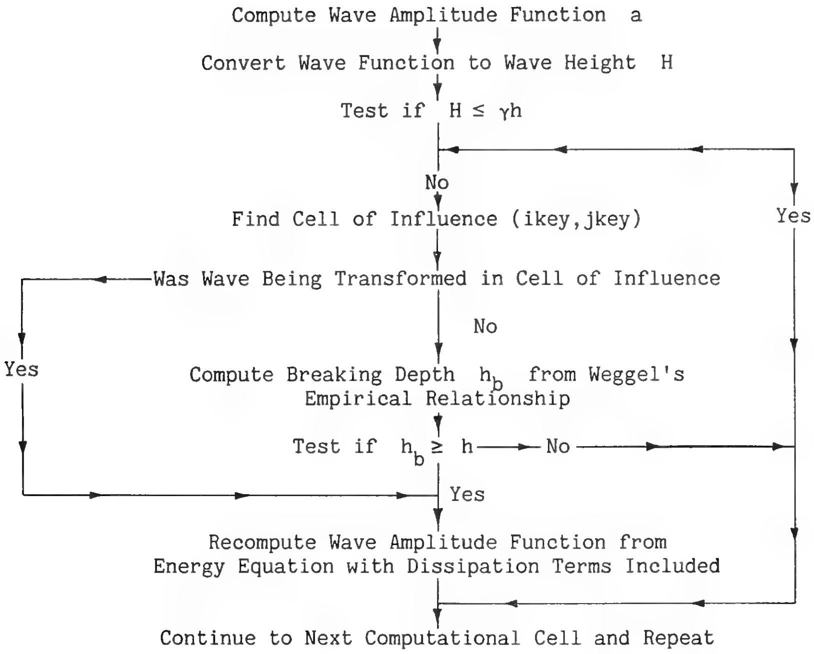


Figure 4. Flow chart of the wave breaking scheme

# PART III: MODEL VERIFICATION

## General Comments

44. Comparisons between model results and observed data were used to verify the model. Both laboratory and field data were used in these tests. The ability of RCPWAVE to simulate wave transformation outside the surf zone was checked using data collected during a laboratory experiment conducted by Berkhoff, Booy, and Radder (1982) and using prototype data obtained during a field experiment at the CERC Field Research Facility (FRF) in Duck, North Carolina. The next two sections describe these comparisons in detail. Figures pertaining to the laboratory and field verification are located in Appendixes A and B, respectively. Only laboratory data were used to verify the surf zone wave transformation part of the model. These data were collected during one-dimensional flume tests performed by Horikawa and Kuo (1966) and Izumiya (1984). Both experiments considered only breaking of monochromatic, plane waves. The former experiment investigated wave transformation on a plane beach only; the latter involved tests using plane, stepped, and barred beaches. These comparisons are discussed in the last section. Figures pertaining to the wave breaking verification are located in Appendix C.

## Elliptical Shoal Case: Comparison with Laboratory Data

45. Berkhoff, Booy, and Radder (1982) performed a wave tank experiment in which wave conditions resulting from the propagation of a monochromatic, plane wave train over complex bathymetry were measured. The bathymetry consisted of an elliptical shoal superimposed on a plane beach. This geometry is shown in Figure A1. The shoal acts as a lens and focuses incoming wave energy into a strong convergence zone. This experiment provided a set of data which could be used to verify the ability of RCPWAVE to compute accurate solutions to problems where refraction theory breaks down. Wave height data were collected at many locations within this zone along the eight cross sections shown in Figure A1. RCPWAVE was used to simulate the same experiment. Simulated wave heights were then compared with observed data.

46. A finite difference grid mesh, which measured 25 m in the x-direction and 20 m in the y-direction was constructed. Rectangular grid

cells measuring 0.25 and 0.20 m in the x- and y-directions, respectively, were used for the simulation. The center of the shoal was located at the point with x- and y-coordinates of 15 and 10 m, respectively. The equation describing the outer extent of the shoal is given by

$$\left(\frac{y'}{3}\right)^2 + \left(\frac{x'}{4}\right)^2 = 1 \tag{50}$$

where x' and y' denote a local coordinate system whose origin is located at the center of the shoal. Also this coordinate system is rotated 20 deg in the clockwise direction relative to the x- and y-coordinate system. All length scales for both coordinate systems are measured in metres. Water depths, denoted by h and measured in metres, were calculated from the following three equations,

$$h = 0.45 \quad \text{for} \quad y' \geq 5.84 \tag{51}$$

$$h = 0.45 - 0.02\,(5.84 - y')\text{(outside the shoal boundary)} \tag{52}$$

$$h = 0.45 - 0.02\,(5.84 - y') + 0.3 - 0.5\left[1 - \left(\frac{x'}{5}\right)^2 - \left(\frac{y'}{3.75}\right)^2\right]^{1/2} \tag{53}$$

(inside the shoal boundary)

An incident wave with a period of 1.00 sec, a height of 1.06 cm, and a direction of approach parallel to the x-axis was used as the deepwater boundary condition for the simulation.

47. Figures A2 through A4 show comparisons between the experimental data (open circles) and model results (solid line) for all eight profiles. Results are presented as profiles of relative wave height (observed wave height divided by incident wave height). A refraction analysis (presented in Berkhoff, Booy, and Radder (1982)) shows that a caustic occurs at a point between profiles 2 and 3. Results show that the model is quite capable of accurately simulating diffractive effects at, and beyond, the caustic location. Consequently, it is a much more powerful tool for simulating wave transformation than refraction theory alone. Berkhoff, Booy, and Radder (1982) and Kirby (1983) also numerically simulated this experiment in order to test their parabolic approximation models. Accuracy of their model results, using linear wave theory, is comparable to that obtained using RCPWAVE. Results obtained

by Kirby (1983) are shown also in the figures (as a dashed line). Kirby showed that much of the discrepancy between simulated and observed data could be eliminated if a nonlinear wave theory were incorporated into the model. He incorporated Stokes' second order theory (which he showed was valid for this experiment) into his model, and the results also showed that nonlinear effects became increasingly important after the waves pass profile 3.

48. An interesting aspect of the RCPWAVE results is evident in profiles 3, 4, and 5. The lobed features in the wave height variation are smoothed by the model. The cause of this smoothing is not known. It may be caused by the dissipative interface or the point-to-point filter used in the numerical scheme. The side lobes seem to be related to the occurrence of an amphidromic point where the wave phase becomes multivalued and the wave height variation contains a discontinuity. The solution scheme forces the magnitude of the phase function gradient to be single valued. This may also cause the local smoothing. The model is intended for use in open coast, prototype applications. For these types of problems, this smoothing property of the model can certainly be tolerated.

## CERC's FRF Cases: Comparisons with Prototype Data

49. In addition to the laboratory verification, RCPWAVE also was verified using field data collected at CERC's FRF in Duck, North Carolina. Bottom bathymetric contours in the area are generally straight and parallel to the coastline except in the immediate vicinity of the research pier. The pier's presence has caused the formation of a deep scour hole along much of its length. The complicated bathymetry, which has resulted from this hole, was one reason for selecting the FRF for field verification. Hubertz (1981) showed that a ray model using refraction theory alone proved incapable of simulating observed conditions. Hubertz (1982) also showed that a short wave model which includes diffractive effects in its governing equations (the System 21 Mark 8 proprietary model developed by the Danish Hydraulic Institute) could accurately simulate wave propagation in the vicinity of the pier up to the breaking point.

50. Another reason for selecting the FRF was the availability of wave data, both offshore and along the pier. During October 1982, an extensive, 1-month field data collection program was undertaken. Two storms

occurred during the month, one lasting from 10-13 October and the other from 23-26 October. The latter was the more severe event. Prototype data collected during this month included bathymetric surveys conducted on October 16 and 27, continuous and synchronous wave data from six Baylor gages along the pier and an offshore Waverider buoy, radar imagery of the sea surface, and continuous tide elevation data. All wave data were available in a spectral form (energy density as a function of frequency). Estimates of significant height and peak period were provided also. Wave directions could be determined from the radar imagery. The availability of clear radar pictures was ultimately the discriminating factor in selecting which time periods were considered for verification purposes.

51. Six cases, or time periods, were ultimately chosen using the following process. As stated above, only those times were considered when clear radar imagery was available. The number of candidate times were further reduced by requiring that wave data be available within approximately 1 hr of the time the image was taken. Next, the wave spectum from the offshore gage was checked for spectral shape. Only times with single-peaked, fairly narrow banded spectra were considered. Six cases which met all the criteria are shown in Table 1.

Table 1

Summary of Field Data Used to Verify RCPWAVE

| Test Case Number | Date | Time G.m.t.* | $H_o$ m | T sec | $\theta_o$ deg | Tide m | Time of Radar Imagery G.m.t. | Bathymetry Survey Date |
|---|---|---|---|---|---|---|---|---|
| 1 | 10-13-82 | 1300 | 1.95 | 13.21 | -23 | 0.12 | 1115 | 10-16-82 |
| 2 | 10-13-82 | 1400 | 1.87 | 14.22 | -25 | -0.18 | 1115 | 10-16-82 |
| 3 | 10-15-82 | 1210 | 0.78 | 12.34 | -25 | 0.78 | 1130 | 10-16-82 |
| 4 | 10-17-82 | 1200 | 1.56 | 6.87 | 43 | 0.91 | 1120 | 10-16-82 |
| 5 | 10-25-82 | 1900 | 3.10 | 12.34 | -25 | 0.68 | 1950 | 10-27-82 |
| 6 | 10-25-82 | 2000 | 2.95 | 12.34 | -25 | 0.63 | 1950 | 10-27-82 |

* G.m.t. denotes Greenwich mean time.

52. For each case the date and time of the recorded wave data are shown. The parameters $H_o$ , T , and $\theta_o$ are the deepwater wave characteristics used as input into RCPWAVE. The value of T was chosen to be the best

estimate of the peak spectral period and was made using data from the Waverider buoy and the seaward-most Baylor gage located at the end of the pier. The deepwater wave angle was computed using this peak period and a wave direction estimated from the radar imagery. The time at which the radar image was taken also is given. Inherent in the procedure used to calculate the wave parameters in deep water is the assumption that the bottom contours seaward of the pier are straight and parallel. This assumption is quite reasonable for this stretch of coastline. The deepwater wave height represents a significant height and was computed using the peak period, deepwater angle, and the significant height recorded by the offshore Waverider buoy. The recorded wave spectra at the offshore gage are shown for all six cases in Figure B1.

53. Bottom bathymetry is required as model input. The total water depth matrix, used in the model, is computed by simply adding some tidal elevation to each depth value. Depth values were taken from one of two surveys shown in Figure B2. The particular survey used for each verification case is shown in Table 1. The tidal elevation (relative to mean sea level (MSL)) also is given in Table 1. The areal extent of each survey is identical, covering 1,200 m in the y-direction and 900 m in the x-direction. The orientation of the survey axes was adopted for use in constructing the model grid system. The x-axis is parallel to the FRF pier. Actual depth values (relative to MSL) were provided for each cell of a grid comprised of 75 cells in the x-direction and 50 cells in the y-direction. This grid completely encompasses the surveyed region. Cell dimensions are 12 and 24 m in the x- and y-directions, respectively.

54. Comparisons between simulated and observed significant wave heights along the pier are shown for each case in Figures B3 and B4. For these tests, the model is being used to propagate some amount of energy (here, designated by the significant height) with a single frequency and some mean direction. By requiring that the radar imagery be clear and contain only a unidirectional wave train, only waves which are nearly planar (long-crested) are being considered. Since most of the wave spectra are narrow-banded (with the exception of Case 4), the cases being considered represent nearly monochromatic conditions. Therefore, assumptions inherent in the model's governing equations are essentially upheld, and the model should be able to simulate these conditions. Results show that RCPWAVE accurately predicts wave propagation for these types of wave conditions over a complex bottom. In all cases the scour hole causes

wave energy to be propagated away from the hole causing a reduction in wave height along the pier. Results from Hubertz (1982) substantiate this observation. The trend of the wave height variation along the pier for Case 4 also is accurately simulated. The magnitude of the simulated significant height consistently underestimates observed data by about 0.1 m. The closeness of fit for this case, which involves a wider spectral bandwidth, suggests that the model may provide a useful method for predicting spectral wave transformations if the waves have a small directional spread. More research is needed to test this hypothesis.

## Verification of the Wave Breaking Scheme: Comparisons with Laboratory Data

55. A number of numerical simulations were performed in order to verify the capability of RCPWAVE to predict wave breaking and surf zone wave transformation. Model results were compared with data from laboratory experiments. Two sources of data were used. The first source was the original work of Horikawa and Kuo (1966) along with additional information concerning that work found in Dally (1980) and Dally, Dean, and Dalrymple (1984). Horikawa and Kuo studied the transformation of waves in the surf zone using two wave tanks and four different uniform bottom slopes. Two slopes, 1:20 and 1:30, were tested in a wave tank 17 m long and 0.6 m deep. The remaining slopes, 1:65 and 1:80, were tested using a larger tank which measured 75 m in length and 1.2 m in depth. The second source of experimental data was the dissertation work of Izumiya (1984), who used a smaller wave tank for his tests. All water depths considered in the experiments were less than 0.3 m, and all breaking wave data were collected within 7 m of the dry "beach." He investigated wave transformation over three different bottom configurations: a plane beach, a stepped beach, and a barred beach. All slopes were 1:20, including the back slope on the barred beach.

56. Wave and bathymetry conditions for each laboratory test used in the model verification process are shown in Table 2. The table shows the data source, an arbitrarily assigned test case number, the type of beach considered, and the beach slope. The following wave parameters for each test are given also: (a) the wave period, (b) the deepwater wave height (if it were available), (c) the incipient breaking wave height, and (d) the water depth at breaking.

Table 2

Summary of Laboratory Data Used to Verify the Wave Breaking Scheme

| Test Case | | Bathymetry | Slope | T<br>sec | $H_o$<br>cm | $H_b$<br>cm | $h_b$<br>cm |
|---|---|---|---|---|---|---|---|
| Horikawa and Kuo | 1 | Plane beach | 1:20 | 1.40 | -- | 13.2 | 15.5 |
| Horikawa and Kuo | 2 | Plane beach | 1:30 | 2.20 | -- | 9.1 | 10.8 |
| Horikawa and Kuo | 3 | Plane beach | 1:30 | 2.20 | -- | 12.2 | 16.4 |
| Horikawa and Kuo | 4 | Plane beach | 1:65 | 1.56 | 14.4 | 17.2 | 19.4 |
| Horikawa and Kuo | 5 | Plane beach | 1:65 | 1.56 | 24.7 | 27.1 | 35.2 |
| Horikawa and Kuo | 6 | Plane beach | 1:80 | 1.40 | -- | 17.7 | 25.0 |
| Izumiya | 7 | Plane beach | 1:20 | 1.19 | 6.0 | 7.7 | 9.4 |
| Izumiya | 8 | Stepped beach | 1:20 | 0.96 | 7.9 | 8.5 | 9.7 |
| Izumiya | 9 | Barred beach | 1:20 | 0.95 | 6.3 | 6.9 | 8.3 |

57. Two series of verification tests were conducted. The first series involved model simulations which were initiated at the break point determined from the data in Table 2. The purpose of these tests was to check the validity of the surf zone transformation part of the breaking scheme. Figures C1 through C6 show plots comparing simulated results with Horikawa and Kuo's data. The horizontal and vertical scales vary from plot to plot. Model results generally show good agreement with observed data. The model tends to underpredict the wave heights very close to shore because the model does not consider the effects of wave setup. Setup would increase the total water depth here and allow for larger simulated wave heights (Dally 1980). Horikawa and Kuo Test 2, having data points 1.0 and 0.5 m from shore, clearly illustrate this model deficiency. However, neglecting wave setup has little effect on model accuracy in the remainder of the surf zone. Steep slopes, 1:20 and 1:30, produce a much more rapid decrease in wave height across the breaking zone than do the milder slopes, 1:65 and 1:80. Qualitatively, this is what is usually observed in the field. Plunging waves are more likely to occur on steep slopes and spilling breakers on mild slopes. Results suggest that the breaking model is applicable under both types of breaking conditions.

58. Figures C7 through C9 show comparisons between model results and Izumiya's data, again for surf zone transformation only. Test 7, a plane beach case, shows very good agreement. The wave height variation across the

surf zone is characterized by a strong gradient, typical of steep slopes. Test 8 was conducted using a stepped beach. The model reproduces the same general wave height variation exhibited by the data but not as accurately as in the plane beach cases. The data show a more rapid decay immediately inside the break point, and the decay seems to be toward a stable height less than that predicted by the model. Some oscillations appear in the data, possibly from reflections, which make an estimation of the stable height difficult. The values of $\kappa$ and $\gamma$ used in the model's breaking scheme were selected to provide a "best" fit to both data sets. Better agreement could have been obtained for individual data sets by using some other values. There is also evidence that the values of $\kappa$ and $\gamma$ are dependent upon the beach slope (Dally, Dean, and Dalrymple 1984). For simplicity, a constant value for both parameters is used in the model. The final comparison is for the barred beach case. Again, good agreement is obtained for the overall shape of the wave height decay. The model miscalculates the location of the second break point by about 0.3 m, but the simulated decay after this point closely parallels the data.

59. A second series of comparisons, using the same laboratory data, were made. Results from these comparisons are provided to show the capability of the model to simulate the entire shoaling and breaking process, including a determination of the break point. Previously, only the accuracy of the decay mechanism was examined. RCPWAVE was used to simulate wave propagation from generation through to breaking. These simulations were performed for those cases in which the deepwater wave height was given by the authors or could be computed. The deepwater wave height is used as model input. Figure C10 shows the model results from Horikawa and Kuo Test 5. The model could not shoal the wave up to the observed incipient breaking height; however, the simulated surf zone transformation matches well with observed data.

60. Results from similar comparisons between model results and laboratory data for the Izumiya Tests 7, 8, and 9 are shown in Figures C11 through C13. In all cases the model failed to reproduce the wave shoaling peak immediately prior to breaking. The model does decay the wave correctly for Tests 7 and 8. In Test 9 the model misses the first break point entirely. This case was included to illustrate the dependency of accurate surf zone simulations on the validity of the incipient breaking criterion used.

61. For the monochromatic wave conditions considered in this

verification, and probably narrow-banded spectra as well, the model is incapable of predicting the full extent of the shoaling peak prior to breaking, probably due to the use of linear wave theory. This limitation, coupled with any errors in the incipient breaking criterion, may cause the location of the break point to be erroneously specified (e.g., Izumiya Test 9). However, the surf zone transformation part of the model seems to be very accurate for plane beaches and quite reasonable for stepped and barred bathymetry. Consequently, the model is usually capable of simulating the general form of the wave height variation across the breaker zone even though there may be a slight horizontal shift between observed and simulated distributions. This is substantiated by the results presented above. Inclusion of this breaking scheme into the model, despite its shortcomings, is an obvious improvement over methods which specify the surf zone wave height to be proportional to the local water depth everywhere, especially for complex bathymetry involving stepped or barred beaches. The accuracy of this model for use in predicting surf zone characteristics under wide-banded spectral wave conditions is questionable. The model assumes wave breaking begins at a well defined point. This assumption is most valid under extremely narrow-banded spectral conditions but is violated otherwise.

# PART IV: MODEL EXECUTION ON THE CONTROL DATA CORPORATION COMPUTING SYSTEM

## General Comments

62. The RCPWAVE model can be run in a remote batch mode on the Control Data Corporation (CDC) computing system. Batch jobs comprised of job control language (JCL) allow users to instruct the computer to perform a series of tasks including file manipulation, compilation, and execution. RCPWAVE can be run on two CDC computers, the CYBER 865 and CYBER 205. Costs are less expensive on the CYBER 865 machine (cost comparisons will be given in Part V); however, available memory within this computer limits its use to applications involving fewer than 9,025 grid cells. The CYBER 205 has more available memory, but it is more expensive to use. It is recommended that users restrict their use of the CYBER 205 to model applications where the total number of grid cells exceeds 9,025.

63. JCL used to run the wave model on the CYBER 865 differs from that used to run it on the CYBER 205. The next two sections explain CYBER 865 JCL and CYBER 205 JCL, respectively. Then the following procedures are explained: submitting batch jobs on both machines, checking job status, and accessing job output. The last two sections give a general description of necessary input files and all output files which are generated in the course of job execution. Part V of the text covers examples of actual applications of RCPWAVE run on both CDC machines, and it includes specific examples of the aforementioned files.

64. It is essential for the user to be familiar with XEDIT* or another text editor available on the CDC system. This knowledge is required in order to make any changes to the JCL files or to examine an output file in a text editor mode. The text editor also is required to create input data files. A limited knowledge of the "UPDATE"* method for making changes to the model source code also is recommended. Discussion concerning modifications to the source code and examples documenting this procedure are given in subsequent sections.

---

* Cybernet services manuals are available from CDC titled "XEDIT, Extended Text Editor," Manual No. 76071000C, and "UPDATE, Version 1 Reference Manual," Manual No. 60449900B.

## CYBER 865 Job Control Language

65. An example of JCL used to run RCPWAVE on the CYBER 865 is given in Figure 5. The file containing this JCL can be obtained by logging into the CDC computing system and typing

```
GET,RCP865J/UN=CER0Q2     .
```

This action will create a local file called RCP865J on the user's work space. In order to save the file permanently, type

```
SAVE,RCP865J     .
```

Each line or "card image" of RCP865J contains a specific instruction to the computer. Note the brief description of important input and output files under the "COMMENT" section. These files will be discussed in greater detail later in Part IV, and specific examples will be given in Part V. At this point, it is only important to know what each file contains. A line-by-line description of the JCL in RCP865J is given in Appendix D.

## Submitting the CYBER 865 Batch Job

66. A series of commands (JCL) has been assembled into a batch job that instructs the computer to gather input, compile and execute the wave model, and save output. The computer is actually given this batch of commands by using the following form of the SUBMIT command:

```
SUBMIT,<JCL FILENAME>,T     .
```

The <JCL filename> of the file shown in Figure 5 is RCP865J; therefore the following command is given:

```
SUBMIT,RCP865J,T     .
```

The parameter T tells the computer to return certain output to the user's terminal once the job is completed. When a batch job is submitted, the computer responds by giving the job an identifier similar to the one shown below:

```
15.21.05. SUBMIT COMPLETE.  JOBNAME IS AKQBRMA     .
```

```
/JOB
JOB,F3,T1000,CM377000.                         RESOURCE LIMITS SPECIFIED
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CER002.                      WAVE MODEL IS OBTAINED
GET,UPDFL=RCPUPDT.                             MODIFICATIONS OBTAINED
GET,TAPE7=RCPDATA.                             DATA OBTAINED
GET,TAPE8=RCPDEPT.        (SEE **NOTE** BELOW) BATHYMETRY OBTAINED
UPDATE(I=SR,N=NEWLIB,F,L=0)
UPDATE(P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F)       MODIFICATIONS ARE INCLUDED
FTN5,I=NEWPLUS,B=BIN,L=OUTPUT.                 WAVE MODEL IS COMPILED
LOAD,BIN.
EXECUTE.                                       WAVE MODEL IS EXECUTED
REWIND,TAPE6,OUTPUT.
REPLACE,TAPE6=RCPPRNT.                         PRINTED RESULTS ARE STORED
REPLACE,OUTPUT=RCPOTPT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.                               DAYFILE IS STORED
EXIT.
REWIND,TAPE6,OUTPUT.
REPLACE,OUTPUT=RCPOTPT.
REPLACE,TAPE6=RCPPRNT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
```

```
COMMENT.***************************************************************
COMMENT.*
COMMENT.*           COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*           THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.***************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   RCPUPDT:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   RCPDATA:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   RCPDEPT:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  OUTPUT FILE CONTAINING A LISTING OF THE PROGRAM
COMMENT.             COMPILATION AND ABORTED JOB INFORMATION.
COMMENT.
COMMENT.***************************************************************
/EOI
```

Figure 5. File RCP865J, JCL to execute RCPWAVE on the CYBER 865 computer

The job identifier (or job name) is denoted by a sequence of seven letters or numbers, here AKQBRMA. The first four characters are uniquely associated with a particular user number. The last three characters identify the job which was submitted.

67. In order to check the progress of a batch job submitted to the CYBER 865, the user can issue the following command:

```
ENQUIRE,JN=RMA     .
```

The computer will respond in one of the following ways:

a. AKQBRMA IN INPUT QUEUE--This means that the batch job AKQBRMA is in the input queue; i.e., the job has not begun execution.

b. AKQBRMA EXECUTING--This means that the batch job AKQBBQF is executing; i.e., the computer is processing the JCL commands.

c. AKQBRMA IN PRINT - TERMINAL QUEUE--This means that the job AKQBRMA is in the PRINT-TERMINAL queue; i.e., the batch job has been completed, and the output is available to the user.

68. By using the T parameter on the SUBMIT command, certain information concerning the batch job is returned to the terminal upon its completion. This information includes, in the following order, a copy of the diary of events, actual user cost information, CDC scheduling information, a compiled listing of RCPWAVE, and abnormal execution information. The following QGET command is used to look at this information:

```
QGET,XYZ     .
```

The user must specify only the last three letters of the computer-generated job name (xyz). For example, if the batch job AKQBRMA is in the PRINT-TERMINAL QUEUE, the following command would be entered:

```
QGET,RMA     .
```

The computer would respond with

```
AKQBRMA ATTACHED     .
```

Then, the text editor could be used to look at this output by typing

```
XEDIT,AKQBRMA     .
```

69. The same information accessed with the QGET command resides on the permanent files RCPDAYF and RCPOTPT. These permanent files can be viewed in

three different ways. They can be accessed with a GET command and then examined via the text editor with the following information:

```
GET,RCPDAYF

XEDIT,RCPDAYF
```

and

```
GET,RCPOTPT

XEDIT,RCPOTPT     .
```

Alternatively, the files can be listed at the user's terminal by typing the following commands:

```
OLD,RCPDAYF

LIST
```

and

```
OLD,RCPOTPT

LIST     .
```

The files can be listed also at a remote printer site by entering

```
ROUTE,RCPDAYF,DC=PR,UN=SC
```

and

```
ROUTE,RCPOTPT,DC=PR,UN=SC
```

where SC is the site code of the device which is to receive the printed file. The printed output file RCPPRNT and the input files RCPDATA, RCPUPDT, and RCPDEPT also can be listed in any of these three ways.

## CYBER 205 Job Control Language

70. Running RCPWAVE on the CYBER 205 is both more complicated and expensive than on the CYBER 865. Before work can be done on the CYBER 205 a separate CYBER 205 user number and password must be obtained. Additionally, a direct access file must be created on the user's account which contains validation information (USER and CHARGE cards for his/her CYBER 205, and CYBER 865 accounts). This file will be called AF205.

71. An example of JCL which creates this file is shown in Figure 6. The file containing this JCL can be copied onto the user's local file space and then saved permanently by typing in the following commands:

```
GET,AFJCL/UN=CER0Q2

SAVE,AFJCL     .
```

```
SENDJOB.
USER(U=<205 USER NAME>,PA=<205 PASSWORD>)ADY
RESOURCE(JCAT=P3,TL=200)
CHARGE(<CHARGE NO.>,<PROJECT NAME>)
TV,10+.
PURGE(AF205)
TV,4+.
COPY,INPUT,AF205.
DEFINE,AF205.
USER(<865 USER>,<865 PASSWORD>,KOE)
CHARGE(<CHARGE NO.>,<PROJECT NAME>)
```

Figure 6. File AFJCL, JCL to create validation information for CYBER 205 usage

By submitting this JCL file for execution, the file AF205 will be created. Certain information must be entered into this file before it is submitted: the user's CYBER 205 user number and password (<205 USERNAME> and <205 PASSWORD>, respectively), the user's charge information (<CHARGE NUMBER> and <PROJECT NAME>) with which he/she logged in, and the user's CYBER 865 user number and password (<865 USERNAME> and <865 PASSWORD>, respectively). Once these changes have been made, the JCL file can be submitted with the following command:

```
SUBMIT,AFJCL,T     .
```

Successful completion of this batch job creates the file AF205 which is required in some of the CYBER 205 commands.

72. An example of JCL used to run RCPWAVE on the CYBER 205 is given in Figure 7. The file containing this JCL can be permanently saved on the user's file space by typing the following commands:

```
GET,RCP205J/UN=CER0Q2

SAVE,RCP205J     .
```

```
/JOB
JOB,P3,T1000,CM377000.                          RESOURCE LIMIT CARD
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CER002.                       WAVE MODEL IS OBTAINED
GET,UPDFL=RCPUPDT.                              MODIFICATIONS OBTAINED
UPDATE,I=SR,N=NEWLIB,F,L=0.
UPDATE,P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F.        MODIFICATIONS ARE INCLUDED
REPLACE,NEWPLUS.                                MODEL WITH MODIFICATIONS
*                                               MADE PERMANEANT FOR USE
*                                               ON THE CYBER 205
COPYBR,INPUT,SENDJOB,1.
SUBMIT,SENDJOB,T.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
/EOR
JOB205.
USER(U=(205 USERNAME),PA=(205 PASSWORD))ADY
RESOURCE(JCAT=P3,TL=2000)                       RESOURCE LIMITS CARD
/CHARGE
LINK,GET,NEWPLUS/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
LINK,GET,TAPE7=RCPDATA/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
LINK,GET,TAPE8=RCPDEPT/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
FORTRAN,I=NEWPLUS.
LOAD,CN=GO/6000,L=M205,GRLPALL= .
GO.
LINK,REPLACE,TAPE6=RCPPRNT/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205.
SUMMARY.
EXIT.
LINK,REPLACE(TAPE6=RCPPRNT/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205)
SUMMARY.
EXIT.
/EOF
```

```
COMMENT.*******************************************************************
COMMENT.*
COMMENT.*            COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*            THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.*******************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   RCPUPDT:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   RCPDATA:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   RCPDEPT:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  DOES NOT EXIST ON THE CYBER205.
COMMENT.
COMMENT.*******************************************************************
/EOI
```

Figure 7. File RCP205J, JCL to execute RCPWAVE on the CYBER 205 computer

This JCL for running RCPWAVE on the CYBER 205 must first pass through the CYBER 865 front-end computer. The first section of lines in the JCL deals with preparation of the program RCPWAVE on the front end and the subsequent relay to the CYBER 205. All JCL is described in detail in Appendix E.

## Submitting the CYBER 205 Batch Job

73. The procedure for submitting a batch job for processing on the CYBER 205 is identical to that used for the CYBER 865. The following command sends the JCL shown in Figure 7 to the front-end CYBER 865 and ultimately to the CYBER 205:

```
SUBMIT,RCP205J,T     .
```

Computer response to the SUBMIT command informs the user of the computer generated job name (AKQBRUD in this case).

74. Status of the job sent to the front-end CYBER 865 is checked in the same manner as was presented before, using the ENQUIRE command:

```
ENQUIRE,JN=RUD     .
```

When the job AKQBRUD is in the PRINT-TERMINAL QUEUE, as shown below,

```
AKQBRUD IN PRINT - TERMINAL QUEUE
```

then a job should have been routed to the CYBER 205. Whether or not this occurred can be determined by checking the diary of events by typing

```
OLD,RCPDAYF

LIST
```

or by typing

```
QGET,RUD

XEDIT,AKQBRUD
```

and then using the editor to locate the diary of events in this file. The dayfile should contain the following lines, including the seven-letter jobname given to the file SENDJOB by the computer:

```
13.40.08.SUBMIT,SENDJOB,T.

13.40.08. SUBMIT COMPLETE.  JOBNAME IS AKQBRUZ.
```

If this line is not found, errors have occurred in the batch job processing; and the job has not been relayed to the CYBER 205 machine.

75. Assuming the job has been successfully sent from the front end to the CYBER 205, the status of the CYBER 205 job can be checked with the following command:

```
LINK,ENQUIRE,JN=JOB205     .
```

The computer will respond with

```
STATUS FOR CERØQ2/KOE

DATE  TIME    USER       SYSTEM    FILE    FILE
MMDD  HHMM  JOB NAME   JOB NAME   TYPE   STATUS

0326  1547    JOB205     AKQBRUZ    TO    ROUTING INITIATED TO ADY
0326  1547    JOB205     JOB2RVB    TO    ARRIVED AT ADY
LINK COMPLETE.
```

When the job status reads

```
STATUS FOR CERØQ2/KOE

DATE  TIME    USER       SYSTEM    FILE   FILE
MMDD  HHMM  JOB NAME   JOB NAME   TYPE  STATUS

0326  1547  JOB205     AKQBRUZ    TO    ROUTING INITIATED TO ADY
0326  1547  JOB205     JOB2RVB    TO    ARRIVED AT ADY
0326  1555  JOB205     AKQBRUZ    WT    OUTPUT AVAILABLE AT KOE/T
```

then the batch job has been completed, and output is available to the user.

76. In order to get a compiled version of RCPWAVE and a dayfile containing execution information and a summary of actual cost information from the CYBER 205, the following QGET command must be used:

```
QGET,RUZ

XEDIT,AKQBRUZ     .
```

The text editor can then be used to locate and print the desired information. Notice that the output file RCPOTPT is absent from the CYBER 205 JCL. Currently it is not possible to have this information saved as a permanent file within the JCL as was done on the CYBER 865.

77. All other permanent files used or created by the JCL can be accessed and viewed in any of the three ways given previously. For example, file RCPPRNT could be viewed by typing

```
GET,RCPPRNT
XEDIT,RCPPRNT
```

or

```
OLD,RCPPRNT
LIST
```

or

```
GET,RCPPRNT
ROUTE,RCPPRNT,DC=PR,UN=SC
```

where SC is the site code of the device which is to receive the printed file.

## Input Files

78. The model source code RCPWAVE is the first file retrieved in the course of JCL processing. Both JCL files RCP865J and RCP205J obtain the source code from the permanent file space assigned to the user number CER0Q2. Users are discouraged from copying the source code onto their file space, making their own permanent modifications, and running their own model version. CERC personnel will support only the source code residing on this user number.

79. A compiler-generated listing of the entire source code, which includes a main program and nine subroutines, is provided in Appendix F. Users are encouraged to read comments within the program listing which explain important variables and input parameters as well as those comments which describe what is being performed in each subroutine. Another important feature contained in the listing is the line identifier to the far right of each FORTRAN statement. The following example of the sixth statement,

```
PROGRAM RCPWAVE (INPUT,OUTPUT,TAPE7,TAPE6,TAPE8,TAPE3)         MAIN       2
```

has as its identifier "MAIN 2" . "MAIN" denotes the main program, and "2" denotes the second line. The identifier associated with each subroutine is the subroutine name itself, and, again, the numbers correspond to line numbers within each subroutine. These identifiers are required when making changes to the model source code using the "Update" method and ensure correct placement of changes.

80. Three additional input files are accessed by RCP865J and RCP205J. They must reside on the user's permanent file space. These files contain information describing grid characteristics and wave conditions to be simulated, data controlling the amount of printed output, bottom bathymetry for each grid cell, and any changes to the model source code. The general format of each of these files is independent of the CDC machine being used to execute the wave model. However, one additional source code modification must be made when running on the CYBER 205. It will be discussed later in this section. In the following text, all three input files will be addressed using the names given to them in Figures 5 and 7--RCPDATA, RCPDEPT, and RCPUPDT.

81. RCPDATA contains grid information, specifically the size and number of cells in the grid. It contains deepwater wave characteristics (height, period, and direction) describing wave conditions to be simulated, and it contains data which control the volume of printed output. These, along with all other input parameters, are described below. Following each parameter, in parentheses, is its corresponding value taken from the sample input data file shown in Figure 8.

```
FIELD RESEARCH FACILITY (DUCK , NC) EXAMPLE
   75      12.0   50      24.0     9.800      0.0    2      0.90
      2.00     12.00     20.00
      1.50      8.00    -35.00
   1   50   1   11   41
   1
```

Figure 8. Sample input data file for a wave model application

82. A detailed description of the input parameters follows:

a. <u>CARD 1 - FORMAT (7A10).</u>

LTITLE - A 70-character array describing the model application being considered.

(FIELD RESEARCH FACILITY (DUCK, NC) EXAMPLE)

b. <u>CARD 2 - FORMAT (I5, F10.4, I5, F10.4, 2F10.2, I5, F10.2).</u>

M - Number of grid cells in the x-direction (75)

DX - Cell size in the x-direction (12.0)

N - Number of cells in the y-direction (50)

DY - Cell size in the y-direction (24.0)

G - Gravitational acceleration constant (9.800)

Note: The parameter G controls the units of <u>all input</u> and <u>output</u> variables. The choice shown above (9.800) requires that all input be in the kilograms, metres, and seconds unit system. All output will also be in these units. Other options for G are 32.2 (pounds, feet, and seconds) and 980.0 (grams, centimetres, and seconds).

CNTRANG - Angle between bathymetric contours and the y axis (0.0)

Note: If the bottom contours deviate from a line parallel to the y axis by a well defined angle, inclusion of this variable may result in faster iterative convergence toward a solution. The angle convention adopted for CNTRANG is shown in Figure 2. All angles are measured in degrees. If a well defined angle does not exist, or if there is doubt, set this parameter to zero.

NCASES - Number of individual wave conditions to be simulated (2)

DLEVEL - Constant added to the entire water depth matrix which adjusts the water level datum (0.90)

### c. CARDS 3a, 3b, ... - FORMAT (3F10.3).

There must be one card for each wave condition considered.

HDEEP - Deepwater wave height (2.00 for case 1, 1.50 for case 2)

TDEEP - Wave period (12.00 for case 1, 8.00 for case 2)

ZDEEP - Deepwater wave angle (20.00 for case 1, -35.00 for case 2)

Note: See Figure 2 for the wave angle convention. All wave angles in both input and output files are given in degrees.

### d. CARD 4 - FORMAT (5I5).

IP1 - Wave model output starts at this "I" row number (1)

IP2 - Wave model output ends at this "I" row number (50)

INC - Row by row output is incremented by this number of lines (1)

JP1 - Wave model output starts at this "J" column number (11)

JP2 - Wave model output ends at this "J" column number (41)

Note: Column by column output is always incremented by one.

### e. CARD 5 - FORMAT (2I5).

IREF - Flag for instructing the model to consider refraction only or combined refraction and diffraction (1)

= 0 refraction only

= 1 combined refraction and diffraction

Note: Users should set this parameter to one.

IGRID - Flag for indicating what type of grid system is being used (omitted)

Note: This must be set to zero or omitted.

83. The model can be run using either constant, or variably sized, rectangular grid cells. This model documentation discusses only applications involving grids with constant sized cells. As stated earlier, technology for creating variable sized grids which are compatible with RCPWAVE does exist at CERC.

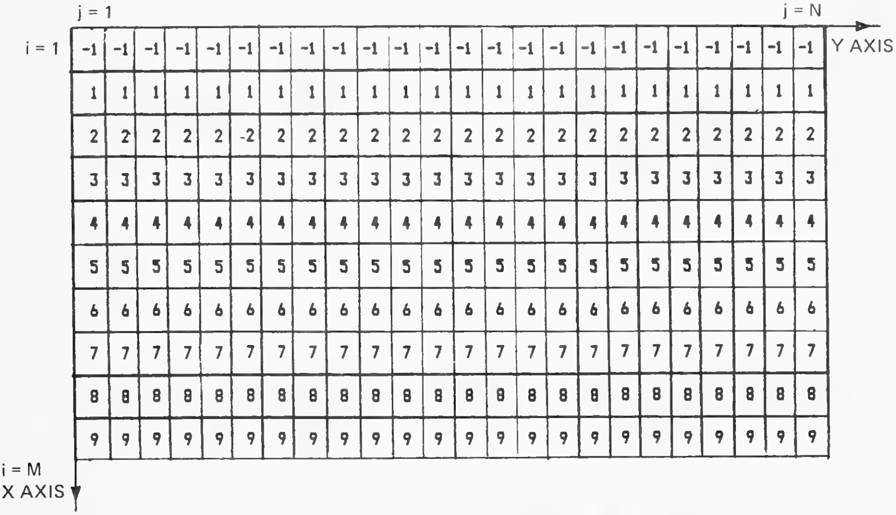
84. Bottom bathymetry for each grid cell must be supplied to the model. The source code is written such that bathymetric data are read from the file RCPDEPT in the following format. Depths along the entire row I=1 (from J=1 to J=N) are read using a 10F8.2 format. Depths along row I=2 are read next, and the procedure is repeated until depths along the offshore row I=M have been read. An example of a bathymetric grid with 10 cells in the x-direction (I coordinate) and 24 cells in the y-direction (J coordinate) is shown in Figure 9. A depth file containing this data set, and written in 10F8.2 format, is also shown. It is a trivial matter to change this section of the source code which reads the bathymetry (in subroutine DEPTH) to some other, more convenient format. Such a modification will be illustrated later in this section.

