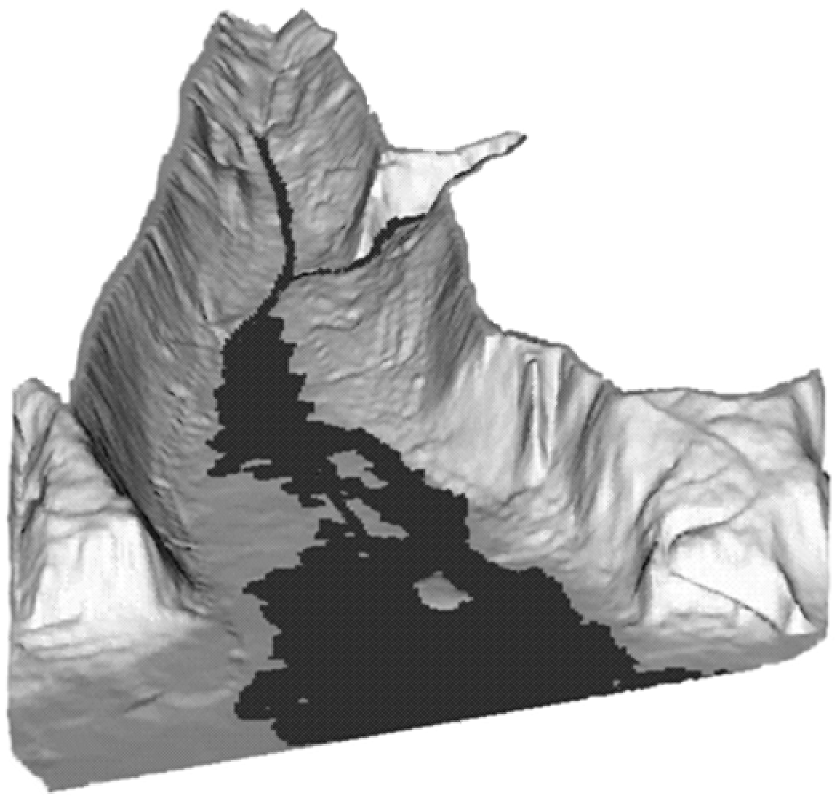
US Army Corps
of Engineers
Hydrologic Engineering Center

HEC-GeoRAS

An extension for support of HEC-RAS using ArcView



User's Manual

Version 3.0
April 2000

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Foreword

HEC-GeoRAS is an extension for use with ArcView GIS, a general purpose Geographic Information System software program developed and copyrighted by the Environmental Systems Research Institute, Inc., (ESRI) Redlands, California. HEC-GeoRAS is written in the Avenue programming language.

The HEC-GeoRAS extension was developed though a Cooperative Research and Development Agreement between the Hydrologic Engineering Center (HEC) and ESRI. HEC-GeoRAS version 3.0 is the result of continued development of the AVRAS 2.2 extension written by ESRI in cooperation with HEC.

Acknowledgements

Cameron T. Ackerman, Planning Analysis Division, HEC, was responsible for HEC-GeoRAS extension development and writing this user's manual. Extensive input in the HEC-GeoRAS software development and user's manual was provided by Gary W. Brunner, HEC-RAS Team Leader, Training Division, Thomas A. Evans, Research Division, and Mark Jensen, Training Division.

Initial software development for the HEC-GeoRAS extension was completed by Dean Djokic, ESRI, in cooperation with HEC. Dudley McFadden III of David Ford Consulting Engineers assisted in the continued software development.

Michael W. Burnham was the Planning Analysis Division Chief and Darryl Davis was the Director during the development of HEC-GeoRAS.

The Hydrologic Engineering Center would like to acknowledge the Honolulu District and Sacramento District for the data sets used in the examples. **Note that the example figures in this manual are provided for illustrative purposes only and are not to be perceived as hydraulically accurate.**

CHAPTER 1

Introduction

HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center River Analysis System (HEC-RAS). The extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Results exported from HEC-RAS may also be processed.

The current version of HEC-GeoRAS creates an import file containing river, reach and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; downstream reach lengths for the left overbank, main channel, and right overbank; and cross-sectional roughness coefficients. Hydraulic structure data are not written to the import file. Water surface profile data and velocity data exported from HEC-RAS may be processed into GIS data sets.

Chapter 1 discusses the intended use of HEC-GeoRAS and provides an overview of this manual.

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Intended Application of HEC-GeoRAS

HEC-GeoRAS creates a file of geometric data for import into HEC-RAS. It also enables viewing of exported results from RAS. The import file is created from data extracted from data sets (ArcView shapefiles) and from a Digital Terrain Model (DTM). HEC-GeoRAS requires a DTM represented by a triangulated irregular network (TIN). The shapefiles and the DTM are referred to collectively as the RAS Themes. Geometric data is developed from calculating the intersection of the RAS Themes.

After the geometric data file has been imported into HEC-RAS, the geometric data set and flow data must be completed before performing hydraulic computations. Exported water surface and velocity results from HEC-RAS simulations may be imported back to the GIS using HEC-GeoRAS for spatial analysis.

Overview of Requirements

HEC-GeoRAS 3.0 is an ArcView GIS (Environmental Systems Research Institute, 1996) extension that provides the user with a set of procedures, tools, and utilities for preparation of GIS data for import into RAS and generation of GIS data from RAS output. While the GeoRAS extension is designed for users with limited geographic information systems (GIS) experience, knowledge of ArcView GIS is advantageous. Users, however, should have experience modeling with HEC-RAS and have a thorough understanding of river hydraulics to properly create and interpret GIS data sets.

Hardware and Software Requirements

HEC-GeoRAS 3.0 is an extension for use with ArcView GIS 3.1, or higher, with the 3D Analyst 1.0 extension. While not required, the availability of the Spatial Analyst extension significantly speeds up post-processing. HEC-GeoRAS presently only runs on Windows 95/98/NT.

The full functionality of HEC-GeoRAS 3.0 requires HEC-RAS 3.0. HEC-RAS 2.2 may be used, however, with limitations on importing roughness coefficients, exporting velocities, and filtering cross-section data points. HEC-RAS limitations are discussed below.

- **Roughness coefficients**
  HEC-RAS 3.0 provides the capability of importing Manning's *n* values written in the HEC-RAS import file format. HEC-RAS has a limit of 20 n-values per cross section. This capability is not available in HEC-RAS 2.2.

- **Velocities**
  HEC-RAS 3.0 velocity results for each cross section may be

written to the HEC-RAS export file. This capability is not available in HEC-RAS 2.2.

- **Cross-sectional points**
  HEC-RAS allows a maximum of 500 station-elevation points. HEC-RAS 3.0 provides a filter to weed out points in cross sections. This filter is not available in HEC-RAS 2.2.

Data Requirements

HEC-GeoRAS requires a DTM in the form of a TIN. The DTM must be a continuous surface that includes the bottom of the river channel and the floodplain to be modeled. Because all cross-sectional data will be extracted from the DTM, only high-resolution DTMs should be considered for hydraulic modeling. Measurement units used are relative to those in the DTM. If the units of the DTM are not specified, they will not be written to the HEC-RAS import file.

User's Manual Overview

This manual provides detailed instruction for using the HEC-GeoRAS ArcView extension to develop geometric data for import into HEC-RAS and view results from HEC-RAS simulations. The manual is organized as follows:

Chapter 1-2 provides an introduction to HEC-GeoRAS, as well as instructions for installing the extension and getting started.

Chapter 3 provides a detailed overview of HEC-GeoRAS.

Chapter 4 describes HEC-RAS pre-processing requirements and detailed instruction for developing an HEC-RAS GIS Import File.

Chapter 5 describes HEC-RAS post-processing options and detailed instruction on developing GIS data set from exported HEC-RAS results.

Chapter 6 provides an example application of HEC-GeoRAS.

Appendix A contains a list of references.

Appendix B contains a sample import and export file.

CHAPTER 2

HEC-GeoRAS Installation

The installation procedure for the HEC-GeoRAS ArcView GIS extension is the same for both Windows 95/98 and NT operating systems.

This chapter discusses ArcView GIS requirements and instructions for installing the HEC-GeoRAS extension.

Contents

Hardware and Software Requirements

HEC-GeoRAS 3.0 requires ArcView 3.1 GIS for Windows 95/98/NT and the 3D Analyst 1.0 extension. The availability of the Spatial Analyst 1.0 extension will speed-up the post-processing, but is not required. There are no additional requirements; however, you should identify the availability of disk space for creating GIS data sets.

Installation

The GeoRAS extension is installed and loaded as any other ArcView extension. To make the extension visible to ArcView, copy the file **hecgeoras.avx** to the ArcView extension subdirectory

(AVHOME\ext32). The AVHOME directory is usually c:\esri\av_gis30.

Once the GeoRAS extension has been copied to the destination directory, it can be loaded from ArcView.

Loading HEC-GeoRAS

ArcView extensions are loaded through the File menu on the main ArcView window. Select the **File** ⇒ **Extensions …** menu item. In the dialog that appears (see Figure 2–1), scroll down to the **HEC-GeoRAS** item and use the corresponding check box to turn it on. Press **OK** to close the dialog and load the HEC-GeoRAS extension.

The 3D Analyst extension automatically loads with the GeoRAS extension. If available, load the Spatial Analyst extension.

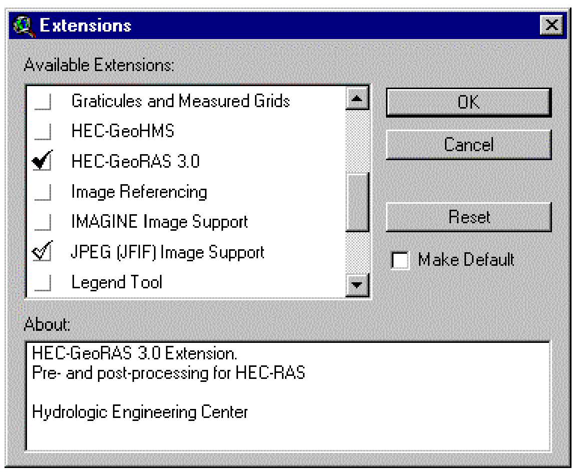

Figure 2–1. Load ArcView extensions dialog.

CHAPTER 3

Working with HEC-GeoRAS – An Overview

HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcView GIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and to process simulation results exported from HEC-RAS.

To create the import file, the user must have an existing digital terrain model (DTM) of the river system in a TIN format. The user creates a series of line themes pertinent to developing geometric data for HEC-RAS. The line themes created are the Stream Centerline, Flow Path Centerlines (*optional*), Main Channel Banks (*optional*), and Cross Section Cut Lines referred to, herein, as the RAS Themes.

Water surface profile data and velocity data exported from HEC-RAS simulations may be processed by HEC-GeoRAS for GIS analysis.

Chapter 3 provides an overview of the steps in developing a RAS GIS Import File and processing the RAS GIS Export File and is designed to familiarize the user with the ArcView environment. An overview diagram of the HEC-GeoRAS process is shown in Figure 3–1. Chapter 4 and Chapter 5 more completely discuss HEC-RAS data pre- and post-processing, respectively.

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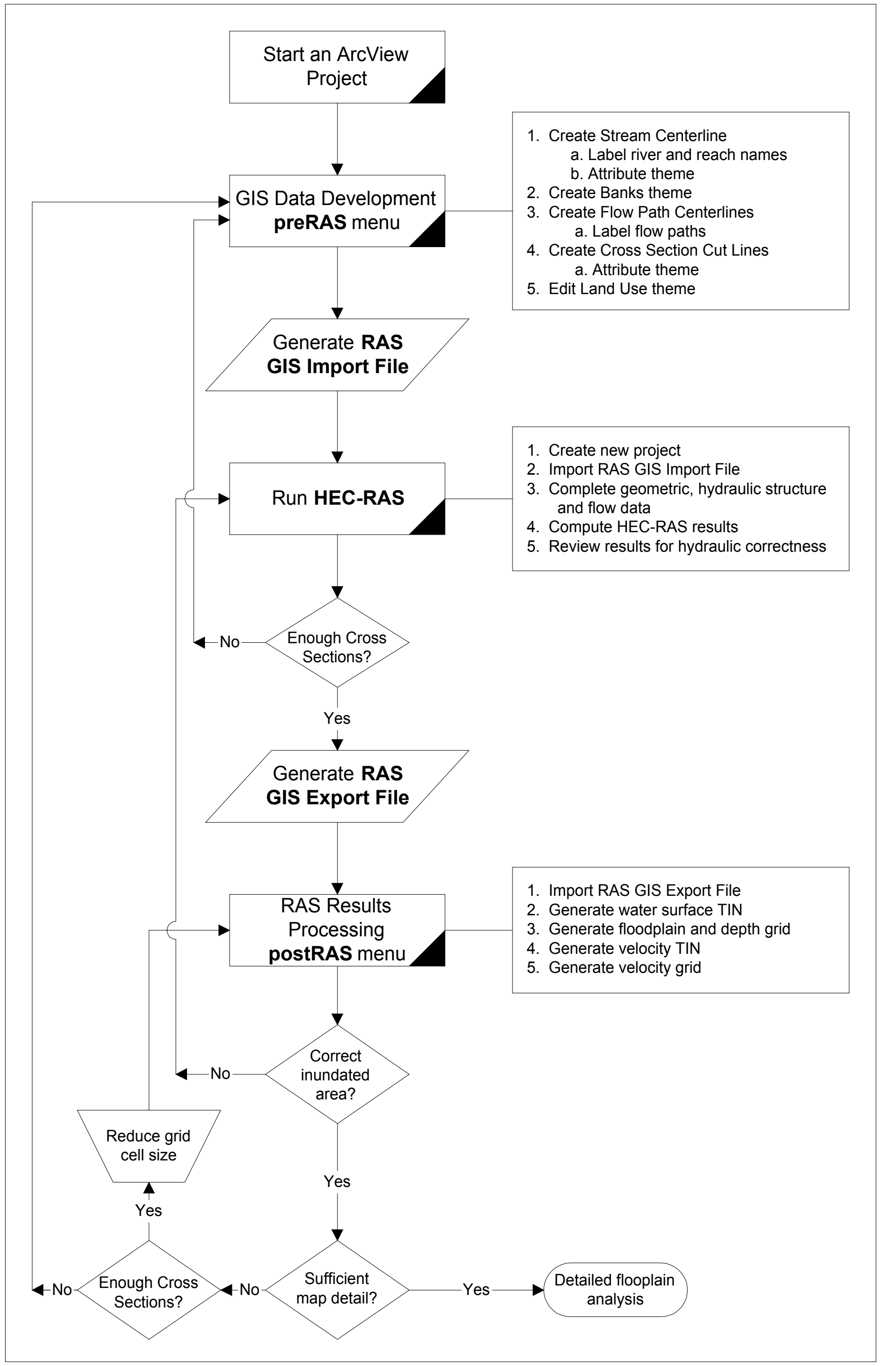


Figure 3–1. Process flow diagram for using HEC-GeoRAS.

Getting Started

Start ArcView GIS. Load the GeoRAS extension by selecting **File ⇒ Extensions...** on the main ArcView window and selecting **HEC-**

GeoRAS from the extension choices. The 3D Analyst extension will automatically load. If available, load the Spatial Analyst extension to speed up post-processing.

When the GeoRAS extension loads, menu, buttons, and tools are added to the ArcView interface. These additions are intended to aid the user in stepping through the geometric data development process and post-processing of exported HEC-RAS simulation results. The GeoRAS extension menu, buttons, and tools are shown in Figure 3–2.

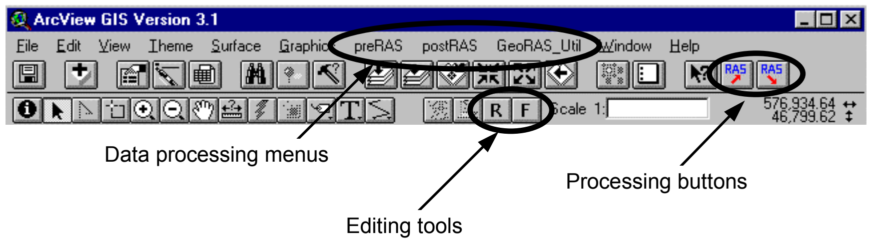


Figure 3–2. HEC-GeoRAS interface additions.

Menus

The HEC-GeoRAS menu options displayed at the top of the ArcView interface are preRAS, postRAS, and GeoRAS_Util and are discussed below.

PreRAS

The preRAS menu option is for pre-processing geometric data for import into HEC-RAS. Items are listed in the preRAS dropdown menu in the recommended (and sometimes required) order of completion. Items available from the preRAS menu items are shown in Figure 3–3.

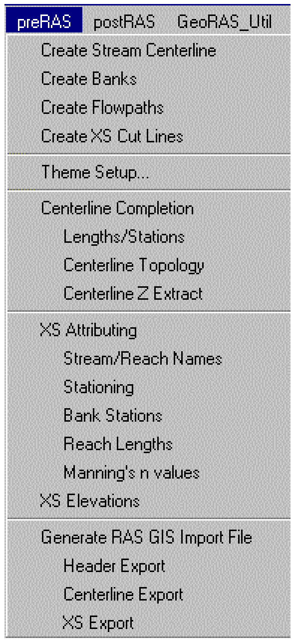


Figure 3–3. Pre-processing menu options.

PostRAS

The postRAS menu option is for post-processing exported HEC-RAS results. Items available from the postRAS dropdown menu are listed in the order they should be completed. Items available from the postRAS menu are shown in Figure 3–4.

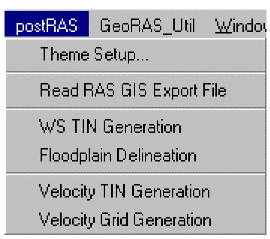


Figure 3–4. Post-processing menu options.

