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WABED Model in the SMS: Part 2. Graphical Interface

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PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes the graphical interface for the **W**ave-**A**ction **B**alance **E**quation **D**iffraction (WABED) model that has been added to the U.S. Army Corps of Engineers (USACE) Surface-water Modeling System (SMS). The theoretical background and user's manual for WABED are given by Lin et al. (2006) and Demirbilek et al. (in preparation). WABED is intended for applications in calculating wave transformation at coastal inlets and is part of the Coastal Modeling System (CMS) developed under the Coastal Inlets Research Program (CIRP) for simulating combined waves, currents, sediment transport, and morphology change.

INTRODUCTION: This CHETN describes the graphical interface of WABED available in SMS Version 9.2, which is similar to that of the half-plane STWAVE Version 3.0 (Smith et al. 2001). The SMS (Zundel 2006) is a graphically interactive computer program designed to facilitate the preparation and application of USACE numerical models. This package currently supports several circulation, wave, and sediment transport models and has recently been modified to generate input files for and visualize computed results of WABED (Mase and Kitano 2000; Mase 2001; Mase et al. 2005; Lin et al. 2006; Demirbilek et al. in preparation).

Grid and input files specific to WABED can be created by users in the SMS. Users can also run WABED with input files of STWAVE Version 3.0. This technical note describes input files required in a WABED simulation and special features of SMS interface implemented for the model. WABED has a theoretically based representation of wave diffraction, reflection, and wind-wave generation and growth processes. Wave diffraction and reflection play a vital role in inlet applications and, in particular, for long and reflective structures protecting inlets and navigation channels. The model is also part of the CMS for simulating combined waves and currents for calculating sediment transport and morphology change in inlet and navigation projects. It can run in the irregular rectilinear grid to minimize computing times for a large region. This feature allows users to use a single grid with different resolution in different parts of the model domain. By doing so, users are able to transform waves over large domains from deep water to nearshore where their coastal project sites are located. WABED also has the nested grid capability as an alternative for wave transformation in the local higher resolution area.

WABED FILES: Four input files are required to perform a WABED simulation (Figure 1). They are the simulation file (*.sim), the model parameters file (*.std), the depths file (*.dep), and the input directional spectrum file (*.eng). Optional input files include a current field file (*.cur), a friction coefficient field (friction.dat), a forward reflection coefficient field (forward.dat), and a backward reflection coefficient field (backward.dat). The name of the simulation file can be passed to WABED as a command line argument or the program will prompt the user for this file. The model may be

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launched from inside of the SMS, in which case the simulation file name is included as an argument, and the user is not prompted for input. Alternatively, the model can run outside the SMS in a DOS prompt by specifying the name of the simulation file (*.sim).

Depending on which options are selected in the *.std file, WABED may generate one to six output files. A wave field conditions file (*.wav) is always generated. Optional output files are: calculated spectra (*.obs) and wave parameters (selhts.out) at selected cells, wave breaking indices (*.brk), wave radiation stress gradients (*.rad), and nesting spectral data (*.nst). Figure 1 shows a chart of input and output files involved in a WABED simulation. Table 1 presents a list of the type and use of all I/O files, where "*projname*" is a prefix given by users.

The simulation file (*.sim) stores the coordinates of origin and orientation of the computational grid, and a list of names of all files used in the simulation. All input and output files, required and optional, are listed in Figure 1, and a description of each file is given in Table 1. Short snippets from sample files are included in Appendix A to familiarize users with these files.

Users can run WABED with input files of STWAVE Version 3.0 without making any changes. In this case, WABED runs in the basic mode. Although doing this may be useful in some project applications, it must be born in mind that WABED has additional capabilities and the basic mode does not take advantage of added features of the model. It is recommended that users run WABED with its special set of parameters as defined in the *.std file (i.e., keep existing input *.sim and *.dep files, but change *.std to add a few additional parameters that are specific to WABED). Guidance on various parameters and recommended values are given in the following paragraphs.