85. The wave model considers only positive, nonzero water depths in its computations. All grid cells which occupy dry land can be designated by negative depths or zeros in the input file, but the model will internally assign a small water depth of 1.0 ft (or a metric equivalent) to each of these cells. Depths in water cells that are less than 1.0 ft will be increased to this minimum value. Bathymetric input data are modified within the program in one other way. Along each row, depths in columns J=1 and J=N are replaced by the depths in columns J=2 and J=N-1, respectively. These changes are consistent with the lateral boundary conditions used in the model.

86. The third input file obtained by the JCL is the file RCPUPDT which contains necessary or desired corrections to the source code via the "Update" method. Figure 10 shows an example of an "Update" file. It is used to illustrate certain points pertaining to this correction method. The first statement in the file

```
*ID MODS
```

identifies all subsequent changes to be made with the identifier "MODS." This



| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

```
-1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
-1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
-1.00   -1.00   -1.00   -1.00
 1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
 1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
 1.00    1.00    1.00    1.00
 2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00
 2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00
 2.00    2.00    2.00    2.00
 3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00
 3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00
 3.00    3.00    3.00    3.00
 4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00
 4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00    4.00
 4.00    4.00    4.00    4.00
 5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00
 5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00
 5.00    5.00    5.00    5.00
 6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00
 6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00    6.00
 6.00    6.00    6.00    6.00
 7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00
 7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00    7.00
 7.00    7.00    7.00    7.00
 8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00
 8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00    8.00
 8.00    8.00    8.00    8.00
 9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00
 9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00    9.00
 9.00    9.00    9.00    9.00
```

Figure 9. Sample bathymetry grid and input file for a wave model application

line must be the first in any update file like RCPUPDT. The next two lines,

```
      *D PARAM.3
```

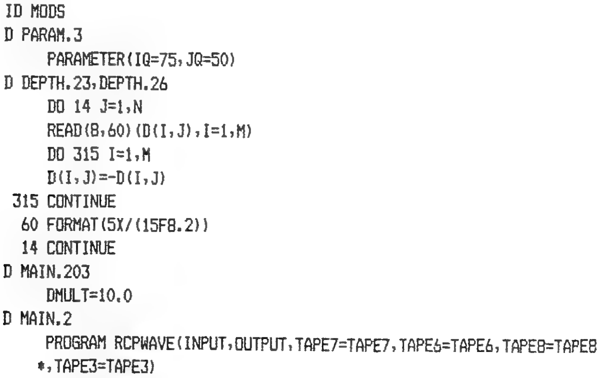
and

```
      PARAMETER (IQ=75,JQ=50)
```

delete the line identified by "PARAM.3" everywhere in the program and replace it with the new PARAMETER statement. This action changes the limits on all arrays within the program to match the number of cells in the grid mesh. The quantity IQ must be set greater than or equal to the number of rows, M , and JQ must be greater than or equal to the number of columns, N . These first three "Update" lines are the only ones required for model applications run on the CYBER 865 machine. For jobs sent to the CYBER 205, two additional lines must be included,

```
      *D MAIN.2
            PROGRAM RCPWAVE (INPUT,OUTPUT,TAPE7=TAPE7,TAPE6=TAPE6,TAPE8=TAPE8
           *,TAPE3=TAPE3)
```

These are required because the PROGRAM statement format is different for each machine's compiler. They are shown also in Figure 10.



```
ID MODS
D PARAM.3
      PARAMETER(IQ=75,JQ=50)
D DEPTH.23,DEPTH.26
      DO 14 J=1,N
      READ(8,60)(D(I,J),I=1,M)
      DO 315 I=1,M
      D(I,J)=-D(I,J)
  315 CONTINUE
   60 FORMAT(5X/(15F8.2))
   14 CONTINUE
D MAIN.203
      DMULT=10.0
D MAIN.2
      PROGRAM RCPWAVE(INPUT,OUTPUT,TAPE7=TAPE7,TAPE6=TAPE6,TAPE8=TAPE8
     *,TAPE3=TAPE3)
```

Figure 10. Sample "Update" file for a wave model application

87. The "Update" modification,

```
      *D DEPTH.23,DEPTH.26
            DO 14 J=1,N
            READ(8,60) (D(I,J),I=M)
            DO 315 I=1,M
```

```
          D(I,J)=-D(I,J)
      315 CONTINUE
       60 FORMAT(5X/(15F8.2))
       14 CONTINUE
```

and the seven subsequent lines of FORTRAN code delete the statements identified by "DEPTH.23" through "DEPTH.26" in subroutine DEPTH and replace them with the seven new lines. These modifications alter the format used to read bottom bathymetry data; and, since the water depths on the file happen to be negative numbers, a sign change is programmed into the procedure. The "Update" correction

```
*D MAIN.203
      DMULT=10.0
```

replaces the line in the main program identified by "MAIN.203" with the subsequent new line of code. This correction changes the accuracy of the depth matrix in the printed output from whole metres (or other units) to tenths of metres (or other units). As it is written, the model prints out water depths to the nearest whole foot (metre or centimetre), wave heights to the nearest tenth foot (metre or centimetre), and wave angles to the nearest degree. Changes in output accuracy must be made via "Update" corrections. Users are referred to the statements "MAIN.194" through "MAIN.206" in Appendix F for further explanation.

88. These "Update" corrections have illustrated the use of the DELETE (*D) command which deletes line(s) of text. Other frequently used "Update" commands are the INSERT (*I) commmand, which inserts text after a certain line, and the BEFORE (*B) command which inserts text before a line. Users interested in making source code changes should first consult the "Update" manual referenced earlier.

## Output Files

89. Two permanent output files are generated during the course of model execution on the CYBER 205. These same two files plus one additional file are generated during the course of execution on the front end (CYBER 865). Output file names given in Figure 7 will be used in this discussion. Information contained on the printed output file RCPPRNT is independent of the choice of

machines, but the diary of events RCPDAYF is machine dependent. The file RCPOTPT is generated only by the front-end machine. At some point in the future, RCPOTPT will be generated also by the CYBER 205.

90. The RCPPRNT file summarizes all model input such as grid characteristics, wave conditions considered, and bathymetry for that window of the grid mesh defined by the parameters IP1, IP2, INC, JP1, and JP2. For each wave condition simulated, a listing of the following wave characteristics is printed for the two-dimensional field defined by the above parameters: (a) breaker indices defining the location of the surf zone (zeros denote cells where no breaking is occurring), (b) wave angles, (c) wave heights, and (d) the magnitude of the wave phase function gradient (in the absence of appreciable diffractive effects this is approximately the wave number, e.g., it is a function of the wave length). Specific examples of this file will not be presented here but rather in Part V, the sample application section.

91. For jobs run on the CYBER 865, a short file (RCPDAYF) is created which summarizes the steps performed during the course of JCL processing. Any errors encountered during compilation and/or execution are indicated on this file. Estimated costs are given also, but these are not the costs which are actually billed to the user's account. Even though this "dayfile" indicates any errors which have caused abnormal job termination, it provides little detail for locating the problem. These details are provided on the file RCPOTPT.

92. This rather large file contains a compiled listing of the model, any compilation errors which may have occurred, and a short variable map. Because of its length, an example is not printed. Any of these output files can be viewed using one of the three methods mentioned previously. It should be noted that the job output returned to the users terminal with the T parameter on the SUBMIT command is very useful and can be viewed using the QGET command. This file contains: (a) the entire RCPDAYF file, (b) actual costs (including the Corps of Engineers discount), and (c) the entire RCPOTPT file.

93. For CYBER 205 model execution the "dayfile," RCPDAYF, contains only those steps actually processed on the front-end CYBER 865 machine. The QGET command must be used to obtain job output from the CYBER 205. This output includes: (a) a file equivalent to the front-end RCPOTPT file (compiled listing and any compilation errors), (b) the diary of events which occurred during CYBER 205 processing, and (c) computer usage and actual cost information.

# PART V: MODEL APPLICATIONS

## General Comments

94. General guidance concerning RCPWAVE applications is provided in this section. Two model applications are given to demonstrate the different scales of prototype problems for which the model can be applied successfully. The next two sections explain each example in greater detail. Listings of JCL files used to run each simulation are provided, as are listings of input files and printed output. Comparisons between model execution costs incurred on both CDC computers are given in the last section.

95. Whenever RCPWAVE is a candidate for solving a wave propagation problem, the area of interest is well defined, and wave conditions to be simulated are known. The user must create a finite difference grid system encompassing the area. Grid characteristics determine the success of the application, so they should be given considerable thought. Two factors completely define the grid, orientation of the axes, and cell resolution.

96. Users should construct the grid system so that the y-axis runs as parallel to the coastline as possible. This causes the x-axis to be directed offshore and probably somewhat perpendicular to the bottom contours. The lateral boundary conditions used in the model are most accurate when this axis configuration is adopted. The boundary conditions assume that the variation of the bathymetry, and wave parameters, in the y-direction is small. The assumption is most accurate when the y-direction is essentially the longshore direction. Ideally this axis configuration also results in the offshore bathymetry having fairly straight and parallel contours and the offshore rows of cells having the greatest depths. The procedure of applying Snell's law to propagate wave information from deep water to the seaward boundary of the model is more accurate if these conditions exist.

97. Waves will generally attempt to advance in directions parallel to the x-axis as a result of the recommended orientation. The model tends to produce erroneous results if computed waves attempt to propagate parallel to the y-axis (wave angles near plus or minus 90 deg). Even with this axis configuration, problems may arise due to very irregular bottom bathymetry and/or very oblique wave incidence. These errors manifest themselves via large local wave angles and occurrences of very large and very small wave heights in

alternating cells. An artificial limit on the absolute value of the wave angle, 86 deg, is written into the model. Problems of this nature can sometimes be eliminated by using finer grid resolution.

98. Cell size is the second factor defining the grid system. Accuracy of model solutions computed using finite difference approximations is dependent upon cell size; smaller cells result in less error. Diffractive effects can become important on spatial scales with orders of magnitude smaller than the wave lengths being considered. In modeled regions of interest where diffraction is important (very complicated bathymetry) cell sizes may need to be some fraction of the wavelength in order to simulate wave propagation accurately. Fine resolution is not a requirement for model applications where the bathymetry is very regular. The physical processes of importance, whether it be refraction or a combination of refraction and diffraction, dictate cell sizes which should be used.

99. The examples in the next two sections represent two different kinds of problems. Example I deals with wave propagation over a rather small region with complex bathymetry. Diffraction was presumed to be an important physical process; therefore, finer grid resolution was used in an attempt to represent this effect more accurately. Example II illustrates the applicability of RCPWAVE for propagating waves over a very large area dominated by very regular bathymetry. Assuming that refractive effects would dominate wave transformation throughout the region, cell sizes were increased to a value on the same order of magnitude as the wave length. These two examples show the diversification of problems which can be addressed using the model.

## Example I: FRF Pier, Duck, North Carolina

100. Bathymetry in the vicinity of CERC's research pier at Duck, North Carolina, is quite complex as seen in Figures 11 and B2. Figure 11 was plotted using similar bathymetric data digitized onto the rectangular grid system comprised of 75 cells in the offshore (x) direction and 50 cells in the longshore (y) direction. Again, cell sizes are 12 and 24 m in the x- and y-directions, respectively. All depths on the bathymetric file are given in metres below MSL. A constant tidal elevation of 0.90 m is added to the bathymetric data. Two wave conditions are considered: (a) 2-m-deep water wave height, 12-sec wave period, and +20 deg deepwater incident angle (refer

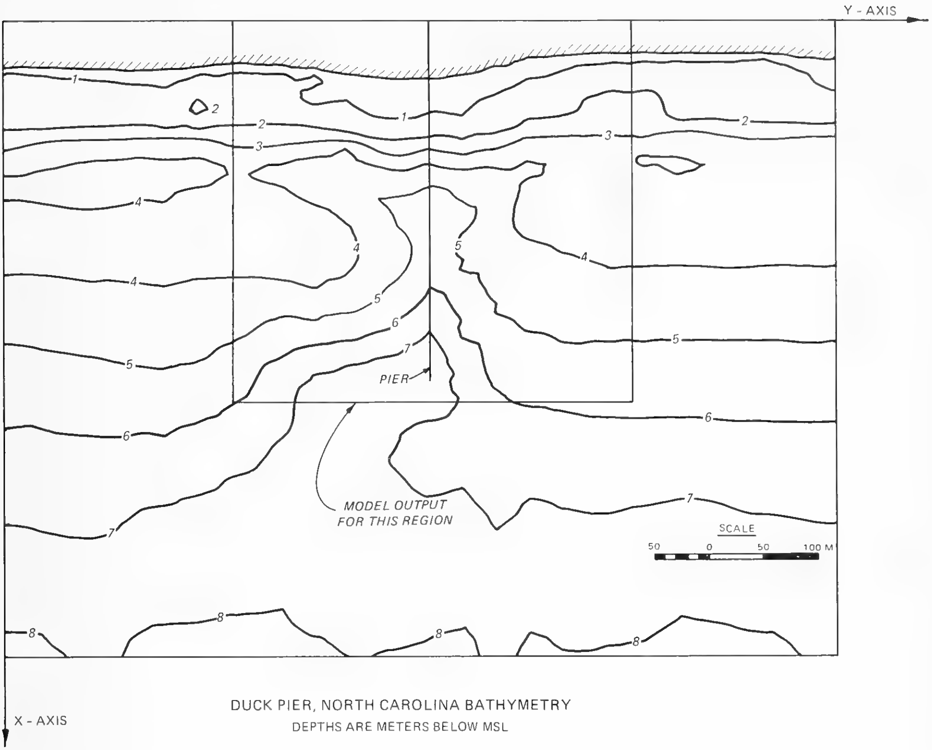


Figure 11. Bathymetry used in the FRF pier, Duck, North Carolina sample application

to the angle convention in Figure 2) and (b) 1.5-m deepwater wave height, 8-sec period, and -35 deg deepwater incident angle.

101. All files associated with this example are listed in Appendix G. Files are arranged in the following sequence:

- a. JCL file to run this application on the CYBER 865, DUCK865 (Figure G1)
- b. JCL file to run this application on the CYBER 205, DUCK205 (Figure G2)
- c. Input data file , DUCKDAT (Figure G3)
- d. Source code correction file for the CYBER 865 run, DUCKUPD (Figure G4)
- e. Source code correction file for the CYBER 205 run, DUCKUP2 (Figure G5)

f. A sample of the bathymetric data file (Figure G6) , DUCKDEP

g. Printed output file (Figure G7) , RCPPRNT

Two-dimensional fields of total water depth, breaker index, wave angle, wave height, and wave number (more precisely, the wave phase gradient) are printed for a portion of the grid extending from rows I=1 to I=50 and from columns J=11 to J=41. Figure 11 shows the extent of this region relative to the entire grid system.

## Example II: Homer Spit, Alaska

102. Bathymetry for this application (see Figure 12) is digitized onto a grid with 96 rows in the offshore (x) direction and 83 cells in the longshore (y) direction. Cell dimensions are approximately 417 ft in the x-direction and 833 ft in the y-direction (about 10 times the resolution used in the Duck, North Carolina, examples. One wave condition is considered in

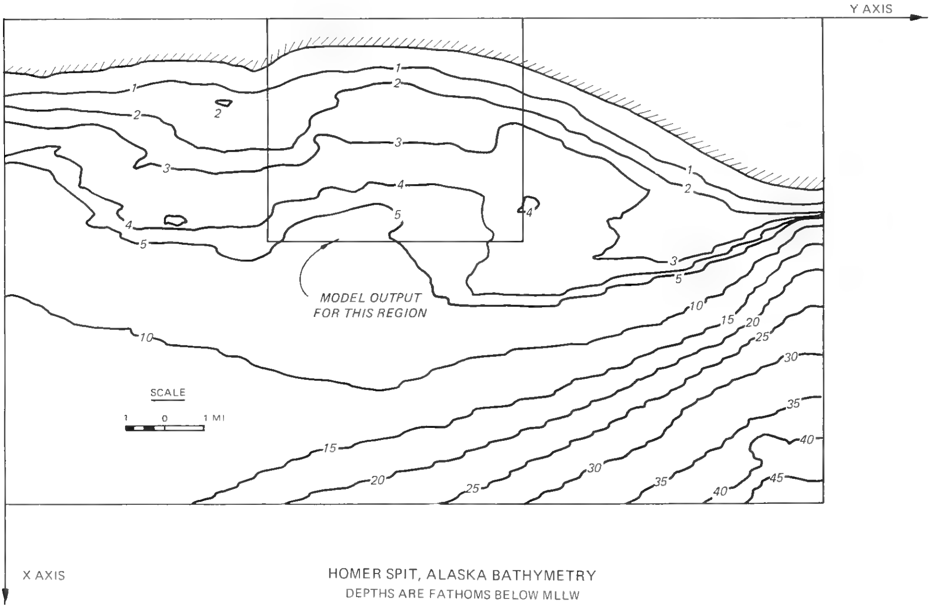


Figure 12. Bathymetry used in the Homer Spit, Alaska, sample application

the simulation. The deepwater wave height is 8 ft, the period is 10 sec, and the deepwater wave angle is -45 deg (see Figure 2 for the wave angle convention). Bathymetry is given in fathoms below mean low water so depths are converted to feet via a correction to the source code. No water level datum adjustment is applied.

103. All files associated with this example are listed in Appendix H. Files are arranged in the following sequence:

a. JCL file to run this application on the CYBER 865, HOMR865 (Figure H1)
b. JCL file to run this application on the CYBER 205, HOMR205 (Figure H2)
c. Input data file, HOMRDAT (Figure H3)
d. Source code correction file for the CYBER 865 run, HOMRUPD (Figure H4)
e. Source code correction file for the CYBER 205 run, HOMRUP2 (Figure H5)
f. A sample of the bathymetric data file, HOMRDEP (Figure H6)
g. Printed output file, RCPPRNT (Figure H7)

Two-dimensional fields of water depth and wave parameters are given also in Appendix H for the subgrid region denoted in Figure 12.

## Cost Comparisons

104. The following tabulation shows cost comparisons between simulations run on both CDC machines. Costs in dollars are shown for Examples I and II which represent the FRF pier and Homer Spit, respectively.

| | Priority | CYBER 865 Cost in Dollars | CYBER 205 Cost in Dollars |
|---|---|---|---|
| Example I | P4 | 2.24 | 6.09 |
| | P3 | 0.86 | 4.74 |
| | P2 | 0.17 | 1.68 |
| Example II | P4 | 2.51 | 6.40 |
| | P3 | 0.96 | 4.98 |
| | P2 | 0.19 | 3.25 |

These are actual costs to the user and include the Corps' fiscal year 1985 (FY 85) discount of 45 percent. Example I was run on a 75 by 50 grid. Two wave conditions were simulated. One wave condition was considered in Example II, but the grid was larger, 96 by 83.

105. The CYBER 865 is a cheaper, easier computer to work on. It does have central memory limitations. Comparisons show that costs incurred during simulations using the CYBER 205 are not excessive. Users should not sacrifice modeling accuracy simply to avoid using the CYBER 205.

# PART VI: GRID INTERPOLATION PROGRAM (INTPRCP)

## General Comments

106. Bathymetry at every cell of the finite difference grid mesh is required as input into RCPWAVE. Since digitization of bathymetric data from survey or nautical charts is both tedious and time consuming, it is desirable to limit the number of times one must perform this task. The grid interpolation program INTPRCP provides a method for determining bathymetry on a "new" grid using depth data from an "old" grid. The origin of the new grid can be rotated and/or translated relative to the old grid origin. This capability for interpolation ensures that the bulk of the digitization is done only once. The program is useful when:

- a. A coarse grid containing bathymetry is available but finer resolution is desired or required.
- b. The axis orientation of the available grid is different from the desired orientation.
- c. The region to be modeled is a subset of the available grid.

A compiled listing of the program is given in Appendix I.

107. The program uses a fairly simple interpolational scheme. For each new grid cell, a search is done for the nearest old depth value in each of the four 90 deg quadrants relative to the new cell center. A weighted average of these four values is used to compute a new depth. The weighting functions are based on relative distances from the new grid center to the cell centers defining the positions of the four old depth values.

108. JCL is available to run the program on the CDC CYBER 205 machine only. The next section briefly describes the procedures performed in the course of job execution. It also explains how an interpolational job is submitted. The third section documents, in detail, all required input files and includes some examples. It also describes the output files created during program execution. A complete example illustrating the use of INTPRCP is presented in the last section.

## Executing INTPRCP on the CDC Computing System

109. The interpolation program is run on the CYBER 205 machine in a

remote batch mode just like the wave model. This machine was chosen instead of the CYBER 865 because it has more available central memory. As a result, users are not limited by the number of grid cells contained in either the old or new grids. A CYBER 205 user number and password must be obtained before attempting to run INTPRCP. The direct access file AF205, mentioned in Part IV, must exist on the user's file space. This file contains validation information for the user's CYBER 205 and CYBER 865 accounts. Refer to Part IV for details concerning these requirements.

110. The JCL file called INTRCPJ, used to run INTPRCP, is shown in Figure 13. A copy of this file can be obtained by logging into the CDC computing system and typing

```
GET,INTRCPJ/UN=CEROQ2     .
```

This action creates a local file called INTRCPJ on the user's work space. To save the file permanently, type the following command:

```
SAVE,INTRCPJ     .
```

The JCL file for executing the interpolation program on the CYBER 205 must first pass through the front-end machine. The first section of JCL commands deals with compilation of the program on the front end and the subsequent relay to the CYBER 205. Commands in the CYBER 205 JCL instruct the computer to gather old and new grid information, retrieve bathymetry data for the old grid, compile and execute the program, and save the new grid bathymetry. The "COMMENT" section of the JCL briefly describes required input data files and output files generated in the course of program execution. Before submitting this JCL file, the user must make a few changes. Users must replace the "<205 USERNAME>," "<205 PASSWORD>," and "<CYBER 865 USERNAME>" with the passwords and user numbers associated with their account.

111. The front-end machine is given the entire batch of commands contained in INTRCPJ by using the SUBMIT command in the following way:

```
SUBMIT,INTRCPJ,T     .
```

The T parameter instructs the computer to return certain output to the user's terminal. The procedure for checking job status and accessing output is identical to that presented in Part IV. No further discussion addressing these points is given.

```
/JOB
JOB,P3,T1000,CM377000.
/USER
/CHARGE
GET,SR=INTPRCP/UN=CER002.                   INTERPOLATION PROGRAM OBTAINED
GET,UPDFL=INTPUPD.                          MODIFICATIONS OBTAINED
UPDATE,I=SR,N=NEWLIB,F,L=0.
UPDATE,P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F.    MODIFICATIONS INCLUDED
REPLACE,NEWPLUS.                            PROGRAM WITH MODIFICATIONS
COMMENT.                                    MADE PERMANENT FOR USE
COMMENT.                                    ON THE CYBER 205
COPYBR,INPUT,SENDJOB,1.                     CARDS AFTER /EOR ARE COPIED
COMMENT.                                    TO FILE SENDJOB
SUBMIT,SENDJOB,T.                           205 BATCH JOB SUBMITTED
DAYFILE,L=INTPDAY.                          DIARY WRITTEN
REPLACE,INTPDAY.                            DIARY SAVED
EXIT.
DAYFILE,L=INTPDAY.
REPLACE,INTPDAY.
/EOR
JOB205.
USER,U=(205 USERNAME),PA=(205 PASSWORD).ADY
RESOURCE,JCAT=P3,TL=2000.                   RESOURCE LIMITS CARD
/CHARGE
LINK,GET,NEWPLUS/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
LINK,GET,TAPE7=INTPGRD/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
LINK,GET,TAPE1=INTDEPO/DD=C6,UN=(CYBER 865 USERNAME),FM=KOE,AF=AF205.
FORTRAN,I=NEWPLUS.                          PROGRAM COMPILED
LOAD,CN=GO/6000,L=M205,GRLPALL= .           PROGRAM LOADED
GO.                                         PROGRAM EXECUTED
LINK,REPLACE,TAPE6=INTPOUT/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205.
LINK,REPLACE,TAPE2=INTDEPN/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205.
SUMMARY.
EXIT.
LINK,REPLACE,TAPE6=INTPOUT/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205.
LINK,REPLACE,TAPE2=INTDEPN/UN=(CYBER 865 USERNAME),FM=KOE,DD=C6,AF=AF205.
SUMMARY.
/EOF
```

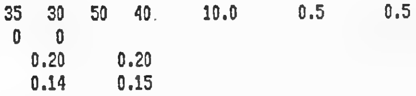
```
COMMENT.*******************************************************************
COMMENT.*
COMMENT.*            COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*            THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.*******************************************************************
COMMENT.
COMMENT.   INTPRCP:  SOURCE CODE FOR THE INTERPOLATION PROGRAM.
COMMENT.
COMMENT.   INTPUPD:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   INTPGRD:  DATA FILE SPECIFYING GRID GEOMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   INTDEPO:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE1)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY, THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   INTPOUT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             INTERPOLATION PROGRAM. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   INTDEPN:  OUTPUT FILE OF NEW BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE2)
COMMENT.
COMMENT.   INTPDAY:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.*******************************************************************
/EOI
```

Figure 13. File INTRCPJ, JCL to execute INTPRCP, the interpolation program, on the CYBER 205 machine

## Input and Output Files

112. The interpolation program reads input data from two files, INTDEPO and INTPGRD. Old grid bathymetry is contained in INTDEPO. The procedure for reading bathymetry into this program is the same as that used in RCPWAVE. The row of depths corresponding to I=1 are read first in "10F8.2" format. A row includes values from J=1 to J=N. The row-by-row procedure is repeated until the offshore row (I=M) has been read. An example of a depth file in this format was shown in Figure 9.

113. Input data contained in INTPGRD are geometric parameters which define the grid characteristics of the old and new grids. The format used by the program to read this information and a description of each parameter are given here. The value for each input parameter, taken from the sample input file shown in Figure 14, is also given in parentheses after the description.



```
35   30   50   40      10.0       0.5       0.5
 0    0
   0.20     0.20
   0.14     0.15
```

Figure 14. Sample input data file
for grid interpolation

a. CARD 1 - FORMAT (4I5, 3F10.5).

M - Number of grid cells in the x-direction for the old grid (35)

N - Number of grid cells in the y-direction for the old grid (30)

N2 - Number of grid cells in the x-direction for the new grid (50)

M2 - Number of grid cells in the y-direction for the new grid (40)

ANG - Angle of rotation measured from the old grid to the new grid (positive angles are measured counterclockwise, negative angles are measured clockwise) (10.0)

XSHIFT - Offset from the old grid to the new grid in the x-direction (positive offsets indicate that the new grid origin is below the old origin, negative offsets indicate that the new grid origin is above the old grid origin) (0.5)

YSHIFT - Offset from the old grid to the new grid in the y-direction (positive offsets indicate that the new grid origin is to the right of the old origin, negative offsets indicate that the new grid origin is to the left of the old grid origin) (0.5)

Note: The conventions for ANG, XSHIFT, and YSHIFT are shown in Figure 15.

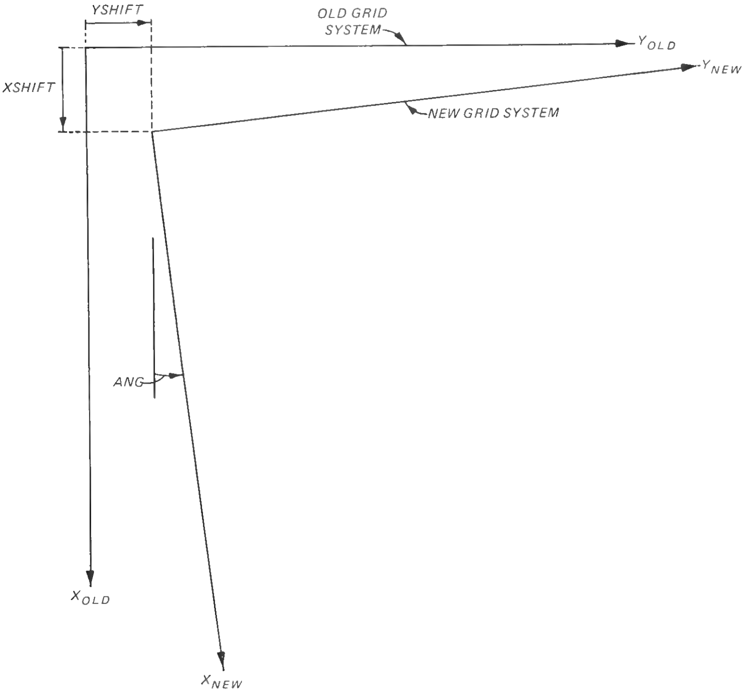


Figure 15. "Old" and "new" grid conventions used in the interpolation program

b. CARD 2 - FORMAT (2I5).

GRDTYP1 - Old grid type (must be set to zero) (0)

GRDTYP2 - New grid type (must be set to zero) (0)

c. CARD 3 - FORMAT (2F10.5).

DX - Old grid cell size in x-direction (0.2)

DY - Old grid cell size in the y-direction (0.2)

d. <u>CARD 4 - FORMAT (2F10.5).</u>

DX2 - New grid cell size in the x-direction (0.14)

DY2 - New grid cell size in the y-direction (0.15)

Note: The parameters DX, DY, DX2, and DY2 must all have consistent units.

114. In addition to bathymetry and grid information, one other input file is required. This is the file INTPUPD which contains any source code changes and must include information specifying the number of cells contained in both the old and new grids. An example of this file is shown in Figure 16. Variables in the PARAMETER statements are defined here; and their values, taken from the example, are shown in parentheses:

IQ - Number of cells in the x-direction for the old grid (35)

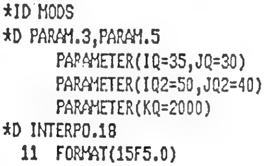
JQ - Number of cells in the y-direction for the old grid (30)

IQ2 - Number of cells in the x-direction for the new grid (50)

JQ2 - Number of cells in the y-direction for the new grid (40)

KQ - Larger of the two products IQ*JQ or IQ2*JQ2 (2000)

Modifications to change the procedure or format for reading the bathymetry into the program should be included in this file. Figure 16 shows an example of such changes. Here, a format different from the one in the program was desired. The section of source code which reads old grid bathymetry is contained in the lines designated by "INTERPO.15" through "INTERPO.18" in Appendix I.



```
*ID MODS
*D PARAM.3,PARAM.5
      PARAMETER(IQ=35,JQ=30)
      PARAMETER(IQ2=50,JQ2=40)
      PARAMETER(KQ=2000)
*D INTERPO.18
 11   FORMAT(15F5.0)
```

Figure 16. Sample "Update" file for grid interpolation

115. There are three output files created as a result of running the program. The file INTPDAY is a dayfile containing a diary of events which occurred on the front-end CYBER 865 machine. This is saved as a permanent file on the user's file space. A file called INTPOUT is created on the CYBER 205 and is saved permanently. It contains a compile listing, execution information, and printed output created during the run. The printed output

includes a listing of both old and new grids and the grid characteristics of each. The file INTDEPN contains the bathymetry for the new grid. This file is written using the same procedure and format as those used for reading the old depth data (row by row in 10F8.2 format).

## Grid Interpolation Example

116. The example problem involves interpolating bathymetry from an old grid with square cells to a new grid with smaller, rectangular-shaped cells. The new grid system is translated and rotated relative to the old grid. Original grid cell dimensions are 0.2 and 0.2 in the x- and y-directions, respectively. The new grid requires 50 cells in the x-direction, each 0.14 in length, and 40 cells in the y-direction, each 0.15 in length. The new grid is shifted by 0.5 in both coordinate directions and rotated 10 deg in the counterclockwise direction relative to the old grid. The input files used in this example, INTPGRD, INTDEPO, and INTPUPD are shown in Appendix J. The order in which the files are listed is:

| | | |
|---|---|---|
| a. | Input data file | ,INTPGRD (Figure J1) |
| b. | Source code correction file | ,INTPUPD (Figure J2) |
| c. | Sample of the input bathymetric file | ,INTDEPO (Figure J3) |
| d. | Sample of the output bathymetric file | ,INTDEPN (Figure J4) |

Figure 17 shows both grids and contour plots of the original and interpolated bathymetry.

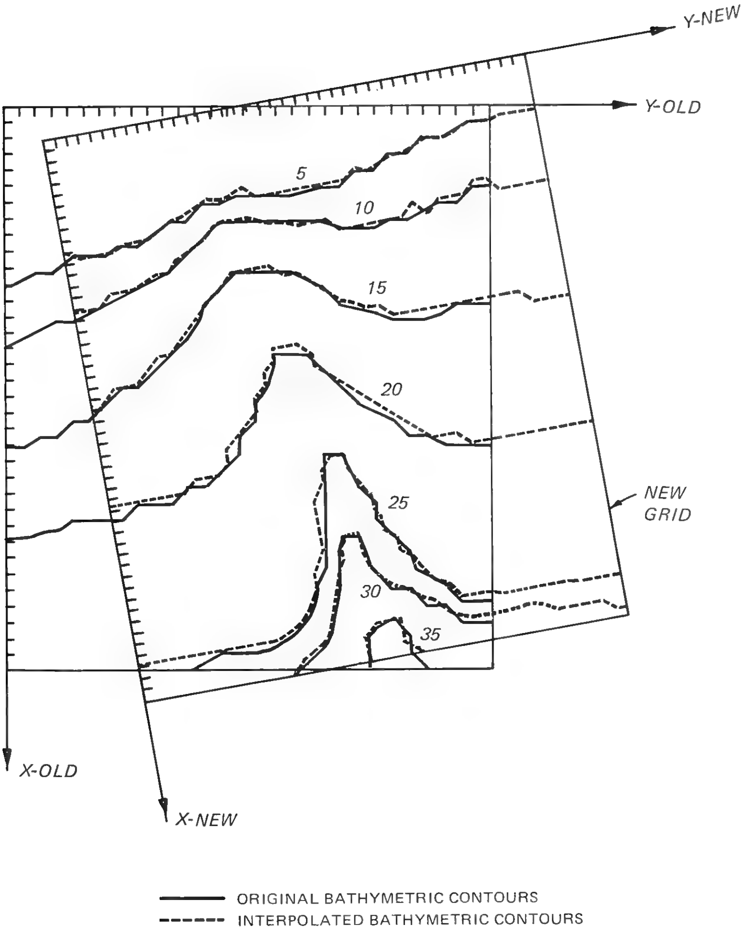


Figure 17. Comparison between original and interpolated bathymetry for the sample grid interpolation application

# PART VII: CONCLUSIONS AND RECOMMENDATIONS

117. The model presented in this report is capable of simulating wave propagation over arbitrary, and potentially complex, bathymetry. The governing equations are theoretically applicable to linear, monochromatic plane wave propagation only. Comparisons between model results and laboratory data showed good agreement, indicating that the model is quite accurate if the above conditions are satisfied. The results also showed the model's ability to simulate not only wave refraction but also bottom-induced diffraction. Comparisons between model results and field data indicated the model is capable of accurately simulating the transformation of single-peaked, narrow-banded, wave spectra. Results from one test suggest potential model use for solving problems involving propagation of wider-banded spectra, if a clearly defined wave direction exists. This hypothesis has not been substantiated in this report.

118. The wave breaking scheme incorporated into the model is a vast improvement over those wave propagation models which assume proportionality between wave height and water depth throughout the surf zone. Comparisons between model results and laboratory data showed the model to be reasonably accurate for a variety of bottom profiles, including plane, stepped, and barred beaches. Since the breaking scheme assumes that all waves break at the same location, the model is most valid for monochromatic waves and very narrow-banded wave spectra. No field data were used to verify the wave breaking aspects of the model.

119. The user's manual portion of the documentation and the sample applications presented show the model's ease of application. Users are reminded to pay close attention to comments made concerning relationships between model accuracy and grid resolution. The problems of interest and the perceived physical processes of importance should dictate cell sizes. Also, the user should remember assumptions inherent in the model's governing equations. Applications in which these assumptions are violated may yield erroneous results.

120. The model provides a tool which can be used by field personnel to solve many types of wave problems in a quantitative way and at a very low cost. If all assumptions inherent in the model development are essentially met, very accurate results can be obtained. Even if the model is applied to

problems in which some of the model assumptions are violated, it may still yield informative results, at least qualitatively if not quantitatively.

121. The JCL files used to execute the wave model and the interpolation program on the CDC computing system utilize commands and procedures which are currently operative (at the time the report is being written). CERC personnel are not responsible for any changes implemented by the CDC which may render these files inoperative. However, CERC personnel will attempt to maintain usable JCL files with the same names as those given in the text.

