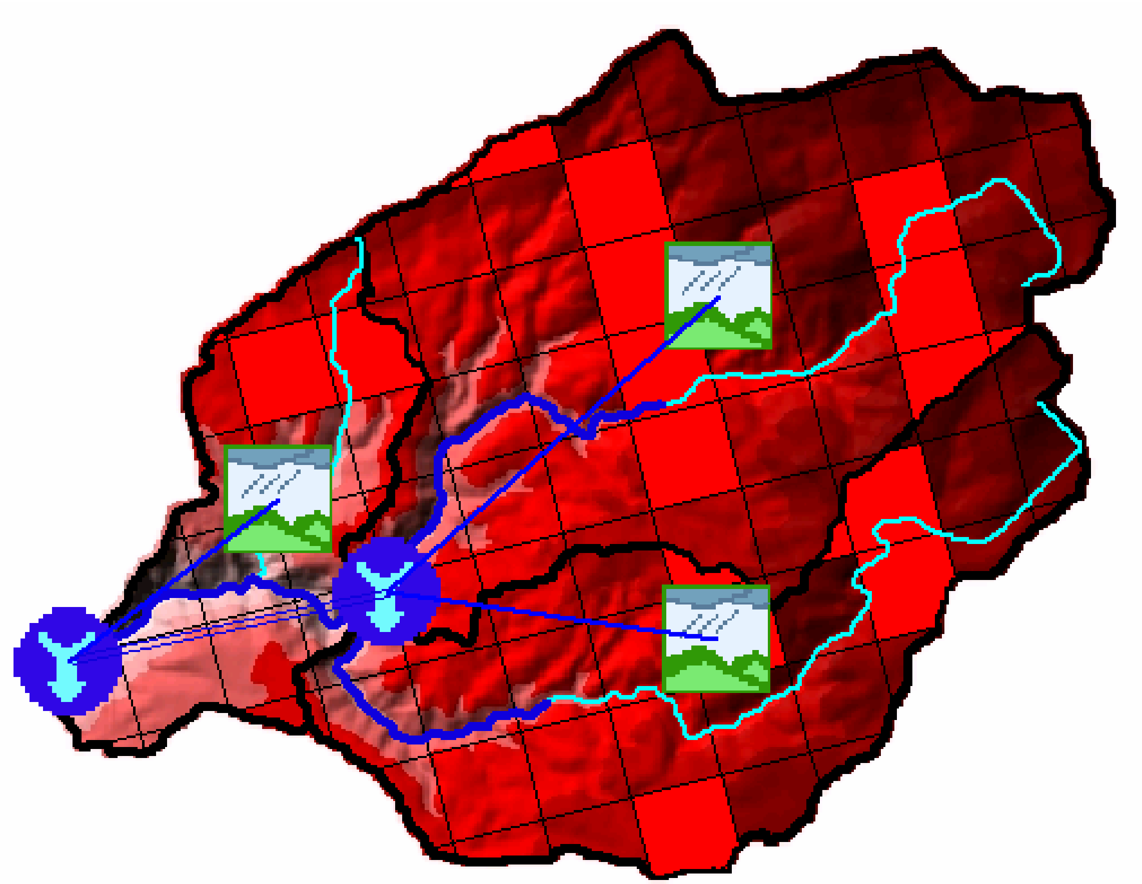
US Army Corps
of Engineers
Hydrologic Engineering Center

Geospatial Hydrologic Modeling Extension

HEC-GeoHMS



User's Manual

Version 1.1

December 2003

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609 Second Street

Davis, CA 95616

530.756.1104

530.756.8250 FAX

www.hec.usace.army.mil

Geospatial Hydrologic Modeling Extension HEC-GeoHMS, User's Manual

The above information and the full License Agreement are presented for acceptance when the software is first used. That information is also provided in Appendix I of this manual for reference.

TABLE OF CONTENTS

List of Figures

List of Tables

Foreword

The Hydrologic Engineering Center's (HEC) recent developments in Geographic Information System (GIS) tools for hydrologic and hydraulic modeling result from many years of interest in geospatial data usage. The earliest work was in the mid 1970's when HEC developed software based on the concepts developed in the Harvard University's School of Landscape Architecture, Honey Hill Project. That early work culminated with the development of the Spatial Analysis Methodology (HEC-SAM), which included a grid-cell data bank and analysis software for hydrologic and flood damage calculations. That early work had the same concepts as those of today, but the limitations in the computer hardware, GIS software, and data availability made widespread engineering applications difficult.

