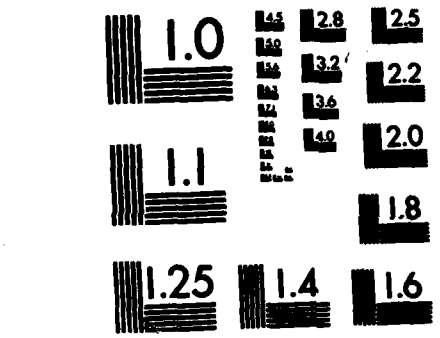
AD-A125 104 PREDICTION OF NEARSHORE WAVE TRANSFORMATION(U) COASTAL 1/1
ENGINEERING RESEARCH CENTER FORT BELVOIR VA
J M HUBERTZ DEC 82 CERC-CETA-82-7

UNCLASSIFIED F/G 8/3 NL

END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12)

CETA 82-7

Prediction of Nearshore Wave Transformation

AD A125104

by

Jon M. Hubertz

COASTAL ENGINEERING TECHNICAL AID NO. 82-7

DECEMBER 1982

Approved for public release;
distribution unlimited.

DTIC
ELECTE
MAR 2 1983
A

DTIC FILE COPY

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER
Kingman Building
Fort Belvoir, Va. 22060

83 03 02

Reprint or republication of any of this material shall give appropriate credit to the U.S. Army Coastal Engineering Research Center.

Limited free distribution within the United States of single copies of this publication has been made by this Center. Additional copies are available from:

National Technical Information Service
ATTN: Operations Division
5285 Port Royal Road
Springfield, Virginia 22161

Contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CETA 82-7	2. GOVT ACCESSION NO. AD-A125 104	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PREDICTION OF NEARSHORE WAVE TRANSFORMATION		5. TYPE OF REPORT & PERIOD COVERED Coastal Engineering Technical Aid 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jon M. Hubertz		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CO) Kingman Building, Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A31592
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, VA 22060		12. REPORT DATE December 1982 13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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

Computer programs	Reflection	Shoaling
Irregular wave conditions	Refraction	Wave transformation

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

The DHI System 21 Mark 8 numerical model for the prediction of both long and short waves is being used in certain studies of coastal engineering problems. Procedures are discussed for using the model to predict nearshore short wave transformations. An example is presented showing the combined effects of refraction, shoaling, reflection, and diffraction. Predicted model results are compared to measured wave heights at the Coastal Engineering Research Center's Field Research Facility in Duck, North Carolina.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

The U.S. Army Coastal Engineering Research Center (CERC) and the U.S. Army Engineer Waterways Experiment Station (WES) entered into an exchange research agreement with the Danish Hydraulic Institute (DHI), Horsholm, Denmark, in March 1980. In this exchange of research the Corps of Engineers received the System 21 Mark 8, which is a proprietary research model used for computing water elevations and vertically averaged currents, for use at CERC and WES. This report discusses use of the model in estimating short wave transformations. The work was carried out under CERC's Wave Estimation for Design work unit, Coastal Flooding and Storm Protection Research Program, Coastal Engineering Area of Civil Works Research and Development.

The report was prepared by Dr. Jon M. Hubertz, Oceanographer, under the supervision of Dr. C.L. Vincent, Chief, Coastal Oceanography Branch, and Mr. R.P. Savage, Chief, Research Division.

Technical Director of CERC was Dr. Robert W. Whalin, P.E., upon publication of the report.

Comments on this publication are invited.

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

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

DTIC COPY INSPECTED 2

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A

CONTENTS

		Page
	CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)	5
I	INTRODUCTION	7
II	APPLICATION ANALYSIS	7
	1. System 21 Mark 8 Model Grid Setup	7
	2. System 21 Mark 8 Model Topography	9
III	SYSTEM 21 MARK 8 MODEL COMPONENTS	9
	1. Initialization Unit (IU)	9
	2. Computational Unit (CU)	10
	3. Example Application	10
IV	SUMMARY	13

FIGURES

1	The region of application of the System 21 Mark 8 model for short waves	8
2	Contours of bathymetry near the pier (October 1980 survey)	10
3	The observed and predicted wave heights	12
4	The spectrum from wave observations at the end of the pier, 24 November 1980	12