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# APPENDIX A: VERIFICATION OF MODEL RESULTS USING THE ELLIPTICAL SHOAL LABORATORY TEST DATA

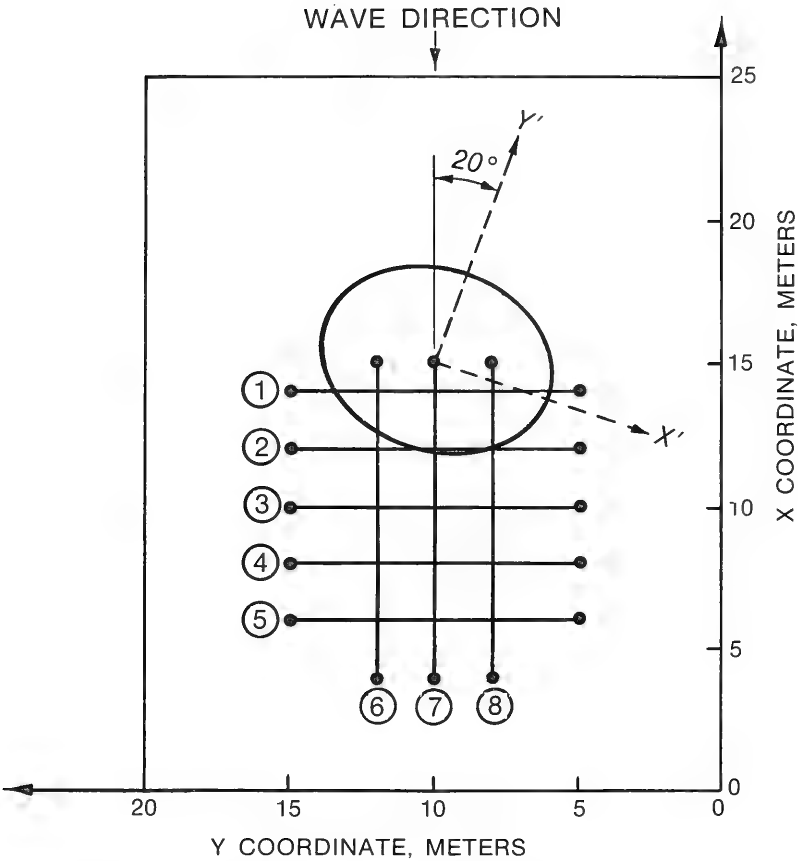

Figure A1. Geometry used in the model simulation of the elliptical shoal case

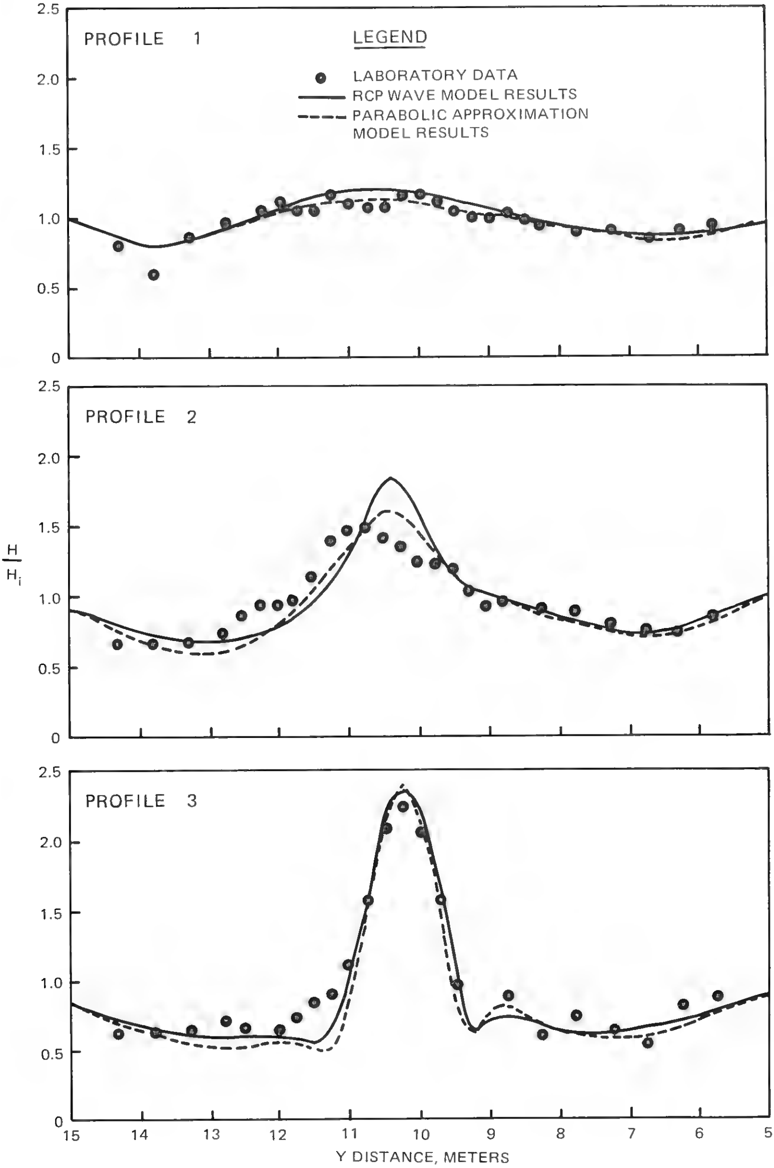

Figure A2. Comparisons between model results and observed data for the elliptical shoal case (profiles 1, 2, and 3)

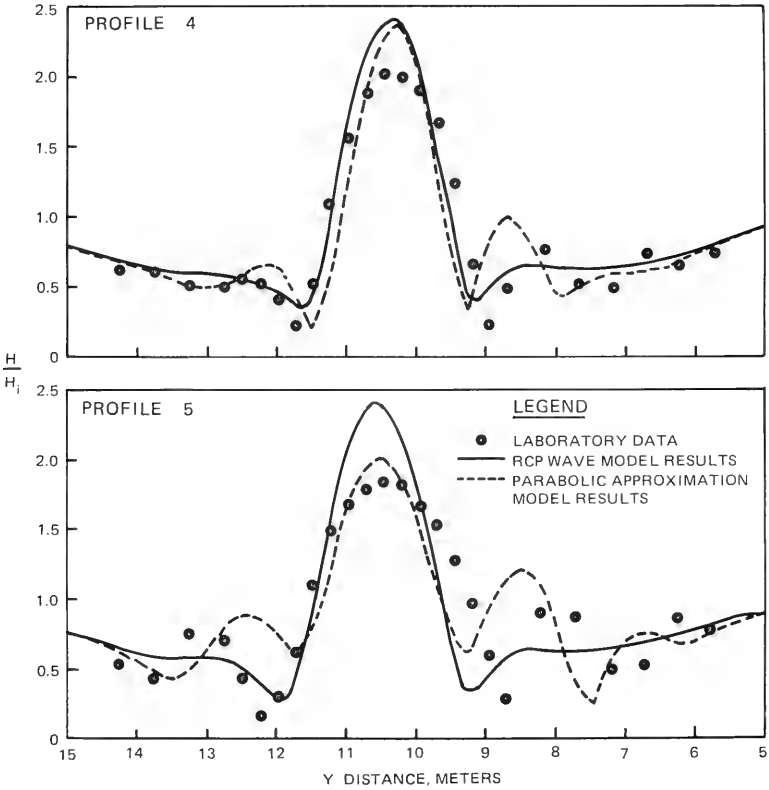

Figure A3. Comparisons between model results and observed data for the elliptical shoal case (profiles 4 and 5)

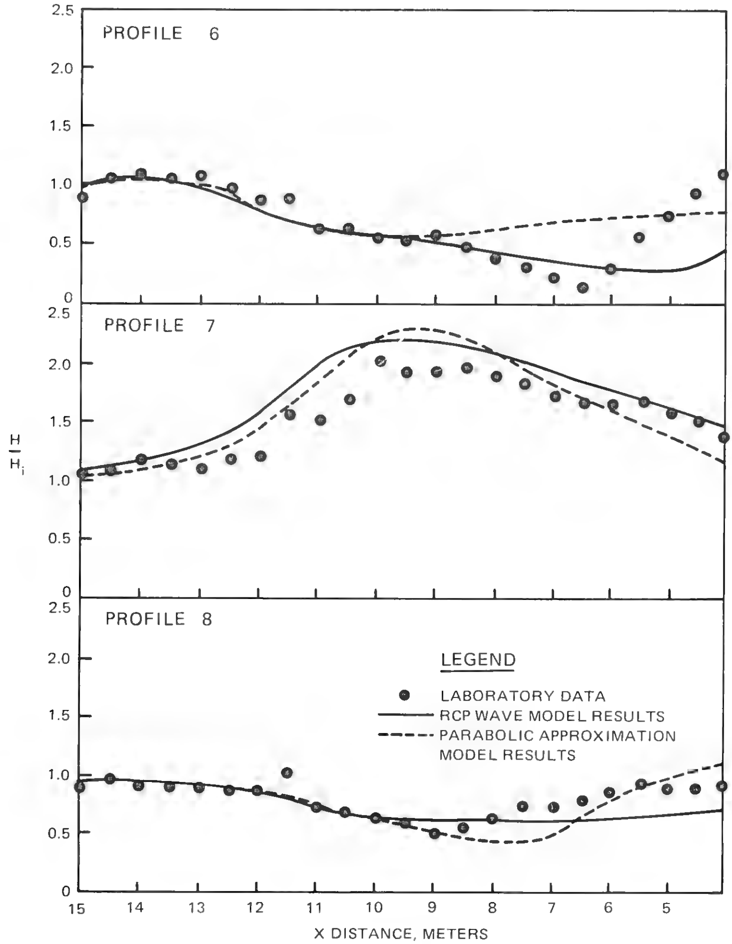

Figure A4. Comparisons between model results and observed data for the elliptical shoal case (profiles 6, 7, and 8)

# APPENDIX B: VERIFICATION OF MODEL RESULTS USING FIELD RESEARCH FACILITY (FRF) PROTOTYPE DATA

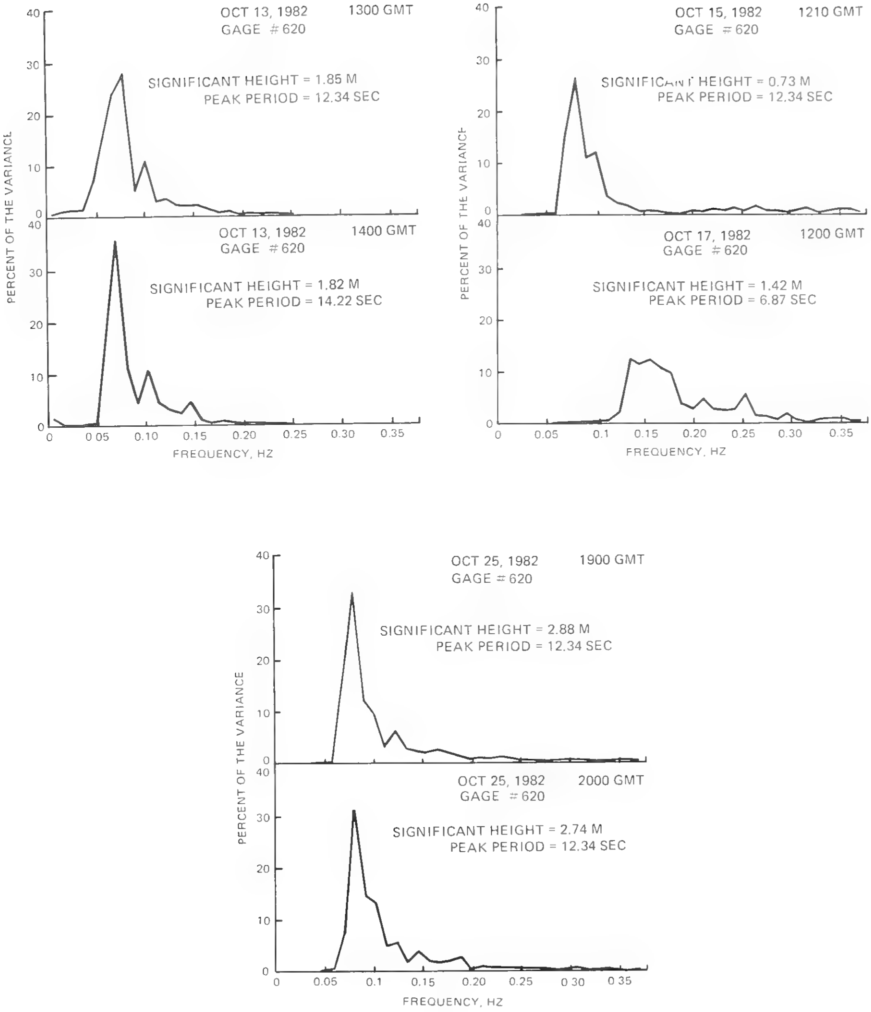

Figure B1. Observed offshore wave spectra during field verification, Cases 1 through 6

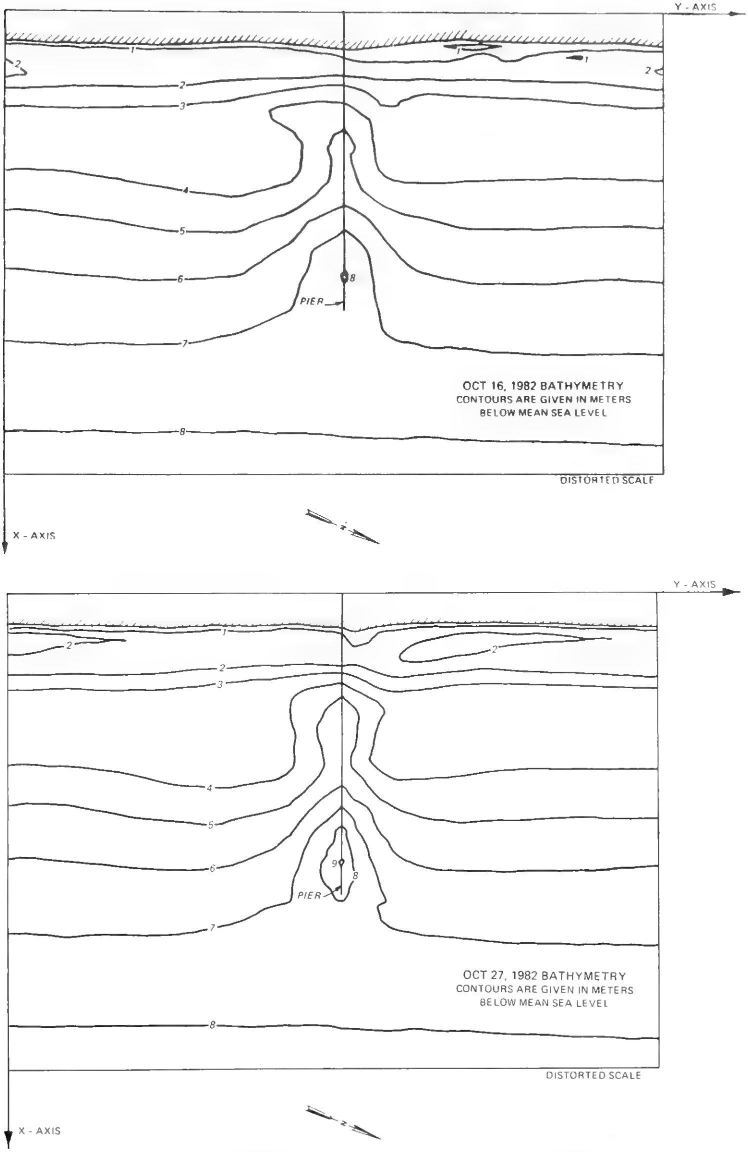

Figure B2. Bathymetry around the FRF pier measured on 16 October 1982 and 27 October 1982

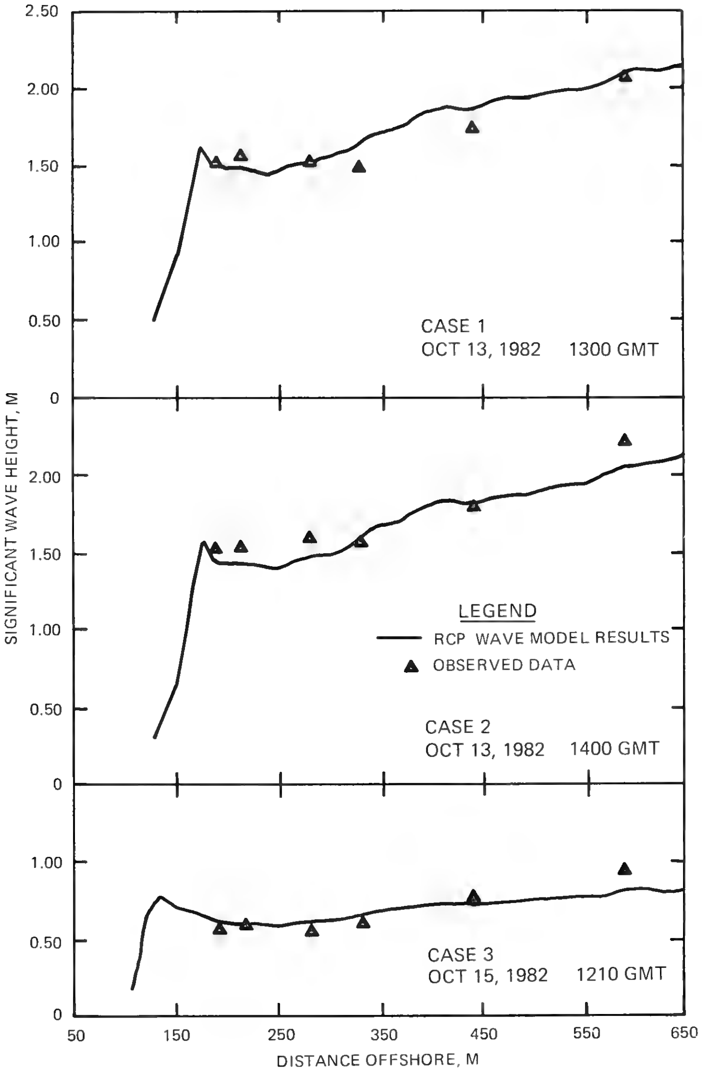

Figure B3. Comparisons between model results and observed data for field verification, Cases 1, 2, and 3

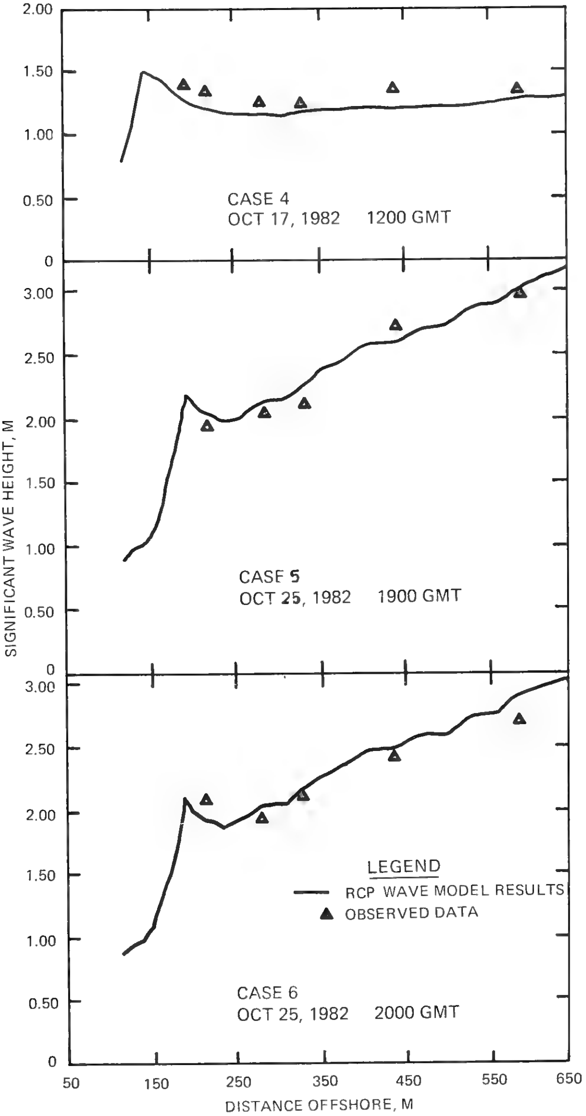

Figure B4. Comparisons between model results and observed data for field verification, Cases 4, 5, and 6

# APPENDIX C: VERIFICATION OF MODEL RESULTS USING BREAKING WAVE DATA COLLECTED IN LABORATORY EXPERIMENTS

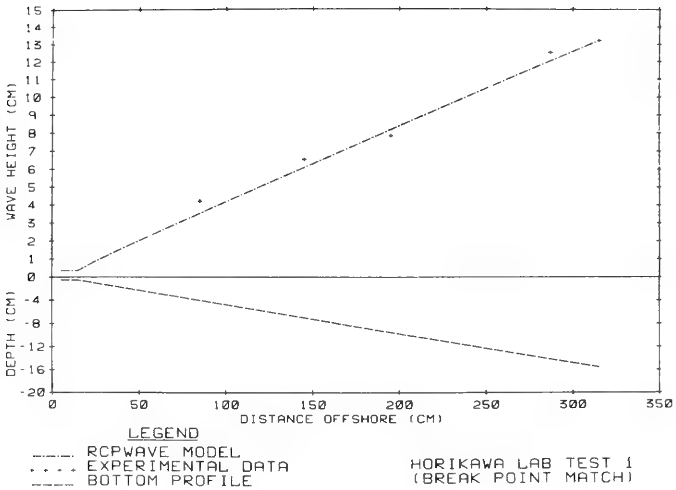

Figure C1. Comparisons between model results and observed data for wave breaking verification, Test 1 (surf zone transformation only)

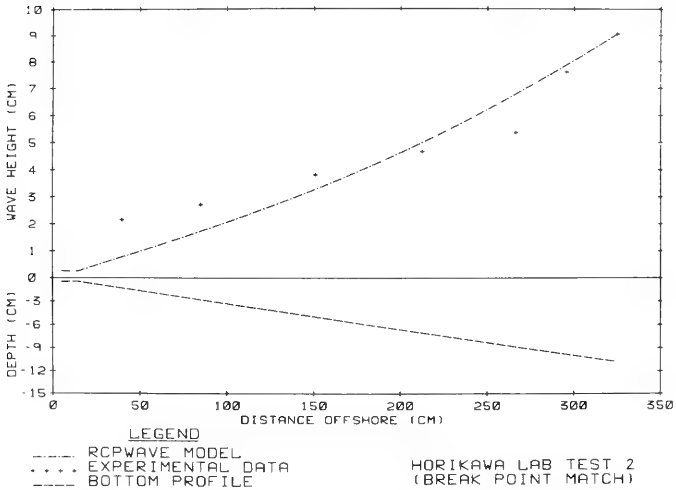

Figure C2. Comparisons between model results and observed data for wave breaking verification, Test 2 (surf zone transformation only)

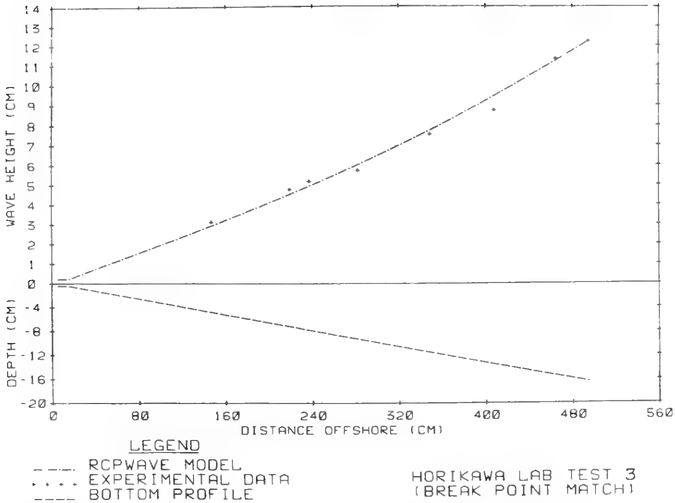

Figure C3. Comparisons between model results and observed data for wave breaking verification, Test 3 (surf zone transformation only)

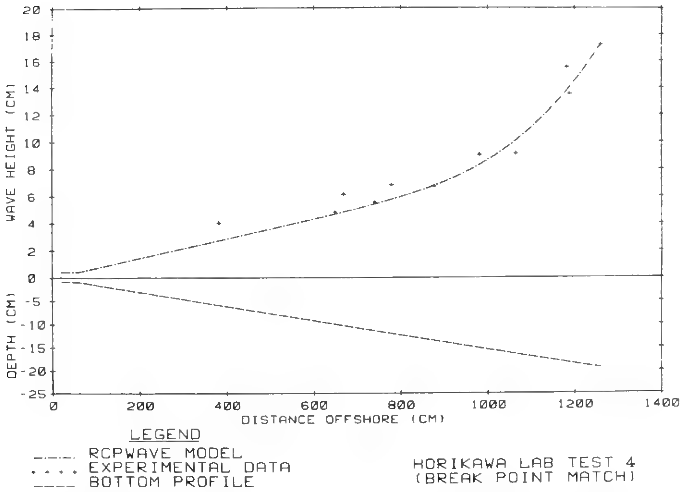

Figure C4. Comparisons between model results and observed data for wave breaking verification, Test 4 (surf zone transformation only)

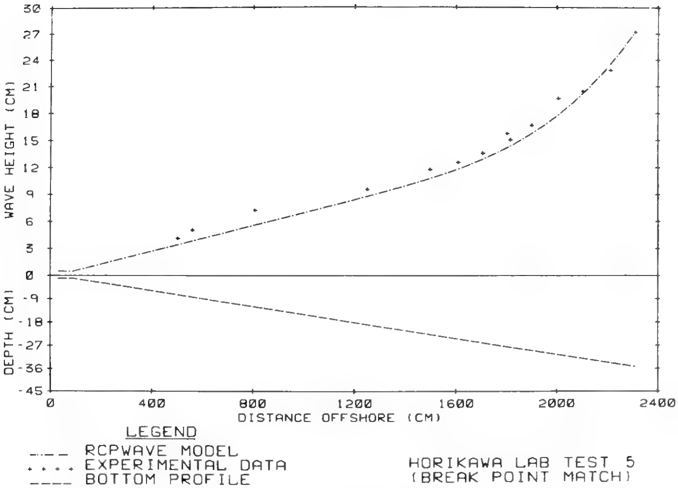

Figure C5. Comparisons between model results and observed data for wave breaking verification, Test 5 (surf zone transformation only)

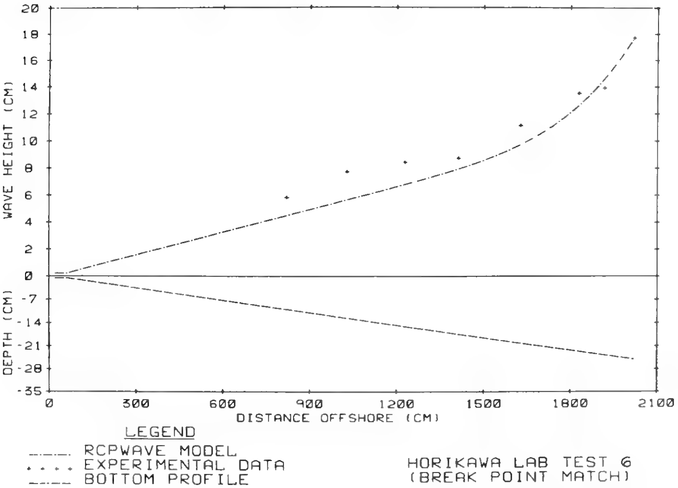

Figure C6. Comparisons between model results and observed data for wave breaking verification, Test 6 (surf zone transformation only)

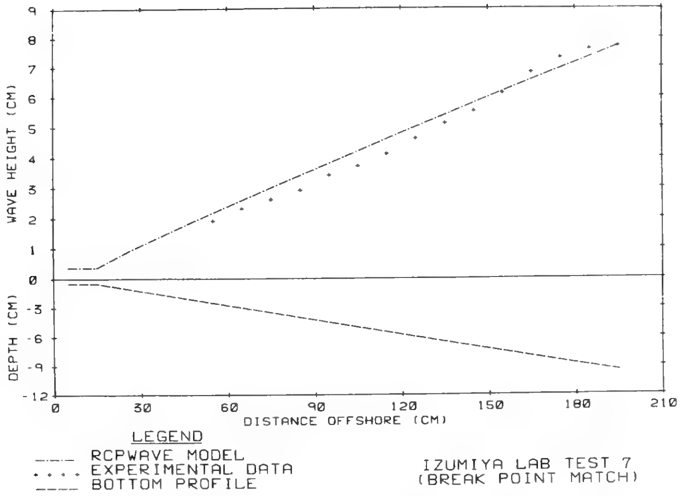

Figure C7. Comparisons between model results and observed data for wave breaking verification, Test 7 (surf zone transformation only)

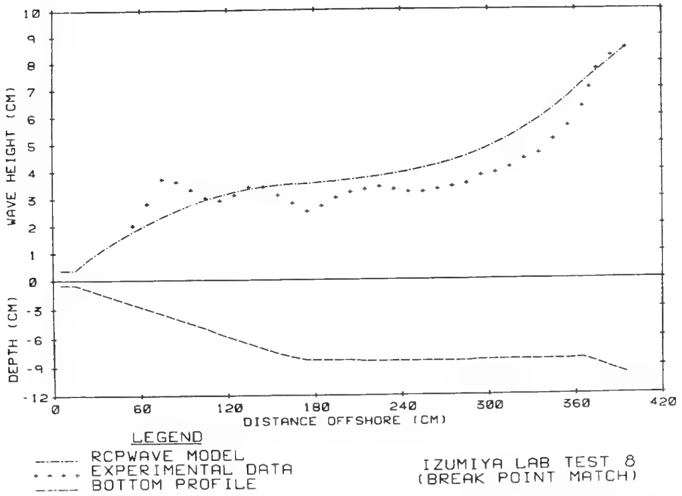

Figure C8. Comparisons between model results and observed data for wave breaking verification, Test 8 (surf zone transformation only)

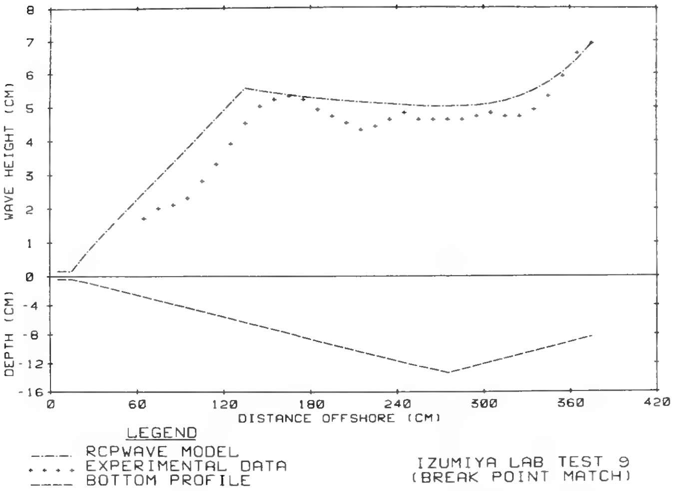

Figure C9. Comparisons between model results and observed data for wave breaking verification, Test 9 (surf zone transformation only)

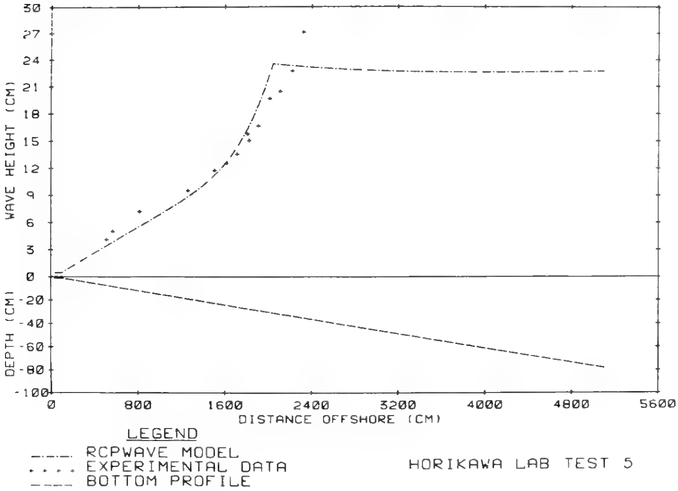

Figure C10. Comparisons between model results and observed data for wave breaking verification, Test 5 (incipient breaking and surf zone transformation)

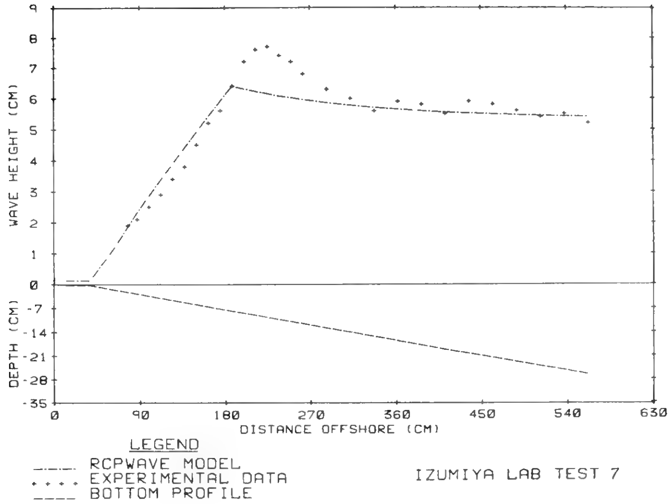

Figure C11. Comparisons between model results and observed data for wave breaking verification, Test 7 (incipient breaking and surf zone transformation)

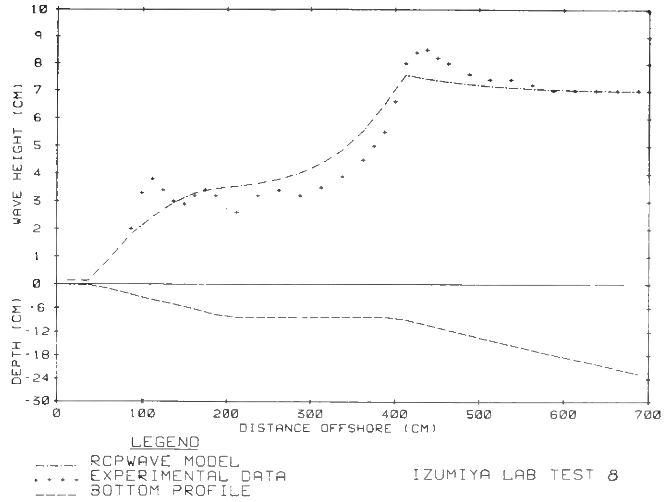

Figure C12. Comparisons between model results and observed data for wave breaking verification, Test 8 (incipient breaking and surf zone transformation)

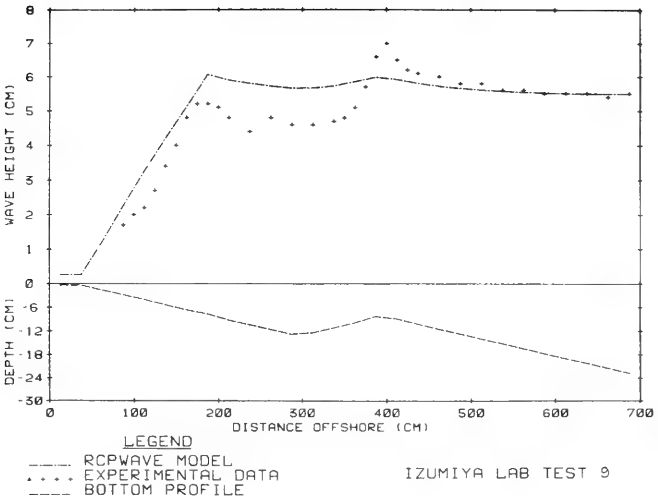

Figure C13. Comparisons between model results and observed data for wave breaking verification, Test 9 (incipient breaking and surf zone transformation)

# APPENDIX D: LINE-BY-LINE DESCRIPTION OF JOB CONTROL LANGUAGE FOR EXECUTING RCPWAVE ON THE CYBER 865 COMPUTER

(1) /JOB

The job card tells the computer that this is a batch job.

(2) JOB,P3,T1000,CM37000.

The resource card informs the computer of the priority (P) of the batch job, the execution time (T), and central memory (CM) limits.

| Priority | Meaning | Guaranteed Response Time, hr | Cost/ SBU* dollars |
|---|---|---|---|
| P1 | Weekend run | ≤48 | 0.01 |
| P2 | Overnight run | ≤24+ | 0.01 |
| P3 | Slower than default | ≤4+ | 0.04 |
| P4 | Default | ≤2+ | 0.12 |
| P6 | Faster than default | ≤1/2+ | 0.13 |

---

* Current Control Data Corporation (CDC) costs (FY 85).

\+ Excluding execution time.

T: SBU account block limit.
This is the job execution time limit (in seconds).

CM: Central memory field length limit is the maximum amount of memory you can use for your batch job (in octal words).

(3) /USER

This form of the user card specifies that the user identification number being used in the current session will be assigned to this batch job.

(4) /CHARGE

The charge card identifies the charge code being used for the current session and bills that charge account for the cost of the batch job.

**Important**

The following "GET" commands instruct the computer to access certain permanent files. Using this form of the "GET" command assumes that all files, except RCPWAVE, reside in the file space assigned to the user number being used in the current session.

|  |  |  |
|---|---|---|
|  |  | The following statements instruct the computer to: |
| (5) | GET,SR=RCPWAVE/UN=CER0Q2. | Get the permanent file RCPWAVE from user number CER0Q2 file space and give it the local file name SR for this batch job. |
| (6) | GET,UPDFL=RCPUPDT. | Get the permanent file RCPUPDT and give it the local file name UPDFL for this batch job. |
| (7) | GET,TAPE7=RCPDATA. | Get the permanent file RCPDATA and give it the local file name TAPE7 for this batch job. |
| (8) | GET,TAPE8=RCPDEPT. | Get the permanent file RCPDEPT and give it the local file name TAPE8 for this batch job. |
| (9) | UPDATE(I=SR,N=NEWLIB,F,L=0) | Take the local file SR and create a full (F), new program library NEWLIB from it, but do not list (L=0) the file NEWLIB. |
| (10) | UPDATE(P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F). | Take the program library NEWLIB and add to it the update information contained in file UPDFL. Do not list the full combined program library called NEWPLUS. |
| (11) | FTN5,I=NEWPLUS,B=BIN,L=OUTPUT. | Compile the file NEWPLUS. Save the relocatable binary code in a local file BIN and the compiled listing in a local file OUTPUT. |
| (12) | LOAD,BIN. | Load the local file BIN. |
| (13) | EXECUTE. | Run the program BIN. |
| (14) | REWIND,TAPE6,OUTPUT. | Rewind the local files TAPE6 and OUTPUT which generated during compilation and execution of the program. |
| (15) | REPLACE,TAPE6=RCPPRNT. | Take the information from local file TAPE6 and save it in the permanent file RCPPRNT. If a permanent file RCPPRNT already exists, it will be replaced with this new information. |
| (16) | REPLACE,OUTPUT=RCPOTPT. | Take the information from local file OUTPUT and save it in the permanent file RCPOTPT. If a permanent file RCPOTPT already exists, it will be replaced with this new information. |
|  |  | The following statements instruct the computer to: |
| (17) | COST. | Estimate the cost of this batch job. This cost excludes the CDC discount to US Army Corps of Engineers users. |

| | | |
|---|---|---|
| (18) | DAYFILE,L=RCPDAYF. | Create a diary of events for this batch job and give the diary a local file name RCPDAYF. |
| (19) | REPLACE,RCPDAYF. | Save RCPDAYF as a permanent file. If a permanent file RCPDAYF already exists, it will be replaced with this new information. |
| (20) | EXIT. | Stop processing information if no errors have occurred. If errors have occurred prior to reaching line 20, the system jumps to this line then continues downward in what is called "error processing." Processing beyond this point consists of saving output and diary files as was done in lines 14 through 19. |

# APPENDIX E: LINE-BY-LINE DESCRIPTION OF JOB CONTROL LANGUAGE FOR EXECUTING RCPWAVE ON THE CYBER 205 COMPUTER

| | | |
|---|---|---|
| (1) | /JOB | The job card tells the computer that this is a batch job. |
| (2) | JOB,P3,T1000,CM377000. | The resource card informs the computer of the priority (P) of your batch job, and the execution time (T) and central memory (CM) limits. |
| (3) | /USER | This form of the user card specifies that the user identification number being used in the current session will be assigned to this batch job. |
| (4) | /CHARGE | The charge card identifies the charge code being used for the current session and bills that charge account for the cost of the batch job. |
| | **Important** | The following "GET" commands instruct the computer to access certain permanent files. Using this form of the "GET" command assumes that all files, except RCPWAVE, reside in the file space assigned to the user number being used in the current session. |
| | | The following statements instruct the computer to: |
| (5) | GET,SR=RCPWAVE/UN=CER0Q2. | Get the permanent file RCPWAVE from user number CER0Q2 file space and give it the local file name SR for this batch job. |
| (6) | GET,UPDFL=RCPPUPDT. | Get the permanent file RCPUPDT and give it the local file name UPDFL for this batch job. |
| (7) | UPDATE,I=SR,N=NEWLIB,F,L=0. | Take the local file SR and create a full (F) new program library NEWLIB from it. Do not list (L=0) the file NEWLIB. |
| (8) | UPDATE,P=NEWLIB,I=UPDFL, C=NEWPLUS,L=0,F. | Take the program library NEWLIB and add in the update information contained in file UPDFL. Do not list the full combined program library NEWPLUS. |
| (9) | REPLACE,NEWPLUS. | Save NEWPLUS as a permanent file. If a permanent file NEWPLUS already exists, it will be replaced with this new information. |
| (10) | COPYBR,INPUT,SENDJOB,1. | Copy one record from the local file INPUT* to the local file SENDJOB. |
| | | *INPUT begins after the EOR card (card 19). One record is defined as all the cards in INPUT until a /EOR or /EOF is encountered (Card 35). |

| | | The following statements instruct the computer to: |
|---|---|---|
| (13) | SUBMIT,SENDJOB,T. | Give the CYBER 205 the batch of commands in file SENDJOB. |
| (14) | DAYFILE,L=RCPDAYF. | Create a diary of events for this batch job and give the diary a local file name RCPDAYF. |
| (15) | REPLACE,RCPDAYF. | Save RCPDAYF as a permanent file. If a permanent file RCPDAYF already exists, it will be replaced with this new information. |
| (16) | EXIT. | Stop processing information if no errors have occurred. If errors occur prior to reaching the EXIT card, the system jumps to this line then continues downward in what is called "error processing." Processing beyond this point consists of saving the diary file as was done in lines 14 and 15. |
| (19) | /EOR | End of record card. All cards following card 19 are part of local file INPUT. |
| (20) | JOB205. | The job card tells the computer that this is a batch job. |
| (21) | USER(U=<205 USERNAME>,<br>PA=<205 PASSWORD>)ADY. | The user card identifies the CYBER 205 user for billing purposes. |
| (22) | RESOURCE(JCAT=P3,TL=2000). | The resource card informs the computer of the priority (P) and time (TL) of the batch job. |

| Priority | Meaning | Guaranteed Response Time, hr | Cost SBU* dollars |
|---|---|---|---|
| P2 | Overnight run | ≤24+ | 0.08 |
| P3 | Slower than default | ≤4+ | 0.12 |
| P4 | Default | ≤2+ | 0.15 |
| P6 | Faster than default | ≤1/2+ | 0.18 |

---

* Current Control Data Corporation (CDC) costs (FY 85).