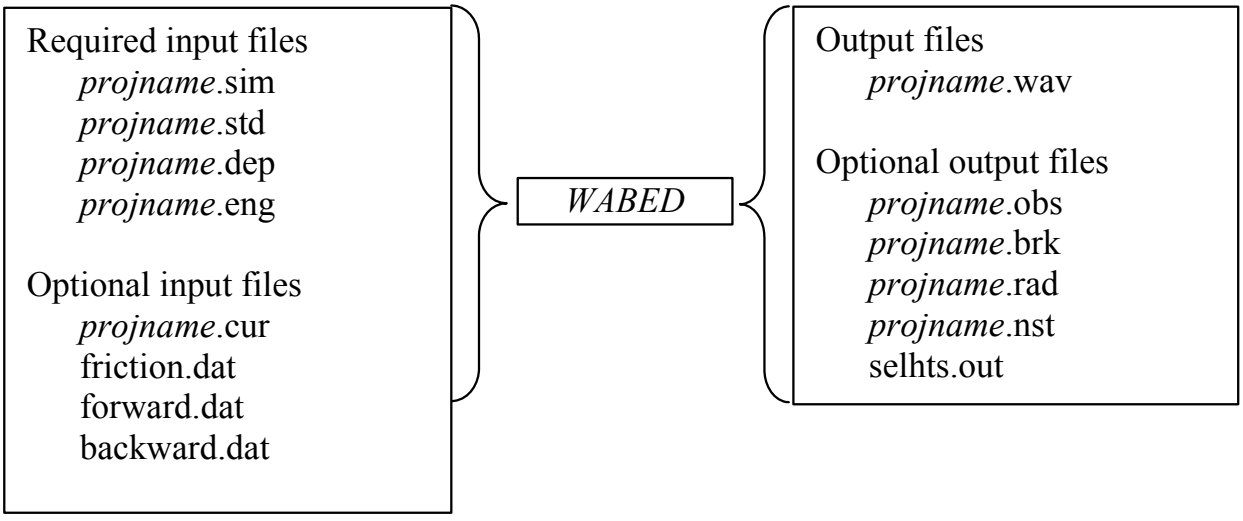

Figure 1. Files used in a WABED simulation.

Table 1
Files Involved in a WABED Simulation

File Name	Type	Description
projname.sim	Input -- required	File names for input/out of a simulation.
projname.std	Input -- required	Model parameters and output options.
projname.dep	Input -- required	Elevation value at each node.
projname.eng	Input -- required	Input energy spectra – this includes one spectra for each open boundary for each wave case. Wave spectra may be repeated.
projname.cur	Input – optional	Current value at each node (components in u,v directions).
projname.wav	Output – always	Wave height, period and direction for each cell.
projname.obs	Output -- optional	Transformed energy spectra at selected cells.
projname.brk	Output -- optional	Breaking flag or energy dissipated at each cell due to breaking depending on breaking option.
projname.rad	Output -- optional	Radiation stress gradients (in u,v directions) at each cell.
projname.nst	Output -- optional	Transformed wave spectra at selected cells
selhts.out	Output -- optional	Wave parameters at selected cells

Users can provide as many as 14 parameters in the *.std. They are iprp, icur, ibrk, irs, kout, ibnd, iwet, ibf, iark, iarkr, akap, bf, ark, arkr.

- iprp = 0, for propagation and wind input
  = 1, for propagation only (no wind input)
- icur = 0, no current
  = 1, with current input (*.cur)
- ibrk = 0 (no *.brk file)
  = 1, for output of wave breaking indices (*.brk)
  = 2, for output of energy dissipation fluxes (*.brk)
- irs = 0 (no *.rad file)
  = 1, for output of wave radiation stresses (*.rad)
- kout = 0 (no *.obs and selhts.out files)
  = 1, for output of spectra (*.obs) and parameters (selhts.out) at selected cells
- ibnd = 0 (no *.nst file)
  = 1, for nested grid output spectra (*.nst)
- iwet = 0, for no wetting/drying (i. e., no effect of tides at wet/dry cells)
  = 1, for wetting/drying
- ibf = 0, for no bottom friction
  = 1, for bottom friction
- iark = 0, no forward reflection
  = 1, with forward reflection
- iarkr = 0, no backward reflection
  = 1, for backward reflection
- akap = diffraction coefficient (0 for no diffraction, 3 for maximum diffraction)

- bf = constant bottom friction coefficient (default value is 0.005)
- ark = constant forward reflection coefficient (default value is 0.5)
- arkr = constant backward reflection coefficient (default value is 0.3)

These parameters are described further in the technical report (Demirbilek et al. in preparation).

WABED INTERFACE: This section describes the principal components of the WABED interface and provides users with engineering guidelines on central features of the model.

Similar to other finite-difference models available in the SMS, WABED is controlled through the two-dimensional (2-D) *Cartesian Grid Module*. The user should select the *Set Current Model* command in the *Edit* menu and choose WABED to activate the model interface. After WABED is selected as the active model, its menu and tools become available. It is recommended that users become familiar with other modules of the SMS to fully exploit complete utility of the interface. For example, the WABED grid can also be generated in the *Map Module* under the WABED coverage. Likewise, users can use the *Scatter Module* to import survey data and digital maps to define the bathymetry for model's grids.

a. **WABED Menu:** The WABED menu (Figure 2) commands are listed in Table 2, along with a description of each command.