The current development builds on those early experiences and takes the technology to several practical engineering products including HEC-GeoHMS. HEC resurrected its earlier efforts by reviewing current GIS capabilities in association with Professor David Maidment from the University of Texas. HEC and Dr. Maidment formulated a watershed data structure that would link GIS and hydrologic models. From that time, the definition and content of the GIS and hydrologic data structures evolved into a hydrologic GIS preprocessor, PrePro. Taking advantage of the wealth of terrain and geographic data readily available over the Internet and from government agencies, PrePro delineates streams and watersheds and builds the hydrologic model structure for HEC-HMS. PrePro was the predecessor to HEC-GeoHMS.

The development of PrePro at the University of Texas was partially supported by HEC via the Corps' Civil Works R&D program. The effort also received substantial support from the Texas Department of Transportation as well as support from other national and international agencies. PrePro development at the Center for Research in Water Resources at the University of Texas has been directed by Dr. Francisco Olivera. GeoHMS has been developed by HEC and ESRI as a component of a Cooperative Research and Development Agreement between those two organizations. Dr. Maidment, Dr. Olivera, and others at the Center for Research in Water Resources have provided valuable assistance for the development of GeoHMS.

Other GIS products that have been released or are under development by HEC include HEC-GeoRAS, a GIS utility for use with the HEC-RAS river hydraulics program, and HEC-GeoFDA, a GIS utility for use with the HEC-FDA flood damage analysis package.

For several years, HEC has developed a number of GIS modules for specific tasks, such as processing terrain for drainage path, generating grid-based rainfall, etc. Those modules required users to be knowledgeable of UNIX, ArcInfo, hydrology, and a number of miscellaneous sub-programs. HEC-GeoHMS combines the functionality of those ArcInfo programs into a package that is easy to use with a specialized interface. With this ArcView capability and a graphical user interface, the user easily accesses customized menus, tools, and buttons instead of the command line interface in ArcInfo. With GeoHMS, users who are new to GIS have access to powerful GIS operations.

GeoHMS Version 1.0 was developed to use readily available digital geospatial information to construct hydrologic models more expediently than using manual methods. Also, development of basic watershed information will aid the user in estimating hydrologic parameters. After gaining adequate experience with using GIS-generated parameters, users can take steps to streamline the process of hydrologic parameter estimation.

The Wisconsin Department of Natural Resources (WDNR) and Environmental System Research Institute's, Inc. (ESRI) contributed greatly to the development of GeoHMS Version 1.1. WDNR's plans to develop completed HMS models with hydrologic parameters and topographic parameters for regional regression analysis provided GeoHMS Version 1.1 with a number of additional program procedures. As a result, GeoHMS Version 1.1 is more robust. Users can extract more watershed characteristics from DEM and GIS data for developing hydrologic parameters. Users can now work with digital elevation models (DEM) in a number of coordinate systems and projections. Users can recondition the DEM by imposing a known stream network onto the terrain grid. Where appropriate, GeoHMS 1.1 facilitates the analysis and computation of hydrologic parameters for the hydrologic basin model. GeoHMS 1.1 also expands its scope to develop the Hydrologic Modeling System (HEC-HMS) meteorologic model and control specifications.

GeoHMS Version 1.1 will be the terminal release of the software using ESRI's ArcView 3.x platform. The next version, 2.0, is currently being built on the ESRI's ArcGIS 8.x platform.

Acknowledgements

This HEC-GeoHMS software implementation of GIS technology for hydrologic engineering has benefited from many years of research and program development. From an institutional perspective, the University of Texas at Austin has contributed important research, development, and demonstration of concepts. Having that basis for the technology, HEC and ESRI contributed extensive software development and documentation through a Cooperative Research and Development Agreement (CRADA) to engineer technology into commercial software. The individuals involved are listed below.

From the Research Division of HEC, Mr. James H. Doan is a co-developer of HEC-GeoHMS and an author of this user's manual. Dr. Thomas Evans provided extensive input and guidance. A number of HEC staff helped in the testing and usage of the program. Mr. Arlen Feldman, Chief of Hydrology & Hydraulics Technology Division, contributed valuable management and review of the program and documentation.