\+ Excluding execution time.

|  |  |  |
|---|---|---|
|  |  | T: SBU account block limit. This is the job execution time limit (in seconds). |
| (23) | /CHARGE | The charge card identifies the charge being used for the current session and bills that charge account for the batch job. |
|  |  | The following statements instruct the computer to: |
| (24) | LINK,GET,NEWPLUS/DD=C6, UN=<CYBER 865 USERNAME> ,FM=KOE,AF=AF205. | Get the permanent file NEWPLUS from the CYBER 865 user account. AF205 is your direct access file containing validation information. |
| (25) | LINK,GET,TAPE7=RCPDATA/DD=C6 UN=<CYBER 865 USERNAME> ,FMd=KOE,AF=AF205. | Get the permanent file RCPDATA from the CYBER 865 user account and give it the local file name TAPE7. |
| (26) | LINK,GET,TAPE8=RCPDEPT/DD=C6,UN=<CYBER 865 USERNAME> ,FM=KOE,AF=AF205. | Get the permanent file RCPDEPT from the CYBER 865 user account and give it the local file name TAPE8. |
| (27) | FORTRAN,I=NEWPLUS. | Compile the file NEWPLUS. The relocatable LGO by default, and the compiled listing is on local file OUTPUT by default. |
| (28) | LOAD,ON=GO/6000,L=M205, GRLPALL=. | Load the relocatable binary code. |
| (29) | GO. | Run the program. |
| (30) | LINK,REPLACE(TAPE6=RCPPRNT/ UN=<CYBER 865 USERNAME> ,FM=KOE,DD=C6,AF=AF205) | Take the information on TAPE6 and save it in the permanent file RCPPRNT. If a permanent file RCPPRNT already exists, it will be replaced with this new information. |
| (31) | SUMMARY. | The summary card tells the computer to list out all system usage (i.e., blocks, disks, SBU's) for this batch job. |
| (33) | /EOF | End of file marker. |

# APPENDIX F: RCPWAVE PROGRAM LISTING

```
      PROGRAM RCPWAVE(INPUT,OUTPUT,TAPE7,TAPE6,TAPE8,TAPE3)             MAIN       2
C*********************************************************************** MAIN       3
C                                                                       MAIN       4
C** NOTE **   'IQ' AND 'JQ' DEFINE THE LENGTH OF THE ONE AND TWO        MAIN       5
C             DIMENSIONAL ARRAYS USED IN THE PROGRAM. 'IQ' CORRESPONDS  MAIN       6
C             TO THE X DIRECTION (ON-OFFSHORE) AND 'JQ' TO THE Y        MAIN       7
C             DIRECTION (LONGSHORE)                                     MAIN       8
C                                                                       MAIN       9
C*********************************************************************** MAIN      10
C                                                                       MAIN      11
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
C                                                                       PARAM      4
C                                                                       MAIN      12
C** NOTE **   THE PRODUCT  IQ * JQ  MUST BE LESS THAN 9025 IF THE MODEL MAIN      14
C             APPLICATION IS TO BE RUN ON THE FRONT END CYBER 865       MAIN      15
C             MACHINE.  ANYTHING LARGER MUST BE RUN ON THE CYBER 205.   MAIN      16
C                                                                       MAIN      17
C*********************************************************************** MAIN      18
C                                                                       MAIN      19
C** DEFINITION OF IMPORTANT VARIABLE ARRAYS USED THROUGHOUT THE PROGRAM MAIN      20
C                                                                       MAIN      21
C              Z - WAVE ANGLE                                           MAIN      22
C             SI - SIN(Z)                                               MAIN      23
C             CO - COS(Z)                                               MAIN      24
C              H - FUNCTION OF THE WAVE AMPLITUDE                       MAIN      25
C            CCG - PRODUCT OF THE WAVE CELERITY AND THE GROUP VELOCITY  MAIN      26
C              D - TOTAL WATER DEPTH RELATIVE TO SOME DATUM             MAIN      27
C            RKA - WAVE NUMBER DEFINED BY THE DISPERSION RELATION       MAIN      28
C           GRDK - GRADIENT OF THE WAVE PHASE FUNCTION                  MAIN      29
C           XMUC - SCALE FACTOR RELATING REAL SPACE X GRID DISTANCES    MAIN      30
C                  TO MAPPED SPACE X GRID DISTANCES AND DEFINED AT THE  MAIN      31
C                  GRID CENTER                                          MAIN      32
C           XMUS - SCALE FACTOR RELATING REAL SPACE X GRID DISTANCES    MAIN      33
C                  TO MAPPED SPACE X GRID DISTANCES AND DEFINED AT THE  MAIN      34
C                  GRID SIDES                                           MAIN      35
C           YMUC - SCALE FACTOR RELATING REAL SPACE Y GRID DISTANCES    MAIN      36
C                  TO MAPPED SPACE Y GRID DISTANCES AND DEFINED AT THE  MAIN      37
C                  GRID CENTER                                          MAIN      38
C           YMUS - SCALE FACTOR RELATING REAL SPACE Y GRID DISTANCES    MAIN      39
C                  TO MAPPED SPACE Y GRID DISTANCES AND DEFINED AT THE  MAIN      40
C                  GRID SIDES                                           MAIN      41
C             XX - REAL SPACE X GRID DISTANCES MEASURED FROM THE GRID   MAIN      42
C                  ORIGIN TO THE GRID CENTER                            MAIN      43
C             YY - REAL SPACE Y GRID DISTANCES MEASURED FROM THE GRID   MAIN      44
C                  ORIGIN TO THE GRID CENTER                            MAIN      45
C                                                                       MAIN      46
C*********************************************************************** MAIN      47
C                                                                       MAIN      48
C**  DEFINITIONS OF INPUT DATA TO BE READ INTO THE PROGRAM **           MAIN      49
C                                                                       MAIN      50
C         ITITLE - ARRAY CONTAINING THE APPLICATION TITLE (70           MAIN      51
C                  CHARACTERS OR LESS)                                  MAIN      52
C              M - NUMBER OF GRID CELLS IN THE X DIRECTION              MAIN      53
C             DX - GRID SIZE IN THE X DIRECTION                         MAIN      54
C              N - NUMBER OF GRID CELLS IN THE Y DIRECTION              MAIN      55
C             DY - GRID SIZE IN THE Y DIRECTION                         MAIN      56
C  **NOTE**    G - GRAVITATIONAL CONSTANT WHICH DETERMINES THE UNITS OF MAIN      57
```

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C                 ALL THE INPUT AND OUTPUT VARIABLES                    MAIN   58
C        CNTRANG - APPROXIMATE ANGLE THE OFFSHORE CONTOURS MAKE WITH    MAIN   59
C                 THE Y AXIS (AIDS IN A BETTER INITIAL GUESS OF THE     MAIN   60
C                 SOLUTION COMPUTED USING SNELL'S LAW)                  MAIN   61
C         NCASES - NUMBER OF INDIVIDUAL DEEP WATER HEIGHT-PERIOD-       MAIN   62
C                 DIRECTION CONDITIONS CONSIDERED                       MAIN   63
C         DLEVEL - CONSTANT WATER LEVEL ADDED TO OR SUBTRACTED FROM     MAIN   64
C                 THE ENTIRE DEPTH MATRIX                               MAIN   65
C          HDEEP - DEEP WATER WAVE HEIGHT INPUT CONDITIONS              MAIN   66
C          TDEEP - DEEP WATER WAVE PERIOD INPUT CONDITIONS              MAIN   67
C          ZDEEP - DEEP WATER WAVE DIRECTION INPUT CONDITIONS           MAIN   68
C            IP1 - STARTING VALUE OF I FOR THE PRINTED OUTPUT           MAIN   69
C            IP2 - ENDING VALUE OF I FOR THE PRINTED OUTPUT             MAIN   70
C            INC - INCREMENT OF I FOR THE PRINTED OUTPUT                MAIN   71
C            JP1 - STARTING VALUE OF J FOR THE PRINTED OUTPUT           MAIN   72
C            JP2 - ENDING VALUE OF J FOR THE PRINTED OUTPUT             MAIN   73
C                 (THE J INCREMENT IS ALWAYS 1)                         MAIN   74
C          IGRID - =0 IF CONSIDERING A CONSTANT SIZED RECTANGULAR GRID  MAIN   75
C                  =1 IF CONSIDERING A VARIABLY SIZED RECTANGULAR GRID  MAIN   76
C                   GENERATED USING THE MAPIT PROCEDURE IN CMSGRID.     MAIN   77
C  **NOTE**         FOR ADDITIONAL INFORMATION ABOUT THE VARIABLY SIZED MAIN   78
C                   GRID INPUT SEE THE COMMENTS IN 'SUBROUTINE GRID'    MAIN   79
C           IREF - =1 DIFFRACTIVE EFFECTS INCLUDED                      MAIN   80
C                  =0 DIFFRACTIVE EFFECTS IGNORED(PURE REFRACTION)      MAIN   81
C                                                                       MAIN   82
C********************************************************************** MAIN   83
C                                                                       MAIN   84
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                        MAIN   85
      COMMON/WVH/H(IQ,JQ),CCG(IQ,JQ)                                    MAIN   86
      COMMON/DEPTHS/D(IQ,JQ)                                            MAIN   87
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                              MAIN   88
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    MAIN   89
     AM,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           MAIN   90
      COMMON/PRINTC/IP1,IP2,INC,JP1,JP2,DMULT,HMULT,ZMULT,RKMULT        MAIN   91
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         MAIN   92
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   MAIN   93
      COMMON/COOR/XX(IQ),YY(JQ)                                         MAIN   94
      COMMON /TRANF/ DECAY,STABL,IBRK(JQ),IBRKM(JQ)                     MAIN   95
      DIMENSION HDEEP(200),TDEEP(200),ZDEEP(200),LTITLE(9)              MAIN   96
C                                                                       MAIN   97
C******** READ INPUT DATA FROM FILE CODE 7                              MAIN   98
C                                                                       MAIN   99
      READ(7,601)(LTITLE(L),L=1,9)                                      MAIN  100
  601 FORMAT(9A8)                                                       MAIN  101
      READ(7,100)M,DX,N,DY,G,CNTRANG,NCASES,DLEVEL                      MAIN  102
  100 FORMAT(I5,F10.4,I5,F10.4,2F10.2,I5,F10.2)                         MAIN  103
      DO 602 L=1,NCASES                                                 MAIN  104
      READ(7,103)HDEEP(L),TDEEP(L),ZDEEP(L)                             MAIN  105
  103 FORMAT(3F10.2)                                                    MAIN  106
  602 CONTINUE                                                          MAIN  107
      READ(7,101)IP1,IP2,INC,JP1,JP2                                    MAIN  108
  101 FORMAT(5I5)                                                       MAIN  109
      READ(7,102)IREF,IGRID                                             MAIN  110
  102 FORMAT(2I5)                                                       MAIN  111
C                                                                       MAIN  112
C******** WRITE OUT INPUT DATA ON FILE CODE 6                           MAIN  113
C                                                                       MAIN  114
      WRITE(6,15)                                                       MAIN  115
   15 FORMAT(/////,2X,'R E G I O N A L   C O A S T A L',3X,             MAIN  116
```

```
     *'P R O C E S S E S   W A V E   T R A N S F O R M A T I O N',      MAIN    117
     *3X,'M O D E L',/,43X,'( R C P W A V E )',////)                    MAIN    118
      WRITE(6,609)(LTITLE(L),L=1,9)                                     MAIN    119
  609 FORMAT(25X,9A8,///)                                               MAIN    120
      WRITE(6,55)                                                       MAIN    121
   55 FORMAT(/,1X,'MODEL INPUT:',//)                                    MAIN    122
      IF(IGRID.GT.0)GO TO 300                                           MAIN    123
      WRITE(6,41)                                                       MAIN    124
   41 FORMAT(1X,'UNIFORMLY SIZED, RECTILINEAR GRID MESH',/)             MAIN    125
      GO TO 301                                                         MAIN    126
  300 WRITE(6,42)                                                       MAIN    127
   42 FORMAT(1X,'VARIABLY SIZED, RECTILINEAR GRID MESH',/)              MAIN    128
  301 WRITE(6,5)M,DX,N,DY                                               MAIN    129
    5 FORMAT(5X,'X - DIRECTION (ON-OFFSHORE)',5X,I5,' CELLS, EACH',     MAIN    130
     *F10.2,'  IN LENGTH',/,5X,'Y - DIRECTION (LONGSHORE)  ',5X,I5,     MAIN    131
     *' CELLS, EACH',F10.2,'  IN LENGTH',/)                             MAIN    132
      WRITE(6,43)G                                                      MAIN    133
   43 FORMAT(1X,'THE ACCELERATION OF GRAVITY IS',F8.2,'.  THESE UNITS ',MAIN    134
     *'DETERMINE THE UNITS OF ALL INPUT AND OUTPUT VARIABLES ',/)       MAIN    135
      DO 604 L=1,NCASES                                                 MAIN    136
      WRITE(6,44)L,HDEEP(L),TDEEP(L),ZDEEP(L)                           MAIN    137
  604 CONTINUE                                                          MAIN    138
   44 FORMAT(' THE DEEP WATER WAVE PARAMETERS FOR CASE',I3,' ARE:',     MAIN    139
     *5X,'HEIGHT=',F7.3,5X,'PERIOD=',F7.3,5X,'ANGLE=',F8.3)             MAIN    140
      WRITE(6,45)CNTRANG                                                MAIN    141
   45 FORMAT(/,1X,'THE OFFSHORE CONTOURS MAKE AN ANGLE OF',F7.2,        MAIN    142
     *' DEGREES WITH THE Y AXIS',/)                                     MAIN    143
      WRITE(6,19)                                                       MAIN    144
   19 FORMAT(1X,'THE BATHYMETRY MATRIX IS VARIABLE IN BOTH HORIZONTAL'  MAIN    145
     *,' DIRECTIONS AND WAS READ FROM FILE CODE 8',/)                   MAIN    146
      WRITE(6,20)DLEVEL                                                 MAIN    147
   20 FORMAT(1X,'A WATER LEVEL CHANGE OF',F7.2,' WAS ADDED TO THE',     MAIN    148
     *' ENTIRE BATHYMETRY MATRIX')                                      MAIN    149
C                                                                       MAIN    150
C******** CONSTANTS USED IN THE PROGRAM                                 MAIN    151
C                                                                       MAIN    152
      PI=3.1415927                                                      MAIN    153
      PI2=PI *2.0                                                       MAIN    154
      RAD=180.0/PI                                                      MAIN    155
      CNTRANG=CNTRANG/RAD                                               MAIN    156
      M2=M-2                                                            MAIN    157
      M1=M-1                                                            MAIN    158
      NM1=N-1                                                           MAIN    159
      NM2=N-2                                                           MAIN    160
      DX2=DX*2.                                                         MAIN    161
      DY2=DY*2.                                                         MAIN    162
      WTA=1.0                                                           MAIN    163
      WTH=1.0                                                           MAIN    164
      TAU=0.167                                                         MAIN    165
      BETA=0.167                                                        MAIN    166
      IDRY=1                                                            MAIN    167
      IWET=2                                                            MAIN    168
      IWETP1=IWET+1                                                     MAIN    169
C                                                                       MAIN    170
C******** 'STABL' AND 'DECAY' ARE USED IN THE WAVE BREAKING             MAIN    171
C******** ROUTINE                                                       MAIN    172
C                                                                       MAIN    173
      STABL=0.4                                                         MAIN    174
      DECAY=0.2                                                         MAIN    175
```

```
C                                                                       MAIN     176
C******** 'HCONVR' AND 'SCONVR' ARE THE CONVERGENCE CRITERIA USED IN    MAIN     177
C******** THE HEIGHT AND ANGLE ITERATIVE SOLUTION SCHEMES               MAIN     178
C                                                                       MAIN     179
      HCONVR=0.0005                                                     MAIN     180
      SCONVR=0.00025                                                    MAIN     181
      IF(G.GT.9.7.AND.G.LT.9.9)HCONVR=HCONVR*0.3048                     MAIN     182
      IF(G.GT.970.0.AND.G.LT.990.0)HCONVR=HCONVR*30.48                  MAIN     183
C                                                                       MAIN     184
C******** 'ITHMX' AND 'ITAMX' CONTROL THE MAXIMUM NUMBER OF ITERATIONS  MAIN     185
C******** ALLOWED IN THE WAVE HEIGHT AND ANGLE SOLUTION SCHEMES         MAIN     186
C******** 'IDIFF' CONTROLS THE NUMBER OF ITERATIONS ALLOWED IN THE      MAIN     187
C******** ITERATIVE DIFFRACTION SCHEME                                  MAIN     188
C                                                                       MAIN     189
      ITHMX=50                                                          MAIN     190
      ITAMX=50                                                          MAIN     191
      IDIFF=15                                                          MAIN     192
C                                                                       MAIN     193
C******** THE FOLLOWING MULTIPLICATION FACTORS CONTROL THE ACCURACY     MAIN     194
C******** OF THE PRINTED OUTPUT(NOT THE ACTUAL COMPUTATION).            MAIN     195
C********     DEPTH (D)           - DMULT                                MAIN     196
C********     WAVE HEIGHT (H)     - HMULT                                MAIN     197
C********     WAVE ANGLE (Z)      - ZMULT                                MAIN     198
C********     WAVE NUMBER (GRADK) - RKMULT                               MAIN     199
C******** THE VARIABLES ARE FIRST MULTIPLIED BY THE SCALE FACTORS       MAIN     200
C******** BELOW, THEN PRINTED OUT IN INTEGER FORM                       MAIN     201
C                                                                       MAIN     202
      DMULT=1.0                                                         MAIN     203
      HMULT=10.0                                                        MAIN     204
      ZMULT=1.0                                                         MAIN     205
      RKMULT=1000.0                                                     MAIN     206
C                                                                       MAIN     207
C******** DEFINE THE GRID SCALE FACTORS AND DISTANCES FOR A CONSTANT    MAIN     208
C******** SIZED RECTANGULAR GRID                                        MAIN     209
C                                                                       MAIN     210
      DO 2 I=1,M                                                        MAIN     211
      XMUC(I)=1.0                                                       MAIN     212
      XMUS(I)=1.0                                                       MAIN     213
      XX(I)=DX*(I-0.5)                                                  MAIN     214
    2 CONTINUE                                                          MAIN     215
      DO 3 J=1,N                                                        MAIN     216
      YMUC(J)=1.0                                                       MAIN     217
      YMUS(J)=1.0                                                       MAIN     218
      YY(J)=DY*(J-0.5)                                                  MAIN     219
    3 CONTINUE                                                          MAIN     220
C                                                                       MAIN     221
C******** CALL SUBROUITNE GRID TO READ IN THE VARIABLE GRID MAPPING     MAIN     222
C******** INFORMATION FROM FILE CODE 3 (X DIRECTION FIRST,THEN Y) AND   MAIN     223
C******** GENERATE THE VARIABLE GRID SCALE FACTORS AND DISTANCES        MAIN     224
C                                                                       MAIN     225
      IF(IGRID.EQ.1)CALL GRID                                           MAIN     226
C                                                                       MAIN     227
C******** CALL SUBROUTINE DEPTH TO GENERATE THE WATER DEPTH MATRIX      MAIN     228
C                                                                       MAIN     229
      CALL DEPTH                                                        MAIN     230
C                                                                       MAIN     231
C******** ADD DLEVEL TO ALL THE WATER DEPTHS AND THEN REQUIRE           MAIN     232
C******** ALL DEPTHS BE GREATER THAN THE MINIMUM DEPTH 'DMIN'           MAIN     233
C******** WHERE 'DMIN' IS 1.0 FEET OR A METRIC EQUIVALENT               MAIN     234
```

```
C                                                                       MAIN     235
      DMIN=1.0                                                          MAIN     236
      IF(G.GT.9.7.AND.G.LT.9.9)DMIN=0.3048                              MAIN     237
      IF(G.GT.970.0.AND.G.LT.990.0)DMIN=30.48                           MAIN     238
      DO 87 I=1,M                                                       MAIN     239
      DO 87 J=1,N                                                       MAIN     240
      D(I,J)=D(I,J)+DLEVEL                                              MAIN     241
      IF(D(I,J).LT.DMIN)D(I,J)=DMIN                                     MAIN     242
   87 CONTINUE                                                          MAIN     243
C·                                                                      MAIN     244
C******** SET THE BOUNDARY CONDITIONS FOR THE WATER DEPTHS              MAIN     245
C                                                                       MAIN     246
      DO 86 I=1,M                                                       MAIN     247
      D(I,1)=D(I,2)                                                     MAIN     248
      D(I,N)=D(I,NM1)                                                   MAIN     249
   86 CONTINUE                                                          MAIN     250
      CALL ONBC(D)                                                      MAIN     251
C                                                                       MAIN     252
C******** PRINT THE TOTAL WATER DEPTH MATRIX (ALL DEPTHS MULTIPLIED BY D MAIN     253
C                                                                       MAIN     254
      CALL POUT(IP1,IP2,INC,JP1,JP2,'  WATER DEPTHS          ',D,DMULT) MAIN     255
C                                                                       MAIN     256
C******** ITERATE OVER THE NUMBER OF WAVE CONDITIONS CONSIDERED         MAIN     257
C                                                                       MAIN     258
      DO 605 L=1,NCASES                                                 MAIN     259
      HO=HDEEP(L)                                                       MAIN     260
      T=TDEEP(L)                                                        MAIN     261
      OMEG=PI2/T                                                        MAIN     262
      HFACT=2.0*OMEG/G                                                  MAIN     263
C                                                                       MAIN     264
C******** 'HFACT' IS A FACTOR TO CONVERT FROM WAVE HEIGHT TO THE        MAIN     265
C******** AMPLITUDE FUNCTION 'H'                                        MAIN     266
C                                                                       MAIN     267
      A=ZDEEP(L)                                                        MAIN     268
      WRITE(6,606)L                                                     MAIN     269
  606 FORMAT(/////,' W A V E   C O N D I T I O N ',I5,/)                MAIN     270
      WRITE(6,44)L,HO,T,A                                               MAIN     271
      A=A+180.0                                                         MAIN     272
      DO 607 J=1,N                                                      MAIN     273
      IBRK(J)=0                                                         MAIN     274
      IBRKM(J)=0                                                        MAIN     275
  607 CONTINUE                                                          MAIN     276
      CALL REFDIF(A,HO,WTA,TAU,WTH,BETA)                                MAIN     277
  605 CONTINUE                                                          MAIN     278
C                                                                       MAIN     279
   99 STOP                                                              MAIN     280
      END                                                               MAIN     281
C*********************************************************************** REFDIF     2
C                                                                       REFDIF     3
      SUBROUTINE REFDIF(THETAO,HH,WTA,TAU,WTH,BETA)                     REFDIF     4
C                                                                       REFDIF     5
C*********************************************************************** REFDIF     6
C                                                                       REFDIF     7
C     THIS SUBROUTINE CONTROLS THE ITERATIVE SOLUTION SCHEME AND        REFDIF     8
C     PRINTING OF THE WAVE INFORMATION                                  REFDIF     9
C                                                                       REFDIF    10
C*********************************************************************** REFDIF    11
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
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C                                                                       PARAM      4
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                        REFDIF    13
      COMMON/WVH/H(IQ,JQ),CCG(IQ,JQ)                                    REFDIF    14
      COMMON/DEPTHS/D(IQ,JQ)                                            REFDIF    15
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                              REFDIF    16
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    REFDIF    17
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           REFDIF    18
      COMMON/PRINTC/IP1,IP2,INC,JP1,JP2,DMULT,HMULT,ZMULT,RKMULT        REFDIF    19
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         REFDIF    20
      COMMON /TRANE/ DECAY,STABL,IBRK(JQ),IBRKM(JQ)                     REFDIF    21
      DIMENSION DUM1(IQ,JQ),GRDOLD(JQ)                                  REFDIF    22
C                                                                       REFDIF    23
C******** CALL SUBROUTINE SNELL TO OBTAIN AN INITIAL GUESS OF THE        REFDIF    24
C******** WAVE HEIGHTS AND ANGLES USING SNELLS LAW                       REFDIF    25
C                                                                       REFDIF    26
      CALL SNELL ((THETAO/RAD),HH)                                      REFDIF    27
      CALL ONBC(H)                                                      REFDIF    28
      CALL ONBC(Z)                                                      REFDIF    29
      CALL ONBC(CO)                                                     REFDIF    30
      CALL ONBC(SI)                                                     REFDIF    31
      CALL ONBC(RKA)                                                    REFDIF    32
      CALL ONBC(GRDK)                                                   REFDIF    33
      CALL ONBC(CCG)                                                    REFDIF    34
C                                                                       REFDIF    35
C******** REMOVE THE 'GO TO 122' STATEMENT TO PRINT OUT THE SNELL'S LAW  REFDIF    36
C******** SOLUTION                                                       REFDIF    37
C                                                                       REFDIF    38
      GO TO 122                                                         REFDIF    39
  177 CONTINUE                                                          REFDIF    40
      DO 13 I=1,M                                                       REFDIF    41
      DO 13 J=1,N                                                       REFDIF    42
      DUM3=Z(I,J)-PI                                                    REFDIF    43
      DUM1(I,J)=DUM3*RAD                                                REFDIF    44
   13 CONTINUE                                                          REFDIF    45
C                                                                       REFDIF    46
C******** ANGLES,HEIGHTS, AND WAVE NUMBERS ARE MULTIPLIED BY ZMULT,      REFDIF    47
C******** HMULT, AND RKMULT RESPECTIVELY IN THE PRINT OUT. THESE MUST BE REFDIF    48
C******** CHANGED INTERNALLY WITHIN THE MAIN PROGRAM IF OTHER VALUES     REFDIF    49
C******** ARE DESIRED                                                    REFDIF    50
C                                                                       REFDIF    51
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE ANGLES    (DEG   ',DUM1,   REFDIF    52
     *ZMULT)                                                            REFDIF    53
      DO 79 I=1,M                                                       REFDIF    54
      DO 79 J=1,N                                                       REFDIF    55
      DUM1(I,J)=H(I,J)*HFACT                                            REFDIF    56
   79 CONTINUE                                                          REFDIF    57
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE HEIGHTS       ',DUM1,      REFDIF    58
     1HMULT)                                                            REFDIF    59
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE NUMBER        ',RKA,       REFDIF    60
     *RKMULT)                                                           REFDIF    61
  122 CONTINUE                                                          REFDIF    62
C                                                                       REFDIF    63
C******** ROW BY ROW MARCHING LOOP                                       REFDIF    64
C                                                                       REFDIF    65
      DO 10 IL=M2,IWETP1,-1                                             REFDIF    66
      ILM1=IL-1                                                         REFDIF    67
C                                                                       REFDIF    68
C******** COMPUTE THE WAVE ANGLES ALONG A ROW                            REFDIF    69
C                                                                       REFDIF    70
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      CALL ANGLE(IL,IL,ITAMX,WTA.TAU,SCONVR)                            REFDIF  71
C                                                                       REFDIF  72
C******** COMPUTE THE WAVE HEIGHTS ALONG A ROW                          REFDIF  73
C                                                                       REFDIF  74
      CALL HEIGHT(IL,IL,ITHMX.WTH,BETA,HCONVR)                          REFDIF  75
C                                                                       REFDIF  76
      IF(IREF.EQ.0) GO TO 114                                           REFDIF  77
      DO 119 J=1,N                                                      REFDIF  78
      GRDOLD(J)=GRDK(ILM1,J)                                            REFDIF  79
  119 CONTINUE                                                          REFDIF  80
      DO 110 LLL=1,IDIFF                                                REFDIF  81
C                                                                       REFDIF  82
C******** COMPUTE NEW GRADIENT OF THE WAVE PHASE FUNCTION ALONG A ROW   REFDIF  83
C                                                                       REFDIF  84
      CALL GRADK(ILM1.ILM1)                                             REFDIF  85
      EPSK=0.5                                                          REFDIF  86
      DO 112 J=1,N                                                      REFDIF  87
      GRDK(ILM1,J)=EPSK*GRDK(ILM1,J)+(1.0-EPSK)*GRDOLD(J)               REFDIF  88
  112 CONTINUE                                                          REFDIF  89
      IFLAG=1                                                           REFDIF  90
      DO 111 J=1,N                                                      REFDIF  91
      IF(ABS(GRDK(ILM1,J)-GRDOLD(J)).GT.0.0025*ABS(GRDK(ILM1,J)))       REFDIF  92
     *IFLAG=0                                                           REFDIF  93
  111 CONTINUE                                                          REFDIF  94
      DO 113 J=1,N                                                      REFDIF  95
      GRDOLD(J)=GRDK(ILM1,J)                                            REFDIF  96
  113 CONTINUE                                                          REFDIF  97
C                                                                       REFDIF  98
C******** RECOMPUTE THE WAVE ANGLES ALONG A ROW                         REFDIF  99
C                                                                       REFDIF 100
      CALL ANGLE(IL,IL,ITAMX,WTA,(TAU*1.0),SCONVR)                      REFDIF 101
C                                                                       REFDIF 102
C******** RECOMPUTE THE WAVE HEIGHTS ALONG A ROW                        REFDIF 103
C                                                                       REFDIF 104
      CALL HEIGHT(IL,IL,ITHMX,WTH,(BETA*1.0),HCONVR)                    REFDIF 105
      IF(IFLAG.EQ.1) GO TO 114                                          REFDIF 106
  110 CONTINUE                                                          REFDIF 107
      WRITE(6,117)ILM1                                                  REFDIF 108
  117 FORMAT(1X,'CONVERGENCE TOWARD A SOLUTION FAILED ON ROW',I5)       REFDIF 109
  114 CONTINUE                                                          REFDIF 110
C                                                                       REFDIF 111
C******** UPDATE BREAKER INDEX                                          REFDIF 112
C                                                                       REFDIF 113
      DO 115 J=1,N                                                      REFDIF 114
         IBRKM(J)=IBRK(J)                                               REFDIF 115
         DUM1(ILM1,J)=IBRK(J)                                           REFDIF 116
         IBRK(J)=0                                                      REFDIF 117
  115 CONTINUE                                                          REFDIF 118
C                                                                       REFDIF 119
   10 CONTINUE                                                          REFDIF 120
      CALL ONBC(GRDK)                                                   REFDIF 121
      CALL ONBC(H)                                                      REFDIF 122
      CALL ONBC(Z)                                                      REFDIF 123
      CALL ONBC(CO)                                                     REFDIF 124
      CALL ONBC(SI)                                                     REFDIF 125
C                                                                       REFDIF 126
C******** PRINT WAVE INFORMATION                                        REFDIF 127
C                                                                       REFDIF 128
C********  BREAKER INDEX ( 0=NON-BREAKING , 11=BREAKING )               REFDIF 129
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C                                                                       REFDIF  130
      DO 219 J=1,N                                                      REFDIF  131
      DUM1(1,J)=DUM1(2,J)                                               REFDIF  132
      DUM1(M,J)=0.0                                                     REFDIF  133
      DUM1(M1,J)=0.0                                                    REFDIF  134
      DUM1(M2,J)=0.0                                                    REFDIF  135
      DO 219 I=1,M                                                      REFDIF  136
      IF(DUM1(I,J).EQ.1.0)DUM1(I,J)=11.0                                REFDIF  137
  219 CONTINUE                                                          REFDIF  138
      CALL POUT(IP1,IP2,INC,JP1,JP2,' BREAKER   INDEX      ',DUM1,1.0)  REFDIF  139
C******** ANGLES,HEIGHTS, AND WAVE NUMBERS ARE MULTIPLIED BY ZMULT,      REFDIF  140
C******** HMULT, AND RKMULT RESPECTIVELY IN THE PRINT OUT.  THESE MUST   REFDIF  141
C******** BE CHANGED INTERNALLY WITHIN THE MAIN PROGRAM IF OTHER VALUES  REFDIF  142
C******** ARE DESIRED                                                   REFDIF  143
C                                                                       REFDIF  144
      DO 23 I=1,M                                                       REFDIF  145
      DO 23 J=1,N                                                       REFDIF  146
      DUM3=Z(I,J)-PI                                                    REFDIF  147
      DUM1(I,J)=DUM3*RAD                                                REFDIF  148
   23 CONTINUE                                                          REFDIF  149
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE ANGLES    (DEG)',DUM1,     REFDIF  150
     *ZMULT)                                                            REFDIF  151
C                                                                       REFDIF  152
C******** CONVERT FROM AMPLITUDE FUNCTION TO WAVE HEIGHT                 REFDIF  153
C                                                                       REFDIF  154
      DO 81 I=1,M                                                       REFDIF  155
      DO 81 J=1,N                                                       REFDIF  156
      DUM1(I,J)=H(I,J)*HFACT                                            REFDIF  157
   81  CONTINUE                                                         REFDIF  158
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE HEIGHTS          ',DUM1,   REFDIF  159
     1HMULT)                                                            REFDIF  160
      CALL POUT(IP1,IP2,INC,JP1,JP2,'   WAVE NUMBER           ',GRDK,   REFDIF  161
     *RKMULT)                                                           REFDIF  162
   99 RETURN                                                            REFDIF  163
      END                                                               REFDIF  164
C*********************************************************************** GRADK     2
C                                                                       GRADK     3
      SUBROUTINE GRADK(ISTART,IEND)                                     GRADK     4
C                                                                       GRADK     5
C*********************************************************************** GRADK     6
C                                                                       GRADK     7
C     THIS SUBROUTINE COMPUTES THE UPDATED VALUES OF THE GRADIENT       GRADK     8
C     OF THE WAVE PHASE FUNCTION ALONG A GIVEN ROW                      GRADK     9
C                                                                       GRADK    10
C*********************************************************************** GRADK    11
C                                                                       PARAM     2
      PARAMETER(IQ=95,JQ=95)                                            PARAM     3
C                                                                       PARAM     4
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                        GRADK    13
      COMMON/DEPTHS/D(IQ,JQ)                                            GRADK    14
      COMMON/WVH/H(IQ,JQ),CCG(IQ,JQ)                                    GRADK    15
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                              GRADK    16
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    GRADK    17
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           GRADK    18
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         GRADK    19
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   GRADK    20
      COMMON /TRANE/ DECAY,STABL,IBRK(JQ),IBRKM(JQ)                     GRADK    21
      DIMENSION DUM1(IQ,JQ),X(JQ)                                       GRADK    22
C                                                                       GRADK    23
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C******** COMPUTE THE DIFFRACTIVE TERMS                                 GRADK  24
C                                                                       GRADK  25
C******** USE 4 POINT BACKWARDS DIFFERENCE FOR THE X CURVATURE OF 'H'   GRADK  26
C******** USE 3 POINT BACKWARDS DIFFERENCE FOR THE X GRADIENT OF 'H,CCG' GRADK  27
C******** USE CENTRAL DIFFERENCES FOR THE Y CURVATURE OF 'H'            GRADK  28
C******** USE CENTRAL DIFFERENCES FOR THE Y GRADIENT OF 'H,CCG'         GRADK  29
C                                                                       GRADK  30
      DO 2 I=ISTART,IEND                                                GRADK  31
      DLX2=DX2*XMUC(I)                                                  GRADK  32
      DLXSQ=(DLX2*0.5)**2                                               GRADK  33
      DO 2 J=2,NM1                                                      GRADK  34
      DLY2=DY2*YMUC(J)                                                  GRADK  35
      DLYSQ=(DLY2*0.5)**2                                               GRADK  36
      CCGIJ=CCG(I,J)                                                    GRADK  37
      HIJ=H(I,J)                                                        GRADK  38
      HJP1=H(I,J+1)                                                     GRADK  39
      HJM1=H(I,J-1)                                                     GRADK  40
      HIP1=H(I+1,J)                                                     GRADK  41
      HIP2=H(I+2,J)                                                     GRADK  42
      DUM6=(-3.0*HIJ+4.0*HIP1-HIP2)/DLX2                                GRADK  43
      DUM4=(2.0*HIJ-5.0*HIP1+4.0*HIP2-H(I+3,J))/DLXSQ                   GRADK  44
      DUM4=DUM4-0.5*DUM6*(XMUC(I+1)-XMUC(I-1))/((XMUC(I)**2)*DX)        GRADK  45
      DUM2=(-3.0*CCGIJ+4.0*CCG(I+1,J)-CCG(I+2,J))/DLX2                  GRADK  46
      DUM7=(HJP1-HJM1)/DLY2                                             GRADK  47
      DUM5=(HJP1-2.0*HIJ+HJM1)/DLYSQ                                    GRADK  48
      DUM5=DUM5-0.5*DUM7*(YMUC(J+1)-YMUC(J-1))/((YMUC(J)**2)*DY)        GRADK  49
      DUM3=(CCG(I,J+1)-CCG(I,J-1))/DLY2                                 GRADK  50
      DUM1(I,J)=(DUM4+DUM5+(DUM2*DUM6+DUM3*DUM7)/CCGIJ)/HIJ             GRADK  51
    2 CONTINUE                                                          GRADK  52
C                                                                       GRADK  53
C******** CHECK FOR POINT TO POINT OSCILLATIONS IN WAVE PHASE GRADIENT  GRADK  54
C                                                                       GRADK  55
      DO 410 I=ISTART,IEND                                              GRADK  56
      DUM1(I,1)=DUM1(I,2)                                               GRADK  57
      DUM1(I,N)=DUM1(I,NM1)                                             GRADK  58
      SMU=4.0                                                           GRADK  59
      SBETA=0.25                                                        GRADK  60
      DO 409 J=1,N                                                      GRADK  61
      X(J)=DUM1(I,J)                                                    GRADK  62
  409 CONTINUE                                                          GRADK  63
      DO 408 J=3,NM2                                                    GRADK  64
      DUM2=ABS(X(J+1)-X(J))                                             GRADK  65
      DUM3=ABS(X(J)-X(J-1))                                             GRADK  66
      DUM4=ABS(X(J+1)-X(J-1))*0.5                                       GRADK  67
      IF((DUM2+DUM3).LT.(SMU*DUM4))GO TO 408                            GRADK  68
      DUM5=X(J+1)-2.0*X(J)+X(J-1)                                       GRADK  69
      DUM6=X(J+2)-2.0*X(J+1)+X(J)                                       GRADK  70
      DUM7=X(J)-2.0*X(J-1)+X(J-2)                                       GRADK  71
      IF((DUM5*DUM6).GE.0.0.AND.(DUM5*DUM7).GE.0.0)GO TO 408            GRADK  72
      DUM1(I,J)=X(J)+SBETA*(X(J+1)-2.0*X(J)+X(J-1))                     GRADK  73
  408 CONTINUE                                                          GRADK  74
  410 CONTINUE                                                          GRADK  75
C                                                                       GRADK  76
      DO 17 I=ISTART,IEND                                               GRADK  77
      DO 17 J=2,NM1                                                     GRADK  78
C                                                                       GRADK  79
C******** DO NOT INCLUDE DIFFRACTIVE EFFECTS INSIDE OR IMMEDIATELY      GRADK  80
C******** ADJACENT TO THE BREAKER ZONE                                  GRADK  81
C                                                                       GRADK  82
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      IBTEST=IBRKM(J-1)+IBRKM(J)+IBRKM(J+1)+IBRK(J-1)+IBRK(J)+          GRADK    83
     *       IBRK(J+1)                                                  GRADK    84
      IF(IBTEST.GT.0) GO TO 17                                          GRADK    85
C                                                                       GRADK    86
C******** LIMIT THE CHANGE IN THE GRADIENT OF THE WAVE PHASE FUNCTION    GRADK    87
C******** FROM THE DISPERSION RELATION WAVE NUMBER TO 50 PERCENT         GRADK    88
C                                                                       GRADK    89
      RKOLD=RKA(I,J)                                                    GRADK    90
      RKADD=0.25*RKOLD                                                  GRADK    91
      RKARG=RKOLD**2+DUM1(I,J)                                          GRADK    92
      IF(RKARG.LE.0.0)RKARG=((OMEG**2/G)**2)                            GRADK    93
      RKNEW=SQRT(RKARG)                                                 GRADK    94
      RKDIFF=RKNEW-RKOLD                                                GRADK    95
      IF(ABS(RKDIFF).LT.(0.0025*RKOLD))GO TO 17                         GRADK    96
      IF(ABS(RKDIFF).LE.RKADD)GO TO 341                                 GRADK    97
      IF(RKDIFF.LT.0.0)RKNEW=RKOLD-RKADD                                GRADK    98
      IF(RKDIFF.GE.0.0)RKNEW=RKOLD+RKADD                                GRADK    99
  341 GRDK(I,J)=RKNEW                                                   GRADK   100
   17 CONTINUE                                                          GRADK   101
C                                                                       GRADK   102
C******** SET LATERAL BOUNDARY CONDITIONS FOR THE GRADIENT OF THE WAVE   GRADK   103
C******** PHASE FUNCTION                                                 GRADK   104
C                                                                       GRADK   105
      DO 38 I=ISTART,IEND                                               GRADK   106
      GRDK(I,1)=GRDK(I,2)                                               GRADK   107
      GRDK(I,N)=GRDK(I,NM1)                                             GRADK   108
   38 CONTINUE                                                          GRADK   109
      RETURN                                                            GRADK   110
      END                                                               GRADK   111
C*********************************************************************** HEIGHT   2
C                                                                       HEIGHT   3
      SUBROUTINE HEIGHT(ISTART,IEND,ITMAX,WT,ALPHA,HCNV)                HEIGHT   4
C                                                                       HEIGHT   5
C*********************************************************************** HEIGHT   6
C                                                                       HEIGHT   7
C     THIS SUBROUTINE ITERATES TO SOLVE FOR THE WAVE HEIGHTS            HEIGHT   8
C     ALONG A GIVEN ROW                                                 HEIGHT   9
C                                                                       HEIGHT  10
C*********************************************************************** HEIGHT  11
C                                                                       PARAM    2
      PARAMETER(IQ=95,JQ=95)                                            PARAM    3
C                                                                       PARAM    4
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                        HEIGHT  13
      COMMON/WVH/H(IQ,JQ),CCG(IQ,JQ)                                    HEIGHT  14
      COMMON/DEPTHS/D(IQ,JQ)                                            HEIGHT  15
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                              HEIGHT  16
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    HEIGHT  17
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           HEIGHT  18
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         HEIGHT  19
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   HEIGHT  20
      COMMON/COOR/XX(IQ),YY(JQ)                                         HEIGHT  21
      COMMON /TRANE/ DECAY,STABL,IBRK(JQ),IBRKM(JQ)                     HEIGHT  22
      DIMENSION DM8(JQ),SLOPE(JQ)                                       HEIGHT  23
C                                                                       HEIGHT  24
C******** SOLVE DIFFERENCED FORM OF CONSERVATION OF WAVE ACTION EQUATION HEIGHT  25
C                                                                       HEIGHT  26
      DO 500 I=IEND,ISTART,-1                                           HEIGHT  27
      IM=I-1                                                            HEIGHT  28
      DO 450 IT=1,ITMAX                                                 HEIGHT  29
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    C                                                                       HEIGHT  30
          DO 200 J=2,NM1                                                    HEIGHT  31
             JP=J+1                                                         HEIGHT  32
             JM=J-1                                                         HEIGHT  33
             DM1=CCG(IM,JP)*GRDK(IM,JP)*SI(IM,JP)                           HEIGHT  34
             DM2=CCG(IM,JM)*GRDK(IM,JM)*SI(IM,JM)                           HEIGHT  35
             DM3=CCG(I,JP)*GRDK(I,JP)*SI(I,JP)                              HEIGHT  36
             DM4=CCG(I,JM)*GRDK(I,JM)*SI(I,JM)                              HEIGHT  37
             DM6=(WT*(DM1*H(IM,JP)**2-DM2*H(IM,JM)**2)                      HEIGHT  38
         -      /(DY2*YMUC(J)))+((1.0-WT)*(DM3*H(I,JP)**2-DM4*              HEIGHT  39
         -      H(I,JM)**2)/(DY2*YMUC(J)))                                  HEIGHT  40
    C                                                                       HEIGHT  41
             DM1=(CCG(I,J)*GRDK(I,J)*CO(I,J))*(H(I,J)*H(I,J))               HEIGHT  42
             DM2=(CCG(I,JM)*GRDK(I,JM)*CO(I,JM))*(H(I,JM)*H(I,JM))          HEIGHT  43
             DM3=(CCG(I,JP)*GRDK(I,JP)*CO(I,JP))*(H(I,JP)*H(I,JP))          HEIGHT  44
             DM4=CCG(IM,J)*GRDK(IM,J)*CO(IM,J)                              HEIGHT  45
             DM5=((DM6)*(DX*XMUS(IM))+ALPHA*DM2+                            HEIGHT  46
         -      (1.0-2.0*ALPHA)*DM1+ALPHA*DM3)/DM4                          HEIGHT  47
    C                                                                       HEIGHT  48
    C******** CONVERT AMPLITUDE FUNCTION TO WAVE HEIGHT                      HEIGHT  49
    C                                                                       HEIGHT  50
             DM7=DM5*(HEACT*HEACT)                                          HEIGHT  51
    C                                                                       HEIGHT  52
    C******** CHECK FOR WAVE HEIGHTS LESS THAN ZERO                          HEIGHT  53
    C                                                                       HEIGHT  54
             IF(DM7.LT.0.00001) DM7=0.00001                                 HEIGHT  55
             DM7=SQRT(DM7)                                                  HEIGHT  56
    C                                                                       HEIGHT  57
    C******** CHECK FOR WAVE BREAKING OR WAVE TRANSFORMATION                 HEIGHT  58
    C                                                                       HEIGHT  59
             IF(DM7.GT.STABL*D(IM,J)) THEN                                  HEIGHT  60
    C                                                                       HEIGHT  61
    C******** CALCULATE ANGLES AND CELLS OF INFLUENCE                        HEIGHT  62
    C                                                                       HEIGHT  63
1               THETA=Z(IM,J)-PI                                            HEIGHT  64
1               IF(THETA.GE.0.) THEN                                        HEIGHT  65
2                  X1=0.5*(XX(IM)+XX(I))-XX(IM)                             HEIGHT  66
2                  X2=XX(I)-XX(IM)                                          HEIGHT  67
2                  Y1=YY(J+1)-YY(J)                                         HEIGHT  68
2                  Y2=0.5*(YY(J)+YY(J+1))-YY(J)                             HEIGHT  69
2                  ANG1=ATAN2(Y1,X1)                                        HEIGHT  70
2                  ANG2=ATAN2(Y2,X2)                                        HEIGHT  71
2   C                                                                       HEIGHT  72
2                  IF(THETA.GT.ANG1) THEN                                   HEIGHT  73
3                     KEY=IBRK(J+1)                                         HEIGHT  74
3                     IKEY=IM                                               HEIGHT  75
3                     JKEY=J+1                                              HEIGHT  76
3                  ELSE IF(THETA.GT.ANG2) THEN                              HEIGHT  77
3                     KEY=IBRKM(J+1)                                        HEIGHT  78
3                     IKEY=I                                                HEIGHT  79
3                     JKEY=J+1                                              HEIGHT  80
3                  ELSE                                                     HEIGHT  81
3                     KEY=IBRKM(J)                                          HEIGHT  82
3                     IKEY=I                                                HEIGHT  83
3                     JKEY=J                                                HEIGHT  84
3                  ENDIF                                                    HEIGHT  85
3   C                                                                       HEIGHT  86
2               ELSE                                                        HEIGHT  87
2                  X3=XX(I)-XX(IM)                                          HEIGHT  88
```