GeoRAS_Util

The GeoRAS_Util menu option provides utilities for editing themes and theme management. The procedures performed by these utilities are not required to develop geometric data sets, but are there to assist the user with various functions. GeoRAS_Util items are shown in Figure 3–5.

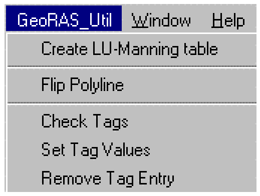


Figure 3–5. Utilities available when using HEC-GeoRAS.

Buttons

There are two buttons provided below the menu bar. A button initiates an action immediately after being pressed. The  button generates the RAS GIS Import File, just as the Generate RAS Import File (summary of Header Export, Centerline Export, XS Export) item under the preRAS menu. The  button imports the RAS GIS Export File by performing the Theme Setup and Read RAS Export File steps under the postRAS menu.

Tools

Tools, provided beneath the button bar on the ArcView interface, allow you to perform a specific action. A tool, when activated, turns a lighter color gray and looks as if it is depressed. The two tools added to the interface by GeoRAS are the  (River ID) and the  (Flowpath) tools. The River ID and Flowpath tools allows you to provide a Stream ID and Reach ID for each reach in the Stream Centerline theme and to identify the left, middle, and right flow paths in the Flow Path Centerlines theme, respectively.

Developing the RAS GIS Import File

The main steps in developing the RAS GIS Import File are as follow:

- Starting a New Project
- Creating RAS Themes
- Generating the RAS GIS Import File

Starting a New Project

You should save the ArcView project to the appropriate directory before creating any themes. This may require using the file browser to create and name a new directory. The directory to which the

ArcView project is stored becomes the default directory when creating or adding new themes. It is the location where the RAS GIS Import File is written.

To save the project, select **File** ⇒ **Save Project…** from the ArcView main interface, select the directory, input the project name, and press **OK**. ArcView projects are given the *.apr* file extension.

Once the project has been saved, start a new v*iew* by pressing the **New** button on the project window. The project window will be titled with the name of the current project. The *view* is composed of two parts: the *table of contents* and the *map display*. The *table of contents* lists the themes and the *map display* shows the features of the theme. **The GeoRAS extension is only visible on the ArcView interface if a *view* document is active.**

Next, load the DTM and any background themes for the river system to the new view. To load the Terrain TIN, press the  (**Add Theme**) button or select the **View** ⇒ **Add Theme…** menu item on the ArcView interface. This invokes a browser. Select “TIN Data Source” as the *Data Source Type* and browse to the location of the TIN. Select the TIN and press **OK**. The TIN is added to the current view.

Load other themes using the same procedure specifying the *Data Source Type* as a Feature, Image, Grid, or TIN.

Creating Contours

If the Terrain TIN is very detailed, it may not be appropriate to use for a background layer. (Extremely large TIN data sets take much longer to display to the screen than small TINs.) Line themes, such as contours, however, will normally display more quickly.

Make the TIN theme active in the view by selecting it from the table of contents with the mouse. This creates a box around the theme making it appear raised. Create a new theme of contour lines by selecting the **Surface** ⇒ **Create Contours…** menu. (The Surface menu was added to the ArcView interface when the 3D Analyst extension was loaded.) This invokes the dialog box shown in Figure 3–6. Next, enter the contouring parameters and press **OK**

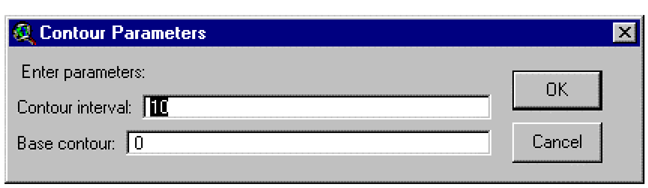


Figure 3–6. Dialog for entering contouring parameters.

ArcView will generate a theme of contours from the selected TIN with the default name of "Contours of TINname", where *TINname* is the name of the active TIN. If the counter interval specified is too fine in relation to the resolution of the TIN, ArcView may not properly process the data. If the interval specified is too large, the contour theme created will not provide an adequate visualization of the land surface.

To display the contour lines, click on the corresponding check box in the table of contents. If the contouring does not provide sufficient definition of the river network and main channel, create the contour theme again using a finer contour interval.

Creating RAS Themes

The next step is to create the RAS Themes that will be used for geometric data development and extraction. The line themes that need to be created are the Stream Centerline, the Main Channel Banks (*optional*), the Flow Path Centerlines (*optional*), and the Cross Section Cut Lines. A polygon theme of land cover may be used to provide Manning's *n* values. Existing shapefiles or ArcInfo coverages may be used for each RAS Theme; however, they will need to contain the attributes as specified in the following sections.

Line themes are created using basic ArcView tools. The GeoRAS preRAS menu helps step through the data development procedure. The following section provides an overview for creating the RAS Themes. Detailed descriptions on creating RAS Themes and theme structure are in Chapter 4.

Stream Centerline

The Stream Centerline theme should be created first. Select the **preRAS ⇒ Create Centerline Theme** menu item. The dialog shown in Figure 3–7 will appear. Enter the theme name and destination directory and press **OK**.

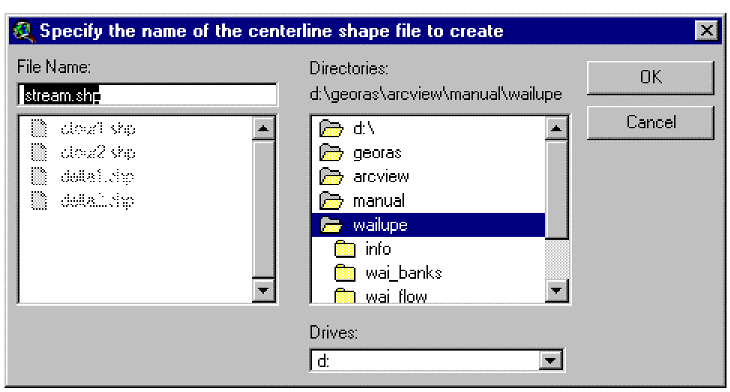


Figure 3–7. Standard file dialog window for specifying theme name.

The Stream Centerline theme is added to the current view, it is active and editable. To start adding features to the Stream Centerline theme, select the (**Draw Line**) tool. Move the cursor over to the view's map display and cross hairs will appear. Draw river reaches one by one, from upstream to downstream using the mouse. Each reach is represented by one line having a series of vertices. To start a line use the mouse to left click, using left clicks to add vertices, and double-click to end a line. After creating the river network, select **View** ⇒ **Stop Editing**.

The Stream Centerline theme, however, is not complete until each River and Reach has been assigned a name. Make sure the Stream Centerline theme is still active and select the (**River ID**) tool. Cross hairs will appear as the cursor is moved over the map display. Use the mouse to select a River Reach. The dialog shown in Figure 3–8 will be invoked to name the river and reach. Previously specified river names are available from a drop down list using the down arrow to the right of the river name field. Reach names for the same river must be unique. River and reach names may be up to 16 characters in length.

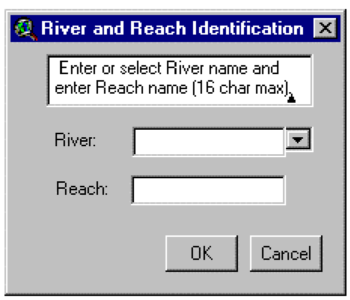


Figure 3–8. River and reach identification window.

Main Channel Banks

Select the **preRAS** ⇒ **Create Banks Theme** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the **Draw Line** tool to draw the location of the channel banks. Separate lines should be used for the left and right bank of the river. Bank lines from tributary rivers may overlap the bank lines of the main stem. After defining each bank line, select **View** ⇒ **Stop Editing**. *Creating the Main Channel Banks theme is optional.*

Flow Path Centerlines

Select the **preRAS** ⇒ **Create Flowpath Theme** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

If the Stream Centerline theme exists, the centerline will be copied as the flow path for the main channel. Use the **Draw Line** tool to draw the hydraulic flow path (center of mass of flow) in the left and right overbank, in the upstream to downstream direction. When finished drawing and editing flow paths, select **View** ⇒ **Stop Editing**.

Each flow path must be labeled with an identifier of *Left*, *Middle*, *Right*, corresponding to the left overbank, main channel, or right overbank. One by one, use the 

(**Flowpath**) tool to label each flow path. After activating the Flowpath tool, select each flow path with the cross-hairs cursor. This dialog shown in Figure 3–9 will appear allowing the user to select the correct flow path label from a list. *Creating the Flow Path Centerlines theme is optional.*

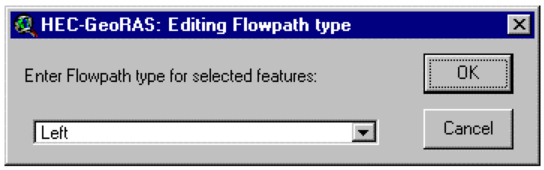


Figure 3–9. Label flow path window.

Cross-Sectional Cut Lines

Select the **preRAS** ⇒ **Create XS Cut Lines** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the **Draw Line** tool to draw the locations where cross-sectional data should be extracted from the Terrain TIN. Each cross section cut line should be drawn from the left overbank to the right overbank, when facing downstream. Cross section cut lines are multi-segment lines that should be drawn perpendicular to the flow path lines. Cut lines must cross the main channel only once and no two cross sections may intersect.

Land Use

Land use data may be used to estimate Manning's *n* values for each cross section. Load the Land Use polyline theme to the view using the **Add Theme** button. Make the theme active and select the **GeoRAS_Util** ⇒ **Create LU-Manning Table** menu item. The dialog shown in Figure 3–10 will be invoked, allowing you to select the land-use description field. Use the drop-down list to pick the field and press **OK**.

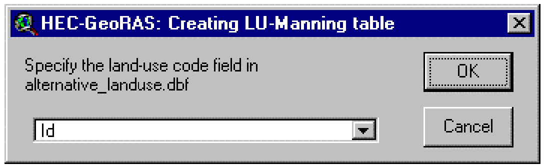


Figure 3–10. The user will need to specify which field to reference for the land use / Manning's n value relationship.

Another dialog will appear allowing you to specify a new table name and destination directory. Enter the table name ("lumanning.dbf" is default) and press **OK**.

The new table is a summary of all land-use descriptions and has a blank *N_value* field for Manning's *n* values. To edit the *N_value* field values the user will need to edit the new table.

From the *project* window, select the *tables* document. The name of the table will appear as an available document. Double-click it to open it or select the table and press the **Open** button. The table will open with the field names across the top shown in italics with a gray background.

To edit the *N_value* field values, select **Table** ⇒ **Start Editing**. Note that the field names are no longer in italics, indicating that the table may be edited. Use the  (**Edit Cells**) tool to edit *n* values in the table. When finished entering *n* values, select **Table** ⇒ **Stop Editing**.

Select the view document used for creating the themes and the GeoRAS interface will appear.

Generating the RAS GIS Import File

After creating/editing each RAS Theme, select the **preRAS** ⇒ **Theme Setup…** menu item. The pre-processing theme setup dialog shown in Figure 3–11 allows you to select the RAS Themes used for data development and extraction and to select the RAS GIS Export File name.

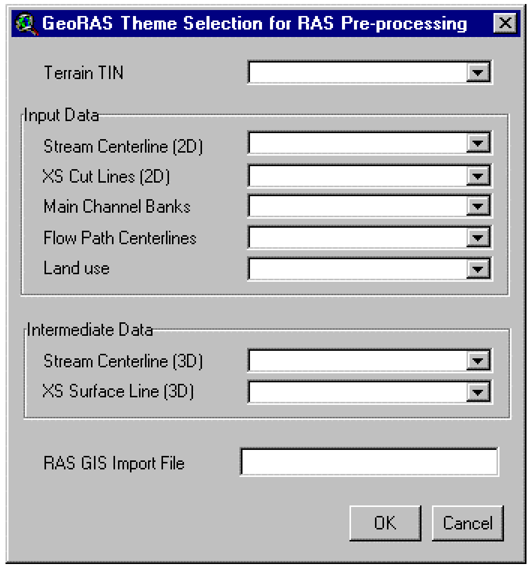


Figure 3–11. Pre-processing theme setup dialog.

Use the drop down lists to select the Terrain TIN and two-dimensional data inputs for processing. The three-dimensional data (intermediate data) will be derived along the way. Also specify the RAS GIS Export File. *There is no default file extension, so the user should supply one. HEC-RAS looks for the " .geo" extension by default.* Press **OK** when finished.

Next, select the **preRAS ⇒ Centerline Completion** menu item. This process completes the centerline topology and creates a new 3D shapefile. The user will be asked to name the shapefile ("stream3D.shp" is default) and select the destination directory.

The next step is to add the geometric attributes to the Cross Section Cut Line theme. Select the **preRAS ⇒ XS Attributing** menu item. Stream and reach, stationing, n values, bank station, and downstream reach length information will be appended to each cross section cut line.

To complete the cross-sectional data, station-elevation data needs to be extracted from the Terrain Tin. Select the **preRAS ⇒ XS Elevations** menu item. This will create a cross-sectional surface line theme (a 3D shapefile, default name "xscutlines3D.shp") from the cross-sectional cut lines.

Lastly, select the **preRAS ⇒ Generate RAS GIS Import File** menu item. This step writes the header information, stream centerline information contained in the *Stream Centerline (3D)* theme, and cross-sectional information contained in the *XS Surface Lines (3D)* theme to a file in the HEC-RAS import file format.

Running RAS

After importing the geometric data extracted from the GIS, completion of the hydraulic data will be necessary. Hydraulic data that is not imported includes contraction and expansion coefficients, hydraulic structure data such as bridges and culverts, and optional data such as levees and ineffective flow areas. Flow data and the associated boundary conditions need to be supplied, as well. For a more complete discussion on importing geometric data, refer to the HEC-RAS User's Manual, Chapter 13 (Hydrologic Engineering Center, 2000).

After running various simulations in HEC-RAS, export the results. For a more complete discussion on exporting GIS data, refer to the HEC-RAS User's Manual, Chapter 13 (Hydrologic Engineering Center, 2000).

Processing the RAS GIS Export File

The main steps in processing HEC-RAS results are as follow:

- Reading the RAS GIS Export File
- Processing RAS Results Data

Reading the RAS GIS Export File

The first step to importing HEC-RAS results into the GIS is to select the RAS GIS Export File. Select the **postRAS ⇒ Theme Setup** menu item. The dialog shown in Figure 3–12 will appear to allow the user to select the RAS GIS Export File. The dialog also allows the user to select the Terrain TIN used for floodplain delineation, identify the directory to write post-processing results to, and the cell rasterization size for grid calculations.

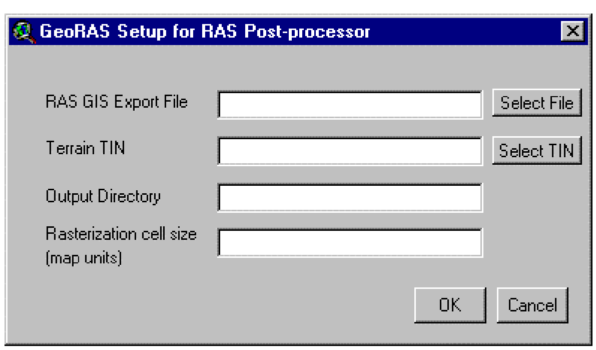


Figure 3–12. Post-processing theme setup dialog.

The output directory specified will be created one level down from where the GeoRAS project is stored. All post-processing results will be stored in the Output Directory.

Select the **postRAS ⇒ Read RAS GIS Export File** menu item. HEC-GeoRAS will read the export file and begin creating preliminary data sets. Preliminary shapefiles created include the following:

- Stream network shapefile
- Cross section cut lines shapefile
- Main channel banks shapefile
- Bounding polygon shapefiles for each water surface profile
- Velocity point shapefile for each water surface profile

These data sets are created without user input and will be used later for building inundation and velocity data sets.

Processing RAS Results Data

Post-processing of RAS results creates GIS themes for inundation and velocity analysis. All GIS themes developed during RAS post-processing are based on the content of the RAS GIS Export File and the Terrain TIN. For data consistency, the same Terrain TIN used for generation of the RAS GIS Import File should be used for post-prcessing.

Inundation Results

Once the RAS GIS Export File has been read, the user can begin creating inundation data sets. The first step is to create water surface TINs for each water surface profile. Select the **postRAS ⇒ WS TIN Generation** menu item. This will invoke a dialog with a pick list of water surface profile names. Multiple water surface profiles may be selected. Press **OK** to build the water surface TINs.

One water surface TIN will be created for each selected water surface profile. The TIN is created based on the water surface elevation at each cross section and a bounding polygon data specified in the RAS GIS Export File. The water surface TIN is generated without considering the impact of the Terrain TIN.

The floodplain may then be identified for each water surface profile for which a water surface TIN exists. Select the **postRAS ⇒ Floodplain Delineation** menu item. This will invoke a dialog with a pick list of water surface profile names for which water surface TINs have been created. Select the water surface profile names and press **OK**.

A floodplain polygon will be created for each water surface profile selected. Each floodplain extent polygon is the result of intersecting the water surface and terrain surface. The floodplain delineation procedure converts the water surface TIN and Terrain TIN to lattices (grids) with the same cell size and origin. A new lattice is then created with values where the water surface lattice is higher than the terrain lattice and then converted to a polygon.

A water depth grid is also computed for each processed floodplain. If the Spatial Analyst extension is available, the grid computations will be optimized. If Spatial Analyst is not present, a point theme will also be generated, with the depth of the water at each point as an attribute.

Velocity Results

Velocity data sets may be generated after performing the floodplain delineation. Select the **postRAS ⇒ Velocity TIN Generation** menu item. A dialog will appear allowing the user to select water surface profiles. The pick list will only contain the names for which the floodplain has been delineated. Velocity TINs will then be created with bounds and identified by the associated floodplain polygon.