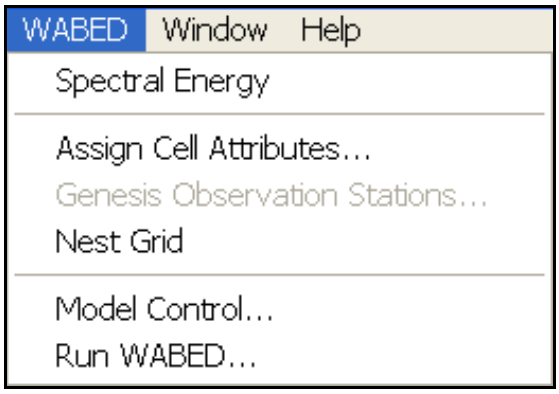

Figure 2. WABED menu.

b. **WABED Tools:** The most frequently used WABED tools in the SMS are listed in Table 3 along with their icon and functionality. Only one tool can be selected (active) at a time. The active tool may be a model specific tool such as those listed in the table, or it may be a general tool such as *Pan, Zoom,* or *Rotate*. The active tool controls what response the program will make when the user clicks or drags the mouse through the graphics window. Typically, there are two types of tools, those that are used to select entities and those that are used to create entities. In the WABED interface, the user can create a grid and may want to select certain cells. Multiple grid entities can be selected using the tools for selecting columns or rows, or by dragging a box or polygon around more that one entity, or by holding down the SHIFT key while sequentially clicking on entities.

Table 2
WABED Menu Commands

Command	Functionality
Spectral Energy	Brings up the spectral energy dialog to define/view wave energy spectra to be used in this simulation. Spectral generation is described in its own section.
Assign Cell Attributes	This command is used to assign cell attributes. A cell can be a typical ocean cell, a special ocean cell (spectral output computed at these), a typical land cell, or a structural cell. It is only available when one or more cells are selected.
Genesis Observation Stations	This command is for future capabilities currently under development.
Nest Grid	This command is for future capabilities currently under development.
Model Control	Brings up the Model Control dialog to specify model parameters.
Run WABED	Launches WABED with the currently loaded simulation. As the model runs, a dialog monitors progress of the model and gives the user status messages. When the run is complete, the spatial solutions are read in for analysis and visualization.

Table 3
WABED Tools

Tool	Icon	Functionality
Select Cell		Allows the user to select a computation point (cell) by graphically clicking on it. WABED works on a "Cell Centered" grid meaning that its computation points are at the centers of the cells. Once selected, the user can adjust the elevation of the cells or assigned cell attributes.
Select Row		Select an entire row of cells by clicking on any cell in the row.
Select Column		Select an entire column of cells by clicking on any cell in the column.
Create Grid		Create a computational grid by clicking three corners of the grid.

c. **Creating a Grid:** The process for creating a WABED grid consists of four steps:

1. **Read in bathymetric data**. These data can be from one or more surveys, or from a previous numerical model simulation. Data should be brought into the SMS as a scattered data set or a digital elevation map (DEM). The most common formats are described as an *.xyz or *.pts file in the SMS documentation. Data for coastlines and structures in the modeling domain could either be included in the bathymetry (recommended) or brought into the SMS separately and merged with the bathymetry data inside SMS.

2. **Select WABED as working model**. In the *Cartesian Grid Module*  , under Data menu, find *Switch Current Model* submenu and select WABED as the working model.

3. **Define modeling domain**. Zoom into the area around the computational domain and select the create grid tool  . To define the extent of your modeling domain, user must click three times in the graphics window. The first click (Pt 1) is at the location where the lower left corner of the grid will lie. Then the user should move the cursor (a line will appear from the selected corner) to the location where the lower right corner of the grid

will be and click again (Pt 2). Finally, the user must move the cursor to the location where the upper right corner of the grid will be and click again (Pt 3). Figure 3 shows a grid being defined. The first two clicks always defined the "I" axis of the grid, which is the x-direction for wave propagation.

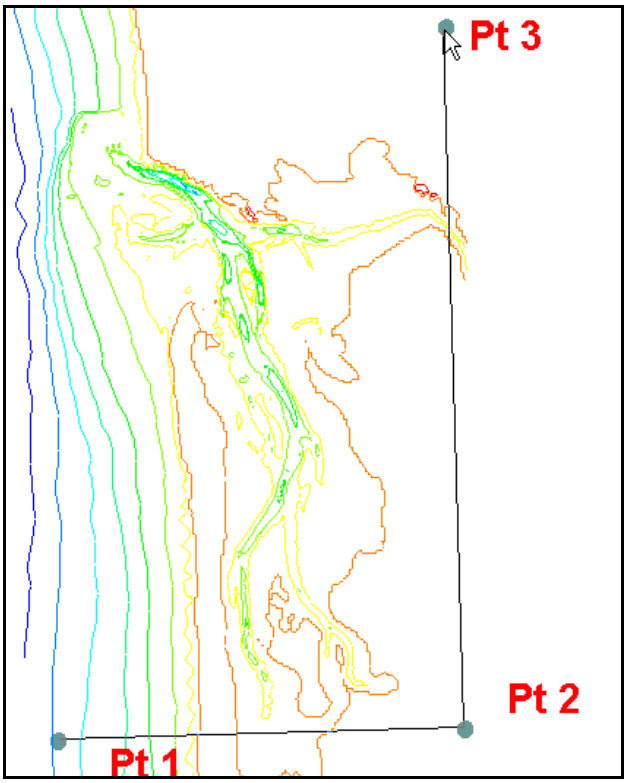

Figure 3. Creating a grid.