From ESRI, Dr. Dean Djokic, Dr. Zichuan Ye, and Mr.Sreeresh Sreedhar contributed valuable software insight, development, and programming in conjunction with HEC.

From the University of Texas at Austin, Dr. David Maidment, Dr. Francisco Olivera, and several graduate students contributed valuable research effort, time, and expertise.

Mr. Darryl W. Davis, Director of HEC, and Mr. Jack Dangermond, President of ESRI, established the CRADA. Mr. Davis was the Director of HEC during the development of HEC-GeoHMS.

CHAPTER 1

Introduction

In recent years, advances in Geographic Information Systems (GIS) have opened many opportunities for enhancing hydrologic modeling of watershed systems. With an openness to share spatial information via the Internet from government agencies, commercial vendors, and private companies, coupled with powerful spatial algorithms, the integration of GIS with hydrologic modeling holds the promise of a cost-effective alternative for studying watersheds. The ability to perform spatial analysis for the development of lumped and distributed hydrologic parameters not only saves time and effort, but also improves accuracy over traditional methods. In addition, hydrologic modeling has evolved to consider radar rainfall and advanced techniques for modeling the watershed on a grid level. Rainfall and infiltration can be computed cell by cell providing greater detail than traditional lumped methods. These advanced modeling techniques have become feasible because the consuming data manipulations can now be generated efficiently with GIS spatial operations. For example, the ability to perform spatial overlays of information to compute lumped or grid-based parameters is crucial for computing basin parameters, especially grid-based parameters.

HEC-GeoHMS has been developed as a geospatial hydrology tool kit for engineers and hydrologists with limited GIS experience. The program allows users to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate subbasins and streams, construct inputs to hydrologic models, and assist with report preparation. Working with HEC-GeoHMS through its interfaces, menus, tools, buttons, and context-sensitive online help, in a windows environment, allows the user to expediently create hydrologic inputs that can be used directly with the Hydrologic Modeling System, HEC-HMS.

Chapter 1 discusses the intended use of HEC-GeoHMS and provides an overview of this manual. Below is an outline of Chapter 1.

Contents

- Technical Capabilities
- Program Features
- Intended Application of HEC-GeoHMS
- User's Manual Overview
- Documentation Conventions

Technical Capabilities

Hydrologic modeling has evolved to represent the subbasin in more detail than the traditional lumped approach where hydrologic parameters are averaged over the subbasin. With the availability of radar rainfall and spatial data, hydrologic modeling on a grid level has introduced a more detailed representation of the basin. This distributive modeling approach utilizes the ModClark (Peters and Easton, 1996; Kull and Feldman, 1998) hydrograph transformation method, which tracks infiltration and excess rainfall on a cell by cell basis. To meet the needs of both the traditional lumped and distributed basin approaches, HEC-GeoHMS can create HMS input files that are compatible with both approaches.

HEC-GeoHMS version 1.0 creates a background map file, lumped basin model, a grid-cell parameter file, and a distributed basin model, which can be used by HMS to develop a hydrologic model. The background map file contains the stream alignments and subbasins boundaries. The lumped basin model contains hydrologic elements and their connectivity to represent the movement of water through the drainage system. The lumped basin file includes watershed areas and reserves empty fields for hydrologic parameters. To assist with estimating hydrologic parameters, GeoHMS can generate tables containing physical characteristics of streams and watersheds. If the hydrologic model employs the distributive techniques for hydrograph transformation, i.e. ModClark, and grid-based precipitation, then a grid-cell parameter file and a distributed basin model can be generated.

HEC-GeoHMS version 1.1 allows the user to analyze DEM's in a number of coordinate systems and projections, including Albers-Equal Area, Universal Transverse Mercator (UTM), Tranverse Mercator, Lambert, and the State Plane Coordinate System. An added capability of version 1.1 allows users to use a more sophisticated "burning in" technique to impose the stream onto the terrain. This is accomplished as a gradual step-wise process to better reproduce stream networks and watershed boundaries. With regards to hydrologic parameters estimation, users are equipped with a process to estimate initial values of some hydrologic parameters. Users are able to compute lumped and gridded curve numbers using both State Soil Geographic Data Base (STATSGO) and Soil Survey Geographic Data Base (SSURGO) soil databases. Time of concentration and simple Muskingum-Cunge routing can also be estimated. Finally, users can generate the meteorologic model based on the user gage-weighting method and generate control specifications based on the user's input of a time window and computational time interval.