After creating a velocity TIN, a velocity grid may be computed using the **postRAS ⇒ Velocity Grid Generation** menu item.

CHAPTER 4

Developing the RAS GIS Import File

The RAS GIS Import File consists of geometric attribute data necessary to perform hydraulic computations in HEC-RAS. The cross-sectional geometric data is developed from an existing Digital Terrain Model (DTM) of the channel and surrounding land surface, while the cross-sectional attributes are derived from points of intersection of RAS Themes. The DTM must be in the form a triangulated irregular network (TIN).

RAS Themes created include the Stream Centerline, Main Channel Banks (*optional*), Flow Path Centerlines (*optional*), and Cross Section Cut Lines. Geometric data and cross-sectional attributes are extracted from the DTM and RAS Themes to generate a file that contains: river, reach, and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; and downstream reach lengths for the left overbank, main channel; and right overbank. Additionally, a land use polygon theme may be specified to extract roughness coefficients.

Expansion/contraction coefficients, hydraulic structure data such as bridges and culverts, and optional cross-sectional properties such as levees and ineffective flow areas are not written to the RAS GIS Import File.

Chapter 4 discusses the steps in developing the RAS GIS Import File.

Contents

- Flow Path Centerlines Theme
- Cross-Sectional Cut Lines Theme
- Land Use Theme
- Generating the RAS GIS Import File

Digital Terrain Model

HEC-GeoRAS requires an existing DTM in the form of a TIN. The TIN must be representative of both the land surface of the channel bottom and adjacent floodplain areas. The cross-sectional geometric data is extracted from the DTM.

Developing a hydraulic model begins with an accurate geometric description of the surrounding landform, especially the channel geometry. Channel geometry normally dictates flow in river systems; therefore, only DTMs describing channel geometry with high accuracy and resolution should be considered for the basis of performing hydraulic analysis. Further, RAS Themes should be created with thoughtful evaluation of the river hydraulics as governed by the terrain.

Contours

Creating a theme of contours from a TIN theme is not required for using GeoRAS. However, it is often a logical first step that helps the user visualize the study area. Displaying the TIN may provide more detailed information on the river network and floodplain, but the display may prove too time-consuming to refresh during panning and zooming. The contour line theme, however, will refresh quickly and provide a good visual for delineating the river network and locating cross sections.

To create contours from a TIN, make the Terrain TIN theme active and select the **Surface ⇒ Create Contours…** menu item. Enter the contour interval in the dialog that appears (see Figure 4–1) and press **OK**. The contour interval should be based on the definition of the Terrain TIN. Contour interval units will be based on the Terrain TIN, while the base contour will be the elevation assigned to the first contour.

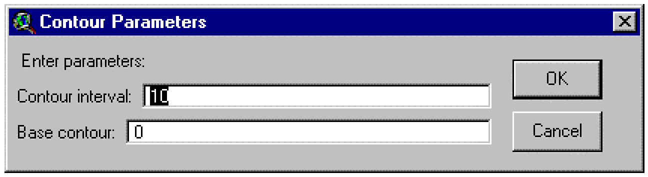


Figure 4–1. Contour parameters dialog.

It should take only a minute or so to create the contours depending on the contour interval specified and the number of points in the Terrain TIN. The status bar at the bottom of the ArcView interface will inform you of the contouring process. When completed, the contour line theme will be added to the current view's table of contents. *The contour theme is intended for visualization only, and is not used during the data extraction process.*

Stream Centerline Theme

The river and reach network is represented by the Stream Centerline theme. The network is created on a reach by reach basis, starting from the upstream end and working downstream following the channel thalweg. Each reach is comprised of a River Name and a Reach Name.

The Stream Centerline is used for assigning river stationing to cross sections and to display as a schematic in the HEC-RAS Geometric editor. It may also be used to define the main channel flow path.

Rules!

- All river reaches must be connected at junctions. Junctions are formed when the downstream node (TO node) of a reach coincides with the upstream node (FROM node) of another reach.
- The Stream Centerline arcs must point downstream: the line must start at the upstream end and finish on the downstream end (the FROM node of the arc upstream of the TO node).
- Each river reach must have a unique combination of its River Name (Stream ID) and Reach Name (Reach ID).
- Stream Centerlines should not intersect, except at junctions.

Creating the River Network

Select the **preRAS ⇒ Create Stream Centerline** menu item. This will create a new shapefile (default name of "Stream.shp*")* with

Stream_ID and *Reach_ID* fields in the associated table. The Stream Centerline theme will be added to the current view and will be active and editable. Create the stream network by connecting reaches in the downstream direction.

To create a river reach, select the **Draw Line** tool. Use the left mouse button to begin a reach. Create the reach downstream using the left mouse button to add vertices along the way. When finished creating a reach, double-click the left mouse button.

Interactive pan and zoom options are available when editing a theme. Use a right mouse click, when digitizing on screen, to invoke the popup menu. When the pan option is selected, for instance, the window will pan to make the current mouse location the center of the screen.

After creating the river network, select **Theme** ⇒ **Stop Editing**. Complete the Stream Centerline theme by adding river and reach identifiers using the 

(**River ID**) tool. After activating the River ID tool, select a reach with the cross-hairs cursor. Enter the River Name and Reach Name in the dialog shown in Figure 4–2.

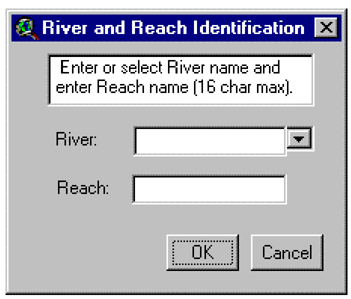


Figure 4–2. River and Reach Name dialog.

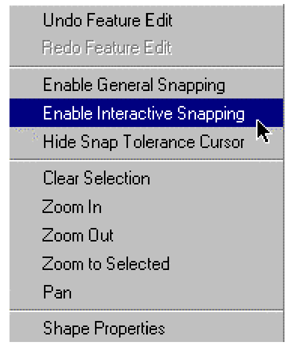
Junctions

Junctions are formed at the confluence of three or more reaches. Note that in HEC-RAS, you may only have a new reach (junction) at a flow change location. In order for a junction to be formed reach endpoints must be coincident. Two ways for insuring junctions are formed at endpoints is discussed below.

Interactive snapping

Interactive snapping is used while creating a line and is the preferred method for snapping endpoints. Before creating a line using the **Draw Line** tool, use the mouse and right click in the display window. From the popup window (contents may vary depending on what mode the user is in) select **Enable Interactive Snapping** using the left mouse button.

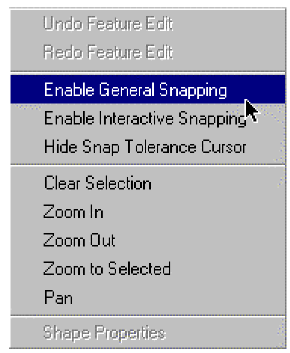
Next activate the  (**Snap**) tool which appears on the tool bar. This allows the user to select the interactive snapping tolerance visually. Use the cursor in the display window to draw the snapping distance (press and hold the left mouse button, release when desired).



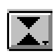
Once the interactive snapping is on and the tolerance has been set the user can snap endpoints on the fly. To snap the endpoint of one reach at a junction, right click on the display screen just before placing the downstream endpoint. Select **Snap to Endpoint** from the popup window.

General snapping

General snapping can be used to form a junction after river reaches have already been created. This method is not recommended because vertices may be snapped to the wrong location.



From the popup window (contents may vary depending on the mode) select **Enable General Snapping** using the left mouse button.

Next activate the  (**Snap**) tool which appears on the tool bar. This allows you to select the interactive snapping tolerance visually. Use the cursor in the display window to draw the snapping distance (choose a small snapping distance).

Once the general snapping has been set the user can adjust vertices of previously created lines. Vertices of new lines will also snap to vertices within the snap tolerance so be wary. To snap the endpoint of an existing line select the  (**Vertex Edit**) tool (a line theme must be active and editable). Select the endpoint to move by clicking once at the endpoint. Move the endpoint near the junction by pressing down on the left mouse button and dragging the endpoint. At the junction release the mouse button. Do not drag the endpoint all the way to the junction, but near the junction. The user will see the endpoint snap to the other endpoint (vertex) if the move was close enough. Make sure the endpoint snaps to the correct vertex.

Uniqueness

The stream network must have unique reach names for each river. Use the River ID tool to check that each reach on a river has a unique name.

Directionality

The Stream Centerline theme must be created in the downstream direction. To check the orientation of the river network, change the line symbol to a line symbol with arrows.

Adding Tributaries to a Network

Tributaries are added to an existing river network at a junction. If the junction already exists, simply add the new river reach using the interactive snapping method described earlier at the endpoint.

To add a tributary to the middle of a river reach, the reach must first be split. To split a river, make the Stream Centerline active and editable and select the (**Split**) tool from the tool bar. This tool allows the user to draw a line across the existing river reach. After the reach is split, use the (**Select Features)** tool to select and delete the extraneous two lines. Second, use the **River ID** tool to edit the reach names so that they are unique. Last, add the tributary using the interactive snapping method, described earlier, to snap the endpoint at the junction.

Adding Reaches to a Network

The Stream Centerline theme must be active and editable. To add a reach to an existing river network, split the reach at the desired location with the **Split** tool. Use the **River ID** tool to edit the two reach names. Note that HEC-RAS only allows a new reach when there is a flow change.

Merging Reaches in a Network

The Stream Centerline theme must be active and editable. Use the **Select Features** tool to select the two river reaches. (The reaches must share common endpoints.) Select the **Edit** ⇒ **Union Features** menu item. Use the **River ID** tool to check the reach name of the new reach.

Main Channel Banks Theme

The separation of the main channel from the overbank areas is defined by the Main Channel Banks Theme.

Cross-sectional bank stations will be assign based on the intersection of this them with the cross-sectional cut lines.

Rules!

- Exactly two bank lines may cross each cross section cut line.
- Bank lines may be broken.
- Orientation of bank lines is not important.
- *Creating this theme is optional*.

Creating the Bank Station Lines

Select the **preRAS** ⇒ **Create Banks** menu item. This will create a new shapefile (default name of "Banks.shp") and add it to the current view. The theme will be active and editable.

Bank station lines should be created on either side of the channel to identify the main conveyance channel from the overbank areas. To add bank station lines, select the **Draw Line** tool. Use the left mouse to start the line and to place vertices. Double click the left mouse button when finished with the line.

Create bank lines for each side of the channel for each river. Bank station lines of tributaries may overlap those of the main channel. Cross section cut lines may only intersect two bank station lines.

When finished editing the **Banks** theme, select **Theme** ⇒ **Stop Editing**.

Flow Path Centerlines Theme

The Flow Path Centerlines theme is used to identify the hydraulic flow path in the left overbank, main channel, and right overbank. If the Stream Centerline Theme already exists you have the option to copy the stream centerline for the flow path in the main channel. Flow paths must be created in the direction of flow (upstream to downstream).

Downstream reach lengths are calculated between cross section cut lines along the flow path centerlines for the left overbank, main channel, and right overbank.

Rules!

- Pointed in the direction of flow (the FROM node upstream of the TO node).

- Each flow path must cross each cross-sectional cut line exactly once.
- Flow path lines should not intersect.
- *Creating this theme is optional.*

Creating the Flow Path Centerlines

Select the **preRAS ⇒ Create Flowpaths** menu item. This will create a new shapefile (default name of "Flowpath.shp*"*) with the *LineType* field and add it to the view. The *LineType* field is used to identify the flow path in the left overbank, channel, or right overbank. The flow path theme will be active and editable.

If the Stream Centerline theme was created previously using the Create Stream Centerline item on the preRAS menu, the dialog shown in Figure 4–3 will be invoked allowing the user to copy the stream centerline shape to the flow path theme.

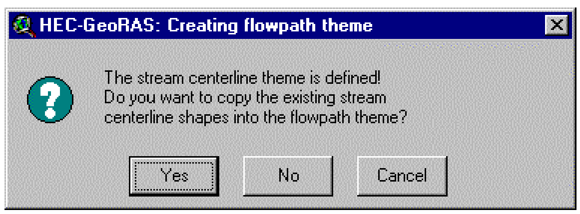


Figure 4–3. Copy flow path centerline choice window.

Complete the Flow Path theme by drawing in the flow paths in the overbank areas. Begin by selecting the **Draw Line** tool. Draw the flow path lines in the direction of flow (upstream to downstream) using the left mouse button to start the line (left click), add vertices (left click), and end the line (double left click).

Be sure the flow path lines are drawn in the downstream direction. To check, change the line symbol to a line symbol with arrows. Each flow path line must cross a cross-sectional cut line exactly once and should not cross each other.

When finished creating the Flow Path theme, select **Theme ⇒ Stop Editing**.

Cross-Sectional Cut Lines Theme

The location, position, and expanse of cross sections is represented by the Cross Section Cut Line theme. Cross sections should be dog-legged perpendicular to the direction of flow.

While the cut lines represent the planar location of the cross sections, the station elevation-data is extracted along the cut line from the DTM.

Rules!

- Cross-sectional cut lines must be pointed from the left overbank to right overbank.
- Cross-sectional cut lines must cross each of the three flow path lines and two bank station lines exactly once.
- Cross-sectional cut lines should be perpendicular to the direction of flow (perpendicular to flow path lines).
- Cross-sections cut lines should not intersect.

Creating Cross-Sectional Cut Lines

Select the **preRAS** ⇒ **Create XS Cut Lines** menu item. This will create a new shapefile (default name of "Xscutlines.shp"), add it to the view, and make it active and editable.

Add the location of each cross section using the **Draw Line** tool. Begin on the left overbank area (when facing downstream) and click the left mouse button to begin the cut line. Use the left mouse button to place vertices and double click when finished with the cut line. The cut lines should be drawn perpendicular to the direction of flow, cross a reach line exactly once, and should not cross another cut line. Be sure that the cut line covers the entire expanse of the floodplain.

Check the cross section by changing the line symbol to a line symbol with arrows, on the symbol palette. If the cut line was constructed in the incorrect direction, it can be flipped using the **Flip Polyline** item available under the utility menu. To flip the cut line, select the line using the **Select Feature** tool. Next, select the **GeoRAS_Util** ⇒ **Flip Polyline** menu item.

When finished editing the Cross-Sectional Cut Line theme, select **Theme** ⇒ **Stop Editing**.

Previewing Cross Sections

Cross section profiles can be previewed through the series of steps described below.

1. Make the Terrain TIN active.
2. Select the  (Interpolate Line) tool.

3. Use the mouse to create a cut line (graphic object) at the cross section location.

4. Create a new layout from the project window.

5. Select the  (Profile Graph) tool and draw a box for the region to plot the cross section.

6. Set parameters in the dialog that appears. The default options are often satisfactory.

Land Use Theme

A polygon theme may be used to estimate Manning's *n* values along each cut line. If the polygon theme used is a land use theme, an additional field titled *N_value* will need to be added.

GeoRAS provides functionality to create a summary table of land uses and user specified n-values. The table of n-values is then joined to the land use data tables. Alternatively, a field titled *N_value* may be added using standard ArcView functionality. Extracting n-values at cross sections is an optional process.

Rules!

- Land use theme must be a polygon data set that encompasses the entire expanse of each cross section.
- The land use theme must have a field titled *N_value*.

Creating the Land Use Table

The Land Use polygon theme must have a *N_value* field. To add the field to the land use shapefile, activate the land use theme and select the **GeoRAS ⇒ Create LU-Manning Table** menu item. This will invoke a dialog (see Figure 4–4) to allow the you specify which field will be referenced for the land use attributes. Select the field name and press **OK**.

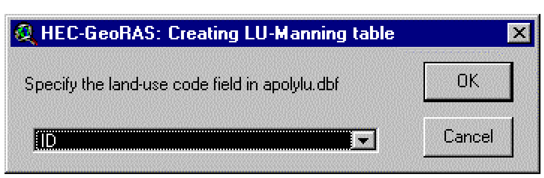


Figure 4–4. Land use field selection dialog.

The attributes of the selected field will be summarized and written to a new table. The default name for the table will be "lumanning.dbf" and will be stored in the project directory. The dialog browser shown in Figure 4–5 will appear and allow you to change the file name and location.

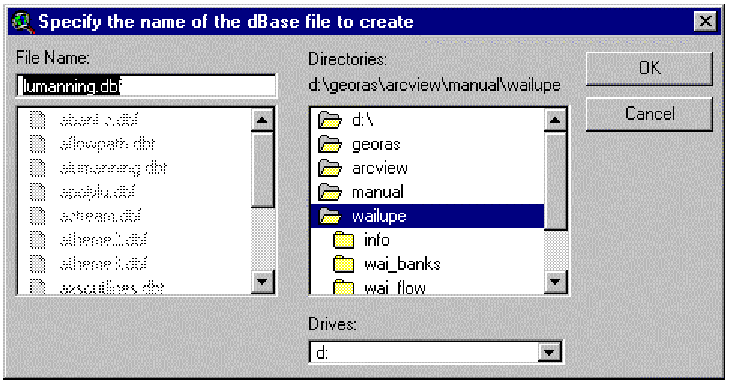


Figure 4–5. Summary n value table naming dialog.

The "lumanning" table created will have the land use field and an *N_value* field. To edit the n-value field, select the **Tables** document from the project window. The new table ("lumanning.dbf") will be listed. Select the table and press the **Open** button. Note that the field headings are in italics, indicating that the table is not editable.

Make the table editable by selecting **Table** ⇒ **Start Editing**. (The field headings will be in normal text.) Use the  (**Edit**) tool to enter n-values corresponding to land use. After entering each n value be sure to hit the Enter key or click in a new cell to record the value (especially on the last entry). When finished entering values, select **Table** ⇒ **Stop Editing**.