Create a grid. After defining the three points, the *Map->2D Grid* dialog will appear (Figure 4). This dialog allows users to modify the size, orientation, position and cell size for the grid that is being created. The grid position and orientation are initialized from the three points digitized in the previous step. If more exact locations are known, users would enter these in the top section of the dialog. In the center section, the individual cell size is entered. The SMS 9.2 interface of WABED supports only square cells. The variable cell-size feature will be available in SMS10. By default, the SMS creates a grid with 10 x 10 cells, but users can change these values as desired.

In the lower section of this dialog, users tell the SMS to interpolate the bathymetry values for the grid from the scattered data. If a scattered data set with a vector functional data set exists in the SMS at the time the grid is created, there is also an option to interpolate current data to the grid. Once this data set is entered, the user clicks the *OK* button, and a grid will be created. Bathymetry values for each cell of the grid along with current values, if that was specified, are interpolated from the scattered bathymetry data at the centroid of cells. Grid cells with a negative depth value are classified as dry land and excluded in the WABED calculations. After the grid is created, the user can select nodes and modify depth values and cell classifications (type).

d. **Editing a Grid:** Cell depths and attributes in the WABED grid may be edited, but the grid itself cannot be repositioned. To reposition or change the resolution of a grid, a new grid must be created. This is required if the domain needs to be enlarged or reduced, the grid cell size needs to be modified, or the grid orientation needs to be adjusted to align it better with the principal wave direction. Various other types of operation are permitted for editing WABED grid cells. These include:

1. **Specification of individual node elevation**. Select one or more nodes using the select cell tool, and specify a elevation value in the edit field located at the top of the application (just below the menus). This feature could be used, for example, to evaluate the effects of a dredging operation on the wave field by deepening parts of a navigation channel or describing dredged material mounds in the modeling domain, etc. This feature is useful if some changes to the underlying bathymetry are desired in a small part of the modeling domain where such changes can be made manually to a subarea or selection of cells.

2. **Classification of node point as land, structure, water, or monitoring (special output) location**. This is done by selecting one or more cells using the *select cell tool* and specifying the cell attributes using the *Assign Cell Attributes* command in the menu. This brings up the *Cell Attributes* dialog.

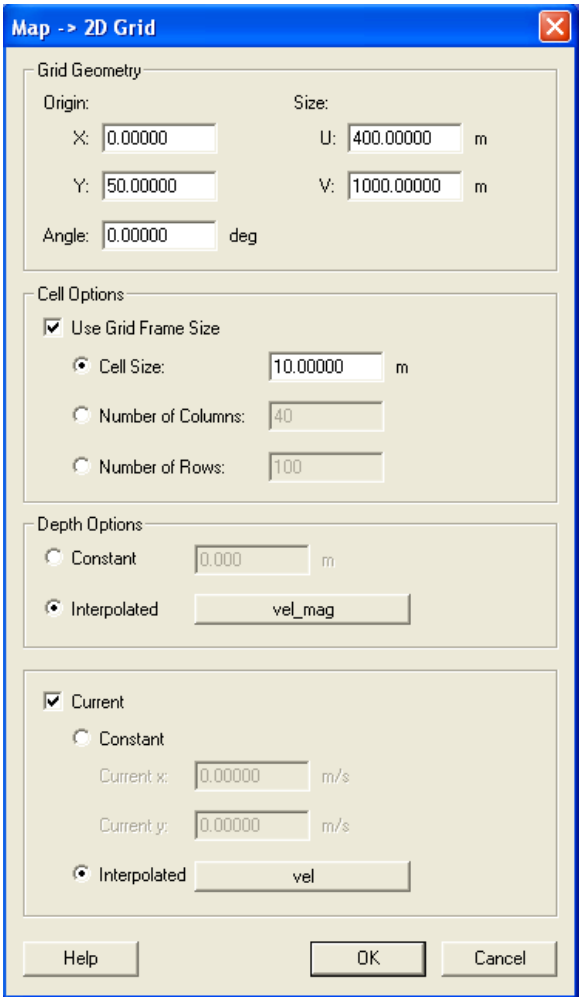

Figure 4. *Map ->2D Grid* dialog.

e. **Monitoring Cells:** The SMS interface for WABED allows for monitoring certain cells in the computational domain. To do this, users select the cells as described in the section on editing the grid, and assign the cell to be a monitoring station (Figure 5). For each monitoring station, WABED saves the entire (half-plane directional) spectrum in the *.obs output file.