Program Features

HEC-GeoHMS is a public-domain extension to the ArcView GIS and Spatial Analyst extension. ArcView GIS and its Spatial Analyst extension are available from the Environmental Systems Research Institute, Inc., ESRI. HEC-GeoHMS runs on the Windows 95/98/NT/2000/XP platforms. The following program features illustrate GeoHMS's functionality and ease of use.

Data Management

GeoHMS performs a number of administrative tasks that help the user manage GIS data derived from the program. The data management feature tracks thematic GIS data layers and their names in a manner largely transparent to the user. Prior to performing a particular operation, the data manager will offer the appropriate thematic data inputs for operation, and prompt the user for confirmation. Other times, the data management feature manages the locations of various projects and also performs error checking and detection.

Terrain Preprocessing

GeoHMS allows users to perform terrain preprocessing in either a step-by-step fashion or batch mode. In the step-by-step process, the user often has the opportunity to examine the outputs and make corrections to the data set, as appropriate. However, if the user has performed the terrain preprocessing a number of times, then batch processing will allow terrain preprocessing to be performed unattended.

Basin Processing

The emphasis of the subbasin delineation, processing, and manipulation capability is on flexibility, ease of use, and user interactivity. As the user subdivides a basin or merges many smaller subbasins together, the results of the operation are displayed immediately for the user's confirmation. The ability to perform subbasin processing interactively is powerful, because the results are presented quickly for the user to make a modeling decision instead of having to reprocess the data. For example, the user can obtain a stream profile and look for significant grade breaks. If a subbasin subdivision at a grade break is desired, the user, using the delineation tool, just clicks on the stream profile at the grade break. Other tools allow the user to delineate subbasins in a batch mode by supplying a data set of point locations of desired outlets.

Hydrologic Parameter Estimation

Users can now compute the Curve Number loss rate parameter based on various soil and landuse databases. The curve number can represent a lumped value for a subbasin or an individual cell for a grid-based subbasin. In addition, watershed and channel characteristics together with a spreadsheet template are linked to GeoHMS to assist the users with estimation of initial values of time of concentration. Also, basin and channel characteristics can be used to calculate CN Lag and simple prismatic Muskingum-Cunge routing parameters.

HMS Model Support

GeoHMS produces a number of hydrologic inputs that are used directly in HMS. In addition, the program supports the estimation of hydrologic parameters by providing tables of physical characteristics of the streams and watersheds. While working with HEC-GeoHMS, the user can toggle HEC-GeoHMS on/off in order to bring in other ArcView extension programs to perform spatial operations and develop additional parameters for populating the hydrologic model.

Intended Application of HEC-GeoHMS

HEC-GeoHMS is intended to process watershed data after the initial compilation and preparation of terrain data is completed. The assembly of GIS data can be performed using standard GIS software packages that support ARC Grid format. Even though this user’s manual provides some guidance and discussions on the proper approach for assembling data, HEC-GeoHMS is not intended as a tool for data assembly. When assembling data, it is important to understand how to use GIS software to put data of different types and formats into a common coordinate system. A few examples of required data include digital elevation model, digital stream alignments, and stream gage locations. The most important data, and often the most difficult, is a “hydrologically corrected” digital elevation model, DEM.

When the data assembly is complete, HEC-GeoHMS processes the terrain and spatial information to generate a number of hydrologic inputs. It is intended that these hydrologic inputs provide the user with an initial HMS model. The user can estimate hydrologic parameters from stream and watershed characteristics, gaged precipitation, and streamflow data. In addition, the user has full control in HMS to modify the hydrologic elements and their connectivity to more accurately represent field conditions.