```
               X4=0.5*(XX(IM)+XX(I))-XX(IM)
               Y3=0.5*(YY(J)+YY(J-1))-YY(J)
               Y4=YY(J-1)-YY(J)
               ANG3=ATAN2(Y3,X3)
               ANG4=ATAN2(Y4,X4)
C
               IF(THETA.GT.ANG3) THEN
                  KEY=IBRKM(J)
                  IKEY=I
                  JKEY=J
               ELSE IF(THETA.GT.ANG4) THEN
                  KEY=IBRKM(J-1)
                  IKEY=I
                  JKEY=J-1
               ELSE
                  KEY=IBRK(J-1)
                  IKEY=IM
                  JKEY=J-1
               ENDIF
            ENDIF
C
C******** COMPUTE INCIPIENT BREAKING WAVE HEIGHT USING METHOD FROM
C******** THE SHORE PROTECTION MANUAL (WEGGEL'S EMPIRICAL METHOD)
C
            JJ=(J+(JKEY-J-1)/2)
            DIST=SQRT((FLOAT(IKEY-IM)*DX*XMUS(IM))**2+
     -                (FLOAT(JKEY-J)*DY*YMUS(JJ))**2)
            SLOPE(J)=(D(IKEY,JKEY)-D(IM,J))/DIST
            SLOPE(J)=AMAX1(0.0,SLOPE(J))
            HSIG=1.0*DM7
            A1=43.75*(1.0-EXP(-19.0*SLOPE(J)))
            B1=1.56/(1.0+EXP(-19.5*SLOPE(J)))
            DEPBRK=HSIG/(B1-(A1*HSIG/(GAT*T)))
            IF(DEPBRK.GT.D(IM,J)) KEY=1
C
C******** CHECK WHETHER TO ACTUALLY TRANSFORM WAVE
C
            IF(KEY.EQ.1) THEN
               IBRK(J)=1
               DM1=0.5*(D(IKEY,JKEY)+D(IM,J))
               DM2=CCG(IKEY,JKEY)*GRDK(IKEY,JKEY)*(H(IKEY,JKEY)**2-
     -            (STABL*D(IKEY,JKEY)/HFACT)**2)-CCG(IM,J)*GRDK(IM,J)*
     -            (STABL*D(IM,J)/HFACT)**2
               DM3=DX*XMUS(IM)*DECAY/(2.0*DM1*DM4)
               DM5=(DM5+DM3*DM2)/(1.0-CCG(IM,J)*GRDK(IM,J)*DM3)
               DM7=DM5*(HFACT*HFACT)
               IF(DM7.LT.((STABL*D(IM,J))**2)) DM7=(STABL*D(IM,J))**2
               DM7=SQRT(DM7)
            ENDIF
         ENDIF
C
         DM8(J)=DM7
C
  200 CONTINUE
C
C******** CHECK FOR WAVE HEIGHT CONVERGENCE
C
      SUM=0.0
      DO 400 J=2,NM1
```

```
         DM7=DM8(J)                                                     HEIGHT   148
         HH2=H(IM,J)*HFACT                                              HEIGHT   149
C                                                                       HEIGHT   150
C******** UPDATE THE WAVE HEIGHT                                        HEIGHT   151
C                                                                       HEIGHT   152
         EPSZ=0.5                                                       HEIGHT   153
         DM7=EPSZ*DM7+(1.0-EPSZ)*HH2                                    HEIGHT   154
         SUM=SUM+ABS(DM7-HH2)                                           HEIGHT   155
C                                                                       HEIGHT   156
C******** CONVERT HEIGHT BACK TO AMPLITUDE FUNCTION                     HEIGHT   157
C                                                                       HEIGHT   158
         H(IM,J)=DM7/HFACT                                              HEIGHT   159
  400 CONTINUE                                                          HEIGHT   160
C                                                                       HEIGHT   161
C******** SET LATERAL BOUNDARY CONDITIONS FOR WAVE HEIGHT               HEIGHT   162
C                                                                       HEIGHT   163
      H(IM,1)=H(IM,2)                                                   HEIGHT   164
      H(IM,N)=H(IM,NM1)                                                 HEIGHT   165
C                                                                       HEIGHT   166
C******** TEST FOR CONVERGENCE                                          HEIGHT   167
C                                                                       HEIGHT   168
      IF(SUM.LT.(FLOAT(NM2)*HCNV)) GO TO 500                            HEIGHT   169
  450 CONTINUE                                                          HEIGHT   170
C                                                                       HEIGHT   171
      IF(IREF.EQ.1)GO TO 500                                            HEIGHT   172
      WRITE(6,475) IM                                                   HEIGHT   173
  475 FORMAT(1X,'RELAXATION FOR WAVE HEIGHTS FAILED ON ROW =',I4)       HEIGHT   174
C                                                                       HEIGHT   175
  500 CONTINUE                                                          HEIGHT   176
      RETURN                                                            HEIGHT   177
      END                                                               HEIGHT   178
C*********************************************************************** SNELL      2
C                                                                       SNELL      3
      SUBROUTINE SNELL (THETAO,HH)                                      SNELL      4
C                                                                       SNELL      5
C*********************************************************************** SNELL      6
C                                                                       SNELL      7
C     THIS SUBROUTINE COMPUTES THE SNELLS LAW SOLUTION OVER THE ENTIRE  SNELL      8
C     GRID                                                              SNELL      9
C                                                                       SNELL     10
C*********************************************************************** SNELL     11
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
C                                                                       PARAM      4
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                        SNELL     13
      COMMON/WVH/H(IQ,JQ),CCG(IQ,JQ)                                    SNELL     14
      COMMON/DEPTHS/D(IQ,JQ)                                            SNELL     15
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                              SNELL     16
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    SNELL     17
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           SNELL     18
      COMMON/PRINTC/IP1,IP2,INC,JP1,JP2,DMULT,HMULT,ZMULT,RKMULT        SNELL     19
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         SNELL     20
C                                                                       SNELL     21
C******** COMPUTE THE WAVE NUMBERS USING THE PADE APPROXIMATION         SNELL     22
C******** (SEE THE COASTAL ENGINEERING NOTEBOOK)                        SNELL     23
C                                                                       SNELL     24
      DO 1 I=IWET,M                                                     SNELL     25
      DO 1 J=1,N                                                        SNELL     26
      DD=D(I,J)                                                         SNELL     27
```

```
      DUM1=(OMEGA**2)*DD/G                                               SNELL     28
      DUM2=DUM1+1.0/(1.0+0.6522*DUM1+0.4622*                             SNELL     29
     *(DUM1**2)+0.0864*(DUM1**4)+0.0675*(DUM1**5))                       SNELL     30
      DUM3=T*SQRT(G*DD/DUM2)                                             SNELL     31
      RKNUM=PI2/DUM3                                                     SNELL     32
      RKA(I,J)=RKNUM                                                     SNELL     33
      GRDK(I,J)=RKNUM                                                    SNELL     34
C                                                                        SNELL     35
C******** COMPUTE THE HEIGHTS AND ANGLES USING SNELL'S LAW               SNELL     36
C******** COMPUTE SIGMA AND CCG                                          SNELL     37
C                                                                        SNELL     38
      DUM1=RKNUM*DD                                                      SNELL     39
      DUM2=2.0*DUM1                                                      SNELL     40
      DUM3=TANH(DUM1)                                                    SNELL     41
      DUM4=SINH(DUM2)                                                    SNELL     42
      SINE=SIN(THETAO-CNTRANG)*DUM3                                      SNELL     43
      ZANG=PI-ASIN(SINE)+CNTRANG                                         SNELL     44
      Z(I,J)=ZANG                                                        SNELL     45
      SI(I,J)=SIN(ZANG)                                                  SNELL     46
      CO(I,J)=COS(ZANG)                                                  SNELL     47
      DUM5=SQRT(COS(THETAO-CNTRANG)/COS(ZANG-CNTRANG))                   SNELL     48
      H(I,J)=HH*DUM5*SQRT(0.5/(0.5*(1.0+DUM2/DUM4)                       SNELL     49
     **DUM3))                                                            SNELL     50
      CCG(I,J)=0.5*(1.0+(DUM2/DUM4))*(OMEG**2)/                          SNELL     51
     *(RKNUM**2)                                                         SNELL     52
    1 CONTINUE                                                           SNELL     53
C                                                                        SNELL     54
C******** CHECK FOR WAVE BREAKING                                        SNELL     55
C                                                                        SNELL     56
      DO 600 I=IWET,M                                                    SNELL     57
      DO 604 J=1,N                                                       SNELL     58
      DUM5=H(I,J)                                                        SNELL     59
      HBRK=0.78*D(I,J)                                                   SNELL     60
      IF(DUM5.GE.HBRK) DUM5=HBRK                                         SNELL     61
C                                                                        SNELL     62
C********CONVERT HEIGHTS TO AMPLITUDE FUNCTION (H*G/2*SIGMA)             SNELL     63
C                                                                        SNELL     64
      H(I,J)=DUM5/HFACT                                                  SNELL     65
  604 CONTINUE                                                           SNELL     66
  600 CONTINUE                                                           SNELL     67
      RETURN                                                             SNELL     68
      END                                                                SNELL     69
C*********************************************************************** ANGLE      2
C                                                                        ANGLE      3
      SUBROUTINE ANGLE(ISTART,IEND,ITMAX,WT,ALPHA,SCNV)                  ANGLE      4
C                                                                        ANGLE      5
C*********************************************************************** ANGLE      6
C                                                                        ANGLE      7
C      THIS SUBROUTINE ITERATES TO SOLVE FOR THE WAVE ANGLES             ANGLE      8
C      ALONG A GIVEN ROW                                                 ANGLE      9
C                                                                        ANGLE     10
C*********************************************************************** ANGLE     11
C                                                                        PARAM      2
      PARAMETER(IQ=95,JQ=95)                                             PARAM      3
C                                                                        PARAM      4
      COMMON/ANGLES/Z(IQ,JQ),SI(IQ,JQ),CO(IQ,JQ)                         ANGLE     13
      COMMON/DEPTHS/D(IQ,JQ)                                             ANGLE     14
      COMMON/WAVNUM/RKA(IQ,JQ),GRDK(IQ,JQ)                               ANGLE     15
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,     ANGLE     16
```

```
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL          ANGLE   17
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         ANGLE   18
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   ANGLE   19
      DIMENSION DUM1(IQ,JQ),X(JQ)                                       ANGLE   20
C                                                                       ANGLE   21
C******** SOLVE THE DIFFERENCED FORM OF THE IRROTATIONALITY OF THE     ANGLE   22
C******** GRADIENT OF THE WAVE PHASE FUNCTION EQUATION                 ANGLE   23
C                                                                       ANGLE   24
      DO 1 I=IEND,ISTART,-1                                             ANGLE   25
      IM=I-1                                                            ANGLE   26
      DO 4 IT=1,ITMAX                                                   ANGLE   27
      DO 2 J=2,NM1                                                      ANGLE   28
      DUM6=ALPHA*(GRDK(I,J+1)*SI(I,J+1))                                ANGLE   29
     *         +(1.0-2.0*ALPHA)*(GRDK(I,J)*SI(I,J))                     ANGLE   30
     *         +ALPHA*(GRDK(I,J-1)*SI(I,J-1))                           ANGLE   31
      DUM2=WT*(GRDK(I-1,J+1)*CO(I-1,J+1)-GRDK(I-1,J-1)*                 ANGLE   32
     *CO(I-1,J-1))/(DY2*YMUC(J))                                        ANGLE   33
     *         +(1.0-WT)*(GRDK(I,J+1)*CO(I,J+1)-GRDK(I,J-1)*            ANGLE   34
     *CO(I,J-1))/(DY2*YMUC(J))                                          ANGLE   35
      DUM3=DUM6-(DX*XMUS(I-1))*DUM2                                     ANGLE   36
      DUM4=DUM3/GRDK(I-1,J)                                             ANGLE   37
      DUM1(I,J)=DUM4                                                    ANGLE   38
    2 CONTINUE                                                          ANGLE   39
      SUM=0.0                                                           ANGLE   40
      DO 22 J=2,NM1                                                     ANGLE   41
      DUM4=DUM1(I,J)                                                    ANGLE   42
      DUM5=Z(I-1,J)                                                     ANGLE   43
      DUM3=SIN(DUM5)                                                    ANGLE   44
C                                                                       ANGLE   45
C******** UPDATE THE SINES                                              ANGLE   46
C                                                                       ANGLE   47
      EPSZ=0.5                                                          ANGLE   48
      DUM4=EPSZ*DUM4+(1.0-EPSZ)*DUM3                                    ANGLE   49
C                                                                       ANGLE   50
C******** LIMIT OBLIQUE WAVE ANGLES                                     ANGLE   51
C                                                                       ANGLE   52
      IF(DUM4.GE.0.997)DUM4=0.997                                       ANGLE   53
      IF(DUM4.LE.-0.997)DUM4=-0.997                                     ANGLE   54
      DUM6=PI-ASIN(DUM4)                                                ANGLE   55
      SUM=SUM+ABS(DUM6-Z(IM,J))                                         ANGLE   56
      Z(IM,J)=DUM6                                                      ANGLE   57
      SI(IM,J)=DUM4                                                     ANGLE   58
      CO(IM,J)=COS(DUM6)                                                ANGLE   59
   22 CONTINUE                                                          ANGLE   60
C                                                                       ANGLE   61
C******** SET LATERAL BOUNDARY CONDITIONS FOR WAVE ANGLES,SINES,AND     ANGLE   62
C******** COSINES                                                       ANGLE   63
C                                                                       ANGLE   64
      Z(IM,1)=Z(IM,2)                                                   ANGLE   65
      CO(IM,1)=CO(IM,2)                                                 ANGLE   66
      SI(IM,1)=SI(IM,2)                                                 ANGLE   67
      Z(IM,N)=Z(IM,NM1)                                                 ANGLE   68
      CO(IM,N)=CO(IM,NM1)                                               ANGLE   69
      SI(IM,N)=SI(IM,NM1)                                               ANGLE   70
C                                                                       ANGLE   71
C******** CHECK FOR ANGLE CONVERGENCE                                   ANGLE   72
C                                                                       ANGLE   73
      IF(SUM.LT.(NM2*SCNV))GO TO 1                                      ANGLE   74
    4 CONTINUE                                                          ANGLE   75
```

```
      IF(IREF.EQ.1)GO TO 1                                              ANGLE     76
      WRITE(6,643)IM                                                    ANGLE     77
  643 FORMAT(1X,'RELAXATION FOR WAVE ANGLES FAILED ON ROW =',I4)         ANGLE     78
    1 CONTINUE                                                          ANGLE     79
   99 RETURN                                                            ANGLE     80
      END                                                               ANGLE     81
C*********************************************************************** DEPTH      2
C                                                                       DEPTH      3
      SUBROUTINE DEPTH                                                  DEPTH      4
C                                                                       DEPTH      5
C*********************************************************************** DEPTH      6
C                                                                       DEPTH      7
C     THIS SUBROUTINE GENERATES THE WATER DEPTH MATRIX                  DEPTH      8
C                                                                       DEPTH      9
C*********************************************************************** DEPTH     10
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
C                                                                       PARAM      4
      COMMON/DEPTHS/D(IQ,JQ)                                            DEPTH     12
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    DEPTH     13
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           DEPTH     14
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         DEPTH     15
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   DEPTH     16
      COMMON/COOR/XX(IQ),YY(JQ)                                         DEPTH     17
C                                                                       DEPTH     18
C******** READ IN VARIABLE BATHYMETRY FROM FILE CODE 8.  FIRST READ     DEPTH     19
C******** IN THE 'ALONGSHORE' ROW CLOSEST TO SHORE, THEN PROCEED        DEPTH     20
C******** ROW BY ROW IN THE OFFSHORE DIRECTION                          DEPTH     21
C                                                                       DEPTH     22
      DO 14 I=1,M                                                       DEPTH     23
      READ(8,50)(D(I,J),J=1,N)                                          DEPTH     24
   14 CONTINUE                                                          DEPTH     25
   50 FORMAT(10F8.2)                                                    DEPTH     26
   99 RETURN                                                            DEPTH     27
      END                                                               DEPTH     28
C*********************************************************************** POUT       2
C                                                                       POUT       3
      SUBROUTINE POUT(II1,II2,IVAL,JSTART,JEND,ITITLE,DUM1,FACT)        POUT       4
C                                                                       POUT       5
C*********************************************************************** POUT       6
C                                                                       POUT       7
C      THIS SUBROUTINE PRINTS OUT SELECTED VALUES OF A PARTICULAR ARRAY  POUT       8
C      ,DUM1, WHICH ARE SCALED BY THE VALUE OF 'FACT'                   POUT       9
C                                                                       POUT      10
C*********************************************************************** POUT      11
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
C                                                                       PARAM      4
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    POUT      13
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           POUT      14
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         POUT      15
      INTEGER IX(JQ+31),ITITLE(3)                                       POUT      16
      DIMENSION DUM1(IQ,JQ)                                             POUT      17
C                                                                       POUT      18
      NC=31                                                             POUT      19
      WRITE(6,100)ITITLE,FACT                                           POUT      20
  100 FORMAT(///,3A10,5X,'(MULTIPLIED BY ',F6.0,')')                    POUT      21
      J1=JSTART                                                         POUT      22
      J2=JSTART+NC-1                                                    POUT      23
```

```
    1 IF(J2.GT.JEND)J2=JEND                                             POUT      24
      WRITE(6,102)(J,J=J1,J2)                                           POUT      25
  102 FORMAT(/,3X,'I/J:',31I4)                                          POUT      26
      WRITE(6,103)                                                      POUT      27
  103 FORMAT(1X,'-----------------------------------------',            POUT      28
     *          '---------------------------------------',              POUT      29
     *          '-------------------------------------------------')    POUT      30
      DO 2 I=II1,II2,IVAL                                               POUT      31
      DO 3 J=J1,J2                                                      POUT      32
      RND=0.5                                                           POUT      33
      IF(DUM1(I,J).LT.0.0)RND=-0.5                                      POUT      34
    3 IX(J)=INT(FACT*DUM1(I,J)+RND)                                     POUT      35
    2 WRITE(6,104)I,(IX(J),J=J1,J2)                                     POUT      36
  104 FORMAT(1X,I3,2X,':',31I4)                                         POUT      37
      J1=J1+NC                                                          POUT      38
      J2=J2+NC                                                          POUT      39
      IF(J1.LE.JEND)GO TO 1                                             POUT      40
      WRITE(6,101)                                                      POUT      41
  101 FORMAT(//)                                                        POUT      42
      RETURN                                                            POUT      43
      END                                                               POUT      44
C*********************************************************************** GRID       2
C                                                                       GRID       3
      SUBROUTINE GRID                                                   GRID       4
C                                                                       GRID       5
C*********************************************************************** GRID       6
C                                                                       GRID       7
C      THIS SUBROUTINE READS THE VARIABLE GRID MAPPING INFORMATION FROM GRID       8
C      FILE CODE 3 (X REGION FIRST,THEN Y) AND GENERATES THE VARIABLE   GRID       9
C      GRID SCALE FACTORS AND DISTANCES TO THE GRID CENTERS             GRID      10
C                                                                       GRID      11
C      WHEN GENERATING A VARIABLY SIZED GRID IT IS RECCOMENDED THAT THE GRID      12
C      MAPPING BE DONE IN MAP INCEHES FROM SOME BATHYMETRIC CHART OF A  GRID      13
C      KNOWN SCALE. THE 'DX' AND 'DY' USED AS INPUT INTO THE MODEL ARE  GRID      14
C      THEN SIMPLY THE NUMBER OF FEET OR METERS PER MAP INCH.  IF MAP   GRID      15
C      INCHES ARE NOT USED IN THE MAPPING, THE VALUES OF 'XSCALE' AND   GRID      16
C      'YSCALE' CAN BE SET TO SOMETHING OTHER THAN 1.0 (IN CONJUNCTION  GRID      17
C      WITH THE CHOICE OF 'DX' AND 'DY') TO CONVERT FROM THE MAPPED     GRID      18
C      SPACE INTO REAL SPACE                                            GRID      19
C                                                                       GRID      20
C*********************************************************************** GRID      21
C                                                                       GRID      22
C  **DEFINITIONS OF VARIABLE GRID MAPPING INPUT REQUIRED BY THE MODEL   GRID      23
C                                                                       GRID      24
C      NREG(X,Y) - IS THE NUMBER OF MAPPING REGIONS IN THE X OR Y       GRID      25
C                  DIRECTION                                            GRID      26
C      NA(X,Y) - IS THE NUMBER OF GRID CELLS IN A PARTICULAR MAPPING    GRID      27
C                REGION IN THE X OR Y DIRECTION                         GRID      28
C      A(X,Y),B(X,Y),C(X,Y) - ARE THE MAPPING COEFFICIENTS FOR A        GRID      29
C             PARTICULAR REGION IN THE X OR Y DIRECTION                 GRID      30
C                                                                       GRID      31
C*********************************************************************** GRID      32
C                                                                       PARAM      2
      PARAMETER(IQ=95,JQ=95)                                            PARAM      3
C                                                                       PARAM      4
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    GRID      34
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           GRID      35
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         GRID      36
      COMMON/MUSC/XMUC(IQ),XMUS(IQ),YMUC(JQ),YMUS(JQ)                   GRID      37
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      COMMON/COOR/XX(IQ),YY(JQ)                                         GRID  38
      DIMENSION AX(50),BX(50),CX(50),NAX(50)                            GRID  39
      DIMENSION AY(50),BY(50),CY(50),NAY(50)                            GRID  40
      CHARACTER*1 STR                                                   GRID  41
C                                                                       GRID  42
      XSCALE=1.0                                                        GRID  43
      YSCALE=1.0                                                        GRID  44
C                                                                       GRID  45
C******** READ MAPPING INFORMATION                                      GRID  46
C                                                                       GRID  47
      J=1                                                               GRID  48
      I=1                                                               GRID  49
  21  CONTINUE                                                          GRID  50
      READ(3,31,END=999) STR,NST,NEND,A1,B1,C1                          GRID  51
  31  FORMAT(A1,7X,2I8,3G16.11)                                         GRID  52
      NEND=NEND-1                                                       GRID  53
      IF(STR.EQ.'Y') GO TO 20                                           GRID  54
      AX(I)=A1                                                          GRID  55
      BX(I)=B1                                                          GRID  56
      CX(I)=C1                                                          GRID  57
      DO 201 LLC=NST,NEND                                               GRID  58
      LL=LLC+1                                                          GRID  59
      ALPHC=LL-0.5                                                      GRID  60
      ALPHS=LL                                                          GRID  61
      XMUS(LL-1)=(B1*C1*(ALPHS**(C1-1.0)))*XSCALE                       GRID  62
      XMUC(LL-1)=(B1*C1*(ALPHC**(C1-1.0)))*XSCALE                       GRID  63
      XX(LL-1)=(A1+B1*(ALPHC**C1))*XSCALE*DX                            GRID  64
  201 CONTINUE                                                          GRID  65
      NAX(I)=NEND+1-NST                                                 GRID  66
      NXREG=I                                                           GRID  67
      I=I+1                                                             GRID  68
      GO TO 21                                                          GRID  69
   20 CONTINUE                                                          GRID  70
      AY(J)=A1                                                          GRID  71
      BY(J)=B1                                                          GRID  72
      CY(J)=C1                                                          GRID  73
      DO 203 LLC=NST,NEND                                               GRID  74
      LL=LLC+1                                                          GRID  75
      ALPHC=LL-0.5                                                      GRID  76
      ALPHS=LL                                                          GRID  77
      YMUS(LL-1)=(B1*C1*(ALPHS**(C1-1.0)))*YSCALE                       GRID  78
      YMUC(LL-1)=(B1*C1*(ALPHC**(C1-1.0)))*YSCALE                       GRID  79
      YY(LL-1)=(A1+B1*(ALPHC**C1))*YSCALE*DY                            GRID  80
  203 CONTINUE                                                          GRID  81
      NAY(J)=NEND+1-NST                                                 GRID  82
      NYREG=J                                                           GRID  83
      J=J+1                                                             GRID  84
      GO TO 21                                                          GRID  85
 999  CONTINUE                                                          GRID  86
C                                                                       GRID  87
C********  WRITE THE VARIABLE GRID INFORMATION ON FILE CODE 6           GRID  88
C                                                                       GRID  89
      WRITE(6,9)                                                        GRID  90
    9 FORMAT(////,20X,'VARIABLE WAVE GRID INFORMATION',///)             GRID  91
      WRITE(6,23)XSCALE,YSCALE                                          GRID  92
   23 FORMAT(///,'EXPANSION COEFFICIENT SCALE FACTORS',/,               GRID  93
     *'XSCALE=',F10.3,5X,'YSCALE=',F10.3,//)                            GRID  94
      WRITE(6,5)                                                        GRID  95
    5 FORMAT(1X,'X EXPANSION COEFS(A,B,C) AND GRIDS PER REGION',//)     GRID  96
```

```
      WRITE(6,4)(I,AX(I),BX(I),CX(I),NAX(I),I=1,NXREG)                  GRID  97
    4 FORMAT(I10,3E20.7,I10)                                            GRID  98
      WRITE(6,6)                                                        GRID  99
    6 FORMAT(///,1X,'Y EXPANSION COEFS(A,B,C) AND GRIDS PER REGION',//) GRID 100
      WRITE(6,4)(I,AY(I),BY(I),CY(I),NAY(I),I=1,NYREG)                  GRID 101
      WRITE(6,7)                                                        GRID 102
    7 FORMAT(///,1X,'X SCALE FACTORS (XMUC,XMUS)',//)                   GRID 103
      WRITE(6,2)(I,XMUC(I),XMUS(I),I=1,M)                               GRID 104
      WRITE(6,8)                                                        GRID 105
    8 FORMAT(///,1X,'Y SCALE FACTORS (YMUC,YMUS)',//)                   GRID 106
      WRITE(6,2)(I,YMUC(I),YMUS(I),I=1,N)                               GRID 107
    2 FORMAT(5(I5,2F10.5))                                              GRID 108
      WRITE(6,10)                                                       GRID 109
   10 FORMAT(///,1X,'X CENTER DISTANCES',//)                            GRID 110
      WRITE(6,11)(I,XX(I),I=1,M)                                        GRID 111
   11 FORMAT(8(I4,F12.3))                                               GRID 112
      WRITE(6,12)                                                       GRID 113
   12 FORMAT(///,1X,'Y CENTER DISTANCES',//)                            GRID 114
      WRITE(6,11)(J,YY(J),J=1,N)                                        GRID 115
      RETURN                                                            GRID 116
      END                                                               GRID 117
C*********************************************************************** ONBC   2
C                                                                       ONBC   3
      SUBROUTINE ONBC(DUM1)                                             ONBC   4
C                                                                       ONBC   5
C*********************************************************************** ONBC   6
C                                                                       ONBC   7
C       THIS SUBROUTINE SETS THE ONSHORE BOUNDARY CONDITION .           ONBC   8
C       THIS BOUNDARY CONDITION IS NOT USED IN THE COMPUTATIONAL SCHEME ONBC   9
C       SINCE IT PROCEEDS FROM OFFSHORE TOWARDS ONSHORE.                ONBC  10
C                                                                       ONBC  11
C*********************************************************************** ONBC  12
C                                                                       PARAM  2
      PARAMETER(IQ=95,JQ=95)                                            PARAM  3
C                                                                       PARAM  4
      COMMON/CONST/ G,PI,PI2,RAD,HCONVR,SCONVR,DX,DY,DX2,DY2,T,OMEG,    ONBC  14
     *M,N,M1,M2,NM1,NM2,IWET,IDRY,IWETP1,CNTRANG,HFACT,DLEVEL           ONBC  15
      COMMON/CONS2/IGRID,IREF,ITAMX,ITHMX,IDIFF                         ONBC  16
      DIMENSION DUM1(IQ,JQ)                                             ONBC  17
      DO 1 I=1,IDRY                                                     ONBC  18
      DO 1 J=1,N                                                        ONBC  19
      DUM1(I,J)=DUM1(IWET,J)                                            ONBC  20
    1 CONTINUE                                                          ONBC  21
      RETURN                                                            ONBC  22
      END                                                               ONBC  23
```

# APPENDIX G: SAMPLE FILES--FIELD RESEARCH FACILITY PIER, DUCK, NORTH CAROLINA, WAVE PROPAGATION EXAMPLE

```
/JOB
JOB,P3,T1000,CM377000.                           RESOURCE LIMITS SPECIFIED
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CEROQ2.                        WAVE MODEL IS OBTAINED
GET,UPDFL=DUCKUPD.                               MODIFICATIONS OBTAINED
GET,TAPE7=DUCKDAT.                               DATA OBTAINED
GET,TAPE8=DUCKDEP.          (SEE **NOTE** BELOW) BATHYMETRY OBTAINED
UPDATE(I=SR,N=NEWLIB,F,L=0)
UPDATE(P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F)         MODIFICATIONS ARE INCLUDED
FTN5,I=NEWPLUS,B=BIN,L=OUTPUT.                   WAVE MODEL IS COMPILED
LOAD,BIN.
EXECUTE.                                         WAVE MODEL IS EXECUTED
REWIND,TAPE6,OUTPUT.
REPLACE,TAPE6=RCPPRNT.                           PRINTED RESULTS ARE STORED
REPLACE,OUTPUT=RCPOTPT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.                                 DAYFILE IS STORED
EXIT.
REWIND,TAPE6,OUTPUT.
REPLACE,OUTPUT=RCPOTPT.
REPLACE,TAPE6=RCPPRNT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
```

```
COMMENT.********************************************************************
COMMENT.*
COMMENT.*             COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*             THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.********************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   DUCKUPD:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   DUCKDAT:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   DUCKDEP:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  OUTPUT FILE CONTAINING A LISTING OF THE PROGRAM
COMMENT.             COMPILATION AND ABORTED JOB INFORMATION.
COMMENT.
COMMENT.********************************************************************
/EOI
```

Figure G1.  DUCK865

```
/JOB
JOB,P3,T1000,CM377000.                          RESOURCE LIMIT CARD
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CER0Q2.                       WAVE MODEL IS OBTAINED
GET,UPDFL=DUCKUP2.                              MODIFICATIONS OBTAINED
UPDATE,I=SR,N=NEWLIB,F,L=0.
UPDATE,P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F.        MODIFICATIONS ARE INCLUDED
REPLACE,NEWPLUS.                                MODEL WITH MODIFICATIONS
*                                               MADE PERMANEANT FOR USE
*                                               ON THE CYBER 205
COPYBR,INPUT,SENDJOB,1.
SUBMIT,SENDJOB,T.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
/EOR
JOB205.
USER(U=       ,PA=       )ADY
RESOURCE(JCAT=P3,TL=2000)                       RESOURCE LIMITS CARD
/CHARGE
LINK,GET,NEWPLUS/DD=C6,UN=       ,FM=KOE,AF=AF205.
LINK,GET,TAPE7=DUCKDAT/DD=C6,UN=       ,FM=KOE,AF=AF205.
LINK,GET,TAPE8=DUCKDEP/DD=C6,UN=       ,FM=KOE,AF=AF205.
FORTRAN,I=NEWPLUS.
LOAD,CN=GO/6000,L=M205,GRLPALL= .
GO.
LINK,REPLACE,TAPE6=RCPPRNT/UN=       ,FM=KOE,DD=C6,AF=AF205.
SUMMARY.
EXIT.
LINK,REPLACE(TAPE6=RCPPRNT/UN=       ,FM=KOE,DD=C6,AF=AF205)
SUMMARY.
EXIT.
/EOF
```

```
COMMENT.*****************************************************************
COMMENT.*
COMMENT.*           COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*           THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.*****************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   DUCKUP2:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   DUCKDAT:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   DUCKDEP:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  DOES NOT EXIST ON THE CYBER205.
COMMENT.
COMMENT.*****************************************************************
/EOI
```

Figure G2. DUCK205

```
FIELD RESEARCH FACILITY (DUCK , NC) EXAMPLE
   75      12.0   50      24.0     9.800       0.0    2      0.90
      2.00     12.00     20.00
      1.50      8.00    -35.00
    1   50    1   11   41
    1
```

Figure G3. DUCKDAT

```
ID MODS
D PARAM.3
     PARAMETER(IQ=75,JQ=50)
D DEPTH.23,DEPTH.26
     DO 14 J=1,N
     READ(8,60)(D(I,J),I=1,M)
     DO 315 I=1,M
     D(I,J)=-D(I,J)
 315 CONTINUE
  60 FORMAT(5X/(15F8.2))
  14 CONTINUE
D MAIN.203
     DMULT=10.0
```

Figure G4. DUCKUPD

```
ID MODS
D PARAM.3
     PARAMETER(IQ=75,JQ=50)
D DEPTH.23,DEPTH.26
     DO 14 J=1,N
     READ(8,60)(D(I,J),I=1,M)
     DO 315 I=1,M
     D(I,J)=-D(I,J)
 315 CONTINUE
  60 FORMAT(5X/(15F8.2))
  14 CONTINUE
D MAIN.203
     DMULT=10.0
D MAIN.2
     PROGRAM RCPWAVE(INPUT,OUTPUT,TAPE7=TAPE7,TAPE6=TAPE6,TAPE8=TAPE8
    *,TAPE3=TAPE3)
```

Figure G5. DUCKUP2

```
1
 5.76   6.05   3.13   2.59   1.18   -.13  -1.62  -1.90  -1.03   -.92  -1.20  -1.44  -1.86  -2.29  -2.78
-3.08  -3.54  -3.83  -4.02  -4.08  -4.05  -3.99  -3.88  -3.81  -3.69  -3.67  -3.69  -3.75  -3.84  -3.93
-4.05  -4.22  -4.33  -4.45  -4.53  -4.69  -4.76  -4.94  -5.03  -5.12  -5.24  -5.37  -5.51  -5.64  -5.72
-5.82  -5.92  -5.97  -6.10  -6.22  -6.28  -6.40  -6.52  -6.60  -6.70  -6.74  -6.80  -6.88  -6.96  -7.01
-7.04  -7.16  -7.28  -7.31  -7.36  -7.41  -7.56  -7.62  -7.68  -7.74  -7.86  -7.92  -8.07  -8.14  -8.19
2
 5.61   4.95   3.49   2.23   1.06   -.23  -1.22  -1.55  -1.34  -1.14  -1.24  -1.53  -1.83  -2.38  -2.87
-3.23  -3.53  -3.83  -4.05  -4.11  -4.08  -4.00  -3.89  -3.80  -3.72  -3.68  -3.70  -3.75  -3.83  -3.92
-4.07  -4.23  -4.34  -4.43  -4.53  -4.65  -4.78  -4.92  -5.01  -5.11  -5.22  -5.35  -5.49  -5.61  -5.69
-5.78  -5.90  -5.99  -6.07  -6.16  -6.28  -6.39  -6.48  -6.58  -6.67  -6.74  -6.80  -6.88  -6.94  -6.99
-7.05  -7.15  -7.25  -7.30  -7.34  -7.43  -7.53  -7.61  -7.67  -7.74  -7.84  -7.93  -8.03  -8.09  -8.14
3
 5.45   4.77   3.65   2.27   1.14   -.13  -1.02  -1.38  -1.43  -1.36  -1.40  -1.61  -1.89  -2.47  -3.01
-3.37  -3.67  -3.94  -4.15  -4.20  -4.17  -4.06  -3.91  -3.81  -3.74  -3.70  -3.71  -3.75  -3.83  -3.91
-4.05  -4.20  -4.31  -4.40  -4.51  -4.62  -4.75  -4.87  -4.97  -5.09  -5.18  -5.28  -5.42  -5.53  -5.62
-5.72  -5.85  -5.94  -6.03  -6.12  -6.24  -6.36  -6.44  -6.55  -6.62  -6.72  -6.78  -6.86  -6.91  -6.96
-7.02  -7.13  -7.21  -7.26  -7.30  -7.40  -7.50  -7.59  -7.65  -7.71  -7.81  -7.89  -7.98  -8.01  -8.06
4
 5.66   4.90   3.67   2.44   1.32   -.00   -.91  -1.30  -1.50  -1.55  -1.56  -1.66  -1.94  -2.55  -3.10
-3.50  -3.83  -4.08  -4.25  -4.29  -4.27  -4.17  -3.95  -3.84  -3.76  -3.71  -3.70  -3.74  -3.82  -3.89
-4.02  -4.15  -4.27  -4.36  -4.47  -4.58  -4.69  -4.79  -4.90  -5.05  -5.14  -5.23  -5.35  -5.46  -5.56
-5.67  -5.78  -5.88  -6.00  -6.10  -6.21  -6.31  -6.40  -6.51  -6.59  -6.69  -6.75  -6.84  -6.88  -6.93
-6.99  -7.11  -7.17  -7.22  -7.26  -7.37  -7.47  -7.56  -7.63  -7.70  -7.78  -7.84  -7.91  -7.95  -7.99
5
 6.39   5.24   3.49   2.59   1.52    .02   -.91  -1.30  -1.55  -1.68  -1.66  -1.59  -1.92  -2.59  -3.13
-3.57  -3.93  -4.16  -4.32  -4.35  -4.33  -4.25  -4.02  -3.84  -3.77  -3.69  -3.67  -3.73  -3.79  -3.88
-3.98  -4.12  -4.23  -4.34  -4.43  -4.55  -4.64  -4.73  -4.86  -5.01  -5.11  -5.20  -5.32  -5.44  -5.55
-5.65  -5.75  -5.85  -5.98  -6.07  -6.20  -6.29  -6.38  -6.49  -6.58  -6.66  -6.76  -6.82  -6.87  -6.91
-6.98  -7.08  -7.16  -7.19  -7.24  -7.35  -7.46  -7.53  -7.62  -7.70  -7.77  -7.81  -7.87  -7.93  -7.98
6
 6.37   5.24   3.51   2.60   1.54    .06   -.88  -1.28  -1.54  -1.69  -1.67  -1.60  -1.94  -2.60  -3.14
-3.58  -3.95  -4.17  -4.33  -4.36  -4.33  -4.24  -4.00  -3.83  -3.76  -3.68  -3.67  -3.72  -3.79  -3.88
-3.97  -4.11  -4.23  -4.33  -4.42  -4.53  -4.63  -4.71  -4.84  -4.99  -5.09  -5.20  -5.31  -5.43  -5.53
-5.64  -5.74  -5.84  -5.98  -6.07  -6.20  -6.28  -6.38  -6.49  -6.59  -6.67  -6.76  -6.83  -6.88  -6.92
-6.99  -7.09  -7.16  -7.20  -7.25  -7.36  -7.47  -7.54  -7.63  -7.70  -7.77  -7.81  -7.87  -7.93  -7.97
```

Figure G6. DUCKDEP

```
R E G I O N A L   C O A S T A L   P R O C E S S E S   W A V E   T R A N S F O R M A T I O N   M O D E L
                                        ( R C P W A V E )


                       FIELD RESEARCH FACILITY (DUCK , NC) EXAMPLE



MODEL INPUT:


UNIFORMLY SIZED, RECTILINEAR GRID MESH

   X - DIRECTION (ON-OFFSHORE)       75 CELLS, EACH     12.00  IN LENGTH
   Y - DIRECTION (LONGSHORE)         50 CELLS, EACH     24.00  IN LENGTH

THE ACCELERATION OF GRAVITY IS    9.80.  THESE UNITS DETERMINE THE UNITS OF ALL INPUT AND OUTPUT VARIABLES

THE DEEP WATER WAVE PARAMETERS FOR CASE  1 ARE:     HEIGHT=  2.000     PERIOD= 12.000     ANGLE=  20.000
THE DEEP WATER WAVE PARAMETERS FOR CASE  2 ARE:     HEIGHT=  1.500     PERIOD=  8.000     ANGLE= -35.000

THE OFFSHORE CONTOURS MAKE AN ANGLE OF    .00 DEGREES WITH THE Y AXIS

THE BATHYMETRY MATRIX IS VARIABLE IN BOTH HORIZONTAL DIRECTIONS AND WAS READ FROM FILE CODE 8

A WATER LEVEL CHANGE OF    .90 WAS ADDED TO THE ENTIRE BATHYMETRY MATRIX
```

Figure G7. RCPPRNT

```
WATER DEPTHS                    (MULTIPLIED BY    10.)