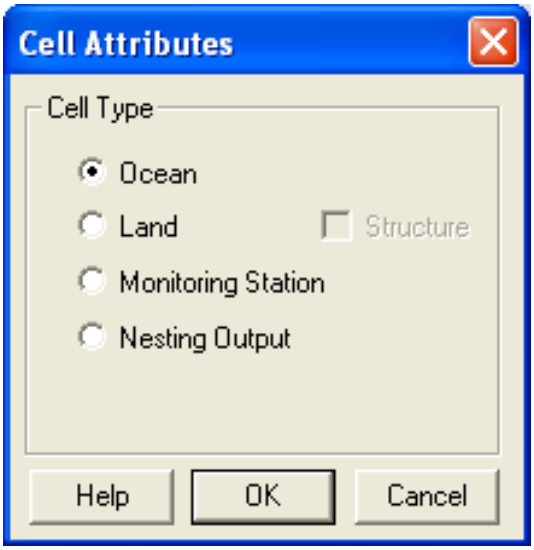

Figure 5. *WABED Cell Attributes* dialog.

f. **Defining Spectra:** Incident wave conditions for WABED consist of specifying an energy spectrum at the model's open boundaries. This requires users to define a proper input wave spectrum for the model to use. The input

spectrum (or spectra for multiple wave conditions) may be generated from an external source and read in from an energy *.eng file, or created using the spectral energy command in the WABED menu. This brings up the dialog shown in Figure 6. The wave spectral generator in WABED is the same generator developed for the Boussinesq model, BOUSS-2D. See Demirbilek and Nwogu (2001) for details about the spectral generator.

When generating the wave spectrum, users first create a spectral grid. The *Create Grid* button allows users to specify the number, distribution of frequencies, and the directional bin size. As default, the model uses 5 deg directional bins distributed over a half plane (Figure 6). Once the spectral grid is created, users can use the *Generate Spectra* button to generate spectra from user-specified spectral wave parameters. The types of parametric wave spectral forms supported are shown in Table 4. Parameters used to generate different wave spectra types are stored in a tabular text file (*.txt) with the simulation for later reference. The *Spectral Energy* dialog allows the user to view the spectra in polar or rectilinear coordinates. It also allows the modeler to rotate the spectra to view it in three dimensions. In the lower section, users can select either or both integrated frequency and directional plots of a generated spectrum.

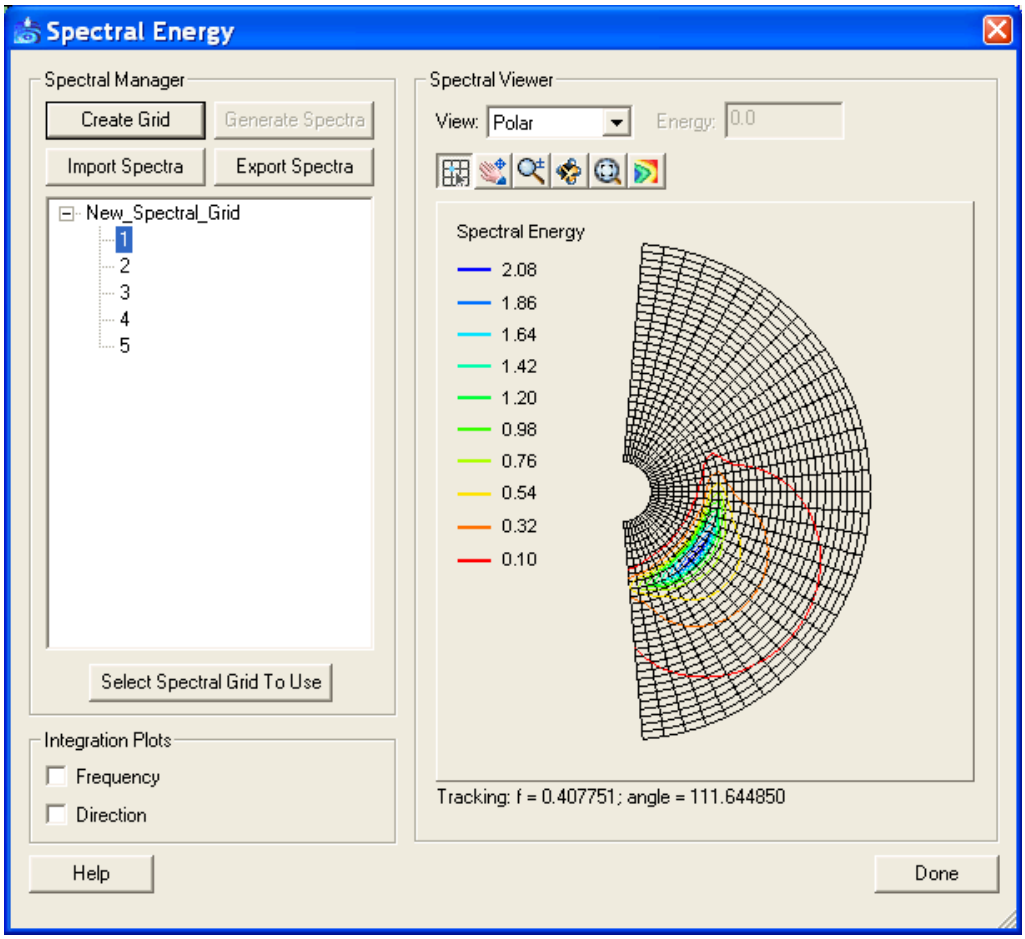

Figure 6. Spectral energy dialog for spectra visualization and generation.

g. **Model Control Parameters:** The *Model Control* command in the WABED menu brings up the *Model Control* dialog shown in Figure 7. This dialog displays the grid dimension and size at the top and model settings in the bottom. Because WABED needs to run in the metric system (m, m/sec, etc.), it is required to set the *Current Coordinates* under *Edit* menu to use 'meter' units for both vertical and horizontal coordinates.