User's Manual Overview

This manual provides detailed instructions for using the HEC-GeoHMS ArcView extension to develop hydrologic inputs for HEC-HMS. The manual is organized as follows:

Chapter 1 - Introduction to HEC-GeoHMS

Chapter 2 - Instructions for installing HEC-GeoHMS and getting started

Chapter 3 - Overview of the major steps in using HEC-GeoHMS

Chapter 4 - Data collection

Chapter 5 - Issues related to data assembly, especially the terrain data

Chapter 6 - Terrain preprocessing

Chapter 7 - Basin processing

Chapter 8 - Physical characteristics extracted for streams and watersheds

Chapter 9 - Hydrologic parameter estimation

Chapter 10 - Input files for HMS

Chapter 11 - Example application of HEC-GeoHMS

Appendix A - References

Appendix B - HMS background map file format

Appendix C - Grid-cell parameter file format

Appendix D - Standard Hydrologic Grid (SHG) specifications

Appendix E - Curve number grid development

Appendix F - Example of SCS curve number computation process

Appendix G - Update procedure for new SSURGO data

Appendix H - Frequently asked questions and corrections

Appendix I - Program license agreement

Documentation Conventions

The following conventions are utilized throughout the manual to describe the windows and screens in the program interface. Window and screen titles are shown in ***bold and italics***. Menu names, menu items, and button names are shown in **bold**. Menus are separated from submenus with the right arrow ⇒. Data to be typed into an input field on a window or screen is shown in `the courier font` and within "double quotes". A column heading, tab name, field title, and name of tables, files, or themes are shown in "double quotes". Names of tables, files, or themes are not case sensitive, but certain letters are capitalized for readability.

CHAPTER 2

HEC-GeoHMS Installation

This chapter discusses the hardware and software requirements and installation procedures for HEC-GeoHMS. Prior to installing this software, ArcView GIS and the Spatial Analyst extension should be installed using their installation guides. The following installation procedures apply to computers running the Windows 95/98 and NT/2000/XP operating systems. After HEC-GeoHMS is installed, guidelines will be provided to load it within ArcView. Below is an outline of Chapter 2.

Contents

- Hardware and Software Requirements
- Installation of HEC-GeoHMS
- Loading HEC-GeoHMS

Hardware and Software Requirements

The minimum hardware and software requirement for using HEC-GeoHMS are similar to those of ArcView GIS. However, when working with GIS, it is important to take into account the size of the data sets as well as the complexity of the analysis when determining adequate computer resources. Even though the program will still work on a slower machine, the user will often experience long computing times. To assure that performance is not being compromised, the following hardware recommendations should be considered with the idea that more computer resources, in terms of central processing unit (CPU) speed, memory, and hard drive space, could improve program performance.

Recommended Hardware Specifications

The recommended hardware specifications are as follows:

CPU: Pentium III 500Mhz

Memory: 256 MB

Hard Drive Space: Hard drive space available should be at least 20 times the size of the terrain data. For example, if the terrain data takes up 50 MB, then the available hard drive space should be about 1 GB. In many cases, having ample hard drive space available will improve performance because the spatial operations often generate many temporary intermediate file and repeatedly perform files caching.

Required Software Specifications

The required hardware specifications are as follows:

Operating System: Windows 95/98/NT/2000/XP

Pre-installed software: ArcView GIS 3.2 or later

Spatial Analyst 1.1 extension or later

Installation of HEC-GeoHMS

The installation of HEC-GeoHMS will copy program files and sample data sets to the location of ArcView and Spatial Analyst. HEC-GeoHMS can be installed using the: Automatic or Manual Installation procedure.

Automatic Installation

- Place the CD in the CD-ROM drive
- If the setup program does not start, then select **Start ⇒Settings ⇒ Control Panel. Click the Add Hardware/Software** icon
- Follow the steps displayed in the message box to complete the installation.

Manual Installation

The manual installation of HEC-GeoHMS consists of copying GeoHMS files to where ArcView is installed. Typically, ArcView is installed in C:\esri\Av_gis30\Arcview\. For the purpose of this installation, the location of the ArcView files is referred to as $AVHOME. Copy the following files to the specified ArcView sub-directories. These files are saved under the **Manual Installation** directory on the CD-ROM.