Note that the "lumanning.dbf" table is joined to the land use data set. Therefore, the land use shapefile and lumanning database file need to be kept together. Each time the ArcView project (*.apr*) is opened, the tables will be joined using the ArcView **Join** function. To keep user defined n-values with the land use data, use the **Theme ⇒ Convert to Shapefile…** menu option to create a new land use theme with the attached n-value data. Make the land use theme active. Make sure that all records are unselected and select the **Theme ⇒ Convert to Shapefile…** menu item.

Theme Attributing

Once the RAS Themes have been created, the geometric data extraction process may begin. The Stream Centerline theme needs to be completed and the cross-sectional attributes (geometric data for each cross section) need to be calculated.

Theme Setup

Before performing calculations on themes, the role of each theme should be specified. Select the **preRAS ⇒ Theme Setup** menu item. The dialog shown in Figure 4–6 will be invoked to allow you to specify the “Input Data” themes.

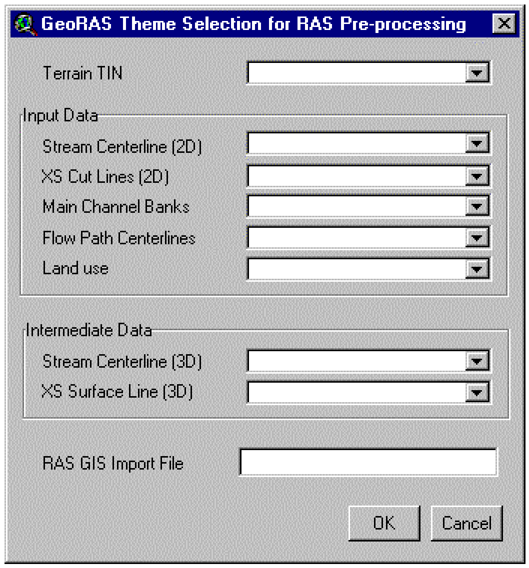


Figure 4–6. Pre-processing theme setup.

If the themes were created using the step outline on the preRAS menu, the “Input Data” field will be filled in; however, the RAS GIS Import File name will need to be specified. Enter the RAS GIS Import File name with a file extension (e.g. *.geo*) and press **OK**.

Centerline Completion

Complete the stream centerline data by selecting the **preRAS ⇒ Centerline Completion** menu item. This process will establish the connectivity and orientation and extract the elevation profile.

There are three processes that take place during the Centerline Completion item on the preRAS menu. The Lengths/Stations item computes the river reach lengths. Centerline Topology, establishes the connectivity and orientation (upstream and downstream ends) of the river network. Centerline Z Extract, will create a 3D shapefile from the Stream Centerline theme.

Lengths/Stations

This function computes the lengths along the stream centerline to the downstream and upstream most point on each river reach. The fields *from_ST* (downstream endpoint) and *to_ST* (upstream endpoint) are added to the Stream Centerline theme.

Centerline Topology

The Centerline Topology process establishes the connectivity and orientation (upstream and downstream ends) of the river network. The Stream Centerline theme must contain the *Stream_ID* and *Reach_ID* fields to complete the centerline topology. This process may be completed by selecting the **preRAS ⇒ Centerline Topology** menu item.

Centerline Z Extract

The Centerline Z Extract function creates a 3D shapefile from the Stream Centerline (2D) theme. Stream centerline data will be written to the RAS GIS Import File from the 3D Stream Centerline shapefile.

XS Attributing

Cross section attributes are added to the Cross Section Cut Line theme using the **preRAS ⇒ XS Attributing** menu item. After all the attributes (river and reach names, stationing, Manning's n values, bank stations, and reach lenghts) are written to the Cross Section Cut Line (2D) shapefile, a 3D shapefile is created by selecting **preRAS ⇒ XS Elevations**.

Stream/Reach Names

This function adds the *Stream_ID* and *Reach_ID* items to the Cross Section Cut Line theme based on the intersection of the cut line with the stream centerline. The Stream Centerline theme must have the *Stream_ID* and *Reach_ID* fields.

Stationing

The stationing function adds the cross-sectional stationing based on the intersection of the cross-sectional cut lines and the stream centerline (2D). The Stream Centerline theme must have the *from_ST* and *to_ST* items. The *Station* field is added to the Cross Section Cut Line theme.

Manning's n values

Manning's n values are extracted from the Land Use theme during this process. The Land Use theme must have an *N_va*lue field and cover the entent of all cross sections.

The field XS_ID is added to the Cross Section Cut Line theme and is joined to a table of Manning's *n* values. Manning's *n* values are reported at each change along the polygon data set as a percent along the cross section cut line. The data extraction process is shown in Figure 4–7.

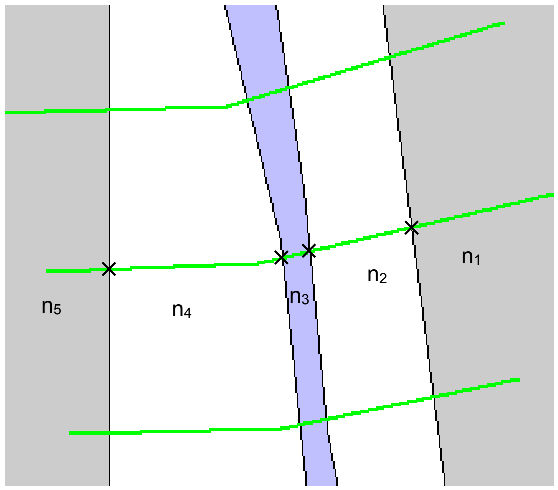


Figure 4–7. Calculation of n-value locations.

Bank Stations

Bank station positions for each cross section are computed from the intersection of the cross-sectional cut lines and bank station lines. Bank station positions are calculated as the percent distance along the cut line from its start in the left overbank. *L_BankP* and *R_BankP* fields are added to the Cross Section Cut Line theme for the left and right bank positions by percent, respectively. The bank station calculation method is shown in Figure 4–8.

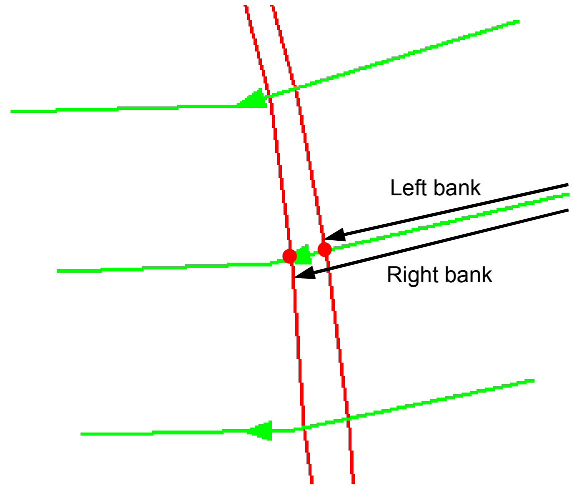


Figure 4–8. Calculation of bank station locations from bank lines and cross section cut lines.

Reach Lengths

This function adds downstream reach lengths to each cross section cut line based on the intersection of the flow path centerlines and the cut lines. *L_ReachL*, *M_ReachL*, and *R_ReachL* fields are added to the Cross Section Cut Line theme for the downstream reach lengths in the left overbank, main channel, and right overbank, respectively. The method for calculating downstream reach lengths is shown in Figure 4–9.

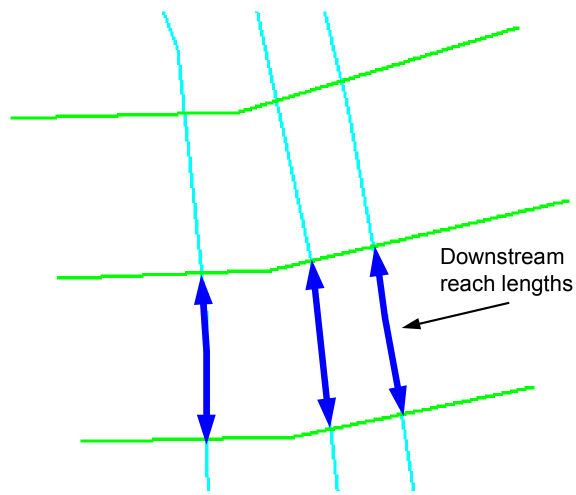


Figure 4–9. Calculation of downstream reach lengths from the flow path centerlines and cross section cut lines.

XS Elevations

The XS Elevation function creates a 3D shapefile from the Cross Section Cut Line theme. Station-elevation data is extracted from the

Terrain TIN at the edge of each triangle along a cut line. The Cross Section Cut Line (2D) theme should be completely processed before converting it to a 3D shapefile. A visualization of the elevation extraction process is shown in Figure 4–10.

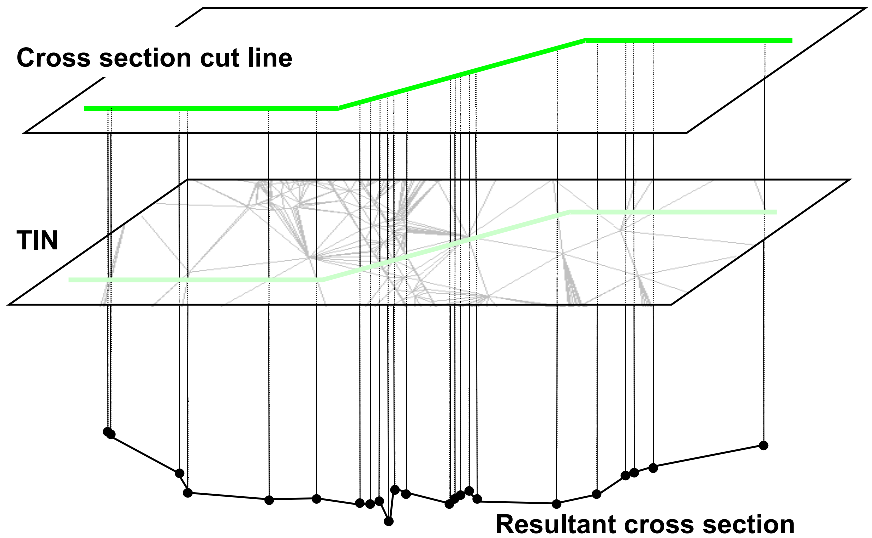


Figure 4–10. Extraction of station-elevation data from a TIN.

Generating the RAS GIS Import File

To generate the RAS GIS Import File, the 3D Stream Centerline and Cross Section Surface Line (3D) shapefile must be created from the RAS Themes. Geometric data from two 3D shapefiles is written to the RAS GIS Export File. The geometric data includes: river, reach, and station identifiers; cross section cut lines; cross section surface lines; cross section main channel bank stations; downstream reach lengths for the left overbank, main channel; and right overbank; and Manning's n values.

Before writing the RAS GIS Import File, select the **preRAS ⇒ Theme Setup …** menu item. In the Theme Setup dialog, check that the Intermediate Data files (3D shapefiles) are correct, the correct Terrain TIN is listed, and that the RAS GIS Import File name is specified correctly (with an extension, if desired). Press OK to save settings and dismiss the setup window.

Generate RAS GIS File

To write the RAS GIS Import File, select the **preRAS ⇒ Generate RAS GIS Import File** menu item. Header, stream network, and cross section information is written to the import file in a specific data exchange format readily importable to HEC-RAS. For more a more detailed discussion of the GIS data exchange file format, refer to Appendix B. The Generate RAS GIS Import menu item performs the three tasks of Header Export, Centerline Export, and XS Export menu items.

Header Export

The Header Export menu item generates the header section for the RAS GIS Import File. It uses the 3D Stream Centerline, Cross Section Surface Line, and Terrain TIN themes to generate the header information.

Projection and unit parameters are taken from the Terrain TIN. If the TIN's projection parameters are missing (TIN's *.prj* file) the user will be asked to specify the unit type (METRIC or ENGLISH), while all the other projection parameters are set to "null".

Centerline Export

The Centerline Export function writes out the stream network to the import file based on the 3D Stream Centerline theme. Each river reach endpoint will be identified in the file separately. The stream centerline coordinates (x,y,z) are reported, including the distance to the downstream endpoint.

XS Export

The XS Export menu item writes out the geometric data for each cross section. Cross section data reported includes: river and reach identifiers, cross section stationing, bank station locations, downstream reach lengths, Manning's *n* values, cross section cut line coordinates (x, y), and cross section surface line coordinates (x, y, z).

CHAPTER 5

Generating GIS Data from HEC-RAS Results

HEC-GeoRAS facilitates the generation of GIS themes from exported HEC-RAS simulation results. Floodplain delineation and water depth themes may be created from exported cross-sectional water surface elevations using HEC-GeoRAS. Velocity themes may also be generated.

Chapter 5 discusses the processing exported HEC-RAS results using HEC-GeoRAS.

Contents

Importing a RAS GIS Export File

Importing a RAS GIS Export File requires two steps. The user must identify the export file and specify the location to store results to pre-process the raw data file. These steps are performed using the Theme Setup and Read RAS GIS Export File items on the postRAS menu.

Theme Setup

Select the **postRAS ⇒ Theme Setup** menu item. This will invoke the dialog shown in Figure 5–1, which allows the user to specify the RAS GIS Export File, Terrain TIN, Output Directory, and Rasterization Cell Size.

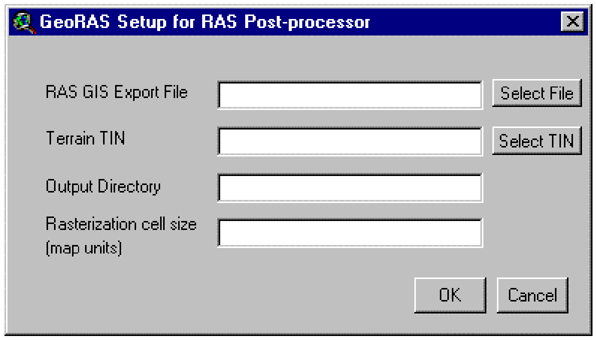


Figure 5–1. Theme setup for GeoRAS post-processing.

Select the RAS GIS Export File using the **Select File** button. HEC-RAS writes the export file with the *.gis* file extension. Select the Terrain TIN using the **Select TIN** button.

Specify the Output Directory name. All post-processing GIS data sets will be written to the Output Directory. The path name of the Output Directory will be the name specified appended to the pathname of the location of the ArcView project file. Use a short (rather than long), meaningful Output Directory name as it will be used for naming several of the GIS themes created later.

Enter the Rasterization Cell Size. This cell size will be used in post-processing to rasterize the Terrain TIN and resulting TINs for grid cell computations (floodplain delineation, flood depth grids, and velocity grids). The smaller the cell size, the longer the processing time, but depending on the resolution of the Terrain TIN, the more accurate spatial location of the floodplain delineation. The Rasterization Cell Size should be selected based on the resolution of the Terrain TIN. *Currently, the maximum number of cells that can be used for the rasterization process is 10,000,000.*

Read RAS GIS Export File

Once the post-processing theme setup is complete, RAS results can be read into the GIS. Select the **postRAS ⇒ Read RAS GIS Export File** menu item. This function will read the RAS results and create base data for GIS post-processing. The initial base themes created include: stream network, cross-sectional cut lines, cross-sectional surface lines, banks station lines, water surface profile bounding polygons, and velocity mass points.

Note: *At this time, only water surface profile names having a maximum of 9 characters are supported.*

Stream Network

A stream network theme is created from the RAS export file. It will identify the location of the stream centerline as represented in HEC-RAS and have the River and Reach names. The stream network shapefile will be named based on the concatenation of the Output Directory name and "_SN".

Cross-Sectional Cut Lines

A cross-sectional cut line theme will be created based on the cross-sectional alignment in RAS during simulation. The cross-sectional cut line theme will include the stream, reach, and station identifiers for each cross section location. Water surface elevations for each flood event are exported at each cross section, and whether or not the cross section was interpolated in HEC-RAS. The cross-sectional cut line shapefile will be named based on the concatenation of the Output Directory and "_XS".

Cross-Sectional Surface Lines

A 3D shapefile of cross sections will be created if the cross section surface line data is present in the RAS GIS Export File. It will have the attributes of the cross-sectional cut line theme. The cross-sectional surface line shapefile will be named based on the concatenation of the Output Directory and "_XS3D".

Bank Stations

If the bank station data is present, a line theme of bank station locations will be created. The cross section surface line shapefile will be named based on the concatenation of the Output Directory and "_Banks".

Bounding Polygons

Bounding polygon shapefiles will be created for each water surface profile exported. The bounding polygon data defines the RAS model extent, thereby limiting the edge of the water surface to the end of cross sections, levees, and bridge and culvert openings. Each bounding polygon shapefile name will be a concatenation of "bp" and the water surface profile name. A "w" will be added to the water surface profile name if it begins with a numeric character.

Velocity Mass Points

If velocity data is present, a point theme of velocity mass points will be created. A separate theme will be created for each water surface profile exported. The shapefile names will be a concatenation of "vp" and the water surface profile name.

Processing Water Surface Elevation Data

Water surface elevations are written to the RAS GIS Export File at each cross section for each flood event. This water surface data in conjunction with the terrain elevation data is used for floodplain delineation and determining water surface depths.

Water Surface TIN Generation

The first step in the delineation process creates a water surface TIN from the water surface elevations attached to each cross section. To build the water surface TIN select the **postRAS ⇒ WS TIN Generation** menu item. An example water surface TIN is shown in Figure 5–2.

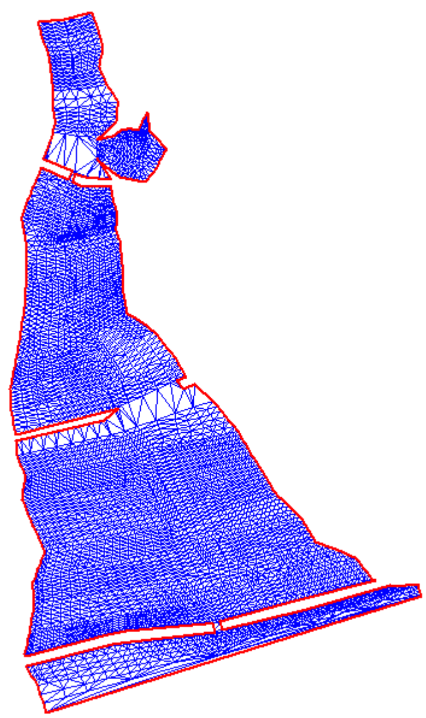


Figure 5–2. Example water surface TIN clipped by a bounding polygon.