Table 4
Spectral parameters

Method	Required Parameters
TMA Spectrum (Shallow Water)	Significant Wave Height (H_s) Peak Wave Period (T_p) Gamma Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
JONSWAP Spectrum	H_s and T_p or Wind Speed and Fetch Distance Gamma Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Bretschneider (ITTC) Spectrum	Significant Wave Height (H_s) Peak Wave Period (T_p) Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Pierson-Moskowitz Spectrum	Wind Speed or H_s or T_p Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not
Ochi-Hubble Double Peak Spectrum	H_s for the low frequency H_s for the high frequency T_p for the low frequency T_p for the high frequency Gamma for the low frequency Gamma for the high frequency Minimum Wave Period (T_{min}) Maximum Wave Period (T_{max}) Whether to rescale the spectrum or not

1. **Model settings**. This section describes the model control dialog for various WABED settings and computational options. If none of the options are selected, the model is run in the basic mode (no wetting and drying allowed, no current effect calculation even with the current input file provided, no reflection, diffraction, and bottom friction calculations). If the option for diffraction is checked, a default number of 1 for diffraction coefficient is provided. Users can change the default number for different diffraction intensity. The range of the diffraction intensity value is 0 to 3 (3 for strong diffraction). For reflection, a default value of 0.5 (50-percent reflection) is provided for the forward reflection, and 0.3 (30-percent reflection) for the backward reflection, if both options are toggled. Users can change these values of global reflection coefficients for all structures and shorelines. Users can provide spatially varied reflection coefficient values for different structures/shoreline segments using input files of forward.dat and backward.dat (with the same format as *.dep).

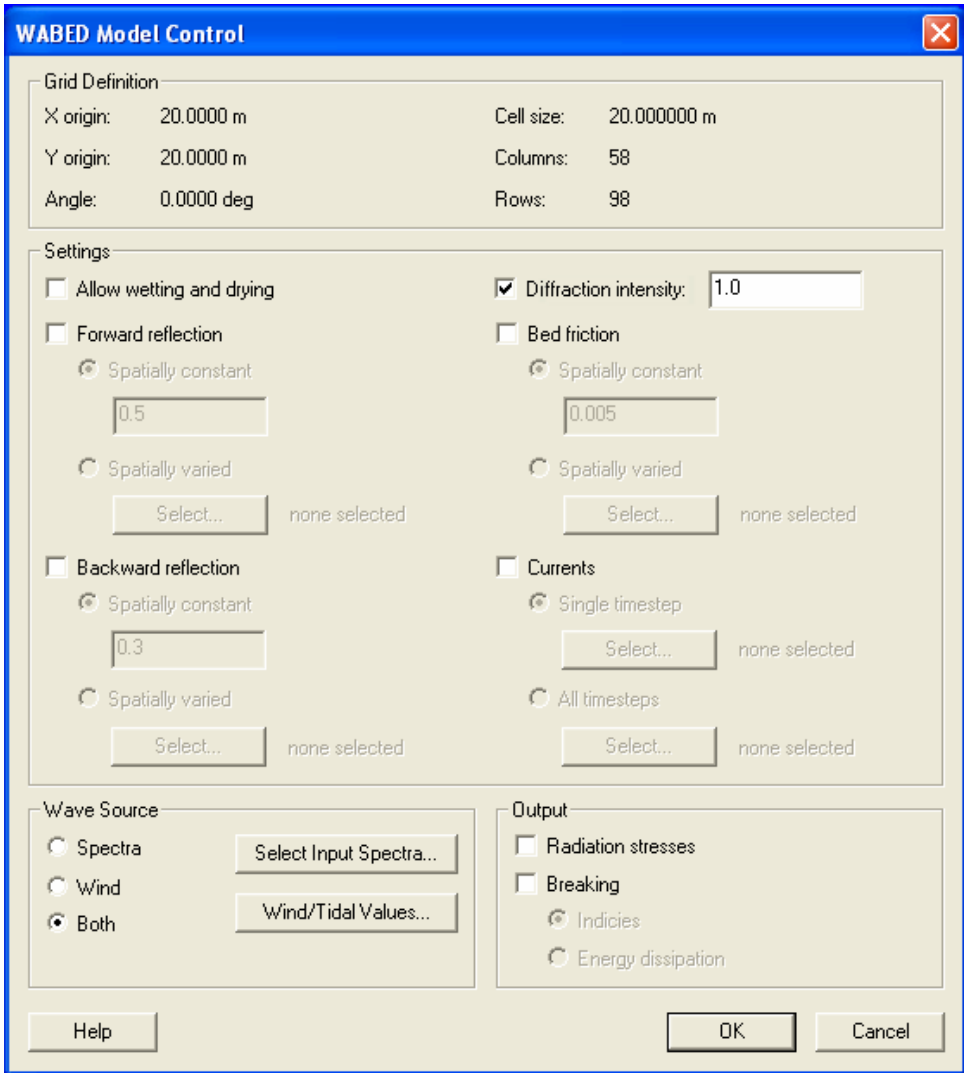

Figure 7. *WABED Model Control* dialog.