Program Files	**Specified Locations**
GeoHMS_readme.txt	$AVHOME\bin32
HEC-GeoHMS.avx	$AVHOME\ext32
g2i.dll	$AVHOME\bin32
DirRemove.exe	$AVHOME\bin32
geohms11.hlp	$AVHOME\help
geohms11.GID	$AVHOME\help
geohms11.CNT	$AVHOME\help
hmspoint.avp	$AVHOME\symbols
hmsmarker.avl	$AVHOME\symbols
hmsline.avl	$AVHOME\symbols
fdr.avl	$AVHOME\symbols
hrap_alb.shp	$AVHOME\tools
hrap_alb.shx	$AVHOME\tools
hrap_alb.dbf	$AVHOME\tools
hrap_alb.sbx	$AVHOME\tools
hrap_alb.sbn	$AVHOME\tools
hmsdesign.control	$AVHOME\etc
hmsdesign.dss	$AVHOME\etc
hmsdesign.gage	$AVHOME\etc
HMSMetDesign.txt	$AVHOME\etc
Tc.xls	$AVHOME\etc
Tc.exe	$AVHOME\etc
StatePlaneLookup.txt	$AVHOME\etc

Loading HEC-GeoHMS

Once HEC-GeoHMS is installed, it can be loaded within ArcView. To do this, open ArcView. ArcView extensions are loaded through the **File** menu on the main ArcView window.

- Select the **File** ⇒ **Extensions**… menu item.
- In the ***Extensions*** dialog that appears, scroll down until **HEC-GeoHMS** is visible.

- Click on the name label **HEC-GeoHMS** to access the **About** information as shown in Figure 2–1.
- Check the box to turn it on.
- Press **OK** to close the dialog and watch the lower portion of the ArcView window for the installation notes.

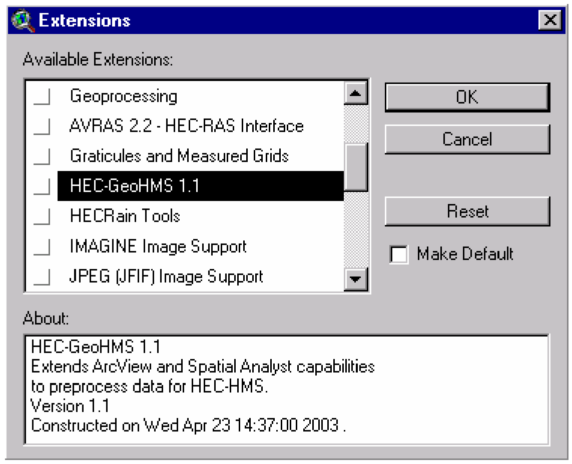


Figure 2–1. Extensions window with HEC-GeoHMS.

In is not necessary to load the Spatial Analyst extension because GeoHMS will automatically load it. When properly installed and loaded, HEC-GeoHMS will create two document types, ***MainView*** and ***ProjView***, as shown in Figure 2–2.