The water surface TIN is created irrespective of the Terrain TIN and is clipped by the bounding polygon. The bounding polygon limits the water surface to the areas as modeled by HEC-RAS and should be scrutinized around meandering portions of the river model. The water surface TINs created will be named as a concatenation of "wstin" and the water surface profile name.

Floodplain Delineation

Floodplain delineation is performed using the **postRAS ⇒ Floodplain Delineation** menu item.

Rasterization of the water surface TIN and Terrain TIN is the next process. The grids are created using the Rasterization Cell Size specified in the post-processing theme setup dialog. The floodplain is then delineated where the water surface grid and terrain grid have the same elevation as shown in Figure 5–3, or the edge of the water surface grid where limited by the bounding polygon.

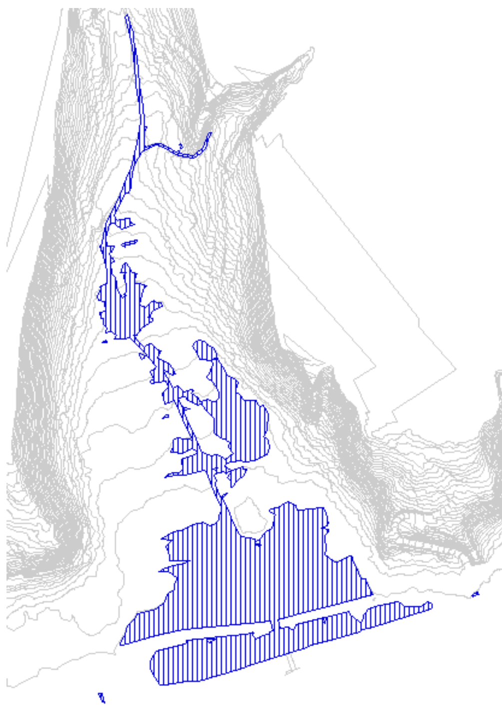


Figure 5–3. Example floodplain delineation with terrrain contours.

The same rasterized water surface TIN and Terrain TIN are subtracted to create a water depth grid. An example grid of water surface depths is shown in Figure 5–4. If Spatial Analyst is loaded (Spatial Analyst is not required), the depth grid will be named from a concatenation of “gd” and the water surface profile name. Otherwise a point theme matching the computational grid layout will be created and named with the concatenation “pd” and the water surface profile name.

Floodplain delineation results should be carefully examined. Spurious ponds may be present and should be deleted in the GIS or modeled behind levees. Inappropriately placed cross sections may result in bounding polygon data incorrectly limiting the floodplain. The floodplain delineation process in GeoRAS is an iterative process that should be used to refine the hydraulic model in HEC-RAS.

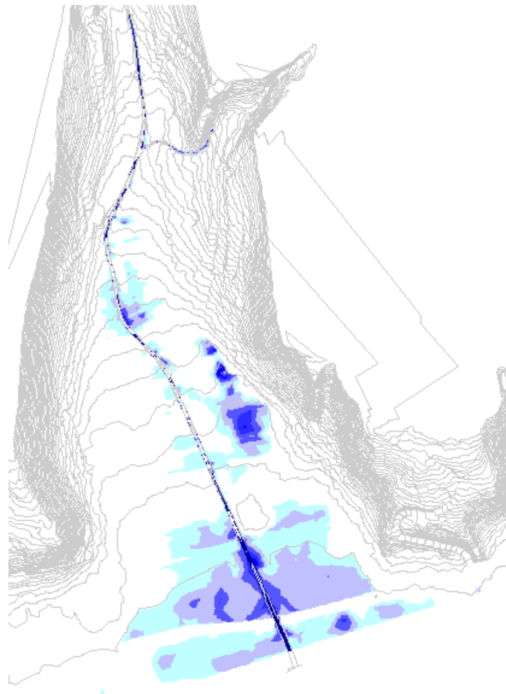


Figure 5–4. Example depth grid displayed with terrain contours.

Processing Velocity Data

Velocity data are written to the RAS GIS Export File at each cross section for each flood event. It is important to consider that velocity results generated from HEC-RAS simulations are the result of a one-dimensional hydraulic model.

Velocity TIN Generation

Select the **postRAS ⇒ Velocity TIN Genration** menu item. This process builds a TIN from the velocity mass point shapefile created in the Read RAS Import File process. The velocity points theme, cut lines theme, bank lines theme, and flood plain polygon theme for the corresponding water surface profile are required inputs to the TIN building process.

Velocity Grid Generation

Select the **postRAS ⇒ Velocity Grid Genration** menu item. This process will create a grid of velocities from the velocity TIN based on the Rasterization Cell Size input in the post-processing theme setup dialog. An example velocity grid is shown in Figure 5–5.

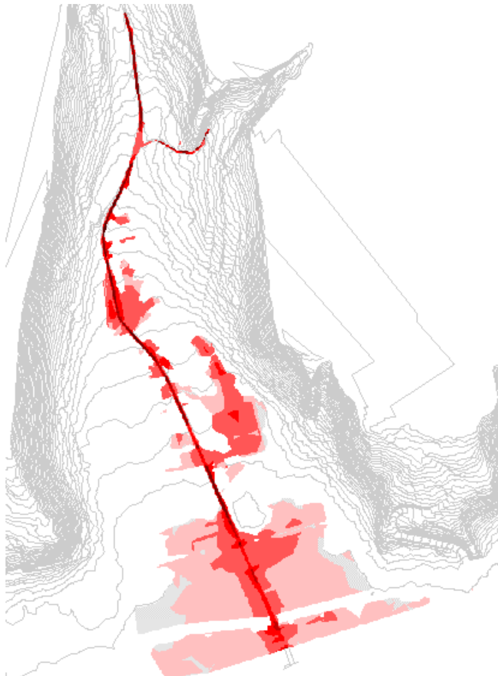


Figure 5–5. Example velocity grid displayed with terrain contours.

Velocity results must be carefully scrutinized and treated with increasing skepticism as they get farther from the cross section. Further, incorrect results may arise dictating hydraulic model refinement.

CHAPTER 6

Example Application

This chapter provides an example application of how to use the HEC-GeoRAS extension in ArcView GIS for supporting hydrualic model development and analysis with HEC-RAS. You will be lead through a step by step procedure of how to develop geometric data for import into HEC-RAS and how to develop GIS data sets from exported results from HEC-RAS simulations.

The example demonstrated is for the Wailupe River, HI, where a TIN exists for the river system. **The figures used may not be hydraulically accurate and are intended for demonstration purposes only**. Chapters 3-5 provide more detailed discussion of the steps performed in this example.

Contents

- Loading HEC-GeoRAS
- Starting a New Project
- Creating Contours from a TIN
- Creating RAS Themes
- Attributing RAS Themes
- Writing the RAS GIS Import File
- Running HEC-RAS
- Importing the RAS GIS Export File
- Generating GIS Data from RAS Results

Loading HEC-GeoRAS

Start ArcView to begin. Load the HEC-GeoRAS extension by selecting **File ⇒ Extensions…** menu item from the main ArcView interface. Activate the HEC-GeoRAS extension by placing a check in the corresponding checkbox. Do the same for 3D Analyst and the Spatial Analyst extension, if available.

Starting a New Project

Before continuing, decide on the directory where the GIS data will be stored. If the directory does not exist, create it using a file manager. For this example, the project directory is "**Wailupe**".

Save the project to the project directory by selecting **File ⇒ Save Project**. In the browser that appears, navigate to the project directory, enter the project name ("**Wailupe**"), and press the **OK** button.

Make sure that the *Project Win*dow (titled "**wailupe.apr**") is active and select **Project ⇒ Properties…**. Set the *Work Directory* in the *Project Properties* window (see Figure 6–1) to the project directory established previously. This insures that data sets created by default ArcView procedures will be stored in the same place as those created by GeoRAS.

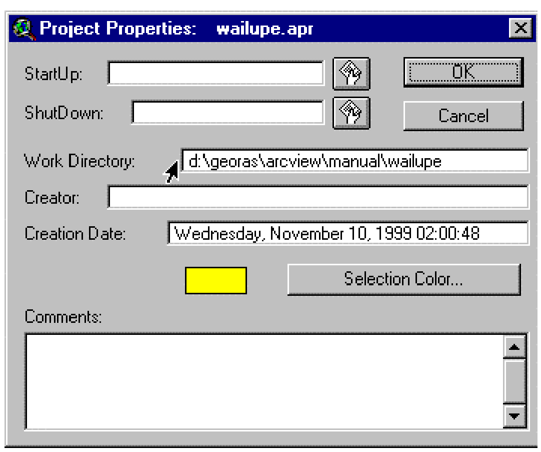


Figure 6–1. Define the "Work Directory" to establish the default location for saving data in ArcView.

From the *Project Window*, select the *View* document and press the **New** button. Make the view (**View1**) active by clicking in the view's window.

Creating Contours from a TIN

Load the Terrain TIN using the **View ⇒ Add Theme…** menu item. Use the "Data Source Types" selection list to select TIN Data Source as shown in Figure 6–2. If the TIN is stored in the Project Directory it will be listed. Otherwise navigate to the correct directory. Select the Terrain TIN.

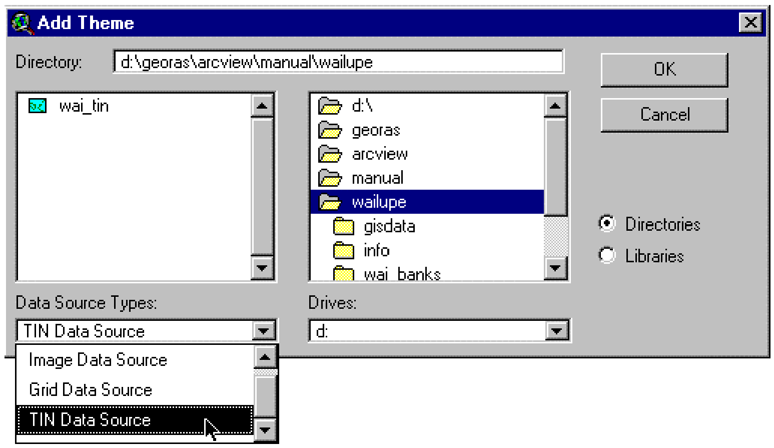


Figure 6–2. Use the "Data Source Types" selection list on the Add Theme dialog.

Create contours from the Terrain TIN by selecting **Surface ⇒ Create Contours….** You will be prompted to enter the contour interval. Use the default (10) and press **OK**. The contour theme will be added to the view's *table of contents*.

Make the contours visible by placing a check in the corresponding checkbox. If the contours do not provide adequate definition, generate a new theme using a smaller contour interval.

Creating RAS Themes

In this next section you will create and edit a series of themes collectively referred to as the RAS Themes. The RAS Themes are created to extract geometric data for hydraulic analysis. These five themes are the Stream Centerline, Banks, Flow Path Centerlines, Cross Section Cut Lines themes, and Land Use themes.

Stream Centerline

The Stream Centerline theme is used to establish the river reach network.

Make the current view (View1) active. The GeoRAS menus, buttons, and tools will be available from the ArcView interface. Select **preRAS ⇒ Create Stream Centerline** menu item. The dialog box shown in Figure 6–3 will appear. Specify a name for the new shapefile and destination directory and press **OK**.

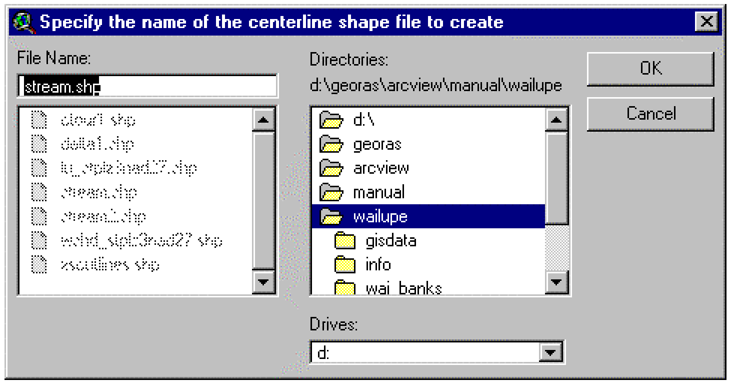


Figure 6–3. The default name for the Stream Centerline theme is "stream."

The Stream Centerline theme shapefile will be added to the view and will be active and editable. You are now ready to create the two river, three-reach river network shown in Figure 6–4.

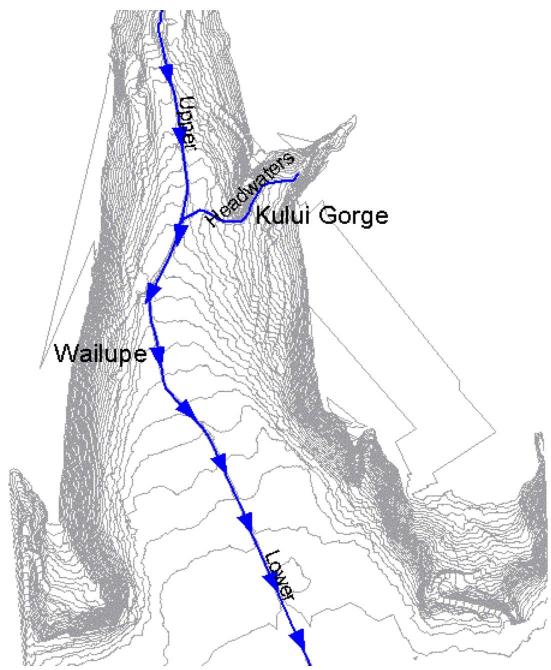
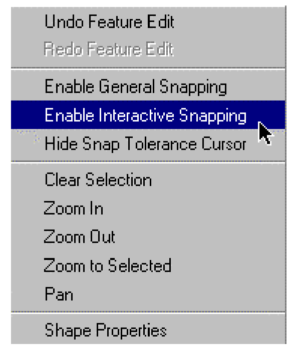


Figure 6–4. River and reach network for the Wailupe River.

Activate the  (**Zoom In**) tool and zoom into the upper portion of the watershed. Next, activate the  (**Draw Line**) tool. Begin the first reach by placing the cursor at the upstream most point and left clicking. This creates the upstream endpoint. Begin creating the reach in the downstream direction by left clicking to add vertices.

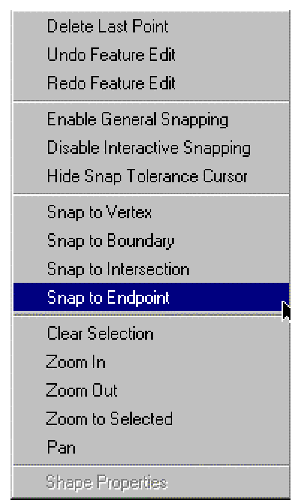
If you run out of digitizing space while creating the river reach, you can pan on the fly. While still in the Draw Line mode, move the cursor to the portion of the window you want to see, right click over the display window, and select **Pan** from the popup window.

When you reach the confluence of the two reaches, double mouse click to end the reach.



Before creating the next reach you should enable snapping. Right click in the display window. In the popup menu that appears, select **Enable Interactive Snapping**.

You also need to set the snapping tolerance. Activate the  (**Snap**) interactive tolerance tool. Move the cursor to the downstream endpoint of the reach you just created and draw a small circle around the endpoint using the cursor (click and hold to draw the circle, let go to finish). Now you are ready to draw the next river reach.



Pan or zoom to the upstream end of the next reach. Activate the Draw Line tool and begin drawing the reach down to the confluence. When you are ready to end the line at the junction, right click on the display window. In the popup menu that appears, select the **Snap to Endpoint** option.

The cursor will change from the standard drawing cross-hairs to a pointer with a circle. The circle defines the interactive snapping tolerance distance. Place the cursor at the junction and double click to end the line.

With the Draw Line tool still active create the third reach. First, right click over the display window and select Snap to Endpoint. (This will snap the first point you place at the junction.) Move near (within the snap tolerance distance) and click to start the reach. The line will automatically snap to the intersection. Use the mouse to draw the remainder of the reach, using the pan and zoom tools as required.

When finished drawing the river reach network, select the **Theme ⇒ Stop Editing** menu item. Use the (**Zoom to Active Theme**) button to zoom to the full extent of the Stream Centerline theme.

Now label each river reach with an identifier. Activate the (**River Reach ID**) tool. Use the cursor in the display window to select a river reach. Upon selection, the dialog shown in Figure 6–5 will appear. Enter the River Name and Reach Name for each reach. In this example the ***Wailupe*** **River** has and ***Upper*** and ***Lower*** reach and the ***Kului Gorge*** is a ***Tributary*** stream.

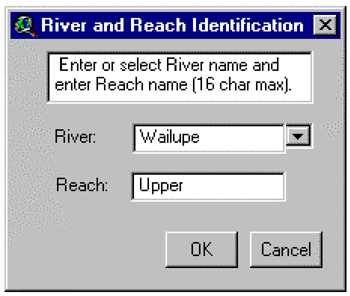


Figure 6–5. Label each river reach with a unique name.

Banks

The Banks theme is used for identify the main channel conveyance area from that of the overbank floodplain areas.

Select the **preRAS ⇒ Create Banks** menu item. The Banks theme shapefile will be created and added to the view. The theme will be active and editable.