By checking the bottom friction option, a default bottom friction coefficient of 0.005 is provided for the entire grid. Users can also specify a different coefficient (between 0 and 0.1) or provide a file for spatially varied bottom friction coefficients. The file name is friction.dat and for file format is the same as *.dep. Details of the file format for spatial varied reflection and bottom friction coefficients are given in the WABED technical report (Demirbilek et al. in preparation). Examples of using different model settings will be presented in the subsequent notes.

2. **Wave source**. WABED allows consideration of multiple wind wave fields in a single run. By selecting the *Select Input Spectra* button, a dialog (Figure 8) appears displaying all the currently loaded spectra. The users choose which spectra should be considered in the current run.

3. **Model output**. Once the WABED simulation is complete, the SMS interface includes tools to read in and present the data in a visual manner. Three output files (*.wav, *.brk, *.rad) and the optional input current file (*.cur) include spatially varied data sets. These sets consist of either one (scalar) or two (vector) output values per cell for each input spectra. These files may be opened in the SMS by either using the *Open* command from the *File* menu or by dragging and dropping files into the SMS application already open. Reading the *.wav file will add three functional data sets (significant wave height, mean wave direction, and spectral peak period) to the data tree, which consist of a listing of files on the left side of the SMS window.

   Reading the *.rad or *.cur file will create a vector data set of radiation stress gradients or currents in the SMS. Reading the *.brk file will create either breaking indices (ibrk = 1) showing where the waves break or energy dissipation fluxes (ibrk = 2) in the model domain. Figure 9 shows an example project explorer in the left section of the SMS main dialog after reading in these solution files.

The model control parameters are listed in the first line of the *.std file. There may be 6 to 14 parameters in the *.std file. The first six parameters are defined for running WABED in the same mode as STWAVE Version 3.0. As noted earlier, this mode does not take advantage of WABED's additional capabilities, and present the same computational condition in STWAVE predictions. The other eight parameters in the *.std file are special feature settings defined specifically for WABED.

The SMS will display contours of the selected scalar data set and vectors over the domain for the selected vector data set. The *.obs file includes spectra computed by the model at the observation cells. These can be displayed and evaluated as the input spectra using the spectral energy dialog.

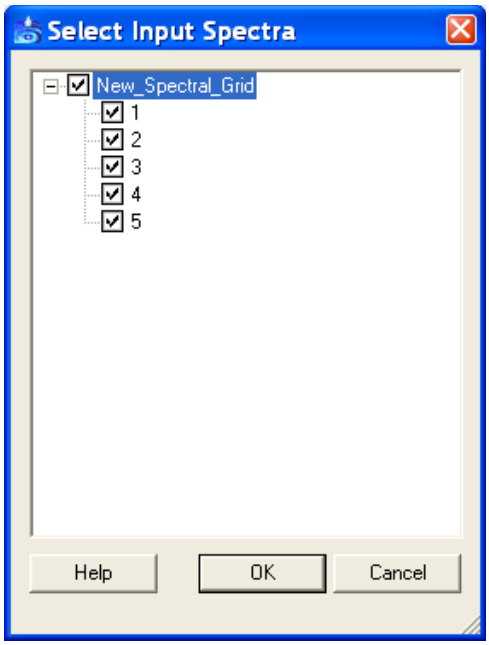

Figure 8. Selecting wave spectra.

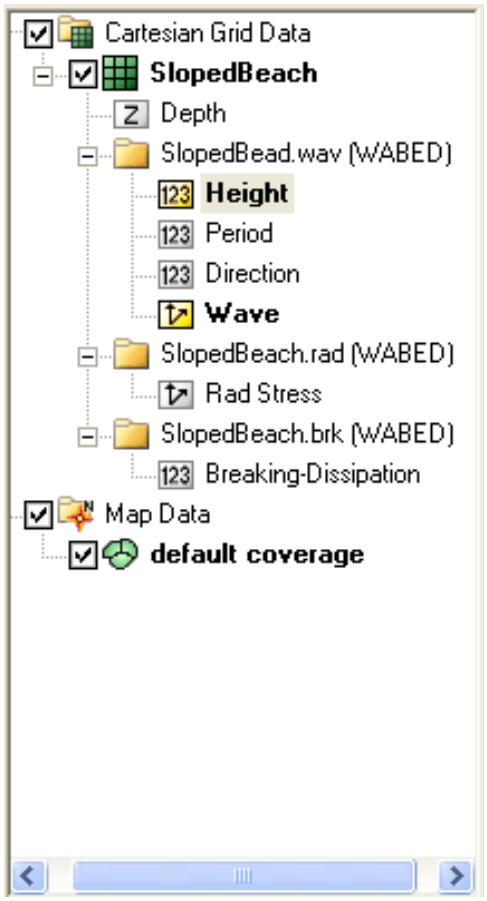

Figure 9. Project explorer with solution read in.