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

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

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

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

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

PREDICTION OF NEARSHORE WAVE TRANSFORMATION

by

Jon M. Hubertz

I. INTRODUCTION

The U.S. Army Coastal Engineering Research Center (CERC) and the U.S. Army Engineer Waterways Experiment Station (WES) entered into an exchange research agreement with the Danish Hydaulic Institute (DHI), Horsholm, Denmark, in March 1980. One of the first benefits to the Corps of Engineers was the transfer of the System 21 Mark 8 model to CERC and WES. The System 21 Mark 8 is a proprietary research model used for computing water elevations and vertically averaged currents. This model has been briefly described in the CERCular of October 1980 and in U.S. Army, Corps of Engineers, Coastal Engineering Research Center (1981a, 1981b)[1,2].

The System 21 Mark 8 model can be used in two modes--the prediction of coastal and estuarine long waves, such as tides or storm surges; and the prediction of short waves, such as waves with periods of about 10 seconds. The steps followed in applying the model are generally the same for both types of application.

This report discusses procedures for using the System 21 Mark 8 model to predict nearshore short wave transformation and to make field personnel more familiar with the type problems for which it can be used. The example discussed illustrates the combined effects of refraction, shoaling, reflection, and diffraction. The material discussed is intermediate in detail compared with that discussed in the publications referenced above and the User's Guide, which would be needed for an actual application.

II. APPLICATION ANALYSIS

1. System 21 Mark 8 Model Grid Setup.

When applying the System 21 Mark 8 model the first step is to determine the characteristics of the waves and the mean water depth in the region of interest. By using these parameters and Figure 1, it can be determined whether the model is applicable. Given the wave height, period, and mean water depth, the ratios H/L_o and D/L_o ($L_o = g/2\pi T^2$) can be plotted on Figure 1. The model applies if the plotted point lies within the shaded region.

The second step is to determine the size of the model area. This is governed primarily by two factors. The area should be large enough to include any proposed structure and have boundaries far enough away from regions of

---

[1]U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Computer Program: S21 Coastal Water Level Variations and Flows," CETN-I-4, Fort Belvoir, Va., Jan. 1981a.

[2]U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Computer Programs - Storm Surge," CETN-I-16, Fort Belvoir, Va., Dec. 1981b.

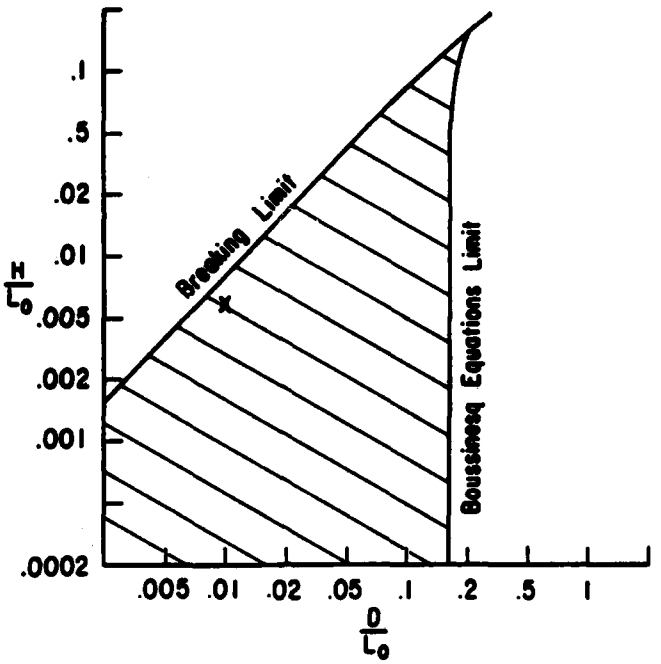


Figure 1. The region of application (shaded area) of the System 21 Mark 8 model for short waves.

interest so that the boundary effects will not influence results. However, it should not be so large that excessive calculations are required. Certain estimates can be made to determine an appropriate region size. One estimate is related to the finite-difference grid that subdivides the region. This grid is a set of equally spaced straight orthogonal lines with spacing (ΔX) of at least 10 gridlines per wavelength in the region of interest. This sets the approximate distance between the gridlines and helps in estimating the region size that can be accommodated.