Establish the bank station locations on either side of the channel for the Wailupe River and Kului Gorge using the **Draw Line** tool. Use the pan and zoom tools discussed earlier to navigate. Make sure that there is only one line for each bank station location. When finished select **Theme ⇒ Stop Editing** menu item. The resultant bank lines should look like those illustrated in Figure 6–6.

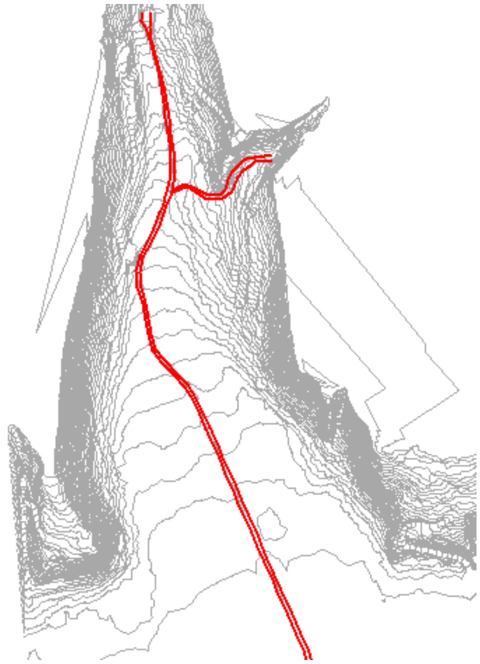


Figure 6–6. Delineation of the main channel from overbanks areas.

Flow Path Centerlines

The Flow Path Centerlines theme is used to determine downstream reach lengths between cross sections in the channel and overbanks areas.

Select the **preRAS ⇒ Create Flowpaths** menu item. Because you have already created the Stream Centerline theme, a dialog box will appear asking you if the center flow path should be copied from the Stream Centerline theme. Press **Yes** to copy the centerline.

Create flow paths in the left and right overbank for each of the rivers using the Draw Line tool. Create the flow paths in the direction of flow (from upstream to downstream) and located to indicate the center of mass of flow for a specific event. When finished, select **Theme ⇒ Stop Editing** menu item. Your flow paths should look similar to those in Figure 6–7.

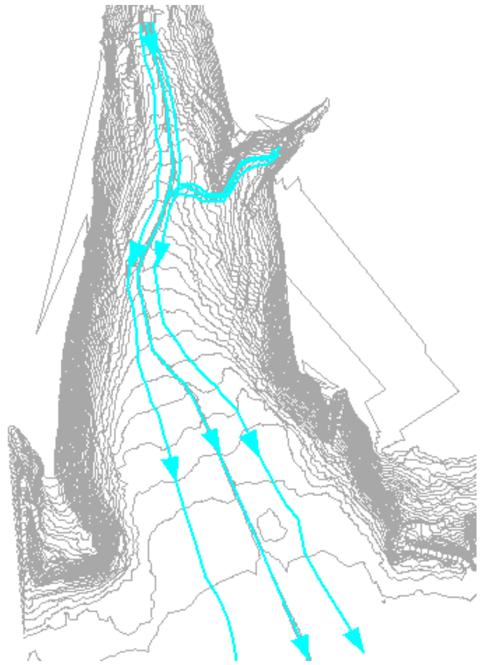


Figure 6–7. Illustration of flow path centerlines.

Now label each flow path with an identifier. Activate the (**Label Flowpaths**) tool. Use the cursor in the display window to select a flow path. Upon selection, the dialog shown in Figure 6–8 will appear. Select from the drop down list the correct label for the left overbank, channel, and right overbank flow paths.

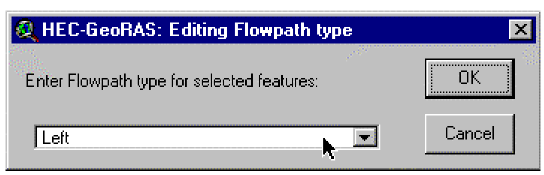


Figure 6–8. Each flow path must have an identifier of "Left"," Channel", or "Right".

Cross-Sectional Cut Lines

Cross section cut lines are used to identify the location at which cross-sectional data will be extracted from the Terrain TIN and for bank station, downstream reach length, and land use computations.

Select the **preRAS ⇒ Create Flowpaths** menu item. Use the Draw Line tool to create cross-sectional location lines. Use the mouse to drawn the cross-sectional lines from the left overbank to the right overbank perpendicular to the direction of flow. When finished, select **Theme ⇒ Stop Editing** menu item. Your cross section cut lines may look similar to those in Figure 6–9.

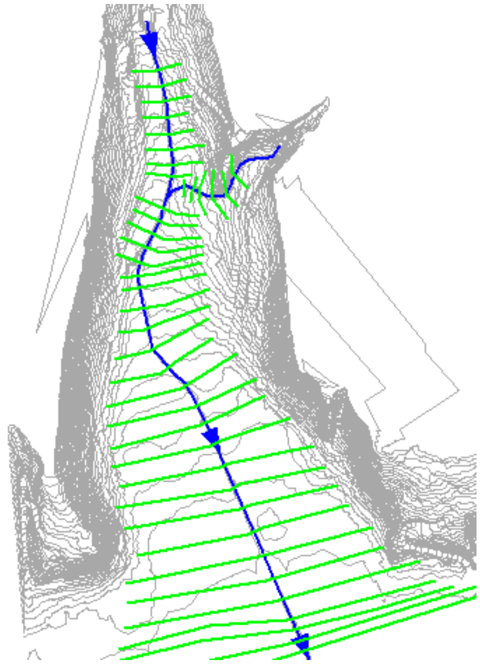


Figure 6–9. Cross section cut lines span the entire floodplain.

Previewing Cross Sections

Cross section profiles similar to that in Figure 6–10 can be previewed through the series of steps described below.

1. Make the Terrain TIN active.
2. Select the  (**Interpolate Line**) tool.
3. Use the mouse to create a cut line (graphic object) at the cross section location. (Create the line similarly to using the Draw Line tool.)
4. Create a new layout from the project window.
5. Select the  (**Profile Graph**) tool and draw a box for the region to plot the cross section.
6. Set parameters in the dialog that appears. The default options are often satisfactory.

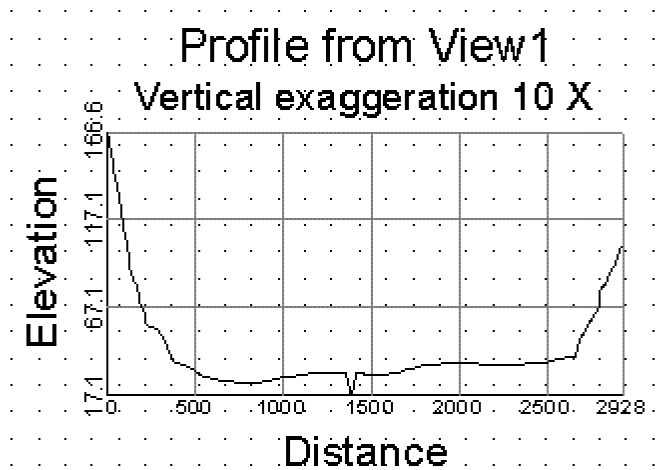


Figure 6–10. Example cross section previewed using the Interpolate Line tool.

Land Use

The Land Use theme is used to reference roughness coefficients for each cross section.

Make the Land Use theme active. Select the **GeoRAS_Util ⇒ Create LU-Manning table** menu item. In the dialog that is invoked, select the field that holds the land-use data values from the selection list. This will create a summary table (default name "lumanning.dbf") of land use values and create a field titled *N_value*.

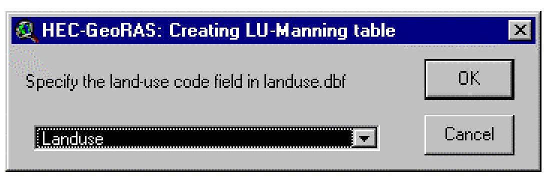


Figure 6–11. Select the landuse field.

From the *project* window, select the *tables* document. The name of the table will appear as an available document. Select the table and press the **Open** button. The table will open with the field names across the top shown in italics with a gray background.

Select **Table** ⇒ **Start Editing** to begin entering n-values. Note that the field names are no longer in italics, indicating that the table may be edited. Use the (**Edit Cells**) tool to edit values in the table. When finished entering *n* values, select **Table** ⇒ **Stop Editing**.

Select the view document used for creating the themes to access the GeoRAS menus.

Attributing RAS Themes

The theme attributing process is where the GIS performs calculations and appends the results to corresponding tables. The two themes which have data appended to their tables are the Stream Centerline and Cross Section Cut Lines themes.

Before attributing the themes make sure you have the correct themes specified. Select the **preRAS ⇒ Theme Setup …** menu item. Using the drop down lists in the pre-processing dialog window, select the theme corresponding to the Terrain TIN and the "Input Data" fields. Also enter the name for the RAS GIS Import File you will create later. Make sure to add a file extension.

Stream Centerline Theme

Select the **preRAS ⇒ Centerline Completion** menu item. This will establish the connectivity and directionality of the reach network and then create a 3D shapefile by extracting elevation data from the Terrain TIN.

Stream and reach fields (*Stream_ID* and *Reach_ID*) were already present in the Stream Centerline theme table. The fields appended to the table and a short description is provided in Table 6–1.

Table 6–1. Fields appended to Stream Centerline theme table.

Field	Description
To_node	Integer assigned to upstream endpoint
From_node	Integer assigned to dwonstream endpoint
To_station	Stationing at upstream endpoint
From_station	Stationing at downstream endpoint
Arclength	Length of line defining reach

Check that each field has been added to the Stream Centerline theme table. Make the Stream Centerline (3D) theme active and press the  (**Table**) button. This will bring up the table for the active theme. Check to ensure that the fields are correctly there and that each value has been filled in.

Cross-Sectional Cut Lines Theme

Select the **preRAS ⇒ XS Attributing** menu item. The XS Attributing item calculates the cross section geometric properties. The fields appended to the table are provided in Table 6–2.

Table 6–2 . Fields appended to the Cross Section Cut Lines theme table.

Field	Description
Stream_ID	Stream Name taken from the Stream Centerline.
Reach_ID	Reach Name taken from the Stream Centerline.
XS_ID	Cross section ID linked to LUManning table.
Station	Cross section stationing.
R_BankP	Fraction of cut line to right bank station.
L_BankP	Fraction of cut line to left bank station.
R_ReachL	Downstream reach length for right overbank.
M_ReachL	Downstream reach length for channel.
L_reachL	Downstream reach length for left overbank.

Dialog boxes will inform you if each step is successful. After all the processing is completed, however, you should check that each field has indeed been added and have reasonable values.

Make the XS Cut Lines (2D) theme active and press the **Table** button. This will bring up the table for the active theme. Check that the fields are correctly there and that each value has been filled in.

Make the view active. Select the **preRAS ⇒ XS Elevations** menu item. This will create a 3D shapefile (XS Surface Line) from the Cross Section Cut Lines (2D) shapefile by extracting elevations from the Terrain TIN. The attribute table for the new 3D shapefile will be identical to 2D shapefile and the elevations.

Writing the RAS GIS Import File

Once you have the 3D Stream Centerline and the 3D XS Surface Line themes created, you are ready to write the RAS FIS Import File. You already specified the RAS GIS Import File name earlier, but if you wish to change it you can using the **preRAS ⇒ Theme Setup…** menu item.

Select the **preRAS ⇒ Generate RAS GIS Import File** menu item. This will create the import file complete with header, stream network, and cross section information. You will be prompted, upon completion, for the name and location of the file.

Running HEC-RAS

To use HEC-RAS in concert with GeoRAS, perform the following steps:

1. Star a new project in HEC-RAS.

2. Import the RAS GIS Import File into HEC-RAS. This is accomplished from the Geometric Data editor by selecting **File ⇒ Import Geometry Data ⇒ GIS Format**. For a more complete discussion on importing geometric data, refer to the HEC-RAS User's Manual, Chapter 13.

3. Complete the hydraulic data. Hydraulic structure data such as bridges and culverts, as well as levees, block obstructions, or ineffective flow areas will need to be completed. Banks station data may need to be modified using the graphical cross section editor. This is available by selection **Tools ⇒ Graphical XS Edit…** menu item on the Geometric Data editor.
   The cross-sectional station-elevation data may need to be filtered down to less than 500 points. This is available by selecting **Tools ⇒ Cross Section Points Filter…** menu item on the Geometric Data editor of HEC-RAS (Version 3.0).

4. Complete the flow data and boundary conditions. Specify water surface profile names.
   GeoRAS will only read the first 9 characters of each water surface profile name; therefore, water surface profile names should have unique names for the first 9 characters. You may need to edit the export file using a global search and replace on water surface profile names.

5. Export the HEC-RAS simulation results to the RAS GIS Export File. This is accomplished by selecting **File ⇒ Export GIS Data** from the main HEC-RAS window. For a more complete discussion on exporting GIS data, refer to the HEC-RAS Users Manual, Chapter 13.

Importing the RAS GIS Export File

Once the file has been exported from HEC-RAS you can read the data into the GIS. Select the **postRAS ⇒ Theme Setup…** menu item. This will invoke the dialog shown in Figure 6–12 (with empty fields). Select the RAS GIS Export File and Terrain TIN, enter the Output Directory and Rasterization Cell Size, and press **OK**. This will create a new directory which contains all the post-processing results from GeoRAS.

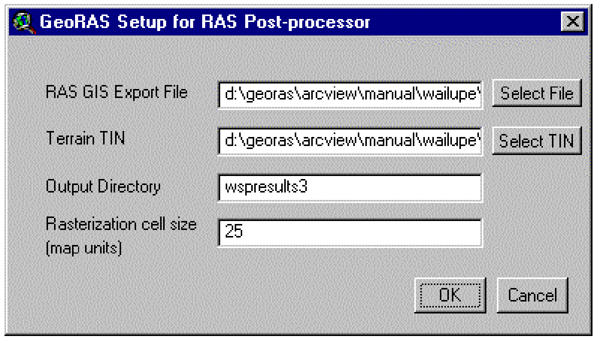


Figure 6–12. Post-processing theme setup dialog.

Next, select the **postRAS ⇒ Read RAS GIS Export File** menu item. This will read the results from the export file and create initial data sets. The stream network, cross section data, and bank station data will be read and shapefiles will automatically be generated.

The shapefile name will be a concatention of the Output Directory and an abbreviation (_SN, _XS, _Banks). The bounding polygon data and velocity point data will be read and shapefiles will be automatically generated. Shapefile names will be a concatenation of an abbreviation (Bp, Vp) and the water surface profile name. Shapefiles created are summarized in Table 6–3.

Table 6–3. Initial post-processing shapefile names.

Shapefile	Description
…_SN	Stream network line shapefile.
…_XS	Cross section cut lines shapefile.
…_Banks	Bank line shapefile.
Vp…	Velocity point shapefile for each water surface.
Bp…	Bounding polygon shapefile for each water surface.

Generating GIS Data from RAS Results

Once the data has been read in from the RAS GIS Export File, you are ready to create water surface and velocity data sets. All the post-processing from this point forward will be using the initial data set you created in the previous step.

Water Surface TIN

Select the **postRAS ⇒ WS TIN Generation** menu item. A dialog will be invoked allowing you to select the water surface profile for which to create the water surface TIN. You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin the TIN generation process.

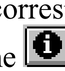
The water surface TIN is created from the cross-sectional cut lines theme (_XS) and the bounding polygon theme (Bp) for the respective water surface profile names. The water surface TINs created will have the water surface profile name prefixed by “Wstin” and will be added to the current view (Output Directory).

Depth Grid

Select the **postRAS ⇒ Floodplain Delineation** menu item. This time a dialog will appear allowing you to select from a list containing water surface profile names for those which have a water surface TIN (created in the previous step). You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin the floodplain delineation.

The floodplain delineation will create a polyline theme identifying the floodplain and a depth grid. The names will be the water surface profile name prefixed by “Fp” and “Gd” for the floodplain and depth grid, respectively.

Turn on the floodplain polygon by selecting the corresponding checkbox. The floodplain should look similar to that shown in Figure 6–13. Use the pan and zoom tools to scrutinize the floodplain delineation.

Next, turn on the depth grid by selecting the corresponding check box. Zoom into an interesting area and use the  **(Identify)** tool tool to find water depths at various locations. An example depth grid and water depth is shown in Figure 6–14.

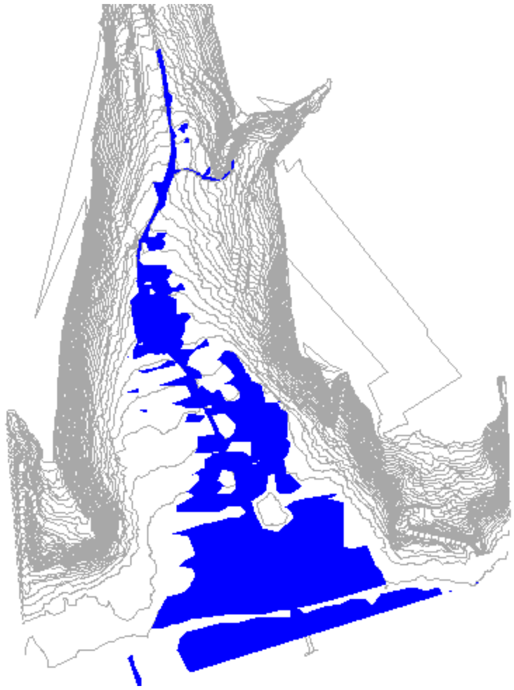


Figure 6–13. Example floodplain delineation.

