Coastal Engineering Technical Note

CURRENT: A COMPUTER MODEL FOR WAVE-INDUCED CURRENTS AND SETUPS

PURPOSE: To introduce a computer model called CURRENT developed at the US Army Engineer Waterways Experiment Station's (WES's) Coastal Engineering Research Center (CERC).

BACKGROUND: When wind waves break and decay in the surf zone, they induce longshore and cross-shore currents as well as changes in the mean water level of the sea surface. A rise in mean water level is known as a "setup" and a drop a "setdown". These wave-induced currents and setups play a major role in sediment transport, pollutant mixing, etc., in the nearshore region. CURRENT may be used to compute these currents and setups for field conditions.

MODEL FEATURES: The model uses a monochromatic (significant) wave approach. The equations for wave-induced currents are depth-averaged and time-averaged with respect to the wave period. They are similar to the long wave equations, except there are additional terms due to "radiation stresses" which arise because of the excess momentum flux due to waves. These are the dominant "forcing" terms. Moreover, friction and lateral mixing (eddy viscosity) are formulated differently from those in the long wave equations. CURRENT uses a linear friction similar to that of Longuet-Higgins (1970) and an anisotropic eddy visocity. The model includes advection (convective acceleration) terms which are nonlinear. CURRENT was developed from an existing, well-tested, long-wave model known as WES Implicit Flooding Model (WIFM). CURRENT uses an alternating-direction, implicit, finite-difference approach, and a three time-level scheme to solve the governing equations. It can be used in a time-dependent mode or marched in time to a steady-state solution. It can use a variable numerical grid so that grid cells may be made finer in regions of greater interest such as the surf zone, inlets, and channels and coarser in regions of less interest, such as those near the lateral and offshore boundaries. In this way, the total number of cells covering a project region may be kept small compared with a uniform grid covering the same region, thereby reducing computation time but maintaining comparable accuracy. Figure 1 shows the variable grid used for the Oregon Inlet, North Carolina, simulation.