SUMMARY: Various features, tools, and analysis capabilities outlined in this document are designed to enhance the ability of engineers to efficiently utilize WABED in the CMS. This CHETN provides guidance on how to effectively use the SMS interface for WABED. The model and its interface are expected to evolve with additional applications, and the current interface will continue to undergo revision. Feedback and suggestions are welcome on the design, implementation, and application of the present version of the WABED interface.

ADDITIONAL INFORMATION: This technical note was developed as a product of the Basic Inlet Processes Work Unit of the Coastal Inlets Research Program. Questions about this CHETN can be addressed to Dr. Zeki Demirbilek (*zeki.demirbilek@erdc.usace.army.mil*, telephone 601-634-2834) or Dr. Lihwa Lin (*lihwa.lin@erdc.usace.army.mil*, telephone 601-634-2704). Questions about CIRP can be addressed to Dr. Nicholas C. Kraus, Program Manager (*Nicholas.C.Kraus@erdc.usace.army.mil*). This technical note should be referenced as follows:

> Demirbilek, Z., L. Lin, and A. Zundel. 2007. *WABED model in the SMS: I. Graphical interface*. Coastal and Hydraulics Engineering Technical Note ERDC/CHL CHETN-I-74. Vicksburg, MS: U.S. Army Engineer Research and Development Center (*http://chl.wes.army.mil/library/publications/chetn/*).

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Appendix A: WABED File Formats

There are 11 files associated with WABED. These are:

- simulation (*.sim)
- options (*.std)
- depth (*.dep)
- energy (*.eng)
- current (*.cur)
- wave output (*.wav)
- observation (*.obs)
- nesting energy spectrum output (*.nst)
- wave breaking/energy dissipation (*.brk)
- radiation stress (*.rad)
- spectral parameters (*.txt)

Several of these files are associated with STWAVE Version 3.0. File formats are described as follows.

Simulation file: *.sim: A sample simulation file is shown below:

The first line contains the keyword "WABED" to indicate this is a WABED simulation file. This line of the file also contains the world origin (x, y) and rotation (measured CCW from east to the local I or x-axis) of the grid.

```
WABED       0.0000      0.0000      0.0000
DEP         SlopedBeach.dep
OPTS        SlopedBeach.std
CURR        SlopedBeach.cur
SPEC        SlopedBeach.eng
WAVE        SlopedBeach.wav
OBSE        SlopedBeach.obs
NEST        SlopedBeach.nst
BREAK       SlopedBeach.brk
SPGEN       SlopedBeach.txt
RADS        SlopedBeach.rad
```

Settings file: *.std: A sample settings file is shown below:

```
1  0  2  1  0  0  0  1  0  0  1.000000  0.005000  0.500000  0.300000
```

Refer to the description of these parameters provided in the "WABED Files" section of this CHETN. Each number defines a setting or option for the run. The first six parameters are the same as defined for STWAVE Version 3.0. The next eight parameters are for special features of WABED. For example, the first number (= 1) specified that a wave spectrum is provided at the offshore boundary and the wind effect is not calculated even it is provided in the spectrum input file (*.eng).

Depth file: *.dep: A portion of a sample depth file is shown here:

The first line contains the number of rows, columns and the size of cells. Depth values are then specified for each cell in the row-to-row order (from top row to bottom row in the model domain).

```
80          80          10.000000
9.931250    9.793750    9.656250    9.518750    9.381250
9.243750    9.106250    8.968750    8.831250    8.693750
8.556250    8.418750    8.281250    8.143750    8.006250
7.868750    7.731250    7.593750    7.456250    7.318750
7.181250    7.043750    6.906250    6.768750    6.631250
6.493750    6.356250    6.218750    6.081250    5.943750
```

Energy file: *.eng: A portion of a sample energy file is shown here:

The first line defines the dimension of the spectral grid (number of frequency bins and number of direction bins). The next several lines define the frequency values for the grid. Following the grid specification, the file includes a definition line for each directional spectrum consisting of an identifier (1 in the following case), wind speed and wind direction for this spectrum (5 m/sec and 10 deg in this sample case), a spectral peak frequency (0.13 hz in the example), a tidal offset (0.5 m above the model mean water level), and then an energy density (m^2/HZ/rad) for each cell in the spectral grid.

```
30       35
0.04000  0.05000  0.06000  0.07000  0.08000  0.09000  0.10000  0.11000
0.12000  0.13000  0.14000  0.15000  0.16000  0.17000  0.18000  0.19000
0.20000  0.21000  0.22000  0.23000  0.24000  0.25000  0.26000  0.27000
0.28000  0.29000  0.30000  0.31000  0.32000  0.33000
1        5.000000 10.00000 0.130000 0.500000
0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
0.00000  0.00000  0.00000  0.02000  0.13000  0.25000
```