 I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
---------------------------------------------------------------------------------------------------------

  1  :  3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
  2  :  3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
  3  :  3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3

  4  :  3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   4   4
  5  :  3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   8   9  13  15  14  15  14
  6  : 14  13  11  10   7   5   3   3   3   3   3   3   3   3   3   3  10  10  16  16  18  19  19  21  20
  7  : 22  21  19  21  16  19  13  11   8   6   5   5   7   6   8  10  16  15  17  18  20  20  22  21  23
  8  : 25  24  23  23  20  22  18  19  15  15  14  13  14  15  16  15  16  17  21  21  22  22  25  27  26
  9  : 24  24  22  19  20  18  18  17  17  16  16  16  16  17  16  17  18  19  23  24  25  26  28  29  29
 10  : 24  23  22  20  20  18  19  19  18  17  17  17  17  17  18  19  20  21  24  25  27  28  30  31  31
 11  : 25  24  23  22  21  20  20  20  19  17  18  18  18  19  18  20  20  22  25  26  28  29  31  33  32
 12  : 26  26  25  24  23  22  22  20  20  18  18  18  19  19  19  21  21  24  28  28  29  29  31  33  32
 13  : 29  29  28  28  27  27  26  24  23  21  21  21  21  21  22  24  25  27  30  31  31  31  32  29  33
 14  : 33  33  33  33  33  32  32  30  28  25  25  25  25  27  26  28  28  31  35  35  36  36  36  35  36
 15  : 36  36  37  36  37  37  38  38  36  31  30  30  32  33  30  32  34  36  40  40  41  41  42  42  42
 16  : 41  41  41  41  42  43  45  49  43  37  35  35  38  36  35  38  39  41  44  44  45  45  46  46  46
 17  : 45  45  46  46  48  49  50  52  47  41  40  40  44  42  40  43  44  45  48  48  47  47  48  49  48
 18  : 48  48  49  50  52  55  53  54  50  48  46  46  50  47  47  48  48  48  50  49  48  47  48  49  49
 19  : 49  49  50  51  53  56  55  56  54  52  51  51  54  54  50  52  51  50  50  49  47  46  47  47  48
 20  : 46  47  49  50  52  54  54  56  55  56  55  56  58  56  53  54  53  51  48  48  46  45  46  46  47
 21  : 43  43  46  46  50  53  53  52  55  58  58  58  61  60  56  56  54  51  47  46  45  45  45  45  46
 22  : 42  42  44  44  48  51  51  52  55  59  59  60  62  62  58  57  52  51  46  46  45  44  44  44  45
 23  : 41  41  42  42  45  47  49  52  54  58  60  61  63  62  64  58  52  50  46  46  45  44  44  44  45
 24  : 42  42  41  41  44  45  48  50  53  57  59  62  64  63  65  58  49  49  47  46  45  45  45  44  45
 25  : 42  42  42  42  43  43  46  48  51  55  59  61  64  63  61  57  49  49  47  47  46  45  45  45  45
 26  : 43  43  42  42  43  42  45  47  50  54  57  60  64  64  59  57  49  50  48  48  47  46  46  46  46
 27  : 44  44  43  42  43  42  45  47  50  53  56  59  65  64  57  57  51  51  49  49  48  47  47  47  47
 28  : 45  45  44  43  44  43  45  47  50  53  55  59  65  63  57  57  52  52  51  50  49  48  48  47  47
 29  : 46  46  45  45  45  43  46  47  50  53  56  60  65  64  59  57  52  52  51  51  50  49  49  48  48
 30  : 48  47  47  46  46  45  47  48  50  54  57  61  66  64  58  58  53  53  52  52  51  50  50  49  49
 31  : 49  49  49  49  48  46  48  49  52  55  58  63  68  66  61  60  54  54  53  53  52  51  51  50  51
 32  : 50  50  51  51  50  49  50  51  54  57  60  64  69  67  60  61  56  55  55  54  53  53  52  52  52
 33  : 51  52  53  53  52  52  53  53  56  59  61  65  70  69  62  62  56  56  55  55  54  53  53  53  53
 34  : 53  53  55  56  55  54  55  57  58  61  63  66  72  71  63  64  59  57  56  56  55  55  54  54  54
 35  : 54  55  57  58  57  57  58  58  61  63  65  69  74  73  67  66  59  58  57  57  56  56  55  55  55
 36  : 55  56  59  60  60  59  61  62  64  66  68  73  78  74  69  67  61  59  58  58  57  56  56  56  56
 37  : 57  58  61  63  63  63  65  65  67  68  70  74  79  75  67  67  60  60  59  58  58  57  57  57  57
 38  : 58  60  64  66  66  67  67  68  69  72  73  76  80  77  68  68  61  61  60  60  59  58  58  58  59
 39  : 60  61  66  67  69  70  71  72  73  75  76  79  82  78  73  70  63  62  61  61  60  59  60  59  60
 40  : 61  62  67  69  71  74  74  76  77  78  79  81  84  79  70  71  63  63  63  62  61  61  61  61  61
 41  : 62  64  69  71  74  77  77  79  79  80  81  83  86  80  71  71  64  64  64  63  63  62  62  62  62
 42  : 64  65  71  73  76  79  79  81  81  82  82  83  86  82  76  72  65  65  65  65  63  63  63  63  63
 43  : 65  67  72  75  77  80  80  82  82  83  83  84  86  82  74  73  66  66  66  66  65  65  64  64  64
 44  : 67  68  73  76  79  83  81  82  82  83  83  84  87  82  73  74  69  68  67  67  66  66  66  65  65
 45  : 68  69  74  76  79  82  82  82  82  83  83  84  88  85  78  75  70  69  68  68  67  67  67  66  66
```

Figure G8. RCPPRNT (Sheet 1 of 9)

```
WAVE CONDITION  1

THE DEEP WATER WAVE PARAMETERS FOR CASE  1 ARE:    HEIGHT=  2.000    PERIOD= 12.000    ANGLE=  20.000


 BREAKER    INDEX              (MULTIPLIED BY     1.)

 I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
----------------------------------------------------------------------------------------------------------
  1 :   0   0  11   0   0   0  11  11  11  11  11  11  11  11  11  11  11   0   0  11  11   0   0   0   0
  2 :   0   0  11   0   0   0  11  11  11  11  11  11  11  11  11  11  11   0   0  11  11   0   0   0   0
  3 :  11  11  11   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11   0  11  11  11  11  11  11
  4 :  11  11  11   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  5 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  6 :  11  11  11   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  7 :  11  11  11   0   0   0  11   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  8 :  11  11  11   0   0   0  11   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  9 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 10 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 11 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 12 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 13 :   0   0   0   0   0   0   0   0   0  11  11  11  11  11  11  11  11  11   0   0   0   0   0   0   0
 14 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 15 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 16 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 17 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 18 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 19 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 20 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 21 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 22 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 23 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 24 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 25 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 26 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 27 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 28 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 29 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 30 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 31 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 32 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 33 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 34 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 35 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 36 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 37 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 38 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 39 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 40 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 41 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 42 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 43 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 44 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 45 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Figure G8. (Sheet 2 of 9)

```
WAVE ANGLES    (DEG)             (MULTIPLIED BY      1.)

I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
-------------------------------------------------------------------------------------------------------------
 1  :   3   2   1   2  -1  -4  -3  -2  -1  -1   1   2   3   4   6   8  10  10   8   6   4   4   4   4   3
 2  :   3   2   1   2  -1  -4  -3  -2  -1  -1   1   2   3   4   6   8  10  10   8   6   4   4   4   4   3
 3  :   3   1   1   3  -2  -5  -2  -2  -1  -1   1   2   3   3   5   8  10  10   9   6   4   4   5   4   3
 4  :   3   1   1   0  -1  -3  -3  -1  -1  -1   1   2   3   3   5   8  10  11   9   5   4   3   5   5   3
 5  :   3   1   1   0  -1  -3  -3  -1  -1  -1   0   2   3   3   5   9   9  12  17   8  10   7   6   6   5
 6  :   6   2   2   0  -2  -4  -3  -1  -2  -1   0   2   3   3   3  10  18   9  11   7   7   7   7   7   5
 7  :   5   4   6   5   5   4   0  -1  -3  -2   0   4   4   4   5   7   9   7   8   6   6   7   7   6   6
 8  :   5   5   6   6   6   6   5   3   1   2   3   4   4   3   2   3   5   8   7   5   5   7   8   6   5
 9  :   4   6   6   7   7   7   6   4   2   2   4   4   3   2   2   3   4   6   6   5   5   6   7   6   6
10  :   5   7   8   8   7   7   7   4   2   3   4   4   3   2   2   3   4   5   5   4   5   6   7   6   6
11  :   6   8   9   9   9   8   7   5   3   3   4   5   3   1   1   2   3   4   4   3   4   5   7   6   6
12  :   7   9  10  11  10   9   7   5   4   3   4   5   3   1   1   1   2   3   3   2   3   5   6   6   6
13  :   7   9  11  12  12  11   9   6   4   4   5   5   3   1   0   0   1   2   2   1   3   4   5   6   6
14  :   8  10  12  13  14  13  11   8   5   5   6   5   3   0  -1  -1   0   1   1   1   3   4   5   6   6
15  :   8  11  13  14  15  15  14  10   7   6   7   6   4  -1  -2  -1  -2  -1   0   1   3   5   6   7   7
16  :   9  11  13  15  16  15  15  13   9   7   7   7   3  -1  -2  -2  -3  -2  -1   0   3   5   6   7   7
17  :   9  12  14  15  17  16  16  14  11   9   8   7   4  -1  -2  -3  -4  -3  -1   0   3   5   6   7   7
18  :  10  12  14  15  17  17  16  15  13  11   9   8   4  -1  -3  -4  -5  -4  -2   0   3   5   6   7   7
19  :  10  12  14  15  17  17  17  17  15  13  10   8   4  -1  -3  -5  -6  -4  -2   1   3   5   6   7   7
20  :  10  12  13  14  16  16  17  17  16  14  11   8   4   0  -3  -5  -6  -4  -2   1   3   5   6   7   7
21  :   9  11  12  13  15  16  16  17  17  15  12   9   4   0  -4  -6  -6  -4  -1   2   3   5   6   6   7
22  :   9  10  11  12  14  15  16  17  17  15  12   9   5   0  -4  -6  -5  -3   0   2   3   5   6   6   7
23  :   9  10  10  11  13  14  15  16  16  15  12   9   5   0  -4  -7  -5  -2   1   3   4   5   6   6   7
24  :  10  10  10  10  11  13  14  15  16  15  13   9   5   0  -4  -6  -4  -1   1   3   4   5   6   6   7
25  :  10  10  10  10  10  12  14  14  15  14  13   9   5   0  -3  -5  -3   0   2   3   4   5   6   6   7
26  :  11  10  10   9  10  11  13  13  14  14  12  10   5  -1  -3  -4  -3   1   2   4   4   5   6   6   7
27  :  11  11  10   9   9  10  12  13  13  13  12  10   5  -1  -3  -3  -2   1   3   4   5   5   6   6   7
28  :  12  11  10   9   9  10  11  12  13  12  11   9   5  -1  -3  -3  -2   1   3   4   5   6   6   6   7
29  :  12  11  11  10   9  10  11  11  12  12  11   9   5   0  -2  -3  -1   2   4   5   5   6   6   7   7
30  :  12  12  11  10   9   9  10  11  11  11  11   9   5   0  -2  -2  -1   2   4   5   5   6   6   7   7
31  :  13  13  12  10   9   9  10  10  11  11  10   8   5   0  -2  -2   0   2   4   5   6   6   7   7   7
32  :  13  13  12  11   9   9  10  10  11  11  10   8   4   0  -1  -1   0   3   4   5   6   6   7   7   7
33  :  13  14  13  11  10   9   9  10  10  10   9   8   4   0  -1  -1   0   3   5   6   6   7   7   7   7
34  :  13  14  13  11  10   9   9   9  10  10   9   8   5   0  -1   0   1   3   5   6   6   7   7   7   7
35  :  13  14  14  12  10  10   9   9   9   9   9   8   5   1   0   0   1   4   5   6   6   7   7   7   8
36  :  13  14  13  12  11  10   9   9   9   9   9   8   4   1   0   0   2   4   6   6   7   7   7   7   8
37  :  13  14  14  12  11  10   9   9   9   9   8   7   4   1   1   1   2   5   6   7   7   7   7   8   8
38  :  13  14  14  12  11  10   9   9   9   9   8   7   4   1   1   2   3   5   6   7   7   7   7   8   8
39  :  13  14  14  12  11  10   9   9   9   9   8   7   5   2   2   2   3   6   7   7   7   7   8   8   8
40  :  13  13  13  12  11  10   9   9   8   8   8   8   5   2   2   3   4   6   7   7   7   7   8   8   8
41  :  12  13  13  12  11  10   9   9   8   8   8   8   6   3   3   3   4   7   7   7   7   7   8   8   8
42  :  12  13  13  12  11  10   9   9   8   8   8   8   6   4   4   4   5   7   8   8   7   8   8   8   8
43  :  12  12  12  11  11  10   9   8   8   8   8   8   6   4   4   5   5   7   8   8   8   8   8   8   8
44  :  11  12  12  11  11  10   9   8   8   8   8   8   6   5   5   5   6   7   8   8   8   8   8   8   8
45  :  11  11  11  11  10   9   9   8   8   8   8   8   7   5   5   6   6   8   8   8   8   8   8   8   8
```

Figure G8. (Sheet 3 of 9)

```
WAVE HEIGHTS                    (MULTIPLIED BY    10.)

I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
---------------------------------------------------------------------------------------------------------
 1 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 2 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 3 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 4 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   4   5   4   4   5
 5 :   3   3   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2   6   6   7   7   7   8   8
 6 :   8   8   7  10   6   7   4   1   1   1   1   1   1   1   1   3   6   6   7   7   8   8   9   9  10
 7 :  10   9   9   9   8   7   7   8   6   5   5   5   5   5   6   6   7   7   8   9   9  10  10  11  11
 8 :  10  10   9   8   8   7   7   7   7   6   6   6   6   7   7   7   7   8   9  10  10  11  12  12  12
 9 :  10  10   9   9   8   7   8   7   7   7   7   7   7   7   7   8   8   9  10  11  12  12  13  13  13
10 :  12  11  11  10   9   9   9   8   8   7   7   7   7   8   8   8   9  10  12  13  13  14  14  15  15
11 :  14  14  14  13  12  12  11  10   9   8   8   8   8   8   9  10  11  13  15  16  16  16  17  17  16
12 :  19  19  19  19  18  17  16  15  13  12  10  10  10  11  12  13  14  17  20  22  22  21  21  20  20
13 :  27  27  27  27  26  25  24  24  23  15  15  14  15  16  16  18  20  21  30  30  30  29  27  27  26
14 :  26  27  26  26  26  25  23  22  22  22  21  21  20  21  24  26  28  29  29  29  28  28  27  26  25
15 :  26  26  26  26  25  24  23  21  21  21  21  20  19  21  23  25  27  28  28  28  27  27  26  25  24
16 :  25  25  25  25  24  24  23  21  20  20  20  19  19  20  22  24  26  27  28  27  27  26  25  24  24
17 :  24  24  24  24  24  23  22  21  20  20  19  19  18  19  21  23  26  27  27  27  26  25  25  24  24
18 :  23  23  23  24  24  23  23  21  20  19  19  18  18  19  21  23  25  27  27  26  26  25  25  24  24
19 :  23  23  23  23  23  23  23  22  20  19  18  18  18  19  21  23  25  27  27  26  26  25  25  24  24
20 :  23  23  23  23  23  23  23  22  21  19  18  18  18  19  21  23  25  26  27  26  26  25  25  24  24
21 :  23  23  23  24  24  23  23  23  21  19  18  18  18  18  21  23  25  26  27  26  25  25  25  24  24
22 :  23  23  23  24  24  24  23  23  21  20  19  18  18  19  20  23  25  26  27  26  25  25  25  24  24
23 :  23  23  23  23  24  24  24  23  22  20  19  18  18  19  20  23  26  26  26  26  25  25  25  24  24
24 :  23  23  23  23  24  24  24  23  22  21  19  18  18  19  20  23  26  26  26  25  25  25  24  24  24
25 :  23  23  23  23  23  24  24  23  22  21  20  19  18  19  21  23  26  26  26  25  25  24  24  24  24
26 :  23  23  23  23  23  24  24  23  22  21  20  19  18  19  21  23  26  26  26  25  25  24  24  24  24
27 :  23  23  22  23  23  24  24  23  23  22  20  19  19  19  22  23  25  26  25  25  24  24  24  24  24
28 :  23  23  22  22  23  24  24  23  23  22  21  19  19  20  22  24  25  26  25  24  24  24  24  24  24
29 :  23  23  22  22  23  23  23  23  23  22  21  20  19  20  22  24  25  25  25  24  24  24  24  24  23
30 :  23  23  22  22  23  23  23  23  23  22  21  20  19  20  22  24  25  25  25  24  24  24  24  24  23
31 :  23  23  22  22  22  23  23  23  23  22  21  20  19  20  22  23  25  25  24  24  24  23  23  23  23
32 :  23  23  22  22  22  23  23  23  23  22  21  20  19  20  22  23  25  25  24  24  23  23  23  23  23
33 :  23  23  22  22  22  22  22  23  22  22  21  20  20  20  22  23  24  24  24  23  23  23  23  23  23
34 :  23  23  22  21  22  22  22  22  22  22  21  20  20  20  22  23  24  24  24  23  23  23  23  23  23
35 :  23  23  22  21  22  22  22  22  22  22  21  20  20  20  22  23  24  24  23  23  23  23  23  23  23
36 :  23  23  22  21  21  22  22  22  22  22  21  20  20  21  22  23  24  24  23  23  23  23  23  23  23
37 :  23  22  22  21  21  21  22  22  22  22  21  20  20  20  22  23  24  24  23  23  23  23  23  23  23
38 :  23  22  22  21  21  21  21  22  22  21  21  20  20  20  22  23  24  23  23  23  23  23  23  23  22
39 :  23  22  22  21  21  21  21  21  21  21  21  20  20  20  22  22  23  23  23  22  22  23  23  23  22
40 :  23  22  22  21  21  21  21  21  21  21  21  20  20  21  22  22  23  23  23  22  22  22  23  23  22
41 :  22  22  21  21  21  21  21  21  21  21  21  20  20  21  22  22  23  23  22  22  22  22  22  22  22
42 :  22  22  21  21  21  21  21  21  21  21  21  21  20  21  22  22  23  23  22  22  22  22  22  22  22
43 :  22  22  21  21  21  21  21  21  21  21  21  21  20  21  22  22  23  23  22  22  22  22  22  22  22
44 :  22  22  21  21  21  21  21  21  21  21  21  21  20  20  21  22  22  22  22  22  22  22  22  22  22
45 :  22  22  21  21  21  21  21  21  21  21  21  21  20  20  21  22  22  22  22  22  22  22  22  22  22
```

Figure G8. (Sheet 4 of 9)

WAVE NUMBER (MULTIPLIED BY 1000.)

| I/J: | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 : | 303 | 303 | 303 | 303 | 300 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 |
| 2 : | 303 | 303 | 303 | 303 | 300 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 |
| 3 : | 303 | 303 | 303 | 303 | 245 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 |
| 4 : | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 253 | 275 |
| 5 : | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 182 | 176 | 148 | 136 | 144 | 139 | 142 |
| 6 : | 142 | 146 | 163 | 165 | 205 | 230 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 172 | 170 | 134 | 134 | 127 | 122 | 122 | 116 | 120 |
| 7 : | 114 | 116 | 121 | 116 | 132 | 122 | 150 | 156 | 184 | 210 | 230 | 235 | 207 | 213 | 182 | 168 | 134 | 138 | 129 | 125 | 121 | 119 | 114 | 116 | 111 |
| 8 : | 108 | 109 | 112 | 111 | 119 | 115 | 127 | 123 | 137 | 139 | 144 | 146 | 140 | 137 | 132 | 138 | 135 | 128 | 118 | 116 | 114 | 113 | 107 | 103 | 105 |
| 9 : | 108 | 109 | 115 | 121 | 120 | 127 | 125 | 130 | 129 | 132 | 133 | 134 | 133 | 131 | 133 | 128 | 126 | 121 | 112 | 110 | 107 | 105 | 102 | 100 | 100 |
| 10 : | 110 | 112 | 114 | 119 | 120 | 128 | 123 | 122 | 126 | 131 | 130 | 130 | 128 | 128 | 125 | 124 | 120 | 116 | 108 | 107 | 103 | 101 | 98 | 96 | 97 |
| 11 : | 108 | 109 | 112 | 114 | 117 | 120 | 120 | 120 | 124 | 128 | 128 | 127 | 124 | 124 | 125 | 121 | 118 | 113 | 108 | 105 | 101 | 100 | 96 | 93 | 95 |
| 12 : | 104 | 105 | 108 | 109 | 111 | 114 | 114 | 120 | 119 | 125 | 125 | 124 | 122 | 122 | 122 | 117 | 116 | 110 | 102 | 101 | 100 | 99 | 96 | 94 | 95 |
| 13 : | 100 | 100 | 101 | 102 | 103 | 103 | 106 | 109 | 112 | 116 | 117 | 118 | 116 | 115 | 113 | 110 | 107 | 103 | 97 | 96 | 96 | 96 | 94 | 98 | 94 |
| 14 : | 93 | 93 | 93 | 94 | 93 | 94 | 95 | 99 | 101 | 106 | 107 | 108 | 107 | 104 | 106 | 101 | 101 | 96 | 91 | 91 | 90 | 90 | 90 | 91 | 90 |
| 15 : | 89 | 89 | 86 | 89 | 88 | 87 | 87 | 88 | 91 | 97 | 98 | 98 | 96 | 94 | 98 | 95 | 93 | 90 | 86 | 85 | 84 | 84 | 84 | 83 | 84 |
| 16 : | 84 | 85 | 84 | 84 | 83 | 83 | 81 | 78 | 83 | 89 | 91 | 91 | 88 | 90 | 91 | 88 | 86 | 84 | 81 | 81 | 81 | 81 | 81 | 80 | 80 |
| 17 : | 82 | 82 | 81 | 80 | 78 | 78 | 77 | 76 | 79 | 85 | 86 | 85 | 82 | 84 | 86 | 83 | 81 | 80 | 79 | 79 | 79 | 79 | 78 | 78 | 78 |
| 18 : | 79 | 79 | 78 | 78 | 76 | 73 | 74 | 75 | 78 | 78 | 80 | 81 | 77 | 79 | 80 | 79 | 78 | 78 | 77 | 77 | 78 | 79 | 78 | 78 | 78 |
| 19 : | 78 | 78 | 77 | 76 | 75 | 72 | 73 | 73 | 74 | 76 | 76 | 76 | 75 | 74 | 77 | 76 | 76 | 76 | 77 | 77 | 79 | 80 | 79 | 79 | 78 |
| 20 : | 79 | 79 | 77 | 77 | 75 | 74 | 74 | 71 | 73 | 74 | 74 | 73 | 73 | 74 | 74 | 74 | 74 | 75 | 77 | 78 | 80 | 80 | 80 | 80 | 79 |
| 21 : | 83 | 82 | 80 | 79 | 76 | 74 | 74 | 74 | 73 | 72 | 72 | 72 | 71 | 71 | 73 | 73 | 74 | 75 | 79 | 79 | 80 | 81 | 81 | 81 | 80 |
| 22 : | 83 | 83 | 82 | 81 | 78 | 76 | 76 | 75 | 74 | 71 | 71 | 71 | 70 | 70 | 73 | 72 | 75 | 76 | 79 | 80 | 81 | 81 | 81 | 81 | 81 |
| 23 : | 84 | 84 | 83 | 83 | 80 | 78 | 77 | 75 | 73 | 71 | 71 | 71 | 69 | 70 | 69 | 71 | 74 | 76 | 80 | 80 | 81 | 82 | 81 | 82 | 81 |
| 24 : | 84 | 84 | 84 | 84 | 82 | 80 | 78 | 76 | 74 | 72 | 71 | 70 | 69 | 69 | 68 | 71 | 76 | 76 | 79 | 80 | 80 | 81 | 81 | 81 | 81 |
| 25 : | 83 | 83 | 84 | 84 | 82 | 82 | 79 | 78 | 76 | 73 | 71 | 70 | 69 | 70 | 70 | 71 | 77 | 77 | 79 | 79 | 80 | 80 | 80 | 81 | 81 |
| 26 : | 83 | 83 | 83 | 83 | 83 | 82 | 80 | 79 | 77 | 74 | 72 | 70 | 70 | 69 | 71 | 72 | 77 | 77 | 78 | 78 | 79 | 79 | 80 | 80 | 80 |
| 27 : | 81 | 82 | 83 | 83 | 82 | 83 | 81 | 79 | 76 | 74 | 72 | 71 | 69 | 69 | 71 | 72 | 76 | 76 | 77 | 77 | 78 | 79 | 79 | 79 | 79 |
| 28 : | 80 | 81 | 82 | 82 | 82 | 82 | 80 | 79 | 77 | 74 | 73 | 71 | 68 | 69 | 73 | 72 | 74 | 75 | 76 | 77 | 78 | 78 | 78 | 79 | 79 |
| 29 : | 79 | 80 | 81 | 81 | 81 | 82 | 80 | 79 | 77 | 75 | 73 | 70 | 68 | 69 | 70 | 72 | 75 | 75 | 76 | 76 | 77 | 77 | 78 | 78 | 78 |
| 30 : | 78 | 79 | 80 | 80 | 80 | 80 | 79 | 78 | 76 | 74 | 72 | 70 | 68 | 68 | 72 | 71 | 74 | 74 | 75 | 75 | 76 | 76 | 77 | 77 | 77 |
| 31 : | 77 | 77 | 78 | 78 | 78 | 79 | 78 | 77 | 75 | 73 | 71 | 69 | 67 | 67 | 68 | 70 | 73 | 73 | 74 | 75 | 75 | 76 | 76 | 76 | 76 |
| 32 : | 77 | 76 | 77 | 76 | 77 | 78 | 76 | 75 | 74 | 71 | 70 | 69 | 67 | 68 | 70 | 70 | 72 | 73 | 74 | 74 | 75 | 75 | 75 | 75 | 75 |
| 33 : | 76 | 75 | 75 | 75 | 75 | 75 | 75 | 74 | 73 | 71 | 70 | 67 | 66 | 67 | 69 | 70 | 73 | 73 | 73 | 73 | 74 | 74 | 74 | 75 | 75 |
| 34 : | 75 | 74 | 73 | 73 | 73 | 74 | 73 | 72 | 71 | 70 | 69 | 67 | 65 | 65 | 69 | 69 | 70 | 72 | 73 | 73 | 73 | 74 | 74 | 74 | 74 |
| 35 : | 74 | 73 | 72 | 71 | 72 | 72 | 71 | 71 | 70 | 68 | 67 | 67 | 65 | 64 | 67 | 67 | 71 | 71 | 72 | 72 | 73 | 73 | 73 | 73 | 73 |
| 36 : | 73 | 73 | 71 | 71 | 70 | 71 | 69 | 69 | 68 | 67 | 66 | 64 | 63 | 64 | 65 | 66 | 69 | 71 | 72 | 72 | 72 | 73 | 73 | 73 | 73 |
| 37 : | 72 | 72 | 70 | 69 | 69 | 69 | 68 | 67 | 66 | 66 | 65 | 64 | 62 | 64 | 67 | 67 | 70 | 70 | 71 | 71 | 72 | 72 | 72 | 72 | 72 |
| 38 : | 71 | 70 | 68 | 67 | 67 | 67 | 67 | 66 | 66 | 64 | 64 | 63 | 62 | 64 | 67 | 67 | 69 | 70 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| 39 : | 70 | 69 | 67 | 67 | 66 | 66 | 65 | 65 | 64 | 63 | 63 | 62 | 62 | 63 | 64 | 65 | 69 | 69 | 70 | 70 | 71 | 71 | 71 | 71 | 70 |
| 40 : | 70 | 69 | 67 | 66 | 65 | 64 | 64 | 63 | 63 | 62 | 62 | 61 | 60 | 62 | 65 | 65 | 68 | 68 | 69 | 69 | 70 | 70 | 70 | 70 | 70 |
| 41 : | 69 | 68 | 66 | 65 | 64 | 63 | 62 | 62 | 62 | 61 | 61 | 61 | 59 | 61 | 65 | 64 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 69 | 69 |
| 42 : | 68 | 68 | 65 | 64 | 63 | 62 | 62 | 61 | 61 | 61 | 61 | 60 | 59 | 60 | 62 | 64 | 67 | 67 | 68 | 68 | 68 | 69 | 69 | 69 | 69 |
| 43 : | 68 | 67 | 65 | 63 | 62 | 62 | 61 | 61 | 61 | 61 | 60 | 60 | 61 | 61 | 64 | 64 | 67 | 67 | 67 | 68 | 68 | 68 | 68 | 68 | 68 |
| 44 : | 67 | 66 | 64 | 63 | 62 | 60 | 61 | 61 | 61 | 60 | 60 | 60 | 61 | 63 | 65 | 64 | 66 | 66 | 67 | 67 | 67 | 67 | 67 | 68 | 68 |
| 45 : | 66 | 66 | 64 | 63 | 62 | 61 | 61 | 61 | 61 | 61 | 61 | 60 | 60 | 61 | 62 | 63 | 65 | 66 | 66 | 67 | 67 | 67 | 67 | 67 | 67 |

Figure G8. (Sheet 5 of 9)

```
WAVE CONDITION   2

THE DEEP WATER WAVE PARAMETERS FOR CASE  2 ARE:     HEIGHT=  1.500     PERIOD=  8.000     ANGLE= -35.000

 BREAKER    INDEX              (MULTIPLIED BY      1.)

 I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
---------------------------------------------------------------------------------------------------------

  1 :   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11   0   0   0   0
  2 :   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11   0   0   0   0
  3 :   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  4 :   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  5 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
  6 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11   0   0   0  11  11  11  11
  7 :   0  11  11  11  11  11   0  11  11  11  11  11  11  11  11  11   0   0   0   0   0   0   0   0   0
  8 :   0  11  11  11  11  11   0  11  11  11  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0
  9 :   0  11  11  11  11  11   0  11  11  11  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0
 10 :   0  11  11  11  11  11   0  11  11  11  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0
 11 :   0   0   0   0   0  11   0  11  11  11  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0
 12 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 13 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 14 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 15 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 16 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 17 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 18 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 19 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 20 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 21 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 22 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 23 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 24 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 25 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 26 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 27 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 28 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 29 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 30 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 31 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 32 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 33 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 34 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 35 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 36 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 37 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 38 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 39 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 40 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 41 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 42 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 43 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 44 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 45 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Figure G8. (Sheet 6 of 9)

```
 WAVE ANGLES     (DEG)             (MULTIPLIED BY      1.)

 I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
-------------------------------------------------------------------------------------------------------

  1 :  -4  -6  -7  -8  -9  -9  -8  -7  -7  -6  -5  -3  -2  -1   1   3   4   4   3   0  -2  -3  -3  -4  -5
  2 :  -4  -6  -7  -8  -9  -9  -8  -7  -7  -6  -5  -3  -2  -1   1   3   4   4   3   0  -2  -3  -3  -4  -5
  3 :  -5  -7  -8  -9  -9  -9  -8  -7  -7  -6  -5  -3  -2  -1   1   3   4   5   3   0  -2  -4  -3  -4  -5
  4 :  -4  -6  -7  -7  -8  -9  -8  -7  -7  -6  -5  -3  -2  -1   1   3   4   5   4  -1  -2  -4  -3  -4  -5
  5 :  -4  -6  -7  -7  -8  -9  -9  -7  -7  -6  -5  -2  -1  -1   0   4   4   6   8  -3  -4 -10 -11 -11 -11
  6 :  -9 -14 -12 -14 -12 -12  -9  -6  -7  -6  -5  -2  -1  -1  -1   5   8  -1  -2  -8 -10 -12 -12 -14 -13
  7 : -15 -16 -14 -14 -10 -11 -11 -11 -12  -9  -6  -2  -2  -2  -2  -2  -3  -5  -6 -10 -12 -13 -14 -14 -15
  8 : -17 -17 -15 -13 -11 -10  -9 -10 -11  -9  -7  -5  -4  -5  -7  -7  -6  -5  -8 -12 -14 -15 -15 -17 -16
  9 : -17 -16 -14 -11 -10  -8  -7  -9 -10  -9  -7  -5  -5  -7  -7  -7  -8  -7 -10 -14 -16 -17 -17 -18 -17
 10 : -17 -14 -13 -10  -9  -7  -7  -9 -10  -9  -7  -5  -5  -7  -8  -8  -9  -9 -12 -15 -18 -18 -18 -19 -18
 11 : -16 -14 -12 -10  -8  -7  -7  -9 -10  -9  -7  -5  -6  -8  -8  -9 -10 -11 -13 -17 -19 -20 -19 -20 -18
 12 : -16 -14 -11  -9  -8  -7  -8  -8  -9  -9  -7  -5  -6  -8  -9 -10 -11 -12 -15 -19 -21 -21 -21 -20 -19
 13 : -16 -14 -11  -9  -8  -7  -8  -8 -10  -9  -7  -6  -6  -9 -10 -12 -13 -15 -18 -21 -22 -22 -22 -19 -18
 14 : -17 -14 -12  -9  -8  -7  -7  -8 -10 -10  -7  -6  -7 -11 -12 -13 -15 -17 -21 -23 -24 -24 -22 -20 -19
 15 : -18 -14 -12 -10  -8  -7  -7  -8 -11 -10  -7  -6  -8 -12 -14 -15 -18 -20 -23 -26 -26 -26 -24 -22 -20
 16 : -18 -15 -12 -10  -8  -8  -7  -9 -11 -10  -8  -6  -9 -13 -15 -17 -21 -23 -26 -28 -28 -27 -24 -22 -20
 17 : -18 -15 -13 -10  -9  -9  -8  -9  -9  -9  -8  -7 -10 -14 -16 -19 -23 -26 -28 -30 -29 -27 -24 -23 -21
 18 : -18 -15 -13 -11  -9  -9  -9  -9  -8  -8  -8  -8 -11 -15 -18 -22 -25 -28 -30 -31 -29 -27 -24 -22 -20
 19 : -18 -15 -13 -11 -10 -10  -9  -8  -8  -7  -8  -9 -11 -16 -19 -23 -27 -30 -31 -31 -29 -26 -23 -22 -20
 20 : -17 -14 -13 -11 -10  -9  -9  -8  -7  -7  -8  -9 -12 -16 -20 -25 -29 -31 -31 -29 -27 -25 -23 -21 -20
 21 : -16 -14 -13 -11 -10 -10  -9  -8  -7  -7  -8  -9 -12 -17 -21 -26 -30 -31 -30 -28 -26 -24 -22 -21 -19
 22 : -15 -14 -13 -11 -10 -10  -9  -8  -7  -7  -9 -10 -13 -17 -22 -27 -30 -31 -29 -27 -26 -24 -22 -20 -19
 23 : -15 -13 -13 -11 -11 -10  -9  -8  -8  -8  -9 -10 -13 -17 -23 -29 -30 -30 -28 -26 -25 -23 -22 -20 -19
 24 : -14 -13 -13 -11 -11 -10  -9  -9  -8  -8  -9 -10 -13 -18 -24 -29 -29 -29 -27 -26 -25 -23 -21 -20 -19
 25 : -14 -13 -13 -12 -12 -11 -10  -9  -9  -9  -9 -10 -14 -19 -24 -28 -29 -28 -27 -26 -24 -23 -21 -20 -19
 26 : -14 -13 -12 -12 -12 -11 -10 -10  -9  -9 -10 -11 -14 -20 -24 -28 -28 -28 -27 -25 -24 -22 -21 -20 -19
 27 : -14 -13 -12 -12 -12 -11 -11 -10 -10 -10 -10 -11 -14 -21 -24 -27 -28 -28 -27 -25 -24 -22 -21 -19 -18
 28 : -14 -13 -12 -12 -12 -12 -11 -11 -11 -11 -11 -12 -15 -21 -24 -27 -28 -28 -26 -25 -23 -22 -21 -19 -18
 29 : -14 -13 -12 -12 -13 -12 -12 -12 -11 -12 -12 -12 -16 -21 -25 -27 -28 -27 -26 -25 -23 -22 -20 -19 -18
 30 : -13 -12 -12 -12 -13 -12 -12 -12 -12 -12 -13 -13 -17 -22 -24 -27 -28 -27 -26 -24 -23 -21 -20 -19 -18
 31 : -13 -12 -12 -12 -13 -13 -13 -13 -13 -13 -14 -14 -17 -23 -26 -28 -28 -27 -26 -24 -23 -21 -20 -19 -19
 32 : -13 -12 -11 -12 -13 -13 -13 -14 -14 -14 -15 -15 -18 -23 -25 -28 -28 -27 -26 -24 -22 -21 -20 -19 -19
 33 : -13 -12 -11 -12 -13 -14 -14 -14 -15 -15 -15 -16 -19 -24 -26 -28 -28 -27 -25 -23 -22 -21 -20 -19 -19
 34 : -14 -12 -12 -12 -14 -14 -14 -15 -16 -16 -16 -17 -19 -24 -26 -28 -29 -27 -25 -23 -22 -21 -20 -19 -19
 35 : -14 -12 -12 -13 -14 -14 -15 -16 -16 -17 -17 -17 -20 -25 -27 -29 -28 -27 -24 -23 -21 -20 -20 -19 -19
 36 : -14 -12 -12 -13 -14 -15 -16 -17 -17 -18 -18 -19 -21 -25 -27 -29 -28 -26 -24 -22 -21 -20 -20 -19 -19
 37 : -14 -13 -13 -13 -14 -15 -17 -17 -18 -19 -19 -19 -22 -26 -27 -28 -28 -25 -23 -22 -21 -20 -20 -19 -19
 38 : -14 -13 -13 -14 -15 -16 -17 -18 -19 -20 -20 -20 -22 -26 -27 -28 -27 -25 -23 -22 -21 -20 -20 -20 -19
 39 : -15 -14 -14 -14 -15 -17 -18 -19 -20 -21 -21 -21 -23 -26 -27 -28 -27 -24 -23 -22 -21 -20 -20 -20 -20
 40 : -15 -14 -14 -15 -16 -17 -19 -20 -21 -21 -22 -22 -23 -27 -27 -27 -26 -24 -22 -21 -21 -20 -20 -20 -20
 41 : -16 -15 -15 -16 -17 -18 -19 -21 -21 -22 -22 -22 -24 -26 -26 -27 -26 -24 -22 -21 -21 -20 -20 -20 -20
 42 : -16 -15 -15 -16 -17 -19 -20 -21 -22 -22 -23 -22 -24 -26 -26 -27 -25 -23 -22 -21 -21 -20 -20 -20 -20
 43 : -17 -16 -16 -17 -18 -19 -21 -22 -22 -23 -23 -23 -24 -26 -26 -26 -25 -23 -22 -21 -21 -20 -20 -20 -20
 44 : -17 -16 -17 -18 -19 -20 -21 -22 -22 -23 -23 -23 -24 -26 -25 -25 -24 -23 -21 -21 -21 -21 -21 -20 -20
 45 : -17 -17 -18 -18 -19 -20 -21 -22 -23 -23 -23 -23 -24 -25 -25 -25 -24 -22 -21 -21 -21 -21 -21 -21 -20
```

Figure G8. (Sheet 7 of 9)

```
WAVE HEIGHTS                     (MULTIPLIED BY     10.)