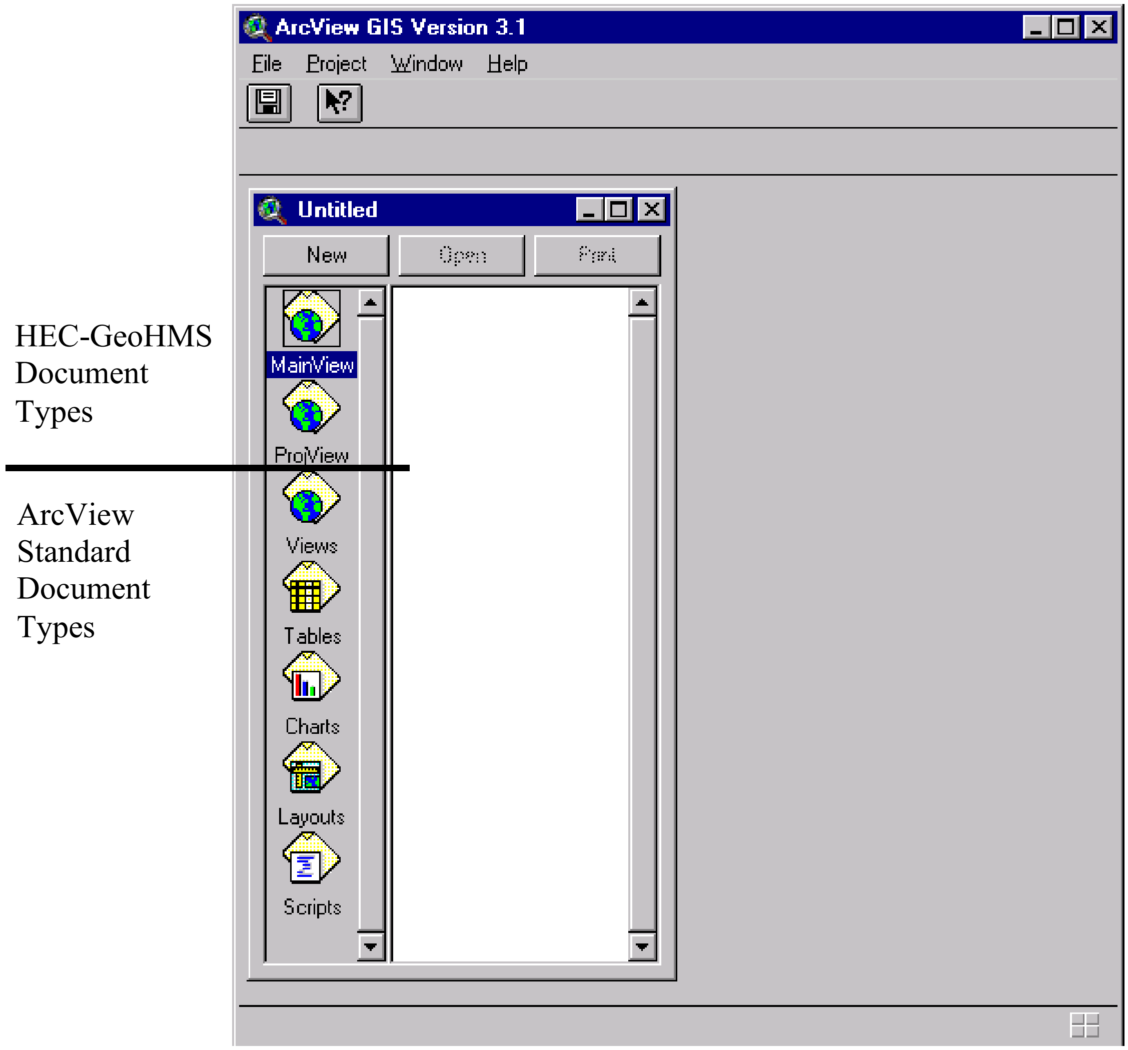


Figure 2–2. HEC-GeoHMS loaded within ArcView.

CHAPTER 3

Working with HEC-GeoHMS – An Overview

HEC-GeoHMS is a set of ArcView scripts developed using the Avenue programming language and Spatial Analyst. It includes integrated data management and a graphical user interface (GUI). Through the GUI, which consists of menus, tools, and buttons, the user can analyze the terrain information, delineate subbasins and streams, and prepare hydrologic inputs.

The relationship between GIS, HEC-GeoHMS, and HEC-HMS is illustrated in Figure 3–1. With the vertical dashed line separating the roles of the GIS and the watershed hydrology, HEC-GeoHMS provides the connection for translating GIS spatial information into hydrologic models. The GIS capability is used for heavy data formatting, processing, and coordinate transformation. The end result of the GIS processing is a spatial hydrology database that consists of the digital elevation model (DEM), soil types, land use information, rainfall, etc. Currently, HEC-GeoHMS operates on the DEM to derive subbasin delineation and to prepare a number of hydrologic inputs. HEC-HMS accepts these hydrologic inputs as a starting point for hydrologic modeling.