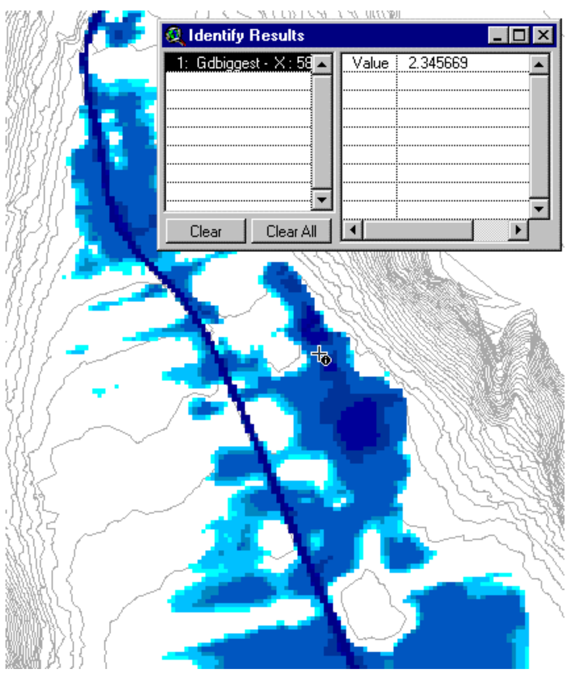


Figure 6–14. Example depth grid with identify results for water depth. Deeper water is indicated by darker blue.

Velocity TIN

Select the **postRAS ⇒ Velocity TIN Generation** menu item. This will provide a dialog that will allow you to pick from a list. The list will contain water surface profile names for which a floodplain delineation (floodplain polygon) has been performed and that have a velocity point shapefile. You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin velocity TIN generation.

The velocity TIN will have the name of the water surface profile prefixed by "Veltin" and will be added to the current view.

Velocity Grid

Select the **postRAS ⇒ Velocity Grid Generation** menu item. Velocity grids (see Figure 6–15) will be generated for from each velocity TIN.

The velocity grids will have the name of the water surface profile prefixed by "Vgd" and will be added to the current view. Display a velocity grid by selecting the corresponding checkbox. Again, pan/zoom to an interesting area and use the identify tool to find areas of high velocity.

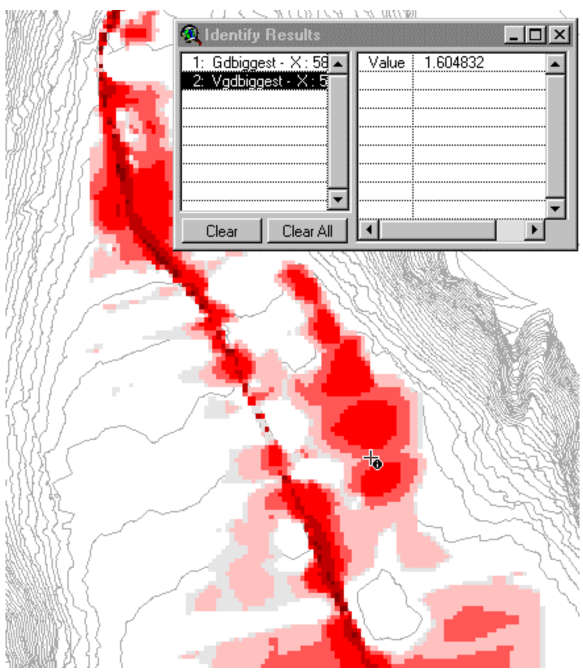


Figure 6–15. Example velocity grid. Higher velocities are indicated by darker red.

A P P E N D I X A

References

Environmental Systems Research Institute (1996). *ArcView GIS: Using ArcView GIS*, Environmental Research Institute, Inc., Redlands, CA

Hydrologic Engineering Center (2000). *HEC-RAS (Version 3.0), River Analysis System, User's Manual*, U.S. Army Corps of Engineers, Davis, CA.

APPENDIX B

HEC-RAS Import/Export Files for Geospatial Data

At version 2.0, HEC-RAS has introduced three-dimensional (3D) geometry for the description of river networks and cross-sections. This capability makes it possible to import channel geometry from CADD or GIS programs without conversion from real-world coordinates to station-elevation descriptions for the cross sections, as HEC-2 required. Similarly, water-surface elevations calculated at cross sections can be exported to CADD or GIS programs, where they can be used to create model water surfaces for inundation mapping.

Supported HEC-RAS Data Exchange

Using a formatted ASCII text file, HEC-RAS will import a basic description of the channel geometry including:

- The structure of the stream network, as represented by interconnected reaches.
- The location and description of cross sections.
- Manning's *n* values for each cross section.

Using the same file format, HEC-RAS can write a file exporting the results of a hydraulic model run to a CADD or GIS program. At a minimum, reported results include the locations of cross sections and the calculated water-surface elevations at those cross sections.

The Import/Export Data File Structure

This section gives general rules for the construction of an HEC-RAS geometric data import or export file. It is not necessary to understand all these rules to build an import file, but they may be useful when debugging failed imports. The rules given here are a portion of the definition of a general-purpose geometric data exchange format being developed at HEC for its NexGen model programs. **Note: These file formats are evolving, in that additional data types will be added, and some of the existing ones may be modified for future versions. If you are writing software to read and write these file formats, please keep in mind that you may need to modify your software to stay compatible with future versions of HEC-RAS.**

Records and Keywords

The HEC-RAS geometric data import file is composed of records, which in turn are composed of keywords and values. All records must contain one keyword, and all keywords end with a colon (:). A record can also contain a value or a set of values following the keyword, i.e., after the colon. Spaces, tabs, or line ends can be placed between a keyword and values within a record.

A record that contains a keyword and no value marks the beginning or the end of a group of related records (for example, the record "BEGIN HEADER:" marks the beginning of the header section of a data file). A record that contains a keyword and a value assigns that value to the part of the model named by the keyword.

When a keyword is read, all spaces up to the colon are removed and all letters are capitalized. The keywords "Begin Header:", "Begin header:", and " Be GiNH eadEr:" are all equivalent to "BEGINHEADER:". For readability, keywords named in this manual will contain internal spaces.

Values

A record can assign a single value to a single variable, or multiple values to an array. Values can be integers, floating point numbers, text strings, or locations (X,Y,Z, label). A single value in an array of values is called an "element" of that array.

A **numerical value (integer or floating point)** cannot contain internal blanks. A floating point number can contain a decimal point; an integer cannot. Elements in an array of numerical values can be separated by commas, blanks, tabs, or line ends.

A **text string** can contain internal blanks, tabs, and commas, but cannot contain internal line ends. Elements in an array of text strings must be separated by line ends.

A **location** consists of three coordinate values and a label (X, Y, Z, label). The first two coordinates are planar, the third gives elevation. The coordinate values are floating point numbers, and the label can be any type of value (although the label can be restricted to a particular data type in a particular context). In certain contexts, the elevation value or the label may not be required. If a label is used, all three coordinate values must be given; the value "NULL" is valid for the elevation coordinate only. The coordinate values and the label can be separated by commas, blanks, or tabs, but a location cannot contain internal line ends. Elements in an array of locations must be separated by line ends.

Data Groups

Records in the data file can be collected in two types of groups: objects and file sections. An object is a group of records that combine to describe an entity within the model, a cross section for example. A file section is a logical or functional grouping of data, the file header, for example, is a section that contains a description of the whole file.

Objects and file sections begin and end with records that contain keywords, but no values. A file section starts with a record containing a keyword composed of the word "BEGIN" followed by the section name and a colon, and ends with a keyword composed of the word "END" followed by the section name and a colon. For example, records containing only the keywords "BEGIN HEADER:" and "END HEADER:" are used to start and end the header section of a file. An object starts with a record containing a keyword naming the object type and ends with a record containing the keyword "END:" only. For example, a cross-section object begins and ends with records containing the keywords "CROSS-SECTION:" and "END:" only.

Comments

Hash characters (#) are used to identify comments. When a hash character is encountered in the file, all data from the hash to the next line end are ignored. A line that begins with a hash is equivalent to a blank line.

HEC-RAS Channel Geometry Import File

HEC-RAS reads channel geometry from a text file composed of three data sections:

- 1. A header, containing descriptions that apply to all data in the file.
- 2. A description of the stream network, containing reach locations and connectivity.
- 3. A descriptions of the model cross-sections, containing their location on the stream network and data required to support the HEC-RAS model.

An example HEC-RAS Channel Geometry Import file and HEC-RAS model results export file is shown at the end of this appendix.

Header

The header is bounded by the records "BEGIN HEADER:" and "END HEADER:" and must contain a record to identify the units system used in the imported data set. The units system can be ENGLISH or METRIC.

```
BEGIN HEADER:
```

```
UNITS: ENGLISH
END HEADER:
```

Records that may be included in the header are listed in the Table B.1:

Table B.1

Keyword	**Value Type**	**Value**
UNITS:	string	ENGLISH or METRIC
PROFILES:	string array	List of profiles exported from HEC-RAS. Not used on import.
DTM TYPE:	string	type (e.g., TIN or raster)
DTM:	string	name of digital terrain model
STREAM LAYER:	string	name of stream layer in CADD or GIS
NUMBER OF REACHES	integer	number of hydraulic reaches contained in the file.
CROSS-SECTION LAYER:	string	name of cross-section layer in CADD or GIS
NUMBER OF CROSS-SECTIONS:	integer	number of cross sections in the file

Keyword	**Value Type**	**Value**
MAP PROJECTION:	string	projection (coordinate) system used (e.g., STATEPLANE)
PROJECTION ZONE:	string	projection zone (if applicable, e.g., 5101)
DATUM:	string	reference datum for planar coordinates
VERTICAL DATUM:	string	reference datum for vertical coordinates

Stream Network

The stream network section is bounded by the records "BEGIN STREAM NETWORK:" and "END STREAM NETWORK:" and contains records describing reaches and reach endpoints. At a minimum, the stream network section must contain at least two endpoints and one reach. The minimum requirements for a stream network are shown below.

```
BEGIN STREAM NETWORK:
   ENDPOINT:  476132.66, 65291.86, 155.28, 1
   ENDPOINT:  478144.53, 64296.61, 123.72, 2

   REACH:
      STREAM ID: Below Springfield
      REACH ID: Blue River
      FROM POINT: 1
      TO POINT: 2
      CENTERLINE:
         476132.66, 65291.86, 155.28, 23.13
         476196.08, 65196.61, 154.47, 23.09
            lines omitted
         478144.53, 64296.61, 123.72, 22.41
   END:
END STREAM NETWORK:
```

A reach endpoint is represented by a record containing the keyword "ENDPOINT:" followed by four comma-delimited fields containing the endpoint's X,Y,Z coordinates and an integer ID.

A reach is represented by a multi-record object that begins with a record containing only the keyword "REACH:" and ends with a record containing only the keyword "END:." At a minimum, a reach object must contain records setting values for a stream ID, a reach ID, a FROM point, and a TO point. A reach's FROM and TO point IDs must match IDs for endpoints listed before the reach object in the file. The reach object must also contain an array of locations defining the stream centerline. This array begins with a record containing only the keyword "CENTERLINE:" and ends when any keyword is encountered. A location element in the array contains the X, Y, and Z coordinates of a point on the stream centerline, and the point's river station. In HEC-RAS, elevation and stationing are optional in the stream network definition. If a location element includes a station value, it must occupy the fourth field in the element. If the elevation is not known, the word "null" must take its place.

Station values are assumed to be in miles for data sets in English units, and in kilometers for data sets in metric units. Stationing is used for indexing locations along reaches, and is not used to precisely locate objects in the model.

Records that may be included in a stream network section are listed in Table B.2:

Table B.2

Keyword	**Value Type**	**Value**
ENDPOINT:	location	coordinates and integer ID
REACH:	none	marks beginning of reach object
END:	none	marks end of reach object
The following records are required for a reach object.		

Keyword	Value Type	Value
STREAM ID:	string	identifies reach's membership in stream
REACH ID:	string	unique ID for reach within stream
FROM POINT:	string	integer reference to upstream endpoint
TO POINT:	string	integer reference to downstream endpoint
CENTERLINE:	location array	array elements contain coordinates and (optionally) floating point station value.

Cross Sections

The cross-sectional file section begins with a record containing the only the keyword "BEGIN CROSS-SECTIONS:" and ends with a record containing the only the keyword "END CROSS-SECTIONS:." A cross section is represented by multi-record object beginning with a record containing only the keyword "CROSS-SECTION:" and ending with a record containing only the keyword "END:."

A cross-sectional object must include records identifying the stream, reach, and station value of the cross-section, a 2D cut line, and a series of 3D locations on the cross section. Stationing is given in miles for data sets with plane units of feet and in kilometers for data sets with plane units of meters. A cut line is composed of the label "CUT LINE:" followed by an array of 2D locations. A cross-sectional polyline consists of the label "SURFACE LINE:" plus 3D coordinates written as comma-delimited X,Y, Z real-number triples, one triple to a line.

Records that may be included in the cross-section file section are listed in Table B.3:

Table B.3

Keyword	**Value Type**	**Value**
CROSS-SECTION:	none	marks beginning of cross-section object
END:	none	marks end of cross-section object
The following records are required for a cross-section object.		
STREAM ID:	string	identifiers for stream and reach where cross-section is located (must refer to existing streams and reaches in the model)
REACH ID:	string	
STATION:	floating point	relative position of cross-section on stream
CUT LINE:	location array	array elements contain 2D coordinates of cross sectione stike line
SURFACE LINE:	location array	array elements contain 3D coordinates of cross section points
The following records are optional for a cross-section object.		
BANK POSITIONS:	floating point (2 elements)	Fraction of length along cut line where main channel bank stations are located. (values 0.0 - 1.0)
REACH LENGTHS:	floating point (3 elements)	Distance along left overbank, center channel, and right overbank flow paths to next cross-section downstream (units are feet or meters).
NVALUES:	floating point (n paired elements)	Manning's n values expressed as fraction along cut line to start of n-value *(fraction, n-valu*e).
WATER ELEVATION:	floating point array	Water surface elevation values. Used for export of model results. Not read on import.

HEC-RAS Model Results Export File

HEC-RAS exports model results to a text file using the same format as the data import file. The contents of the files, however, are not identical. The stream network section is not required for data export, and the surface line may be omitted from the cross-section objects. An example HEC-RAS model export file is shown at the end of this discussion. Model results are reported with the following elements (Table B.4), which are not required (and are not read) in the import file**.**

Table B.4

Keyword	**Value Type**	**Value**
The following record is optional in the Header section of the export file.		
PROFILE NAMES:	string array	name(s) of water surface profiles reported in the file. This record is required if more than one profile is reported.
The following record is required for each cross-section object.		
WATER ELEVATIONS:	floating point array	Elevation of water surface at the cross-section. The array must contain one value for each profile.
The following records are optional for a cross-section object.		
PROFILE ID:	string	Water surface profile name. This must match a name in the Profile Names record in the header.
VELOCITIES:	floating point (pair)	Fraction along cut line and value of velocity (*fraction, value*). *Velocities record must follow Profile ID record.*
WATER SURFACE EXTENTS:	location array	A series of 2D locations marking the limits of a water surface.
The following records make up a section defining a bounding polygon of the water surface limits.		
BEGIN BOUNDARIES:	none	Marks start of boundaries file section.
END BOUNDARIES:	none	Marks end of boundaries file section.
PROFILE LIMITS:	none	Marks start of an object defining the limits of a single water surface profile.
PROFILE ID:	string	Name of profile. This must match a name in the Profile Names record in the header.
POLYGON	location array	A series of 2D locations marking the limits of a water surface. A single profile limit can be merged from multiple polygons.

1. HEC-RAS allows the user 16 character profile names.

However, **profile names can contain up to 9 characters for HEC-GeoRAS ArcView Extension Version 3.0 or 11 characters for HEC-GeoRAS for ArcInfo.** They must begin with a letter.

2. If no profile name is provided, only one water elevation will be written for each cross section.

Water Surface Bounding Polygon

In addition to a water surface elevation at each cross section (one for each profile), the HEC-RAS program sends a bounding polygon for each hydraulic reach in the model (the program outputs a new set of bounding polygons for each profile computed). The bounding polygon is used as an additional tool in assisting the GIS (or CADD) software to figure out the boundary of the water surface on top of the terrain.

In most cases, the bounding polygon will represent the outer limits of the cross section data, and the actual intersection of the water surface with the terrain will be inside of the polygon. In this case, the GIS software will use the water surface elevations at each cross section and create a surface that extends out to the edges of the bounding polygon. That surface is then intersected with the terrain data, and the actual water limits are found as the location where the water depth is zero.

However, is some cases, the bounding polygon may not represent the extents of the cross-section data. For example, if there are levees represented in the HEC-RAS model, which limit the flow of water, then the bounding polygon will only extend out to the levees at each cross section. By doing this, when the information is sent to the GIS, the bounding polygon will prevent the GIS system from allowing water to show up on both sides of the levees.

In addition to levees, the bounding polygon is also used at hydraulic structures such as bridges, culverts, weirs, and spillways. For example, if all of the flow is going under a bridge, the bounding polygon is brought into the edges of the bridge opening along the road embankment on the upstream side, and then back out to the extent of the cross-section data on the downstream side. By doing this, the GIS will be able to show the contraction and expansion of the flow through the hydrualic structures, even if the hydraulic structures are not geometricaly represented in the GIS.

Another application of the bounding polygon is in FEMA floodway studies. When a floodway study is done, the first profile represents the existing conditions of the flood plain. The second and subsequent profiles are run by encroaching on the floodplain until some target increase in water surface elevation is met. When the encroached profile is sent to the GIS, the bounding polygon is set to the limits of the encroachment for each cross section. This will allow the GIS to display the encroached water surface (floodway) over the terrain, even though the water surface does not intersect the ground.

Import/Export Guidelines

The following rules apply to channel and cross-sectionimport/export data.

Defining The Stream Network

1. The stream network is represented by a set of interconnected reaches. A stream is a set of one or more connected reaches that share a common stream ID.

2. A stream is composed of one or more reaches with the same stream ID, and each reach in a stream must have a unique reach ID. Every reach must be identified by a unique combination of stream and reach IDs.