I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
-------------------------------------------------------------------------------------------------------------
  1 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  2 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  3 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  4 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2   1   4   4   4   4   4
  5 :   1   1   1   1   1   1   2   1   1   1   1   1   1   1   1   1   2   4   5   6   7   9   8   9   9
  6 :  10   9   8   8   6   8   1   2   1   1   1   1   2   1   1   5   5   6  13  13  15  11  11  12  13
  7 :  17  11   9   9   8   9  12   8   6   5   5   5   3   4   6   5  12  12  12  13  15  16  17  19  19
  8 :  18  12  10   9   8   9  12   8   7   7   6   7  12  13  12  13  12  12  12  13  14  16  17  18  19
  9 :  18  12  10   9   9   9  14   9   7   7   7   7  12  13  12  12  12  12  12  13  14  16  17  18  19
 10 :  19  14  13  12  11  11  15  10   8   8   7   8  13  13  12  12  12  12  12  13  14  16  17  18  19
 11 :  19  19  19  19  18  12  17  11  10  10   9   9  13  13  12  12  12  12  12  13  15  16  17  18  19
 12 :  18  19  19  18  18  17  16  16  16  16  16  15  13  12  12  12  12  12  12  13  15  17  18  19  19
 13 :  18  18  18  18  17  16  16  15  15  16  15  14  13  12  12  11  11  11  12  13  15  17  18  19  19
 14 :  18  18  18  17  16  15  15  15  15  15  15  14  12  12  11  11  11  11  12  14  15  17  18  18  18
 15 :  17  17  17  16  16  15  14  14  14  14  14  13  12  11  11  11  11  11  12  14  15  17  18  18  18
 16 :  17  17  17  16  15  14  14  13  14  14  13  13  11  11  11  10  11  11  12  14  16  17  17  17  17
 17 :  17  16  16  15  15  14  14  13  13  13  13  12  11  11  10  10  11  12  13  14  16  17  17  17  17
 18 :  16  16  16  15  14  14  14  13  13  13  13  12  11  11  10  10  11  12  13  15  16  17  17  17  17
 19 :  16  16  15  15  14  14  13  13  13  13  12  12  11  10  10  10  11  12  14  15  16  17  17  17  17
 20 :  16  16  15  15  14  14  13  13  13  13  12  12  11  10  10  10  11  13  14  16  17  17  17  17  16
 21 :  16  16  15  15  14  14  13  13  13  13  12  12  11  10  10  11  12  13  15  16  17  17  17  17  16
 22 :  16  16  15  15  14  14  13  13  13  13  12  12  11  11  10  11  12  14  15  16  17  17  17  17  16
 23 :  16  16  15  15  14  14  13  13  13  13  12  12  11  11  10  11  13  14  15  16  17  17  17  17  16
 24 :  16  16  15  15  14  14  13  13  13  13  12  12  11  11  11  12  13  14  15  16  17  17  17  16  16
 25 :  16  15  15  15  14  14  13  13  13  13  12  12  11  11  11  12  13  14  15  16  17  17  16  16  16
 26 :  16  15  15  14  14  14  13  13  13  13  13  12  11  11  11  12  13  14  15  16  16  17  16  16  16
 27 :  16  15  15  14  14  14  13  13  13  13  13  12  11  11  12  12  13  14  15  16  16  16  16  16  15
 28 :  15  15  15  14  14  14  13  13  13  13  13  12  12  11  12  12  14  15  15  16  16  16  16  16  15
 29 :  15  15  14  14  14  14  13  13  13  13  13  12  12  12  12  13  14  15  16  16  16  16  16  15  15
 30 :  15  15  14  14  14  13  13  13  13  13  13  12  12  12  12  13  14  15  16  16  16  16  15  15  15
 31 :  15  15  14  14  13  13  13  13  13  13  13  13  12  12  12  13  14  15  16  16  16  16  15  15  15
 32 :  15  15  14  13  13  13  13  13  13  13  13  13  12  12  13  13  14  15  16  16  16  15  15  15  15
 33 :  15  14  14  13  13  13  13  13  13  13  13  13  12  12  13  13  14  15  16  16  15  15  15  15  14
 34 :  15  14  14  13  13  13  13  13  13  13  13  13  12  12  13  13  14  15  16  16  15  15  15  15  14
 35 :  14  14  14  13  13  13  13  13  13  13  13  13  12  13  13  14  15  15  15  15  15  15  15  14  14
 36 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  13  14  15  15  15  15  15  15  14  14  14
 37 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  13  14  15  15  15  15  15  15  14  14  14
 38 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  13  14  15  15  15  15  15  14  14  14  14
 39 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  14  14  15  15  15  15  14  14  14  14  14
 40 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  14  14  15  15  15  15  14  14  14  14  14
 41 :  14  14  13  13  13  13  13  13  13  13  13  13  13  13  14  14  15  15  15  14  14  14  14  14  14
 42 :  14  13  13  13  13  13  13  13  13  13  13  13  13  13  14  14  14  15  14  14  14  14  14  14  14
 43 :  14  13  13  13  13  13  13  13  13  13  13  13  13  13  14  14  14  14  14  14  14  14  14  14  14
 44 :  14  13  13  13  13  13  13  13  13  13  13  13  13  14  14  14  14  14  14  14  14  14  14  14  14
 45 :  13  13  13  13  13  13  13  13  13  13  13  13  13  14  14  14  14  14  14  14  14  14  14  14  14
```

Figure G8. (Sheet 8 of 9)

```
WAVE NUMBER                    (MULTIPLIED BY  1000.)

I/J:  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38
----------------------------------------------------------------------------------------------------------

 1  : 454 454 455 455 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456
 2  : 454 454 455 455 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456
 3  : 404 405 415 415 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456
 4  : 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 380 414
 5  : 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 456 275 266 223 206 218 210 215
 6  : 215 221 245 249 309 347 456 456 456 456 456 456 456 456 456 456 260 256 203 203 192 186 185 176 182
 7  : 174 177 184 177 202 185 227 238 278 316 347 353 311 321 275 254 203 208 195 190 183 181 173 177 168
 8  : 164 166 170 169 180 174 192 186 208 210 218 221 212 206 200 210 204 194 179 177 173 172 164 157 160
 9  : 165 166 174 184 183 192 189 197 195 199 201 203 202 199 202 195 192 184 171 168 163 161 156 153 153
10  : 167 170 173 180 183 193 187 186 192 198 198 197 194 194 190 188 182 177 165 163 157 155 151 147 148
11  : 164 166 169 173 177 182 182 182 188 194 193 192 189 187 189 183 179 172 164 161 155 152 147 143 145
12  : 159 160 163 165 169 173 173 182 181 189 189 188 184 184 186 178 175 167 156 154 152 151 145 142 144
13  : 152 153 154 155 156 157 161 167 169 176 177 179 177 175 172 168 163 158 149 148 148 147 145 151 144
14  : 143 144 143 144 143 144 146 150 154 162 163 164 162 158 161 155 154 147 140 139 138 138 137 139 137
15  : 137 137 136 137 135 135 134 134 138 148 150 150 145 144 150 145 142 138 132 131 129 129 129 127 128
16  : 129 130 130 130 128 127 124 120 127 136 140 139 134 137 139 135 133 130 126 125 124 124 123 123 122
17  : 125 124 123 123 121 120 119 116 122 129 131 131 126 129 131 127 126 124 122 121 121 121 121 120 120
18  : 120 121 120 119 117 114 115 115 118 120 123 123 119 122 122 122 122 121 119 119 120 121 121 120 120
19  : 120 120 118 117 115 113 114 113 115 116 117 117 114 115 118 117 118 119 119 119 122 122 122 122 121
20  : 122 122 120 119 117 115 114 112 113 113 113 113 112 113 115 115 116 117 120 121 123 124 123 123 122
21  : 127 126 123 122 118 115 116 116 114 111 111 111 109 109 113 113 115 117 122 122 124 125 124 124 123
22  : 128 128 126 126 121 118 117 116 114 110 110 109 108 108 112 112 116 117 122 123 124 125 125 125 124
23  : 129 129 128 128 124 121 119 117 114 111 110 109 107 108 107 111 116 118 123 123 125 126 125 126 125
24  : 129 129 129 129 126 124 121 118 116 112 110 108 107 107 106 111 119 119 122 123 124 125 125 125 125
25  : 128 128 128 129 127 126 123 120 117 113 110 108 107 107 109 111 119 119 121 122 123 124 124 124 124
26  : 127 127 128 128 127 128 124 122 118 115 112 109 107 107 110 112 119 119 120 121 122 123 123 123 123
27  : 125 126 127 127 127 128 125 122 118 115 113 110 106 106 111 112 118 117 119 120 121 121 122 122 122
28  : 124 124 126 126 126 126 124 122 119 116 113 110 106 107 112 112 116 117 118 118 120 120 121 122 121
29  : 122 123 124 124 125 126 123 122 119 116 113 109 106 107 110 111 116 116 117 117 118 119 120 120 120
30  : 121 121 122 123 123 124 122 120 118 115 112 109 105 107 112 111 115 115 116 116 118 118 119 119 119
31  : 120 120 120 120 121 123 120 119 117 114 111 107 104 105 108 110 114 114 115 115 116 117 118 118 118
32  : 118 118 118 118 119 120 118 117 115 111 109 107 103 104 109 109 113 113 114 114 115 116 116 117 117
33  : 117 117 115 115 116 117 116 115 113 110 108 105 103 103 108 108 112 113 113 114 115 115 115 116 116
34  : 116 115 114 113 114 115 113 112 111 109 107 104 101 102 107 106 110 112 112 113 114 114 114 115 115
35  : 115 114 112 111 111 112 111 111 109 107 105 103 100 101 105 105 110 110 111 112 113 113 113 114 113
36  : 113 113 110 109 109 110 108 108 106 105 104 100  98 100 103 105 108 110 111 111 112 113 113 113 113
37  : 112 111 108 107 107 107 106 106 104 103 102 100  98  99 104 104 109 109 110 111 111 111 112 112 112
38  : 111 109 106 105 105 104 104 104 103 101 100  99  97  99 104 104 108 108 109 110 110 111 111 111 110
39  : 110 108 105 104 103 102 102 101 100 100  99  97  96  98 100 103 107 108 108 109 110 110 110 110 109
40  : 109 108 104 103 102 100 100  99  98  98  97  96  95  97 102 102 107 107 107 108 108 109 109 109 109
41  : 108 107 103 102 100  99  98  97  97  97  96  96  94  97 102 102 106 106 107 107 107 108 108 108 108
42  : 107 106 102 101  99  97  97  96  97  96  96  95  94  96  99 101 105 106 106 106 107 107 107 107 107
43  : 105 105 101 100  98  97  97  96  96  96  95  95  94  96 100 101 105 105 105 105 106 106 106 106 106
44  : 104 104 100  99  98  96  96  96  96  95  95  95  94  96 101 100 103 104 104 104 105 105 105 106 105
45  : 104 103 100  99  97  96  96  96  96  96  96  95  94  95  98  99 102 103 104 104 104 104 105 105 105
```

Figure G8. (Sheet 9 of 9)

# APPENDIX H: SAMPLE FILES--HOMER SPIT, ALASKA, WAVE PROPAGATION EXAMPLE

```
/JOB
JOB,P3,T1000,CM377000.                          RESOURCE LIMITS SPECIFIED
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CER092.                       WAVE MODEL IS OBTAINED
GET,UPDFL=HOMRUPD.                              MODIFICATIONS OBTAINED
GET,TAPE7=HOMRDAT.                              DATA OBTAINED
GET,TAPE8=HOMRDEP.         (SEE **NOTE** BELOW) BATHYMETRY OBTAINED
UPDATE(I=SR,N=NEWLIB,F,L=0)
UPDATE(P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F)        MODIFICATIONS ARE INCLUDED
FTN5,I=NEWPLUS,B=BIN,L=OUTPUT.                  WAVE MODEL IS COMPILED
LOAD,BIN.
EXECUTE.                                        WAVE MODEL IS EXECUTED
REWIND,TAPE6,OUTPUT.
REPLACE,TAPE6=RCPPRNT.                          PRINTED RESULTS ARE STORED
REPLACE,OUTPUT=RCPOTPT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.                                DAYFILE IS STORED
EXIT.
REWIND,TAPE6,OUTPUT.
REPLACE,OUTPUT=RCPOTPT.
REPLACE,TAPE6=RCPPRNT.
COST.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
```

```
COMMENT.******************************************************************
COMMENT.*
COMMENT.*            COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*            THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.******************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   HOMRUPD:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   HOMRDAT:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   HOMRDEP:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  OUTPUT FILE CONTAINING A LISTING OF THE PROGRAM
COMMENT.             COMPILATION AND ABORTED JOB INFORMATION.
COMMENT.
COMMENT.******************************************************************
/EOI
```

Figure H1. HOMR865

```
/JOB
JOB,P3,T1000,CM377000.                           RESOURCE LIMIT CARD
/USER
/CHARGE
GET,SR=RCPWAVE/UN=CER0Q2.                        WAVE MODEL IS OBTAINED
GET,UPDFL=HOMRUP2.                               MODIFICATIONS OBTAINED
UPDATE,I=SR,N=NEWLIB,F,L=0.
UPDATE,P=NEWLIB,I=UPDFL,C=NEWPLUS,L=0,F.         MODIFICATIONS ARE INCLUDED
REPLACE,NEWPLUS.                                 MODEL WITH MODIFICATIONS
*                                                MADE PERMANEANT FOR USE
*                                                ON THE CYBER 205
COPYBR,INPUT,SENDJOB,1.
SUBMIT,SENDJOB,T.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
EXIT.
DAYFILE,L=RCPDAYF.
REPLACE,RCPDAYF.
/EOR
JOB205.
USER(U=      ,PA=      )ADY
RESOURCE(JCAT=P3,TL=2000)                        RESOURCE LIMITS CARD
/CHARGE
LINK,GET,NEWPLUS/DD=C6,UN=      ,FM=KOE,AF=AF205.
LINK,GET,TAPE7=HOMRDAT/DD=C6,UN=      ,FM=KOE,AF=AF205.
LINK,GET,TAPE8=HOMRDEP/DD=C6,UN=      ,FM=KOE,AF=AF205.
FORTRAN,I=NEWPLUS.
LOAD,CN=GO/6000,L=M205,GRLPALL= .
GO.
LINK,REPLACE,TAPE6=RCPPRNT/UN=      ,FM=KOE,DD=C6,AF=AF205.
SUMMARY.
EXIT.
LINK,REPLACE(TAPE6=RCPPRNT/UN=      ,FM=KOE,DD=C6,AF=AF205)
SUMMARY.
EXIT.
/EOF
```

```
COMMENT.******************************************************************
COMMENT.*
COMMENT.*           COMMENTS CONCERNING FILES REQUIRED BY
COMMENT.*           THE ABOVE JOB CONTROL LANGUAGE  (JCL)
COMMENT.*
COMMENT.******************************************************************
COMMENT.
COMMENT.   RCPWAVE:  SOURCE CODE FOR THE WAVE PROPAGATION MODEL.
COMMENT.
COMMENT.   HOMRUP2:  UPDATE FILE CONTAINING MODIFICATIONS TO
COMMENT.             THE SOURCE CODE.
COMMENT.
COMMENT.   HOMRDAT:  DATA FILE SPECIFYING GRID GEOMETRY AND WAVE
COMMENT.             CHARACTERISTICS CONSIDERED.
COMMENT.             (LOGICAL UNIT DEVICE TAPE7)
COMMENT.
COMMENT.   HOMRDEP:  DATA FILE CONTAINING BATHYMETRY
COMMENT.             (LOGICAL UNIT DEVICE TAPE8)
COMMENT.   **NOTE**  IF THE BATHYMETRY IS GENERATED WITH FORTRAN CODE IN
COMMENT.             THE UPDATE FILE AND NOT READ IN EXPLICITLY,THE JCL
COMMENT.             LINE WHICH ACCESSES THE BATHYMETRY FILE IS NOT
COMMENT.             REQUIRED AND MUST BE REMOVED.
COMMENT.
COMMENT.   RCPDAYF:  DAYFILE OR DIARY OF JOB EXECUTION EVENTS.
COMMENT.
COMMENT.   RCPPRNT:  OUTPUT FILE CONTAINING THE RESULTS OF THE
COMMENT.             WAVE MODEL RUN. (LOGICAL DEVICE UNIT TAPE6)
COMMENT.
COMMENT.   RCPOTPT:  DOES NOT EXIST ON THE CYBER205.
COMMENT.
COMMENT.******************************************************************
/EOI
```

Figure H2.  HOMR205

```
HOMER SPIT , ALASKA EXAMPLE
   96     416.7   83     833.3    32.200       0.0    1      0.00
      8.00     10.00    -45.00
    1   50    1   25   55
    0
```

Figure H3. HOMRDAT

```
*ID MODS
*D PARAM.3
      PARAMETER(IQ=96,JQ=83)
*I DEPTH.26
      DO 10 I=1,M
      DO 10 J=1,N
      D(I,J)=D(I,J)*6.0
   10 CONTINUE
```

Figure H4. HOMRUPD

```
*ID MODS
*D PARAM.3
      PARAMETER(IQ=96,JQ=83)
*I DEPTH.26
      DO 10 I=1,M
      DO 10 J=1,N
      D(I,J)=D(I,J)*6.0
   10 CONTINUE
*D MAIN.2
      PROGRAM RCPWAVE(INPUT,OUTPUT,TAPE7=TAPE7,TAPE6=TAPE6,TAPE8=TAPE8
     *,TAPE3=TAPE3)
```

Figure H5. HOMRUP2

```
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .03
.06   .11   .15   .23   .34   .32   .17   .13   .18   .20
.20   .13   .05   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .03
.08   .14   .20   .28   .35   .32   .20   .16   .24   .27
.23   .16   .06   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .03
.06   .20   .40   .51   .51   .50   .50   .51   .53   .54
.54   .49   .44   .37   .31   .23   .11   .06   .06   .04
.01   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .06   .17   .25   .31   .33   .30   .25
.20   .13   .04   .00   .00   .00   .00   .07   .21   .28
.28   .39   .55   .67   .70   .78   .91   .96   .91   .88
.87   .87   .87   .80   .68   .52   .37   .26   .23   .16
.06   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00   .00   .00   .00   .00   .00   .00   .00
.00   .00   .00
```

Figure H6. HOMRDEP

```
R E G I O N A L   C O A S T A L   P R O C E S S E S   W A V E   T R A N S F O R M A T I O N   M O D E L
                                       ( R C P W A V E )



                  HOMER SPIT , ALASKA EXAMPLE



MODEL INPUT:


UNIFORMLY SIZED, RECTILINEAR GRID MESH

    X - DIRECTION (ON-OFFSHORE)         96 CELLS, EACH    416.70  IN LENGTH
    Y - DIRECTION (LONGSHORE)           83 CELLS, EACH    833.30  IN LENGTH

THE ACCELERATION OF GRAVITY IS   32.20.  THESE UNITS DETERMINE THE UNITS OF ALL INPUT AND OUTPUT VARIABLES

THE DEEP WATER WAVE PARAMETERS FOR CASE  1 ARE:     HEIGHT=  8.000     PERIOD= 10.000     ANGLE= -45.000

THE OFFSHORE CONTOURS MAKE AN ANGLE OF    .00 DEGREES WITH THE Y AXIS

THE BATHYMETRY MATRIX IS VARIABLE IN BOTH HORIZONTAL DIRECTIONS AND WAS READ FROM FILE CODE 8

A WATER LEVEL CHANGE OF    .00 WAS ADDED TO THE ENTIRE BATHYMETRY MATRIX
```

Figure H7. RCPPRNT

```
WATER DEPTHS                      (MULTIPLIED BY     1.)

 I/J:  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
----------------------------------------------------------------------------------------------------------
  1 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  2 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  3 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  4 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  5 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  6 :   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  7 :   1   1   1   1   1   1   1   2   2   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  8 :   1   1   1   1   1   1   2   2   2   1   1   1   2   1   1   1   1   1   1   1   1   1   1   1   1
  9 :   1   1   1   1   1   2   3   3   3   3   3   3   3   3   3   3   2   2   1   1   1   1   1   1   1
 10 :   1   1   2   2   2   3   4   4   5   5   6   5   5   5   5   5   5   4   3   2   2   1   1   1   1
 11 :   1   3   4   4   4   6   6   6   6   7   7   7   7   7   7   7   7   5   4   4   3   3   2   2   1
 12 :   2   4   6   7   8   8   8   7   8   9   9   9   9  10   9   9   8   7   6   5   5   5   4   3   2
 13 :   4   6   9  10  11   9   9   9  10  11  11  11  12  12  11  10   9   8   7   7   6   6   6   4   3
 14 :   7   8  10  11  11  11  10  11  11  12  13  13  13  13  12  11  10   9   9   9   8   8   7   6   5
 15 :   8   8  10  11  12  12  12  13  13  13  14  14  14  14  13  12  11  11  11  10  10   9   8   7   6
 16 :   8   8   9  11  12  11  12  13  14  14  15  16  16  15  14  13  13  12  12  12  12  11  10   9   8
 17 :   9   8   9  10  11  11  12  13  14  14  15  16  16  15  14  14  14  14  14  14  14  13  11  10   9
 18 :   8   8   9  10  11  11  12  13  14  14  15  16  16  15  14  15  15  15  15  16  15  15  13  12  11
 19 :   7   8   9  11  12  12  13  13  13  14  14  14  14  14  15  16  16  15  15  16  17  16  15  14  13
 20 :   7   8  10  11  13  13  14  13  14  14  14  13  12  13  15  16  16  16  16  16  17  16  16  16  15
 21 :   7   8  10  11  13  15  15  14  14  15  15  14  14  14  15  16  17  16  16  16  16  16  17  18  18
 22 :   8   8  10  11  13  16  16  15  15  16  16  16  16  16  16  17  17  17  16  16  16  16  17  18  19
 23 :   7   8  10  13  15  17  17  16  16  17  17  17  17  17  17  17  17  17  17  16  16  16  17  19  20
 24 :   8   8  11  15  18  18  18  17  17  17  17  17  17  17  17  17  17  17  16  16  16  16  18  19  21
 25 :  10  10  12  16  19  19  19  18  17  17  18  18  18  18  17  17  17  17  17  16  16  16  18  20  21
 26 :  11  11  12  15  18  19  20  19  19  19  19  18  18  19  19  18  18  19  18  17  16  16  18  20  22
 27 :  13  12  14  16  18  20  20  19  19  20  20  20  20  20  21  21  21  20  19  18  17  17  18  20  22
 28 :  15  15  15  17  19  20  21  20  20  21  21  21  21  21  22  22  22  21  20  20  19  20  20  21  22
 29 :  17  16  17  18  20  21  22  21  21  21  21  21  22  22  22  22  22  21  21  21  21  22  22  21  21
 30 :  18  18  18  19  20  22  23  22  22  21  21  21  21  21  22  22  22  21  21  22  22  23  22  21  21
 31 :  19  19  20  20  21  22  23  23  23  22  22  21  21  21  21  22  22  21  21  22  22  23  22  20  20
 32 :  20  20  21  21  22  23  23  23  23  23  23  22  22  21  21  23  23  22  21  21  21  22  22  20  20
 33 :  21  21  21  22  22  23  23  22  23  24  24  22  22  22  22  23  24  23  22  22  22  22  22  21  21
 34 :  21  21  21  22  23  24  23  22  22  24  25  24  24  24  25  25  24  24  23  23  22  22  21  22  22
 35 :  22  21  22  22  24  25  25  24  24  26  27  28  27  26  26  26  25  25  25  25  24  23  22  22  23
 36 :  22  22  22  23  24  25  26  26  27  28  29  29  28  27  27  26  26  26  26  26  25  24  23  22  23
 37 :  24  24  24  24  25  26  27  27  28  29  30  29  29  28  27  26  26  26  26  26  25  24  22  21  22
 38 :  25  27  27  26  27  27  28  29  30  31  31  30  29  29  27  27  26  25  25  26  25  24  23  22  23
 39 :  26  28  29  29  29  29  30  30  31  32  32  31  30  28  27  27  27  26  26  26  25  23  23  23  24
 40 :  26  28  29  30  30  31  31  31  32  33  33  33  31  28  27  28  28  27  27  28  26  23  22  23  24
 41 :  26  28  30  31  32  32  32  32  33  34  34  34  32  29  27  27  27  26  27  28  27  23  21  22  23
 42 :  27  29  32  33  34  34  34  34  33  33  33  33  31  28  26  26  26  26  26  27  27  24  23  22  22
 43 :  28  31  33  34  35  36  36  34  33  33  32  31  29  27  26  26  26  26  26  26  26  25  24  22  21
 44 :  28  31  33  34  35  36  36  34  33  33  32  31  29  27  26  26  26  26  26  26  26  25  24  22  21
 45 :  30  32  34  35  36  37  36  35  34  34  34  33  31  27  26  26  26  26  25  26  25  24  23  22  22
```

Figure H8. RCPPRNT output (Sheet 1 of 5)

```
WAVE CONDITION  I

THE DEEP WATER WAVE PARAMETERS FOR CASE  1 ARE:    HEIGHT=  8.000    PERIOD= 10.000    ANGLE= -45.000

 BREAKER    INDEX              (MULTIPLIED BY     1.)

 I/J:  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
---------------------------------------------------------------------------------------------------------
  1 :  11   0   0   0   0   0   0   0   0   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  2 :  11   0   0   0   0   0   0   0   0   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  3 :  11   0   0   0   0   0   0   0   0   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  4 :  11   0   0   0   0   0   0   0   0  11  11   0   0   0   0   0   0   0   0   0  11   0   0   0   0
  5 :  11   0   0  11  11   0  11  11  11  11  11  11   0   0   0   0   0   0   0   0  11   0   0   0   0
  6 :  11   0   0  11  11  11  11  11  11  11  11  11  11  11  11  11   0   0   0  11  11   0   0   0   0
  7 :  11   0   0  11  11  11  11   0   0  11  11  11  11  11  11  11  11   0   0  11  11   0   0   0   0
  8 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11   0   0   0
  9 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11   0
 10 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 11 :  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
 12 :  11  11  11  11   0   0  11  11  11   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11  11
 13 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11  11  11  11  11  11  11  11  11
 14 :   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11  11  11  11  11  11  11  11
 15 :   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11  11  11  11  11
 16 :   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11  11  11
 17 :   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11  11
 18 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  11  11
 19 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 20 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 21 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 22 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 23 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 24 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 25 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 26 :  11  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 27 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 28 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 29 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 30 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 31 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 32 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 33 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 34 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 35 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 36 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 37 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 38 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 39 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 40 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 41 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 42 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 43 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 44 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 45 :   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Figure H8. (Sheet 2 of 5)

```
WAVE ANGLES    (DEG)              (MULTIPLIED BY     1.)

I/J:  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
-----------------------------------------------------------------------------------------------------------

  1 :   8  10  10  10  10   8   5   1  -3  -4  -4  -3  -4  -6  -8  -9 -10 -11 -12 -13 -13 -13 -14 -16 -17
  2 :   8  10  10  10  10   8   5   1  -3  -4  -4  -3  -4  -6  -8  -9 -10 -11 -12 -13 -13 -13 -14 -16 -17
  3 :   9  10  10  10  10   9   6   1  -3  -5  -4  -3  -4  -7  -8  -9 -10 -11 -13 -13 -13 -13 -14 -16 -17
  4 :   9  11  10  10  10   9   6   1  -4  -6  -3  -2  -4  -7  -9  -9 -10 -11 -13 -13 -13 -13 -14 -16 -18
  5 :  10  11  10  10  10  10   7   1  -5  -6  -3  -2  -4  -7  -9  -9 -10 -12 -13 -14 -13 -13 -14 -16 -18
  6 :  10  12  10   9  10  11   8   2  -6  -7  -3  -1  -4  -8  -9  -9 -10 -12 -14 -14 -13 -13 -14 -16 -18
  7 :  11  12  10   9  10  11  10   3 -10  -9  -2   0  -4 -10 -10  -9 -10 -12 -14 -14 -13 -13 -15 -17 -19
  8 :  12  13   9   8  11  11   6   0  -5  -6  -1   0  -6 -10  -9  -8 -10 -12 -15 -14 -12 -13 -15 -17 -19
  9 :  13  14   9   8  11  12   2  -1  -1  -2  -4  -6  -8  -9 -11 -13 -15 -17 -18 -14 -12 -13 -15 -18 -20
 10 :  15  18  11   8   9   5   0  -2  -1  -2  -7  -9 -10 -11 -13 -16 -19 -21 -20 -18 -14 -15 -16 -18 -20
 11 :  15  25  13   8   6   2  -3  -4  -3  -4  -8 -10 -11 -13 -16 -19 -21 -21 -18 -17 -15 -16 -21 -23 -21
 12 :  12  16  14  10   4  -1  -4  -4  -4  -6  -9 -11 -13 -16 -19 -20 -20 -20 -18 -17 -16 -18 -22 -25 -26
 13 :   5  10  13  10   3  -2  -3  -4  -6  -8 -11 -13 -15 -18 -20 -21 -20 -19 -19 -18 -18 -20 -22 -23 -21
 14 :  -1   6  12  10   4  -1  -3  -5  -8 -10 -12 -14 -17 -19 -20 -20 -19 -19 -19 -19 -20 -21 -22 -21 -20
 15 :  -5   4  11  10   4  -1  -4  -7 -10 -12 -13 -15 -18 -20 -20 -19 -19 -20 -20 -20 -22 -23 -22 -21 -19
 16 :  -6   2  10  10   4  -1  -4  -8 -11 -12 -14 -17 -19 -20 -19 -19 -20 -21 -21 -21 -23 -24 -23 -21 -19
 17 :  -6   2   9   9   4  -2  -5  -9 -11 -13 -15 -18 -20 -20 -18 -18 -20 -22 -22 -23 -24 -25 -23 -20 -19
 18 :  -5   3   8   8   3  -2  -7 -11 -12 -14 -16 -19 -20 -19 -18 -19 -21 -23 -23 -24 -26 -25 -22 -20 -19
 19 :  -4   3   7   7   3  -3  -9 -12 -13 -14 -16 -18 -18 -18 -18 -19 -22 -24 -24 -25 -26 -25 -22 -20 -20
 20 :  -4   2   6   6   2  -4 -10 -14 -14 -15 -17 -18 -17 -17 -18 -20 -23 -24 -25 -26 -27 -25 -21 -19 -20
 21 :  -6   0   5   5   2  -5 -12 -15 -14 -15 -17 -18 -19 -19 -20 -21 -23 -25 -26 -27 -27 -24 -20 -19 -20
 22 :  -8  -2   4   4   0  -6 -12 -15 -15 -16 -18 -19 -20 -21 -22 -23 -24 -25 -27 -28 -27 -23 -20 -19 -21
 23 : -10  -4   3   3  -2  -8 -13 -16 -17 -17 -18 -19 -21 -22 -22 -23 -24 -26 -27 -28 -26 -23 -20 -20 -21
 24 : -11  -5   1   1  -5 -10 -14 -16 -17 -17 -18 -20 -21 -22 -23 -24 -24 -26 -28 -28 -26 -23 -21 -21 -22
 25 : -12  -8  -3  -3  -6 -10 -14 -17 -18 -18 -19 -21 -22 -22 -23 -24 -25 -26 -28 -27 -25 -23 -22 -22 -23
 26 : -13  -9  -6  -5  -7 -11 -15 -18 -18 -19 -20 -21 -22 -23 -24 -25 -26 -28 -29 -27 -25 -23 -23 -24 -24
 27 : -13 -11  -8  -7  -8 -12 -16 -18 -18 -19 -21 -22 -23 -24 -25 -27 -28 -30 -29 -27 -25 -24 -24 -26 -25
 28 : -14 -12 -10  -9 -10 -13 -16 -18 -19 -20 -21 -23 -25 -26 -26 -27 -29 -30 -29 -27 -26 -26 -28 -28 -26
 29 : -15 -13 -11 -11 -11 -14 -17 -19 -20 -21 -22 -24 -25 -26 -27 -28 -29 -30 -29 -28 -27 -28 -30 -29 -25
 30 : -15 -13 -12 -12 -13 -15 -18 -20 -21 -21 -22 -24 -25 -26 -27 -28 -29 -30 -29 -28 -28 -29 -30 -29 -25
 31 : -14 -13 -13 -13 -14 -16 -18 -20 -21 -21 -23 -24 -26 -27 -27 -28 -30 -30 -29 -28 -28 -29 -30 -28 -24
 32 : -14 -13 -13 -14 -15 -17 -19 -21 -21 -21 -23 -25 -27 -27 -27 -29 -30 -30 -29 -28 -27 -29 -29 -27 -23
 33 : -14 -14 -14 -14 -15 -17 -19 -21 -21 -21 -24 -25 -27 -28 -29 -30 -31 -30 -29 -28 -28 -29 -29 -26 -23
 34 : -14 -14 -14 -15 -16 -18 -20 -21 -21 -22 -24 -26 -28 -30 -31 -32 -32 -31 -29 -28 -28 -29 -28 -26 -23
 35 : -14 -14 -14 -15 -17 -18 -21 -22 -22 -24 -26 -28 -30 -32 -32 -33 -32 -31 -29 -28 -29 -30 -29 -26 -23
 36 : -13 -14 -15 -16 -17 -19 -21 -23 -24 -26 -27 -29 -31 -32 -33 -33 -32 -31 -29 -29 -30 -30 -29 -26 -22
 37 : -14 -14 -16 -18 -19 -20 -22 -24 -25 -27 -28 -30 -31 -33 -33 -33 -32 -30 -29 -28 -29 -30 -28 -25 -21
 38 : -14 -15 -17 -19 -20 -21 -24 -25 -27 -28 -29 -31 -32 -34 -33 -32 -31 -30 -28 -28 -29 -29 -27 -24 -22
 39 : -15 -16 -18 -20 -21 -23 -25 -27 -28 -29 -30 -31 -32 -33 -33 -32 -31 -30 -28 -28 -29 -29 -27 -24 -22
 40 : -16 -16 -18 -20 -22 -24 -26 -28 -29 -30 -30 -31 -33 -33 -32 -32 -31 -30 -28 -28 -29 -28 -26 -24 -22
 41 : -17 -17 -19 -21 -23 -25 -27 -30 -31 -31 -31 -31 -33 -33 -32 -31 -30 -29 -28 -27 -28 -27 -25 -23 -21
 42 : -17 -18 -21 -23 -24 -26 -29 -31 -32 -31 -30 -30 -31 -32 -31 -30 -30 -29 -27 -27 -27 -27 -25 -23 -20
 43 : -18 -20 -22 -24 -25 -27 -30 -32 -32 -30 -29 -29 -30 -31 -30 -30 -30 -29 -27 -26 -26 -26 -25 -23 -20
 44 : -19 -21 -23 -25 -26 -28 -31 -32 -31 -30 -28 -28 -29 -30 -30 -30 -29 -28 -27 -26 -26 -25 -24 -21 -19
 45 : -21 -23 -25 -26 -27 -29 -31 -32 -31 -29 -28 -28 -30 -31 -30 -30 -29 -28 -26 -26 -25 -24 -22 -20 -19
```

Figure H8. (Sheet 3 of 5)

```
WAVE HEIGHTS                    (MULTIPLIED BY    10.)

I/J:  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
------------------------------------------------------------------------------------------------------
 1 :   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 2 :   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 3 :   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 4 :   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 5 :   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 6 :   4   4   4   4   4   4   4   5   5   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
 7 :   4   4   4   4   4   4   6   8   7   4   4   4   5   5   4   4   4   4   4   4   4   4   4   4   4
 8 :   4   4   4   4   4   5   7   8   8   6   4   7   7   6   4   5   4   4   4   4   4   4   4   4   4
 9 :   4   4   4   4   5  10  13  13  13  12  13  13  13  13  13  11  11   8   6   4   4   4   4   4   4
10 :   4   5   7   7  11  15  16  17  19  23  24  23  22  22  21  23  19  17  12  10   7   6   5   4   4
11 :   4  12  17  20  18  23  28  25  27  27  28  27  27  29  33  30  27  22  18  15  13  13   9   7   4
12 :   9  15  22  29  60  61  32  30  30  67  68  70  71  76  38  38  31  27  22  22  20  20  18  12   7
13 :  17  28  57  58  57  59  62  64  65  65  66  67  69  72  79  39  38  34  31  26  25  26  22  19  13
14 :  35  34  56  58  57  58  60  61  63  64  65  66  69  72  75  81  40  37  35  38  34  30  29  24  20
15 :  33  34  57  60  58  58  59  60  62  64  65  66  68  72  75  76  77  79  85  42  39  42  33  31  27
16 :  32  34  59  62  59  59  59  60  62  64  65  66  69  72  74  74  75  78  80  82  93  44  45  36  32
17 :  31  34  61  64  62  60  60  61  64  65  65  66  69  73  74  73  74  77  79  82  87 100  46  46  39
18 :  30  33  62  66  63  61  60  63  65  66  66  68  70  73  74  73  74  76  79  81  87  94 102  48  43
19 :  30  33  63  67  63  60  60  63  66  67  68  70  72  73  73  73  74  77  79  82  88  94  95  93  91
20 :  30  34  64  68  64  60  61  64  67  68  69  72  74  74  74  74  75  77  80  84  89  94  93  89  88
21 :  30  35  66  70  65  60  61  65  67  68  69  71  73  74  75  75  75  77  80  85  91  93  91  87  86
22 :  30  34  68  72  66  61  61  64  67  68  68  70  72  73  75  75  76  78  81  87  92  93  89  86  85
23 :  30  33  71  72  65  62  61  64  67  68  69  70  72  73  75  76  77  78  83  88  92  92  88  85  85
24 :  32  32  74  71  64  62  62  64  67  68  69  70  72  74  76  77  78  79  84  90  92  90  86  85  86
25 :  40  42  76  73  65  62  62  64  67  68  69  70  72  74  76  77  78  80  85  91  92  89  86  85  87
26 :  43  42  83  74  67  62  62  64  67  68  69  71  73  74  75  77  78  81  86  90  91  88  85  85  88
27 :  92  89  81  73  67  63  62  65  67  68  69  71  72  74  75  76  77  82  86  89  89  87  85  87  89
28 :  89  85  78  72  66  63  63  65  67  68  69  70  72  74  76  76  78  82  86  87  86  84  84  88  91
29 :  86  82  76  70  66  63  63  65  67  69  70  71  73  75  76  77  79  83  86  86  84  82  84  89  91
30 :  84  79  74  69  66  63  63  65  68  69  71  73  75  76  77  78  80  84  86  86  84  82  85  90  90
31 :  83  77  72  68  65  64  64  66  68  69  71  73  76  77  78  78  81  84  86  86  84  82  85  90  90
32 :  81  75  70  67  65  64  64  66  68  69  71  74  76  78  78  79  81  85  86  86  84  83  86  89  88
33 :  79  74  69  67  65  64  65  67  69  70  72  75  77  78  79  80  82  84  86  85  83  83  86  88  86
34 :  78  73  69  66  65  64  65  68  69  70  73  75  77  78  79  81  82  84  85  84  83  84  86  87  84
35 :  76  72  68  66  65  65  65  67  69  71  73  76  77  78  80  81  82  83  83  82  82  83  86  86  82
36 :  75  70  67  66  66  65  65  67  69  72  75  77  78  79  80  81  82  83  83  81  81  83  85  85  81
37 :  73  69  66  66  66  66  66  67  70  73  76  78  79  79  80  81  81  82  82  81  81  83  85  84  79
38 :  72  67  65  66  66  66  66  68  71  74  78  79  79  80  80  80  81  82  82  81  81  83  84  82  78
39 :  71  67  65  65  66  66  67  69  72  76  79  80  79  80  80  79  79  81  82  81  81  82  82  80  76
40 :  70  66  65  66  66  66  67  70  74  77  80  80  79  80  80  78  79  80  81  80  80  82  81  78  75
41 :  69  66  65  66  67  67  68  71  75  79  81  80  79  79  79  78  79  80  81  80  80  81  80  78  74
42 :  68  66  65  67  67  67  68  72  77  80  81  80  78  78  78  78  79  81  81  80  79  79  79  77  73
43 :  67  66  66  68  68  68  69  74  78  81  82  80  78  78  77  77  78  81  82  80  79  78  77  75  72
44 :  67  66  67  69  69  69  71  75  79  81  81  79  78  77  77  77  79  81  81  80  78  77  76  74  71
45 :  66  67  68  69  69  70  72  76  80  81  80  78  77  77  76  76  79  81  81  79  78  76  74  72  69
```