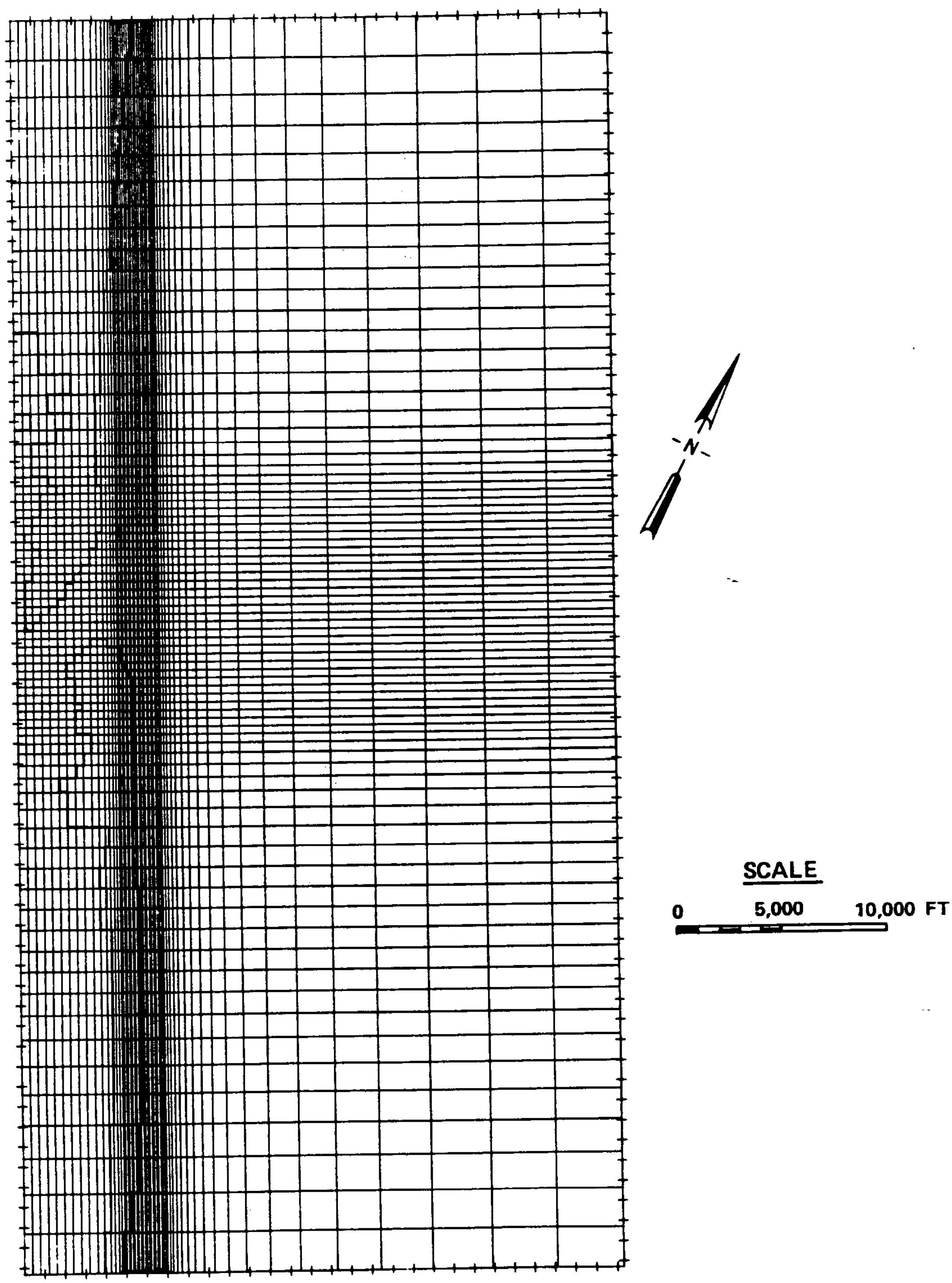

Figure 1. Numerical grid used for Oregon Inlet, North Carolina, simulation

The model is designed for field applications involving irregular bathymetries and large numerical grids containing thousands of cells. It is very efficient computationally. Model results show excellent agreement with available analytic solutions and experimental data. The model has been applied in a mission support study at Oregon Inlet, North Carolina, for the Corps' Wilmington District and is currently being used in studies at St. Marys Inlet, Florida, and Yaquina Bay, Oregon, for the US Navy and the Portland District, respectively.

Boundary conditions. CURRENT uses a "no flow" (wall) boundary condition at the shoreline. A uniform flux type boundary condition is employed at the lateral boundaries, which are chosen to be far from the area of interest. The flux at a lateral boundary cell is made equal to the flux at the adjoining interior cell. At the offshore boundary, which is chosen far from the surf zone, a radiation type boundary condition is used. It permits the transients developed during start-up of the numerical solution to propagate out of the grid. It was found to be superior in performance to the no flow and constant elevation conditions (employed by other investigators), which are highly reflective.

Effects of structures. CURRENT can consider the effects of impermeable, non-overtopping structures such as jetties, breakwaters, and groins, provided the diffraction effects of the structures are accounted for in the wave model which furnishes input to CURRENT.

APPLICATION OF THE MODEL TO A FIELD PROJECT:

Numerical grid. The coastal area of interest is modeled with a variable numerical grid. The lateral and offshore boundaries are located far away from the area of interest and the influence of any structures. The variable grid for the project is developed by using a special interactive program called MAPIT which maps the variable grid in the physical plane to a uniform grid in the computational plane. The grid cell expansion coefficients from MAPIT are stored in a separate file for later use. Another program called GRID can be used to plot the grid to any desired scale. The bed elevations at the centers of the grid cells are obtained by overlaying the grid on bathymetric charts, such as those of the National Ocean Service, and digitizing the charts.