A second estimate approximates the time step (Δt) of the model, expressed as

$$\Delta t = (10 \text{ to } 15) \frac{\Delta X}{(2gh)^{0.5}} \qquad (1)$$

where g is gravity and h the mean depth. This states that the time step could be about 10 to 15 times the Courant stability criteria for an explicit model. However, it may not be practical to have a time step this large since the time step might be larger than the wave period; therefore, the wave may not be resolved in time.

An estimate of the computer time needed for a System 21 Mark 8 model run can be made using the estimates of the ΔX, Δt, size of the grid region, and the length of the simulation. This is expressed as

$$\text{Run time} = \frac{M \times N \times (T/\Delta t)}{3{,}000} \text{ (seconds)} \qquad (2)$$

where M is the total number of gridlines in the x direction, N the total number of gridlines in the y direction, and T the total time simulated in seconds. The number 3,000 is the approximate number of computational points per second the model processes on an IBM 3033; on a CRAY computer, it would be approximately 20,000.

It is evident that the grid region, grid spacing, time step, wave characteristics, and depth are interrelated and that certain limits are imposed on the grid spacing and the time step for proper model performance. A number of parameter variations may be required before an acceptable combination is determined. If waves of different heights and periods are used in the model, each case should be checked for conformance to limitations.

2. System 21 Mark 8 Model Topography.

Once the model grid has been established, certain information must be supplied at each gridline. First the elevation of each gridline must be specified. This process is automated since the large number of gridlines precludes it being done manually.

If elevations on the base map are randomly spaced, they can be located in the grid by the x and y gridline that is closest. Values of x, y, and z (elevation) can then be processed by the interpolation program described in Herchenroder (1981)[3] to obtain elevations along each gridline. The resolution of topographic features in the region is directly related to how much information is supplied to the interpolation program. If a topographic feature is not defined by spot values, it will not be present in the interpolated values.

An alternative method to specifying the spot value of an elevation is to specify the location of contours of an elevation. By choosing the contour interval, control is kept over which features are to be resolved in the region. The contours can be digitized to obtain a set of x, y, and z values for input into the interpolation program. This program, in turn, supplies the depth values along each gridline.

III. SYSTEM 21 MARK 8 MODEL COMPONENTS

1. Initialization Unit (IU).

The IU creates the input to the computational unit (CU) and also checks for errors in the data. Further, it allows the user to make changes or additions to a set of basic model parameters that define the type run to be made. Examples of such parameters would be the number of time steps, the size of a time step, and any options used to print and store the results. In addition, it allows for the adjustment of parameter fields, such as the initial surface level, the frictional bed resistance eddy coefficients (which are related to the diffusion of momentum), and the porosity coefficients (which are related to energy loss due to flow through porous media). Boundary data are also specified through the IU. These data designate which sections of the grid

[3]HERCHENRODER, B.E., "Products From Two Computer Programs Which Process Digital Bathymetric Data," CETA 81-13, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Oct. 1981.

boundaries are open and the type boundary condition to be imposed on each. The program can be run in an interactive mode from a terminal, allowing errors in the input data to be corrected efficiently and changes made to the parameters.

2. Computational Unit (CU).

The CU is the program that does the actual calculations of the water level and x,y components of the water velocity along each gridline at every time step. It is submitted as a batch job with the user having no control as opposed to the IU, which is interactive. The CU uses the data prepared by the IU and produces a simulation through the time period specified. The printout of water level and velocity components can be obtained at specified time increments. Results also can be stored at specified time increments for use later in plotting the water levels and currents in one, two, or three dimensions at a given time or versus time at specified points.

3. Example Application.

The System 21 Mark 8 model is applied to an area around the CERC Field Research Facility at Duck, North Carolina. Contours of the bathymetry in the region modeled are shown in Figure 2. A 60 by 130 grid with a uniform spacing