Figure H8. (Sheet 4 of 5)

```
WAVE NUMBER                      (MULTIPLIED BY  1000.)

I/J:  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
---------------------------------------------------------------------------------------------------------

 1  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 2  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 3  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 4  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 5  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 6  : 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111 111
 7  : 111 111 111 111 111 111  95  78  80 110 111 107 101 101 111 111 111 111 111 111 111 111 111 111 111
 8  : 111 111 111 111 111 101  86  77  80 101 111  93  87  95 111 111 111 111 111 111 111 111 111 111 111
 9  : 111 111 111 111 101  72  64  64  64  64  64  63  62  62  65  69  75  82  95 111 111 111 111 111 111
10  : 111  99  86  86  73  61  56  55  52  48  47  48  49  49  49  49  51  55  63  75  89  95 111 111 111
11  : 107  65  56  57  53  46  45  47  46  43  42  43  43  42  41  41  44  49  55  58  62  64  73  91 111
12  :  82  58  47  42  39  39  40  41  41  38  37  37  37  37  37  38  41  44  47  50  51  50  54  63  83
13  :  55  45  38  36  35  37  38  38  37  35  33  33  33  33  34  36  38  39  41  44  45  45  47  53  64
14  :  42  39  36  34  34  35  35  35  33  33  32  32  31  31  32  34  36  37  38  39  40  41  43  46  50
15  :  40  39  36  34  33  33  33  32  31  31  31  30  30  30  31  33  34  34  35  35  36  37  39  41  44
16  :  39  39  37  35  33  34  33  31  31  30  30  29  29  30  30  31  32  32  33  33  33  34  36  38  40
17  :  38  39  38  36  34  34  33  32  31  30  29  28  29  30  30  30  31  31  31  30  31  32  34  35  37
18  :  40  40  38  36  34  34  33  32  31  30  29  29  29  30  30  30  30  30  30  29  29  30  31  33  34
19  :  41  40  37  35  33  32  32  32  31  31  30  31  31  30  30  29  29  29  29  28  28  29  29  30  31
20  :  41  39  36  34  32  31  31  31  31  30  31  32  32  31  30  29  28  29  29  28  28  28  28  28  29
21  :  41  39  36  34  31  30  29  31  31  29  29  30  31  30  29  29  28  28  29  28  28  28  28  27  27
22  :  41  39  36  34  31  29  28  29  30  29  28  28  29  29  29  28  28  28  28  28  28  28  28  27  26
23  :  41  40  36  32  29  28  28  28  29  28  28  28  28  28  28  28  28  28  28  28  28  28  28  26  26
24  :  40  40  35  29  27  27  27  28  28  28  28  28  28  28  28  28  28  28  28  29  29  28  27  26  25
25  :  36  36  33  29  27  26  27  27  27  27  27  27  27  27  28  28  28  28  28  29  29  29  27  26  25
26  :  35  35  32  29  27  26  26  26  27  26  27  27  27  27  27  27  27  27  27  28  29  28  27  26  25
27  :  32  32  31  29  27  26  26  26  26  26  26  26  26  26  25  25  25  26  26  27  28  28  27  26  25
28  :  29  30  29  28  26  26  25  26  26  25  25  25  25  25  25  25  25  25  26  26  26  26  26  25  25
29  :  28  28  28  27  26  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  25
30  :  27  27  27  26  26  25  24  25  25  25  25  25  25  25  25  25  25  25  25  25  24  24  25  25  25
31  :  26  26  26  26  25  25  24  24  24  25  25  25  25  25  25  25  25  25  25  25  25  24  25  26  26
32  :  26  26  25  25  25  24  24  24  24  24  24  25  25  25  25  24  24  25  25  25  25  25  25  26  26
33  :  25  25  25  25  25  24  24  25  24  24  24  24  25  25  24  24  24  24  25  25  25  25  25  25  25
34  :  25  25  25  25  24  24  24  25  24  24  23  24  24  24  24  24  24  24  24  24  25  25  25  25  25
35  :  25  25  25  25  24  23  23  24  24  23  22  22  22  23  23  23  23  23  23  23  24  24  25  25  24
36  :  25  25  24  24  24  23  23  23  23  22  22  22  22  22  23  23  23  23  23  23  23  24  24  25  24
37  :  24  24  24  24  23  23  23  22  22  22  22  22  22  22  23  23  23  23  23  23  23  24  25  25  25
38  :  23  23  22  23  23  22  22  22  22  21  21  21  22  22  22  23  23  23  23  23  23  24  24  25  24
39  :  23  22  22  22  22  22  22  22  21  21  21  21  22  22  23  23  23  23  23  23  23  24  24  24  24
40  :  23  22  22  22  21  21  21  21  21  21  21  21  21  22  23  22  22  22  22  22  23  24  25  24  24
41  :  23  22  22  21  21  21  21  21  21  20  20  20  21  22  23  23  23  23  23  22  23  24  25  25  24
42  :  23  22  21  21  20  20  20  20  21  21  21  21  21  22  23  23  23  23  23  23  23  24  24  25  25
43  :  22  21  21  20  20  20  20  20  21  21  21  21  22  23  23  23  23  23  23  23  23  23  24  25  25
44  :  22  21  21  20  20  20  20  20  21  21  21  21  22  23  23  23  23  23  23  23  23  23  24  25  25
45  :  22  21  20  20  20  20  20  20  20  20  20  21  21  22  23  23  23  23  23  23  23  24  24  25  25
```

Figure H8. (Sheet 5 of 5)

# APPENDIX I: INTPRCP PROGRAM LISTING

```
*****    *COMDECK PARAM
         C
               PARAMETER(IQ=95,JQ=95)
               PARAMETER(IQ2=95,JQ2=95)
               PARAMETER(KQ=IQ*JQ)
         C
*****    *DECK MAIN
               PROGRAM GRID(TAPE1=TAPE1,TAPE2=TAPE2,TAPE3=TAPE3,TAPE4=TAPE4,
              1TAPE6=TAPE6,TAPE7=TAPE7)
*****    *CALL PARAM
         C**********************************************************
         C
         C                    DOCUMENTATION
         C
         C**********************************************************
         C
         C THIS PROGRAM PROVIDES A METHOD FOR INTERPOLATING BATHYMETRY
         C FROM ONE GRID TO ANOTHER.  THE NEW GRID ORIGIN CAN BE
         C TRANSLATED AND/OR ROTATED RELATIVE TO THE OLD GRID ORIGIN
         C
         C**********************************************************
         C
         C                   INPUT DATA (TAPE7)
         C
         C**********************************************************
         C
         C      READ(7,500) M,N,M2,N2,ANG,XSHIFT,YSHIFT
         C 500  FORMAT(4I5,3F10.5)
         C
         C      M=  NUMBER OF GRID CELLS IN THE X-DIRECTION ON THE OLD GRID
         C      N=  NUMBER OF GRID CELLS IN THE Y-DIRECTION ON THE OLD GRID
         C      M2=  NUMBER OF GRID CELLS IN THE X-DIRECTION ON THE NEW GRID
         C      N2=  NUMBER OF GRID CELLS IN THE Y-DIRECTION ON THE NEW GRID
         C
         C      ANG=THE ANGLE OF ROTATION MEASURED
         C          FROM THE OLD GRID TO THE NEW GRID
         C             +COUNTER-CLOCKWISE
         C             -CLOCKWISE
         C
         C      XSHIFT=THE X OFFSET FROM THE OLD GRID TO THE NEW GRID
         C             +  NEW GRID ORIGIN IS BELOW THE OLD ORIGIN
         C             -  NEW GRID ORIGIN IS ABOVE THE OLD ORIGIN
         C      YSHIFT=THE Y OFFSET FORM THE OLD GRID TO THE NEW GRID
         C             +  NEW GRID ORIGIN IS TO THE RIGHT OF THE OLD ORIGIN
         C             -  NEW GRID ORIGIN IS TO THE LEFT OF THE OLD ORIGIN
         C
         C****
         C
         C     READ(7,505) GRDTYP1,GRDTYP2
         C 505 FORMAT(2I5)
         C
         C     GRDTYP1=OLD GRID TYPE
         C           0 = CONSTANT SIZED, RECTILINEAR
```

```
C           1 = VARIABLY SIZED, RECTILINEAR
C
C     GRDTYP2=NEW GRID TYPE
C           0 = CONSTANT SIZED, RECTILINEAR
C           1 = VARIABLY SIZED, RECTILINEAR
C
C****
C
C     IF: GRDTYP1=0 THEN:
C
C     READ(7,501) DX,DY
C 501 FORMAT(2F10.5)
C
C****
C
C     IF: GRDTYP2=0 THEN:
C
C     READ(7,501) DX2,DY2
C 501 FORMAT(2F10.5)
C
C****
C
C     IF: GRDTYP1=0 & GRDTYP2=0 THEN:
C
C     READ(7,501) DX,DY
C     READ(7,501) DX2,DY2
C 501 FORMAT(2F10.5)
C
C      DX=CELL LENGTH IN THE X DIRECTION (OLD GRID) IN MAP INCHES OR CM
C      DY=CELL LENGTH IN THE Y DIRECTION (OLD GRID) IN MAP INCHES OR CM
C      DX2=CELL LENGTH IN THE X DIRECTION (NEW GRID) IN MAP INCHES OR CM
C      DY2=CELL LENGTH IN THE Y DIRECTION (NEW GRID) IN MAP INCHES OR CM
C
C**********************************************************
C
C                   INPUT DATA (TAPE3)
C                      -OLD GRID-
C
C**********************************************************
C
C                        **NOTE**
C             ONLY USE TAPE3 IF GRDTYP1=1
C
C*************************************************************
C
C     IF GRDTYP1=1 THEN:
C
C
C     READ(3,31,END=999) STR,NST,NEND,A1,B1,C1
C
C     STR=X OR Y STRETCHING DIRECTION
C     NST=STARTING CELL NUMBER FOR THE REGION
C     NEND-NST=NUMBER OF CELLS IN THE REGION
C     A1,B1,C1=STRETCHING COEFFICIENTS FOR THE REGION
```

```
C                                                                       MAIN     102
C  31 FORMAT(A1,7X,2I8,3G16.11)                                         MAIN     103
C                                                                       MAIN     104
C*********************************************************              MAIN     105
C                                                                       MAIN     106
C                    INPUT DATA (TAPE4)                                 MAIN     107
C                       -NEW GRID-                                      MAIN     108
C                                                                       MAIN     109
C*********************************************************              MAIN     110
C                                                                       MAIN     111
C                        **NOTE**                                       MAIN     112
C              ONLY USE TAPE4 IF GRDTYP2=1                              MAIN     113
C                                                                       MAIN     114
C************************************************************           MAIN     115
C     IF GRDTYP2=1 THEN:                                                MAIN     116
C                                                                       MAIN     117
C     READ(4,31,END=998) STR,NST,NEND,A1,B1,C1                          MAIN     118
C                                                                       MAIN     119
C     STR=X OR Y STRETCHING DIRECTION                                   MAIN     120
C     NST=STARTING CELL NUMBER FOR THE REGION                           MAIN     121
C     NEND-NST=NUMBER OF CELLS IN THE REGION                            MAIN     122
C     A1,B1,C1=STRETCHING COEFFICIENTS FOR THE REGION                   MAIN     123
C                                                                       MAIN     124
C  31 FORMAT(A1,7X,2I8,3G16.11)                                         MAIN     125
C                                                                       MAIN     126
C                                                                       MAIN     127
C                                                                       MAIN     128
C*********************************************************              MAIN     129
C                                                                       MAIN     130
C                    INPUT DATA (TAPE1)                                 MAIN     131
C                                                                       MAIN     132
C*********************************************************              MAIN     133
C                                                                       MAIN     134
C      DO 10 I=1,M                                                      MAIN     135
C      READ(1,11) (DD(I,J),J=1,N)                                       MAIN     136
C  10  CONTINUE                                                         MAIN     137
C  11  FORMAT(10F8.2)                                                   MAIN     138
C                                                                       MAIN     139
C      DD(I,J)=DEPTH AT EACH CELL OF THE OLD GRID                       MAIN     140
C                                                                       MAIN     141
C**************************************************************         MAIN     142
      COMMON/CONST/M,N,M2,N2,DX,DY                                      MAIN     143
      COMMON/COOR/XX(IQ),YY(JQ)                                         MAIN     144
      COMMON/COOR2/XX2(IQ2),YY2(JQ2)                                    MAIN     145
      COMMON/COOR3/XOWRTN(IQ,JQ),YOWRTN(IQ,JQ)                          MAIN     146
      COMMON/DEPTHS/D(IQ2,JQ2),DD(IQ,JQ)                                MAIN     147
      CHARACTER*1 STR                                                   MAIN     148
      READ(7,500) M,N,M2,N2,ANG,XSHIFT,YSHIFT                           MAIN     149
      ANG=-1.0*(ANG)                                                    MAIN     150
      READ(7,505) GRDTYP1,GRDTYP2                                       MAIN     151
  505 FORMAT(2I5)                                                       MAIN     152
 500  FORMAT(4I5,3F10.5)                                                MAIN     153
      ANG=ANG*3.1415927/180.0                                           MAIN     154
      SCALE=1.0                                                         MAIN     155
```

```
      XSHIFT=XSHIFT*SCALE
      YSHIFT=YSHIFT*SCALE
      IF(GRDTYP1.EQ.0) GO TO 506
 21   CONTINUE
      READ(3,31,END=999) STR,NST,NEND,A1,B1,C1
 31   FORMAT(A1,7X,2I8,3G16.11)
      NEND=NEND-1
      IF(STR.EQ.'Y') GO TO 20
      DO 201 LLC=NST,NEND
      LL=LLC+1
      ALPHC=LL-0.5
      ALPHS=LL
      XX(LL-1)=(A1+B1*(ALPHC**C1))*SCALE
 201  CONTINUE
      GO TO 21
 20   CONTINUE
      DO 203 LLC=NST,NEND
      LL=LLC+1
      ALPHC=LL-0.5
      ALPHS=LL
      YY(LL-1)=(A1+B1*(ALPHC**C1))*SCALE
 203  CONTINUE
      GO TO 21
999   CONTINUE
 506  CONTINUE
      WRITE(6,9)
   9  FORMAT(////,20X,'VARIABLE WAVE GRID INFORMATION',///)
      WRITE(6,23)SCALE
  23  FORMAT(///,'EXPANSION COEFFICIENT SCALE FACTOR',/,
     *'SCALE=',F10.3,//)
      IF(GRDTYP1.EQ.0) GO TO 507
      GO TO 513
 507  READ(7,501) DX,DY
 501  FORMAT(2F10.5)
      DO 511 L=1,M
      XX(L)=(L-0.5)*DX*SCALE
 511  CONTINUE
      DO 512 L=1,N
      YY(L)=(L-0.5)*DY*SCALE
 512  CONTINUE
 513  CONTINUE
      WRITE(6,10)
  10  FORMAT(///,1X,'X CENTER DISTANCES',//)
      WRITE(6,11)(I,XX(I),I=1,M)
  11  FORMAT(8(I4,F12.3))
      WRITE(6,12)
  12  FORMAT(///,1X,'Y CENTER DISTANCES',//)
      WRITE(6,11)(J,YY(J),J=1,N)
      IF(GRDTYP2.EQ.0) GO TO 539
  28  CONTINUE
      READ(4,31,END=998) STR,NST,NEND,A1,B1,C1
      NEND=NEND-1
      IF(STR.EQ.'Y') GO TO 27
      DO 271 LLC=NST,NEND
```

```
      LL=LLC+1
      ALPHC=LL-0.5
      ALPHS=LL
      XX2(LL-1)=(A1+B1*(ALPHC**C1))*SCALE
  271 CONTINUE
      GO TO 28
  27  CONTINUE
      DO 273 LLC=NST,NEND
      LL=LLC+1
      ALPHC=LL-0.5
      ALPHS=LL
      YY2(LL-1)=(A1+B1*(ALPHC**C1))*SCALE
  273 CONTINUE
      GO TO 28
 998  CONTINUE
      GO TO 560
  539 CONTINUE
      READ(7,555) DX2,DY2
  555 FORMAT(2F10.5)
  560 CONTINUE
      WRITE(6,19)
   19 FORMAT(////,20X,'VARIABLE SECOND GRID INFORMATION',///)
      WRITE(6,23)SCALE
      IF(GRDTYP2.EQ.0) GO TO 515
      GO TO 525
  515 CONTINUE
      DO 520 L=1,M2
      XX2(L)=(L-0.5)*DX2*SCALE
  520 CONTINUE
      DO 524 L=1,N2
      YY2(L)=(L-0.5)*DY2*SCALE
  524 CONTINUE
  525 CONTINUE
      WRITE(6,40)
   40 FORMAT(///,1X,'X2 CENTER DISTANCES',//)
      WRITE(6,11)(I,XX2(I),I=1,M2)
      WRITE(6,42)
   42 FORMAT(///,1X,'Y2 CENTER DISTANCES',//)
      WRITE(6,11)(J,YY2(J),J=1,N2)
      DO 26 JJ=1,N
      DO 26 II=1,M
      XOWRTN(II,JJ)=(XX(II)-XSHIFT)*COS(ANG)+(YSHIFT
     1-YY(JJ))*SIN(ANG)
      YOWRTN(II,JJ)=(XX(II)-XSHIFT)*SIN(ANG)+(YY(JJ)
     1-YSHIFT)*COS(ANG)
  26  CONTINUE
      CALL INTERPO

   99 STOP
      END
*****   *DECK INTERPO
C*************************************************************************
C*
      SUBROUTINE INTERPO
C*
```

```
      C***********************************************************************
*****  *CALL PARAM
          COMMON/CONST/M,N,M2,N2,DX,DY
          COMMON/COOR/XX(IQ),YY(JQ)
          COMMON/COOR2/XX2(IQ2),YY2(JQ2)
          COMMON/COOR3/XOWRTN(IQ,JQ),YOWRTN(IQ,JQ)
          COMMON/DEPTHS/D(IQ2,JQ2),DD(IQ,JQ)
          DIMENSION R(KQ),IVAL(KQ),JVAL(KQ),DIST(KQ)
          INTEGER MD2,ND2
          DO 10 I=1,M
          READ(1,11) (DD(I,J),J=1,N)
       10 CONTINUE
       11 FORMAT(10F8.2)
          CALL POUT(1,M,1,1,N,'OLD DEPTHS (X,1)',DD,1.0,IQ,JQ)
          DO 1 I=1,M2
          DO 1 J=1,N2
          XD=XX2(I)
          YD=YY2(J)
          K=0
          IF(I.EQ.1.AND.J.EQ.1) GO TO 601
          IF(J.NE.1) GO TO 550
          I1FP=I1FM+30
          DO 599 II=I1FM,I1FP
          IF(II.LE.0.OR.II.GT.M) GO TO 599
          DO 5 JJ=1,N
          K=K+1
          DIST(K)=SQRT((XOWRTN(II,JJ)-XD)**2+(YOWRTN(II,JJ)-
         1YD)**2)

          CS=XOWRTN(II,JJ)-XD
          SN=YOWRTN(II,JJ)-YD
          IF(CS.GE.0.0.AND.SN.GE.0.0)R(K)=1.0
          IF(CS.LT.0.0.AND.SN.GE.0.0)R(K)=2.0
          IF(CS.LT.0.0.AND.SN.LT.0.0)R(K)=3.0
          IF(CS.GE.0.0.AND.SN.LT.0.0)R(K)=4.0
          IF(CS.EQ.0.0.AND.SN.EQ.0.0) GO TO 603
          IVAL(K)=II
          JVAL(K)=JJ
          IF(K.GT.1) GO TO 565
          DMIN=DIST(1)
          I1=IVAL(1)
          J1=JVAL(1)
          K1=1
      565 IF(DIST(K).GE.DMIN) GO TO 5
          DMIN=DIST(K)
          K1=K
        5 CONTINUE
      599 CONTINUE
          I1=IVAL(K1)
          J1=JVAL(K1)
          R1=R(K1)
          I1FM=I1-15
          GO TO 552
      601 MD2=(M*1.0)
          ND2=(N*1.0)
```

```
      DO 602 II=1,MD2
      DO 602 JJ=1,ND2
      K=K+1
      DIST(K)=SQRT((XOWRTN(II,JJ)-XD)**2+(YOWRTN(
     1II,JJ)-YD)**2)
      CS=XOWRTN(II,JJ)-XD
      SN=YOWRTN(II,JJ)-YD
      IF(CS.GE.0.0.AND.SN.GE.0.0)R(K)=1.0
      IF(CS.LT.0.0.AND.SN.GE.0.0)R(K)=2.0
      IF(CS.LT.0.0.AND.SN.LT.0.0)R(K)=3.0
      IF(CS.GE.0.0.AND.SN.LT.0.0)R(K)=4.0
      IF(CS.EQ.0.0.AND.SN.EQ.0.0) GO TO 603
      IVAL(K)=II
      JVAL(K)=JJ
      IF(K.GT.1) GO TO 610
      DMIN=DIST(1)
      I1=II
      J1=JJ
      K1=1
610   IF(DIST(K).GE.DMIN) GO TO 602
      DMIN=DIST(K)
      K1=K
  602 CONTINUE
      I1=IVAL(K1)
      J1=JVAL(K1)
      R1=R(K1)
      I1FM=I1-15
      GO TO 552
  603 I1=IVAL(K)
      J1=JVAL(K)
      I1FM=I1-15
  609 D(I,J)=DD(I1,J1)
      GO TO 717
  613 SUM1=DMIN+DMIN2
      SUM2=SUM1/DMIN+SUM1/DMIN2
      SF1=SUM1/(DMIN*SUM2)
      SF2=SUM1/(DMIN2*SUM2)
      D(I,J)=SF1*DD(I1,J1)+SF2*DD(I2,J2)
      GO TO 717
  614 SUM1=DMIN+DMIN2+DMIN3
      SUM2=SUM1/DMIN+SUM1/DMIN2+SUM1/DMIN3
      SF1=SUM1/(DMIN*SUM2)
      SF2=SUM1/(DMIN2*SUM2)
      SF3=SUM1/(DMIN3*SUM2)
      D(I,J)=SF1*DD(I1,J1)+SF2*DD(I2,J2)+SF3*DD(I3,J3)
      GO TO 717
  550 I1M4=I1-4
      I1P4=I1+4
      J1M4=J1-4
      J1P4=J1+4
      DO 551 II=I1M4,I1P4
      IF(II.LE.0.OR.II.GT.M)  GO TO 551
      DO 553 JJ=J1M4,J1P4
      IF(JJ.LE.0.OR.JJ.GT.N) GO TO 553
```

```
      K=K+1
      DIST(K)=SQRT((XOWRTN(II,JJ)-XD)**2+(YOWRTN(II,JJ)-YD)**2)
      CS=XOWRTN(II,JJ)-XD
      SN=YOWRTN(II,JJ)-YD
      IF(CS.GE.0.0.AND.SN.GE.0.0)R(K)=1.0
      IF(CS.LT.0.0.AND.SN.GE.0.0)R(K)=2.0
      IF(CS.LT.0.0.AND.SN.LT.0.0)R(K)=3.0
      IF(CS.GE.0.0.AND.SN.LT.0.0)R(K)=4.0
      IF(CS.EQ.0.0.AND.SN.EQ.0.0) GO TO 603
      IVAL(K)=II
      JVAL(K)=JJ
      IF(K.GT.1) GO TO 560
      DMIN=DIST(1)
      I1=IVAL(1)
      J1=JVAL(1)
      K1=1
  560 IF(DIST(K).GE.DMIN) GO TO 553
      DMIN=DIST(K)
      K1=K
 553  CONTINUE
 551  CONTINUE
      I1=IVAL(K1)
      J1=JVAL(K1)
      R1=R(K1)
 552  CONTINUE
      DO 700 III=1,K
      R2=R(III)
      IF(R2.EQ.R1) GO TO 700
      K2=III
      I2=IVAL(III)
      J2=JVAL(III)
      DMIN2=DIST(III)
      GO TO 701
  700 CONTINUE
      IF(R2.EQ.R1) GO TO 609
  701 CONTINUE
      DO 570 L=III,K
      IF(L.EQ.K1) GO TO 570
      IF(R(L).EQ.R1) GO TO 570
      IF(DIST(L).GE.DMIN2) GO TO 570
      DMIN2=DIST(L)
      K2=L
 570  CONTINUE
      R2=R(K2)
      I2=IVAL(K2)
      J2=JVAL(K2)
      DO 703 JJJ=1,K
      R3=R(JJJ)
      IF(R3.EQ.R1.OR.R3.EQ.R2) GO TO 703
      K3=JJJ
      I3=IVAL(JJJ)
      J3=JVAL(JJJ)
      DMIN3=DIST(JJJ)
      GO TO 704
```

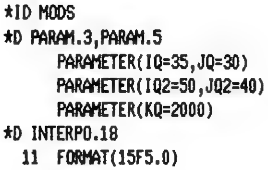
```
  703 CONTINUE
      IF(R3.EQ.R2.OR.R3.EQ.R1) GO TO 613
  704 CONTINUE
      DO 580 LL=JJJ,K
      IF(LL.EQ.K1.OR.LL.EQ.K2) GO TO 580
      IF(R(LL).EQ.R1.OR.R(LL).EQ.R2) GO TO 580
      IF(DIST(LL).GE.DMIN3) GO TO 580
      DMIN3=DIST(LL)
      K3=LL
  580 CONTINUE
      I3=IVAL(K3)
      J3=JVAL(K3)
      R3=R(K3)
      DO 588 III=1,K
      R4=R(III)
      IF(R4.EQ.R3.OR.R4.EQ.R2.OR.R4.EQ.R1) GO TO 588

      K4=III
      I4=IVAL(III)
      J4=JVAL(III)
      DMIN4=DIST(III)
      GO TO 589
  588 CONTINUE
      IF(R4.EQ.R3.OR.R4.EQ.R2.OR.R4.EQ.R1) GO TO 614
  589 CONTINUE
      DO 590 LLL=III,K
      IF(LLL.EQ.K1.OR.LLL.EQ.K2) GO TO 590
      IF(LLL.EQ.K3) GO TO 590
      IF(DIST(LLL).GE.DMIN4) GO TO 590
      IF(R(LLL).EQ.R1.OR.R(LLL).EQ.R2.OR.R(LLL).EQ.R3) GO TO 590
      DMIN4=DIST(LLL)
      K4=LLL
  590 CONTINUE
      I4=IVAL(K4)
      J4=JVAL(K4)
      R4=R(K4)
      D1=DMIN
      D2=DMIN2
      D3=DMIN3
      D4=DMIN4
      SUM1=D1+D2+D3+D4
      SUM2=SUM1/D1+SUM1/D2+SUM1/D3+SUM1/D4
      SF1=SUM1/(D1*SUM2)
      SF2=SUM1/(D2*SUM2)
      SF3=SUM1/(D3*SUM2)
      SF4=SUM1/(D4*SUM2)
      D(I,J)=SF1*DD(I1,J1)+SF2*DD(I2,J2)+SF3*DD(I3,J3)+SF4*DD(I4,J4)
  717 CONTINUE
    1 CONTINUE
      CALL POUT(1,M2,1,1,N2,'NEW DEPTHS (X,1)',D,1.0,IQ2,JQ2)
      DO 1112 I=1,M2
      WRITE(2,1113) (D(I,J),J=1,N2)
 1112 CONTINUE
 1113 FORMAT(10F8.2)
      RETURN
```

# APPENDIX J: SAMPLE FILES--GRID INTERPOLATION EXAMPLE

```
 35   30   50   40      10.0      0.5       0.5
  0    0
    0.20      0.20
    0.14      0.15
```

Figure J1. INTPGRD



```
*ID MODS
*D PARAM.3,PARAM.5
      PARAMETER(IQ=35,JQ=30)
      PARAMETER(IQ2=50,JQ2=40)
      PARAMETER(KQ=2000)
*D INTERPO.18
   11 FORMAT(15F5.0)
```

Figure J2. INTPUPD

```
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  4.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  5.0  5.0  6.0  6.5  6.5
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  5.0  5.0  6.0  6.5  7.0  7.5  7.5
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  1.0  5.0  5.0  7.0  7.0  7.0  7.5  8.0  9.0  9.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.0  2.0  4.0
  4.0  4.0  4.5  4.5  5.0  5.0  6.0  7.0  8.0  8.0  8.5  9.0  9.0 10.0 10.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  4.0  5.0  5.0  6.0
  6.0  6.0  5.5  6.5  7.5  7.0  7.0  8.0  9.0  9.0  9.0 10.0 10.0 11.0 11.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  1.0  5.0  5.0  7.5 10.0 10.0
 10.0 10.0 10.0 10.0 10.0  9.5  9.0  9.0 10.0 10.0 11.0 11.0 11.5 12.0 12.0
  0.0  0.0  0.0  0.0  0.0  0.0  1.0  4.0  4.0  5.0  7.5  7.5 10.0 11.5 12.0
 12.0 11.5 11.0 11.0 10.5 10.5 11.0 11.0 11.0 11.0 11.5 11.5 12.0 12.5 12.5
  0.0  1.0  3.0  4.0  5.0  5.0  5.0  6.0  6.0  7.0  9.5 10.0 11.0 13.0 13.5
 14.0 13.5 13.0 13.0 12.0 12.0 11.5 11.5 11.5 11.5 12.0 12.0 12.5 13.0 13.0
  3.0  4.0  5.0  5.0  6.0  6.0  7.0  7.0  8.0  9.0 10.0 11.0 12.0 14.0 15.0
 15.0 15.0 15.0 14.0 14.0 13.0 12.0 12.0 12.0 12.0 12.5 12.5 13.0 13.5 13.5
  5.0  6.0  6.0  7.0  8.0  8.0  9.0  9.0 10.0 11.0 11.0 12.0 13.0 15.0 16.0
 16.0 16.0 16.0 16.0 15.0 14.0 13.0 13.0 13.0 13.0 13.0 13.0 14.0 14.0 14.0
  6.0  7.0  8.0  9.0  9.0  9.0 10.0 11.0 11.0 11.5 12.0 13.0 15.0 16.0 17.0
 17.0 17.0 17.0 17.0 16.0 15.0 14.0 14.0 14.0 14.0 14.0 14.0 15.0 15.0 15.0
  7.0  8.0  9.0 10.0 10.0 11.0 11.0 11.5 11.5 12.0 13.0 14.0 15.5 17.0 18.0
 18.0 18.0 18.0 18.0 17.0 17.0 17.0 16.0 15.0 15.0 15.0 15.5 15.5 15.5 15.5
  9.0 10.0 11.0 11.0 11.0 11.5 11.5 12.0 12.0 13.0 14.0 15.0 16.0 18.0 18.0
 19.0 19.0 19.0 19.0 18.0 18.0 18.0 17.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0
 11.0 11.0 11.5 11.5 11.5 12.0 12.0 13.0 13.0 14.0 15.0 16.0 17.0 18.0 18.0
 19.0 20.0 20.0 20.0 19.0 18.5 18.5 18.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0
 11.5 11.5 12.0 12.0 12.0 12.5 13.0 14.0 14.0 15.0 15.5 16.5 17.5 18.0 18.5
 19.0 20.0 21.0 21.0 20.0 19.0 19.0 18.5 18.0 17.5 17.5 17.5 17.5 17.5 17.5
 12.0 12.0 12.5 12.5 13.0 13.0 14.0 15.0 15.0 15.5 16.0 17.0 18.0 18.5 18.5
 19.0 20.5 21.0 21.5 21.0 20.0 19.5 19.0 18.5 18.0 18.0 18.0 18.0 18.0 18.0
 13.0 12.5 13.0 13.0 14.0 14.0 15.0 15.5 15.5 16.0 16.5 17.5 18.0 18.5 19.0
 20.0 20.5 21.0 21.5 22.0 21.0 20.0 19.5 19.0 18.5 18.5 18.5 18.5 18.5 18.5
 14.0 13.5 14.0 14.5 15.0 15.0 15.5 16.0 16.5 16.5 17.0 17.5 18.0 19.0 19.0
 20.0 20.5 21.0 22.0 23.0 22.0 21.0 20.5 20.0 19.0 19.0 19.0 19.0 19.0 19.0
 14.5 14.0 15.0 15.0 15.5 15.5 16.0 16.5 17.0 17.0 17.5 18.0 18.5 19.0 20.0
 20.5 21.0 22.0 23.0 24.0 23.0 22.0 21.0 20.5 20.0 20.0 19.5 19.5 19.5 19.5
 15.5 16.0 15.5 15.5 16.0 16.0 17.0 17.0 17.5 18.0 18.0 18.5 19.0 19.0 20.0
```

Figure J3.  INTDEPO

```
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .49    1.00    1.00    1.00    1.00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .49    1.00    1.00    1.00    1.00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .51    1.00    1.00    1.00    1.00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .14     .22     .86     .52     .45     .54     .82     .72     .67     .63
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .24    1.04
     .70    1.11    1.75    2.76    2.93    2.76    2.71    2.85    2.91    2.93
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
     .00     .29     .28     .28     .00     .00     .00     .00     .00     .00
     .00     .00     .00     .00     .00     .24    1.06    1.31    1.93    2.71
    3.66    3.44    4.25    5.28    5.54    5.25    5.53    5.66    5.70    5.71
     .00     .00     .00     .00     .00     .00     .00     .00     .15     .19
     .84     .99    1.57    1.27    1.64    1.91    1.47    1.34     .67     .00
     .00     .00     .24    1.10    1.67    2.09    2.52    4.10    3.62    4.51
    5.61    5.70    6.08    6.60    6.46    6.31    5.85    5.76    5.75    5.74
     .00     .00     .00     .00     .00     .15     .23     .36     .28    1.12
    1.92    2.99    3.59    3.31    4.10    4.66    3.86    3.68    2.67    2.58
    2.36    2.00    2.22    2.35    4.81    3.67    4.79    6.11    5.93    6.18
    6.59    6.53    6.95    6.96    7.09    6.75    6.98    6.98    6.99    6.99
     .00     .00     .00     .25     .90     .64    1.09     .67    1.70    3.26
    3.94    5.28    6.23    5.51    5.97    5.30    5.27    5.04    4.96    5.11
    5.29    5.17    4.67    4.51    5.79    5.88    6.77    7.38    6.94    6.98
    6.94    7.33    7.69    7.97    8.15    7.66    8.14    8.19    8.21    8.22
    2.22    2.06    1.38    1.92    2.44    2.95    2.97    2.95    4.41    5.93
    5.65    6.50    7.38    8.62    8.31    8.06    7.78    7.22    6.76    6.41
    6.18    6.62    6.25    6.24    6.79    7.25    7.96    8.00    7.80    7.91
    8.11    8.33    8.70    9.02    8.92    8.28    8.32    8.27    8.25    8.25
    4.94    4.47    4.44    3.69    4.32    5.02    5.16    5.36    7.02    7.48
    7.47    8.27    9.87   10.83   10.77   10.68    9.77    9.03    9.00    8.46
    8.59    8.47    7.89    7.77    7.59    7.92    8.42    8.58    8.62    8.79
```

Figure J4. INTDEPN

# APPENDIX K:  NOTATION

| | |
|---|---|
| $a$ or $a(x,y)$ | Wave amplitude function |
| $\bar{a}$ | Function of the bottom slope |
| $A$ | Function of dependent variables |
| $\bar{b}$ | Function of the bottom slope |
| $B$ | Function of dependent variables |
| $c$ or $c(x,y)$ | Wave celerity |
| $c_g$ or $c_g(x,y)$ | Group velocity |
| $c_o$ | Deepwater wave celerity |
| $D$ | Energy dissipation function |
| $D^*$ | Energy dissipation function |
| $E$ | Wave energy |
| $F$ | Function of dependent variables |
| $\bar{F}$ | Function of dependent variables |
| $g$ | Gravitational acceleration constant |
| $G$ | Function of dependent variables |
| $\bar{G}$ | Function of dependent variables |
| $h$ or $h(x,y)$ | Water depth |
| $h_b$ | Water depth at incipient breaking |
| $H$ or $H(x,y)$ | Wave height |
| $H_b$ | Wave height at incipient breaking |
| $H_o$ | Deepwater wave height |
| $i$ | Arbitrary subscript designating the x-direction |
| $i$ | Complex number equal to $\sqrt{-1}$ |
| $\vec{i}$ | Unit vector in the x-direction |
| ikey | Specific subscript designating the x-direction |
| $j$ | Arbitrary subscript designating the y-direction |
| $\vec{j}$ | Unit vector in the y-direction |
| jkey | Specific subscript designating the y-direction |
| $k$ or $k(x,y)$ | Wave number |
| $L_b$ | Wave length at incipient breaking |
| $L_o$ | Deepwater wave length |
| $m$ | Bottom slope |
| $M$ | Total number of grid cells in the x-direction |
| $N$ | Total number of grid cells in the y-direction |
| $Q$ | Flow across a hydraulic jump |

| | |
|---|---|
| $s$ or $s(x,y)$ | Wave phase function |
| $s$ | Subscript denoting stable wave conditions |
| $T$ | Wave period |
| $W$ | Weighting factor |
| $x$ | Coordinate direction |
| $x'$ | Coordinate direction |
| $y$ | Coordinate direction |
| $y'$ | Coordinate direction |
| $Y_1$ | Water depth on the high end of a hydraulic jump |
| $Y_2$ | Water depth on the low end of a hydraulic jump |
| $\alpha$ | Weighting factor |
| $\alpha^*$ | Coefficient |
| $\beta$ | Coefficient |
| $\gamma$ | Coefficient |
| $\delta$ | Rate of energy loss |
| $\Delta x$ | Grid size in the x-direction |
| $\Delta y$ | Grid size in the y-direction |
| $\theta$ | Wave angle |
| $\theta_c$ | Contour angle |
| $\theta_o$ | Deepwater wave angle |
| $\kappa$ | Rate of energy dissipation coefficient |
| $\kappa^*$ | Coefficient |
| $\kappa_r$ | Refraction coefficient |
| $\kappa_s$ | Shoaling coefficient |
| $\nu_e$ | Coefficient |
| $\rho$ | Water density |
| $\sigma$ | Angular wave frequency |
| $\phi$ | Velocity potential function |

Mathematical symbols

| | |
|---|---|
| $\partial$ | Partial differentiation |
| $\nabla$ | Horizontal gradient operator |
| $\cdot$ | Vector dot product |
| x | Vector cross product |
| $\| \|$ | Absolute value |