Wave information. CURRENT requires, as input, wave climate information (wave height, wave direction, and wave number) at every grid cell corresponding to the particular significant wave of interest in deepwater. This information has to be provided by a monochromatic wave model that accounts for shoaling, refraction, and diffraction due to bathymetry, and diffraction due to structures. Such a wave model called RCPWAVE is available at CERC and has been used to furnish wave information to CURRENT.

INPUT: The input data necessary for a typical run of CURRENT are:

1. Model grid dimensions (number of cells).

2. Time step used and cell dimensions for uniform grid in computational plane.

3. Number of time steps the simulation is to be run.

4. Time steps at which results for the whole grid are to be printed.

5. Shoreline and breaker line locations.

6. Location and type of boundaries and barriers.

7. Choice of method for computing eddy viscosity coefficients. Eddy viscosity coefficients may be computed using the Longuet-Higgins (1970) method, the Jonsson, Skovgaard, and Jacobsen (1974) method, or input to the model directly.

In addition to the above data, input files containing wave data, bed elevations, and grid expansion coefficients for all the grid cells are required.

OUTPUT: The model first "echo prints" all of the input data read in so the data can be checked for correctness. Next, it prints the eddy viscosity coefficients and wave orbital velocities computed during the course of the run. The water surface elevations and the two horizontal velocity components at all the grid cells are printed at the end of the simulation as well as at intermediate stages, if so desired. These results can be saved on a file and used with special plotting programs to obtain three-dimensional plots of the water surface and vector plots of the currents. If desired, the results may be averaged over a specified number of time steps toward the end of the run. Recording gages may be located at selected cells in the grid either to check on the solution and to verify that the solution has reached approximate steady state or to compare model results with field observations taken at the same locations. At the end of the run, time histories of water surface elevations and velocity components at the recording gage locations may be printed. This information may be stored in a file and, during post-processing, used with a graphics program to plot time series of surface elevations and velocity components at the gages. If desired, the model stores in a separate file the information necessary to run a numerical sediment transport model.

ADDITIONAL INFORMATION: CURRENT has been developed and tested on the CRAY 1 computers of Kirtland Air Force Base, New Mexico, and Boeing Computer Services (BCS). It is now available on CYBERNET computers. In view of the large core storage needed for efficiency of computation, it must be run on the CYBER 205 computer of CYBERNET. As for typical computation costs, for the Oregon Inlet application, involving 4,158 grid cells (covering an area approximately 62,400 ft x 29,400 ft) and 67 time-steps, a run of the model on CYBER 205 takes 285 SBU's which at priority P2 costs approximately $23. More details on the model can be found in Vemulakonda (1984) and Vemulakonda, Houston, and Butler (1982). The numerical wave model, RCPWAVE, is available at present for Corps district use. Programs MAPIT and GRID are part of the Coastal Modeling System (CMS) being developed at CERC. CMS is designed to be the major medium for releasing CERC numerical models to Corps districts. Full documentation on RCPWAVE and CMS will be available before the end of FY 85. CURRENT will be released to district personnel through CMS during 1986-87. For further information, contact Dr. S. Rao Vemulakonda, Coastal Processes Branch, CERC (WESCR-P), at (601) 634-2842

REFERENCES:

Jonsson, I.G., Skovgaard, O., and Jacobsen, T.S. 1974. "Computation of Longshore Currents," Proceedings of the 14th International Conference on Coastal Engineering, ASCE, Copenhagen, Denmark, pp 699-714.

Longuet-Higgins, M.S. 1970. "Longshore Currents Generated by Obliquely Incident Sea Waves, 1 and 2," Journal of Geophysical Research, Vol 75, No. 33, pp 6778-6789 and pp 6790-6801.

Vemulakonda, S.R. 1984. "Erosion Control of Scour During Construction; Report 7, CURRENT -- A Wave-Induced Current Model," Technical Report HL-80-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Vemulakonda, S.R., Houston, J.R., and Butler, H.L. 1982. "Modeling Longshore Currents for Field Situations," Proceedings of the 18th Coastal Engineering Conference, ASCE, Cape Town, South Africa, pp 1659-1676.