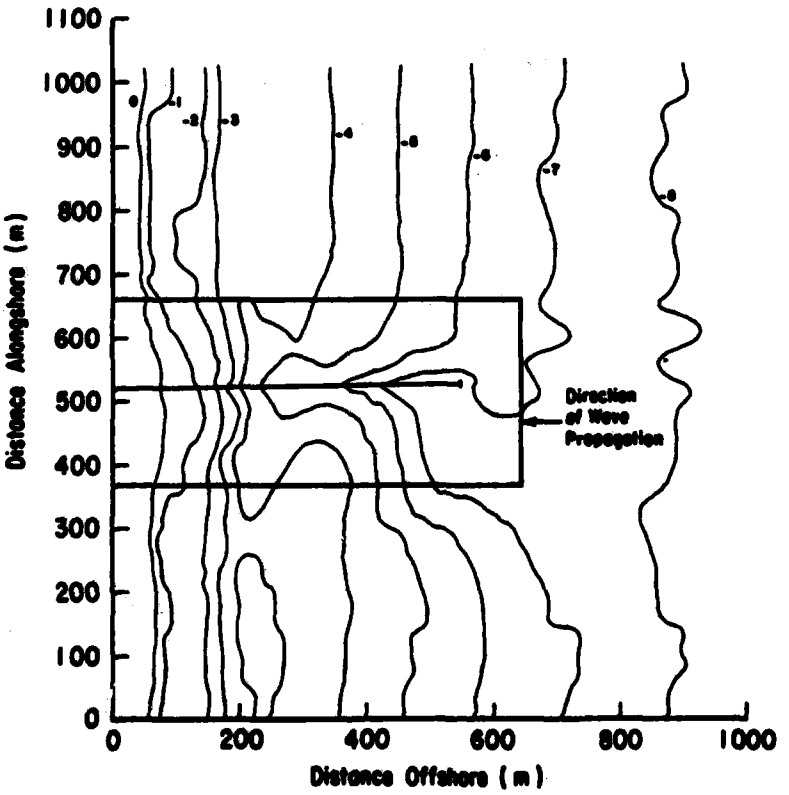


Figure 2. Contours of bathymetry near the pier (October 1980 survey). The rectangular boundary near the pier is the region modeled. The contour interval is 1 meter.

of 16.4 feet (5 meters) was prepared for the bordered region near the pier. The wave transformation is expected to be greater within this region than it is outside it where the bathymetry is more uniform.

A wave with a period of 14 seconds and height of 6.9 feet (2.1 meters) is input that is normal to the seaward boundary. The value for H/L_o and D/L_o are respectively 0.0068 and 0.01 using a mean water depth of 13.1 feet (4.0 meters). These values are within the applicable region as shown by the (X) in Figure 1. A time step of 1.0 second is chosen to resolve the wave in time, giving 14 time steps per wavelength. The grid spacing of 16.4 feet (5 meters) gives about 20 points per wavelength in space for shallow water. Equation (2) indicates that a computer run of 15 wave periods requires about 9 minutes of IBM 3033 computer time. The actual model run required 10 minutes and cost $26.

A plot of the wave height from various positions offshore is shown in Figure 3. The measured values are from gages located along the pier, while the computed values are from the model along a line adjacent to the pier. The two wave heights (observed and predicted) are not directly comparable. The observed wave heights are significant wave height estimates from the peak energy of a spectrum, while the predicted values are from a monochromatic input. This difference is minimized in this example since the observed spectrum is very narrow (Fig. 4). Another difference between the modeled and the observed is wave direction. The best estimate of the wave direction from pressure and current sensors at the pier end is toward 238° (North being 0°), which is 14° from being straight down the pier.

This report indicates that the System 21 Mark 8 model provides a reasonable reproduction of the measured field wave conditions for the case of a nearly monochromatic wave spectrum. Tests representing a broad wave spectra by a single height and period are less successful because the energy is spread over waves that propagate at different speeds, which violate the basic assumptions of the model. Thus, the model's use appears best when restricted to comparison studies where test cases (different structure configurations, etc.) can be run with either idealized linear or cnoidal waves, or where the basic refraction-diffraction patterns are to be studied. The model cannot simulate wave breaking; care must be taken to insure that breaking-wave conditions do not occur in a simulation.

The simulation discussed in this report covered about 0.2 square kilometer and cost $26 in computer time. If the same grid spacing, depths, and wave periods are applicable, the costs per simulation are about $130 per square kilometer per model run or $336 per square mile on an IBM 3033 computer. On a faster computer the costs may be reduced by a factor of up to 6, although the machine costs may be more. Often, the largest cost is in setting up the grids. In any case, practical constraints generally will limit the economic usefulness of the model to a small area and only a few runs. If a study envisions the need for many runs it may be more economical and perhaps more reliable to use a physical model.