3. Stream IDs and Reach IDs are alphanumeric strings up to 16 characters long. Reach endpoint IDs are integers.

4. Streams cannot contain parallel flow paths. (If three reaches connect at a node, only two can have the same

stream ID.) This prevents ambiguity in stationing along a stream.

5. A reach is represented by an ordered series of 3D coordinates, and identified by a stream ID, a reach ID, and IDs for its endpoints.

6. A reach endpoint is represented by its 3D coordinates and identified by an integer ID.

7. Reaches are not allowed to cross, but can be connected at their endpoints (junctions) to form a network.

8. The normal direction of flow on a reach is indicated by the order of its endpoints. One point marks the upstream or "from" end of the reach, the other marks the downstream or "to" end of the reach.

Defining Cross Sections

1. Each cross section is defined by a series of 3D coordinates, and identified by a stream name and reach name (which must refer to an existing stream and reach) and a station, indicating the distance from the cross-section to the downstream end of the stream.

2. Stationing is given in miles for projects using English units and in kilometers for projects using metric units.

3. A cross-section line can cross a reach line exactly once, and cannot cross another cross-section line.

Results of a water surface calculation are exported in a file that contains cross-section locations in plane (2D) coordinates, water-surface elevations for the cross-sections, and boundary polygons for the reaches.

The Following Rules Apply to Water-Surface Export Data

1. A cross-section is represented by a water surface elevation and a series of 2D coordinates on the cross-section cut line. The full width of the cross-section is included.

2. One bounding polygon is created for each reach in the stream network, and for each profile.

3. A reach's bounding polygon is made up of the most upstream cross-section on the reach, the endpoints of all cross-sections on the reach, and the most upstream cross-sections of reaches downstream of the reach.

4. For purposes of defining bounding polygons *only*, the endpoints of a cross-section are adjusted to the edge of the water surface at the cross-section if the cross-section is part of a floodway, a leveed section of the reach, or the water extent is controlled by a hydraulic structure. This allows calculated water surfaces that are higher than the land surface to be reported back to the CADD or GIS program.

Sample HEC-RAS Geometry Import File

```
BEGIN HEADER:

  DTM TYPE: TIN
  DTM: d:\georas\arcview\manual\wailupe\wai_tin
  STREAM LAYER: d:\georas\wailupe\stream3d.shp
  NUMBER OF REACHES: 3
  CROSS-SECTION LAYER: d:\georas\wailupe\xscutlines3d.shp
  NUMBER OF CROSS-SECTIONS: 40
  MAP PROJECTION: STATEPLANE
  PROJECTION ZONE: 5103
  DATUM: NAD27
  UNITS: ENGLISH

END HEADER:


BEGIN STREAM NETWORK:

  ENDPOINT: 582090.487, 49258.898, 218.609, 1
  ENDPOINT: 582331.707, 47063.536, 114.164, 2
  ENDPOINT: 583735.405, 47715.344, 278.222, 3
  ENDPOINT: 584138.295, 41249.225, 1.140, 4

  REACH:
    STREAM ID: Wailupe
    REACH ID: Upper
    FROM POINT: 1
    TO POINT: 2
    CENTERLINE:
      582090.487, 49258.898, 218.609, 8640.151
242 lines omitted
      582331.707, 47063.536, 114.164, 6402.057
  END:

  REACH:
    STREAM ID: Kului Gorge
    REACH ID: Tributary
    FROM POINT: 3
    TO POINT: 2
    CENTERLINE:
      583735.405, 47715.344, 278.222, 1813.116
214 lines omitted
      582331.707, 47063.536, 114.164, -0.000
  END:

  REACH:
    STREAM ID: Wailupe
    REACH ID: Lower
```

```
      FROM POINT: 2
      TO POINT: 4
      CENTERLINE:
        582331.707, 47063.536, 114.164, 6402.057
```
642 lines omitted
```
        584138.295, 41249.225, 1.140, 0.000
    END:

END STREAM NETWORK:

BEGIN CROSS-SECTIONS:

    CROSS-SECTION:
      STREAM ID: Wailupe
      REACH ID: Lower
      STATION: 220.827
      BANK POSITIONS: 0.503, 0.515
      REACH LENGTHS: 87.418, 220.827, 159.365
      NVALUES:
        0.00,0.150
        0.50,0.035
        0.53,0.150
      CUT LINE:
        586214.122, 42127.918
        581980.991, 40806.059
      SURFACE LINE:
        586214.122, 42127.918, 4.007
```
274 lines omitted
```
        581980.991, 40806.059, 6.390
    END:
```

21 Cross sections omitted

```
    CROSS-SECTION:
      STREAM ID: Wailupe
      REACH ID: Lower
      STATION: 6269.258
      BANK POSITIONS: 0.524, 0.569
      REACH LENGTHS: 170.100, 164.521, 158.965
      NVALUES:
        0.00,0.066
        0.19,0.150
        0.47,0.035
        0.56,0.150
        0.94,0.066
      CUT LINE:
        582723.174, 46846.449
        582426.438, 46878.916
        581953.514, 47082.992
      SURFACE LINE:
        582723.174, 46846.449, 161.917
```

```
     117 lines omitted
           581953.514, 47082.992, 165.010
       END:

       CROSS-SECTION:
         STREAM ID: Wailupe
         REACH ID: Upper
         STATION: 6822.378
         BANK POSITIONS: 0.492, 0.555
         REACH LENGTHS: 142.689, 139.905, 126.201
         NVALUES:
           0.00,0.066
           0.27,0.150
         CUT LINE:
           582774.257, 47502.740
           582593.433, 47493.464
           582343.062, 47465.635
           582083.418, 47502.740
         SURFACE LINE:
           582774.257, 47502.740, 170.548
     111 lines omitted
           582083.418, 47502.740, 164.059
       END:
```

5 Cross sections omitted

```
       CROSS-SECTION:
         STREAM ID: Wailupe
         REACH ID: Upper
         STATION: 8032.371
         BANK POSITIONS: 0.426, 0.477
         REACH LENGTHS: 206.927, 210.604, 211.292
         NVALUES:
           0.00,0.066
           0.15,0.150
           0.68,0.066
         CUT LINE:
           582496.067, 48736.476
           582190.057, 48657.628
           581893.321, 48625.161
         SURFACE LINE:
           582496.067, 48736.476, 241.056
     88 lines omitted
           581893.321, 48625.161, 231.414
       END:

       CROSS-SECTION:
         STREAM ID: Kului Gorge
         REACH ID: Tributary
         STATION: 1089.584
         BANK POSITIONS: 0.373, 0.579
```

```
      REACH LENGTHS: 263.179, 255.877, 223.864
      NVALUES:
        0.00,0.150
        0.48,0.055
        0.59,0.150
        0.70,0.066
      CUT LINE:
        583337.968, 47187.952
        583207.930, 47327.062
        583153.496, 47381.496
        583126.279, 47608.306
      SURFACE LINE:
        583337.968, 47187.952, 257.736
```
108 lines omitted
```
        583126.279, 47608.306, 326.921
    END:

    CROSS-SECTION:
      STREAM ID: Kului Gorge
      REACH ID: Tributary
      STATION: 833.707
      BANK POSITIONS: 0.375, 0.541
      REACH LENGTHS: 197.573, 189.074, 185.550
      NVALUES:
        0.00,0.066
        0.16,0.150
        0.44,0.055
        0.60,0.150
        0.95,0.066
      CUT LINE:
        583223.051, 46967.190
        583071.844, 47103.276
        583020.434, 47402.665
      SURFACE LINE:
        583223.051, 46967.190, 232.596
```
102 lines omitted
```
        583020.434, 47402.665, 286.581
    END:
```

4 Cross sections omitted

```
    CROSS-SECTION:
      STREAM ID: Kului Gorge
      REACH ID: Tributary
      STATION: 273.138
      BANK POSITIONS: 0.541, 0.655
      REACH LENGTHS: 139.815, 273.138, 79.293
      NVALUES:
        0.00,0.150
        0.37,0.055
        0.62,0.035
```

```
      0.64,0.150
    CUT LINE:
      582546.842, 47088.605
      582555.984, 47189.171
      582550.499, 47240.368
      582552.327, 47295.223
    SURFACE LINE:
      582546.842, 47088.605, 145.787
65 lines omitted
      582552.327, 47295.223, 144.778
  END:

END CROSS-SECTIONS:
```

Sample HEC-RAS Geographic Data Export File

```
BEGIN HEADER:
  UNITS: ENGLISH
  DTM TYPE: TIN
  DTM: d:\georas\arcview\manual\wailupe\wai_tin
  STREAM LAYER: d:\georas\wailupe\stream3d.shp
  CROSS-SECTION LAYER: d:\georas\wailupe\xscutlines3d.shp
  MAP PROJECTION: STATEPLANE
  PROJECTION ZONE: 5103
  DATUM: NAD27
  VERTICAL DATUM:
  NUMBER OF PROFILES:  3
  PROFILE NAMES:
    Big
    Bigger
    Biggest
  NUMBER OF REACHES:  3
  NUMBER OF CROSS-SECTIONS:  103
END HEADER:

BEGINSTREAMNETWORK:

ENDPOINT:582331.71,47063.54, , 1
ENDPOINT:582090.49,49258.90, , 2
ENDPOINT:584138.30,41249.23, , 3
ENDPOINT:583735.41,47715.34, , 4

REACH:
 STREAM ID: Wailupe
 REACH ID: Upper
 FROM POINT:  2
 TO POINT:  1
 CENTERLINE:
     582090.49,     49258.90, ,
 242 line omitted
     582331.71,     47063.54, ,
 END:

REACH:
 STREAM ID: Wailupe
 REACH ID: Lower
 FROM POINT:  1
 TO POINT:  3
 CENTERLINE:
     582331.71,     47063.54, ,
642 lines omitted
```

```
     584138.30,     41249.23, ,
 END:

REACH:
 STREAM ID: Kului Gorge
 REACH ID: Tributary
 FROM POINT:  4
 TO POINT:  1
 CENTERLINE:
     583735.41,     47715.34, ,
```
213 lines omitted
```
     582331.71,     47063.54, ,
 END:

ENDSTREAMNETWORK:

BEGIN CROSS-SECTIONS:

  CROSS-SECTION:
    STREAM ID:Wailupe
    REACH ID:Upper
    STATION:8032.371
    CUT LINE:
      582496.067 , 48736.476
      582190.057 , 48657.628
      581893.321 , 48625.161
    BANK POSITIONS:0.42600,0.47700
    WATER ELEVATION:199.3957,200.6774,203.5746
    WATER SURFACE EXTENTS:
      582242.56,   48671.16,   582212.81,   48663.49
      582246.10,   48672.07,   582209.73,   48662.70
      582262.79,   48676.37,   582197.27,   48659.49
    PROFILE ID:Big
        VELOCITIES:
          0.43251,   5.29
          0.44147,   11.31
          0.45140,   11.48
          0.46148,   10.50
          0.46968,   4.35
    PROFILE ID:Bigger
        VELOCITIES:
          0.42484,   1.25
          0.43231,   5.93
          0.44145,   12.24
          0.45141,   12.40
          0.46151,   11.44
          0.47008,   4.88
          0.47839,   1.21
    PROFILE ID:Biggest
```

```
            VELOCITIES:
              0.41496,   3.61
              0.43201,   6.82
              0.44142,   13.32
              0.45143,   13.44
              0.46155,   12.59
              0.47070,   6.09
              0.48537,   3.64
      END:
```

Many cross sections (and interpolated cross sections) omitted

```
      CROSS-SECTION:
        STREAM ID:Wailupe
        REACH ID:Upper
        STATION:6682.474
        CUT LINE:
          582641.922 , 47366.533
          582444.447 , 47335.449
          582336.567 , 47337.277
          582062.296 , 47381.161
        BANK POSITIONS:0.38000,0.47199
        WATER ELEVATION:133.7104,135.6018,139.3349
        WATER SURFACE EXTENTS:
          582417.69,   47335.90,   582377.28,   47336.59
          582419.39,   47335.87,   582375.14,   47336.62
          582437.89,   47335.56,   582370.92,   47336.69
        PROFILE ID:Big
            VELOCITIES:
              0.39480,   4.79
              0.40794,   10.33
              0.42583,   11.09
              0.44240,   7.20
              0.45444,   1.62
        PROFILE ID:Bigger
            VELOCITIES:
              0.39368,   4.71
              0.40788,   10.07
              0.42586,   10.67
              0.44287,   7.40
              0.45565,   2.49
        PROFILE ID:Biggest
            VELOCITIES:
              0.36681,   2.52
              0.39108,   5.05
              0.40781,   10.10
              0.42589,   10.52
              0.44336,   7.84
              0.45805,   3.38
```

```
END:

CROSS-SECTION:
  STREAM ID:Kului Gorge
  REACH ID:Tributary
  STATION:1089.584
  CUT LINE:
    583337.968 , 47187.952
    583207.93 , 47327.062
    583153.496 , 47381.496
    583126.279 , 47608.306
  BANK POSITIONS:0.37300,0.57900
  WATER ELEVATION:219.1924,220.2025,221.5454
  WATER SURFACE EXTENTS:
    583192.52,   47342.48,   583177.65,   47357.34
    583193.66,   47341.33,   583176.64,   47358.36
    583195.18,   47339.81,   583175.29,   47359.70
  PROFILE ID:Big
      VELOCITIES:
        0.44533,   10.34
        0.46033,   8.44
  PROFILE ID:Bigger
      VELOCITIES:
        0.44432,   11.33
        0.46129,   9.32
  PROFILE ID:Biggest
      VELOCITIES:
        0.44296,   12.44
        0.46257,   10.34
END:
```

Many cross sections (and interpolated cross sections) omitted

```
CROSS-SECTION:
  STREAM ID:Kului Gorge
  REACH ID:Tributary
  STATION:273.138
  CUT LINE:
    582546.842 , 47088.605
    582555.984 , 47189.171
    582550.499 , 47240.368
    582552.327 , 47295.223
  BANK POSITIONS:0.54099,0.65500
  WATER ELEVATION:135.2666,136.3284,137.8818
  WATER SURFACE EXTENTS:
    582554.32,   47204.74,   582552.81,   47218.77
    582554.37,   47204.24,   582552.76,   47219.30
    582554.45,   47203.51,   582552.67,   47220.11
  PROFILE ID:Big
```

```
          VELOCITIES:
            0.56337,   1.54
            0.57644,   10.95
            0.59787,   15.34
            0.61730,   13.10
      PROFILE ID:Bigger
          VELOCITIES:
            0.56256,   2.97
            0.57620,   12.59
            0.59789,   17.18
            0.61875,   14.67
            0.63251,   1.86
      PROFILE ID:Biggest
          VELOCITIES:
            0.56137,   4.30
            0.57597,   14.31
            0.59791,   19.12
            0.61927,   16.89
            0.63330,   5.09
    END:

    CROSS-SECTION:
      STREAM ID:Wailupe
      REACH ID:Lower
      STATION:6269.258
      CUT LINE:
        582723.174 , 46846.449
        582426.438 , 46878.916
        581953.514 , 47082.992
      BANK POSITIONS:0.52401,0.56900
      WATER ELEVATION:123.9078,125.2825,127.845
      WATER SURFACE EXTENTS:
        582309.53,   46929.36,   582276.02,   46943.82
        582309.55,   46929.35,   582275.92,   46943.87
        582326.40,   46922.09,   582195.49,   46978.57
      PROFILE ID:Big
          VELOCITIES:
            0.52365,   2.47
  4 lines omitted
            0.56408,   1.21
      PROFILE ID:Bigger
          VELOCITIES:
            0.52363,   2.70
  4 lines omitted
            0.56380,   1.27
      PROFILE ID:Biggest
          VELOCITIES:
            0.51786,   2.90
  6 lines omitted
```

```
          0.66018,   0.35
    END:
```

Many cross sections (and interpolated cross sections) omitted

```
    CROSS-SECTION:
      STREAM ID:Wailupe
      REACH ID:Lower
      STATION:220.827
      CUT LINE:
        586214.122 , 42127.918
        581980.991 , 40806.059
      BANK POSITIONS:0.50300,0.51500
      WATER ELEVATION:5.503006,5.881266,6.600093
      WATER SURFACE EXTENTS:
        586214.12,   42127.92,   583114.30,   41159.95
        586214.12,   42127.92,   583049.46,   41139.70
        586214.12,   42127.92,   581980.99,   40806.06
      PROFILE ID:Big
          VELOCITIES:
            0.00851,   0.55
  11 lines omitted
            0.71676,   0.18
      PROFILE ID:Bigger
          VELOCITIES:
            0.00855,   0.63
  11 lines omitted
            0.72186,   0.25
      PROFILE ID:Biggest
          VELOCITIES:
            0.01783,   0.55
  11 lines omitted
            0.99398,   0.11
    END:

  END CROSS-SECTIONS:

  BEGIN BOUNDS:

    PROFILE LIMITS:
      PROFILE ID:Big
      POLYGON:
        581893.32 , 48625.16
  43 lines omitted
        581908.77 , 48563.31
      POLYGON:
        583126.27 , 47608.3
  29 lines omitted
        583090.99 , 47539.75
```

```
      POLYGON:
        581953.51 , 47082.99
145 lines omitted
        581934.96 , 47008.78
    END:

    PROFILE LIMITS:
      PROFILE ID:Bigger
      581893.32 , 48625.16
43 lines omitted
        581908.77 , 48563.31
      POLYGON:
        583126.27 , 47608.3
29 lines omitted
        583090.99 , 47539.75
      POLYGON:
        581953.51 , 47082.99
145 lines omitted
        581934.96 , 47008.78
    END:

    PROFILE LIMITS:
      PROFILE ID:Biggest
      581893.32 , 48625.16
43 lines omitted
        581908.77 , 48563.31
      POLYGON:
        583126.27 , 47608.3
29 lines omitted
        583090.99 , 47539.75
      POLYGON:
        581953.51 , 47082.99
145 lines omitted
        581934.96 , 47008.78
    END:
END BOUNDS:
```