A physical model should be used if wave breaking and reformation is a major concern to the effort. The numerical model appears most useful for quick studies of small areas where only a few alternatives are being considered. It also may be useful when an initial study (perhaps during the reconnaissance

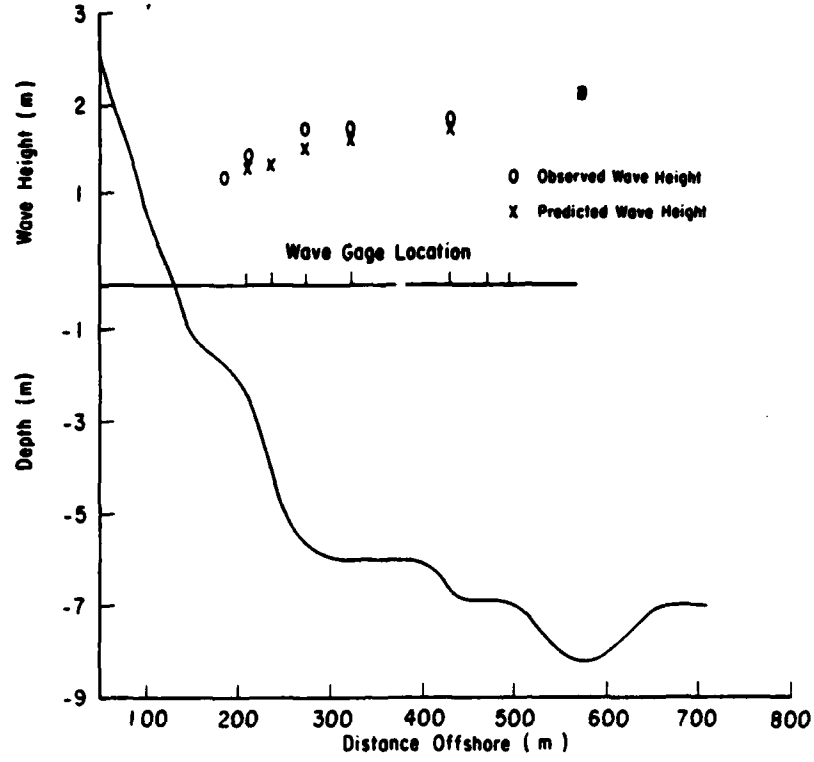


Figure 3. The observed and predicted wave heights.

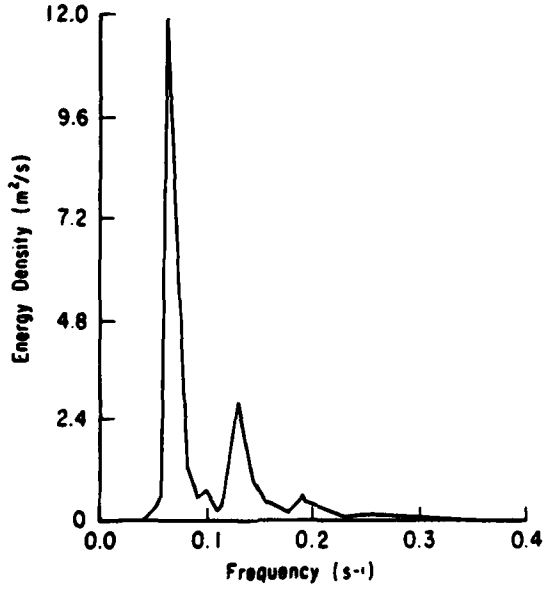


Figure 4. The spectrum from wave observations at the end of the pier, 24 November 1980. Significant wave height at peak frequency is used as input to the model.

stage of a study or early in the phase I planning stage) with the model is needed to help determine the cause of a problem to aid in directing future field, laboratory, or numerical investigations required to obtain a viable engineering solution to the problem.

The principal value of the System 21 Mark 8 model is the combination of refraction and diffraction, providing improved wave calculations relative to refraction models which are more widely used. There are hydrodynamic processes the model cannot handle, but it is more sophisticated than most other short wave numerical wave codes available. It is also well documented and should be considered a helpful addition to the other numerical and laboratory tools available for use in analyzing coastal engineering problems.

IV. SUMMARY

This report has discussed the range of application of the short wave DHI System 21 Mark 8 model for various wave conditions and depths. The general steps used in applying the model are presented, along with an example of the wave transformation, which simultaneously included refraction, diffraction, shoaling, and reflection.

Possible uses of the System 21 Mark 8 model in the short wave mode are: the study of wave transformation near small harbors, shore-connected or offshore breakwaters, inlets, or in shallow areas of complicated bathymetry. Use of the model for short waves in areas larger than 1 square mile (2590 square kilometers) for normal wave periods is not usually cost effective. In these cases, a combination of models, where one model treats the large-scale area and another treats the small-scale area, would be more appropriate.

Hubertz, Jon M.
Prediction of nearshore wave transformation / by Jon M. Hubertz.—Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center ; Springfield, Va. : available from NTIS, 1982.
[13] p. : ill. ; 28 cm.—(Coastal engineering technical aid ; no. 82-7)
Cover title.
"December 1982."
Report discusses use of the Danish Hydraulic Institute (DHI) System 21 Mark 8 numerical model in estimating nearshore short wave transformations. An example is presented showing the combined effects of refraction, shoaling, reflection, and diffraction. Predicted model results are compared to measured wave heights at CERC's Field Research Facility in Duck, North Carolina.
1. Computer programs. 2. Wave reflection. 3. Wave refraction. 4. Shoaling. 5. Wave transformation. 6. Wave diffraction. I. Title. II. Coastal Engineering Research Center (U.S.). III. Series: Technical Aid (Coastal Engineering Research Center (U.S.)); no. 82-7.
TC203 .U581ta no. 82-7 627

Hubertz, Jon M.
Prediction of nearshore wave transformation / by Jon M. Hubertz.—Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center ; Springfield, Va. : available from NTIS, 1982.
[13] p. : ill. ; 28 cm.—(Coastal engineering technical aid ; no. 82-7)
Cover title.
"December 1982."
Report discusses use of the Danish Hydraulic Institute (DHI) System 21 Mark 8 numerical model in estimating nearshore short wave transformations. An example is presented showing the combined effects of refraction, shoaling, reflection, and diffraction. Predicted model results are compared to measured wave heights at CERC's Field Research Facility in Duck, North Carolina.
1. Computer programs. 2. Wave reflection. 3. Wave refraction. 4. Shoaling. 5. Wave transformation. 6. Wave diffraction. I. Title. II. Coastal Engineering Research Center (U.S.). III. Series: Technical Aid (Coastal Engineering Research Center (U.S.)); no. 82-7.
TC203 .U581ta no. 82-7 627

Hubertz, Jon M.
Prediction of nearshore wave transformation / by Jon M. Hubertz.—Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center ; Springfield, Va. : available from NTIS, 1982.
[13] p. : ill. ; 28 cm.—(Coastal engineering technical aid ; no. 82-7)
Cover title.
"December 1982."
Report discusses use of the Danish Hydraulic Institute (DHI) System 21 Mark 8 numerical model in estimating nearshore short wave transformations. An example is presented showing the combined effects of refraction, shoaling, reflection, and diffraction. Predicted model results are compared to measured wave heights at CERC's Field Research Facility in Duck, North Carolina.
1. Computer programs. 2. Wave reflection. 3. Wave refraction. 4. Shoaling. 5. Wave transformation. 6. Wave diffraction. I. Title. II. Coastal Engineering Research Center (U.S.). III. Series: Technical Aid (Coastal Engineering Research Center (U.S.)); no. 82-7.
TC203 .U581ta no. 82-7 627

Hubertz, Jon M.
Prediction of nearshore wave transformation / by Jon M. Hubertz.—Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center ; Springfield, Va. : available from NTIS, 1982.
[13] p. : ill. ; 28 cm.—(Coastal engineering technical aid ; no. 82-7)
Cover title.
"December 1982."
Report discusses use of the Danish Hydraulic Institute (DHI) System 21 Mark 8 numerical model in estimating nearshore short wave transformations. An example is presented showing the combined effects of refraction, shoaling, reflection, and diffraction. Predicted model results are compared to measured wave heights at CERC's Field Research Facility in Duck, North Carolina.
1. Computer programs. 2. Wave reflection. 3. Wave refraction. 4. Shoaling. 5. Wave transformation. 6. Wave diffraction. I. Title. II. Coastal Engineering Research Center (U.S.). III. Series: Technical Aid (Coastal Engineering Research Center (U.S.)); no. 82-7.
TC203 .U581ta no. 82-7 627