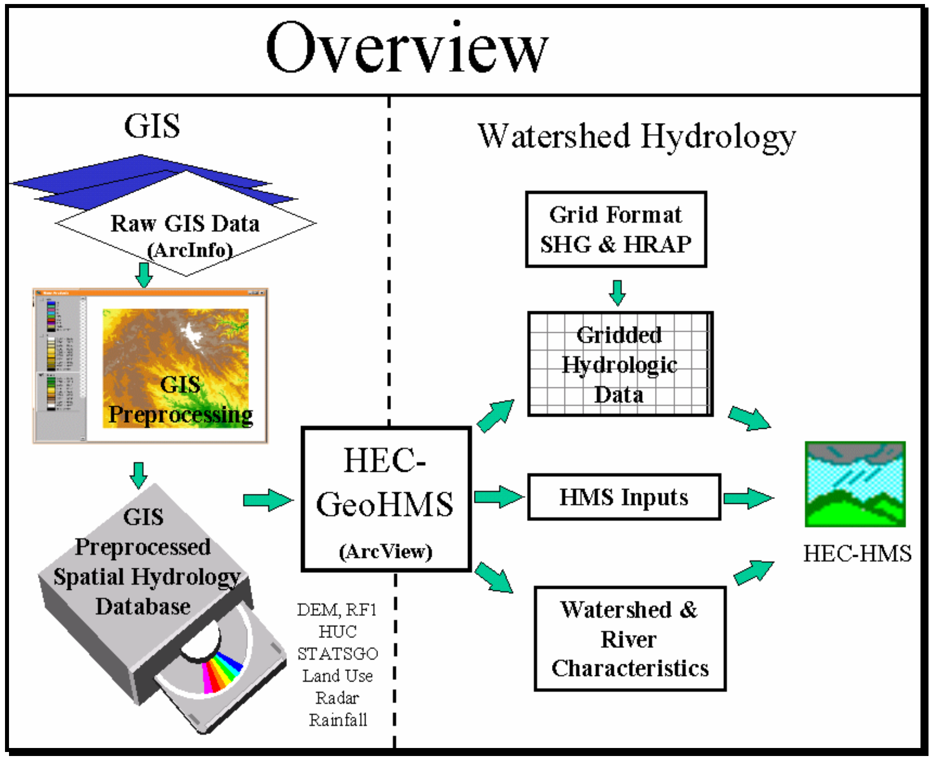


Figure 3–1. Overview of GIS and hydrology programs.

The following steps describe the major steps in starting a project and taking it through the GeoHMS process. Below is an outline of Chapter 3.

Contents

- Data Processing
    - Data Collection
    - Data Assembly
- Terrain Preprocessing
- Hydrologic Processing
    - Basin Processing
    - Stream and Watershed Characteristics
    - HMS Model Files
- Hydrologic Parameters and HEC-HMS

Data Processing

Data Collection

With the volume of spatial data available, it is important to identify the data that will meet project needs. Spatial data comes in many formats, resolutions, intended uses, quality, and prices. Prior to collecting data, the project specifications should be thoroughly reviewed for any recommendations. When a project does not specify a particular data set, review the project's goals and objectives to help define acceptable data in terms of data storage, resolution, and accuracy. In addition, economic factors should be considered to determine the cost effectiveness in collecting and assembling the data or purchasing the data from a vendor. Whether the data are collected or purchased, metadata must also be acquired to provide necessary documentation for the data. Data collection is discussed in greater detail in Chapter 4.

Data Assembly

Data assembly often requires efforts of an experienced GIS user. Because GIS data have many forms and formats, users often need to convert the data into a common format and then into a common coordinate system. For example, data describing the terrain should be in ESRI's ARC Grid format while vector data, such as stream alignments and streamflow gage locations, should be in the shapefile format. By having a common coordinate system, these data sets can be overlaid and spatial operations can be performed on them. Often times, data sets are provided in rectangular portions. When assembling data, especially terrain, special efforts are required to ensure that data are continuous along the edges. Terrain data assembly is discussed in Chapter 5.

Terrain Preprocessing

Using the terrain data as input, the terrain preprocessing is a series of steps to derive the drainage networks. The steps consist of computing the flow direction, flow accumulation, stream definition, watershed delineation, watershed polygon processing, stream processing, and watershed aggregation. These steps can be done step by step or in a batch manner. Once these data sets are developed, they are used in later steps for subbasin and stream delineation. It is important to recognize that the watershed and stream delineation developed in the terrain preprocessing steps is preliminary. In the next step - basin processing, the user has the capability to delineate and edit basins in accordance with project specifications. Terrain preprocessing is performed in the ***MainView*** document and is discussed in greater detail in Chapter 6.

The ***MainView*** document is generally responsible for terrain preprocessing and spatial database setup. Figure 3–2, Table 3-1, Table 3-2, and

Table 3-3 show the menus, buttons, and tools added by HEC-GeoHMS when the ***MainView*** document is active.

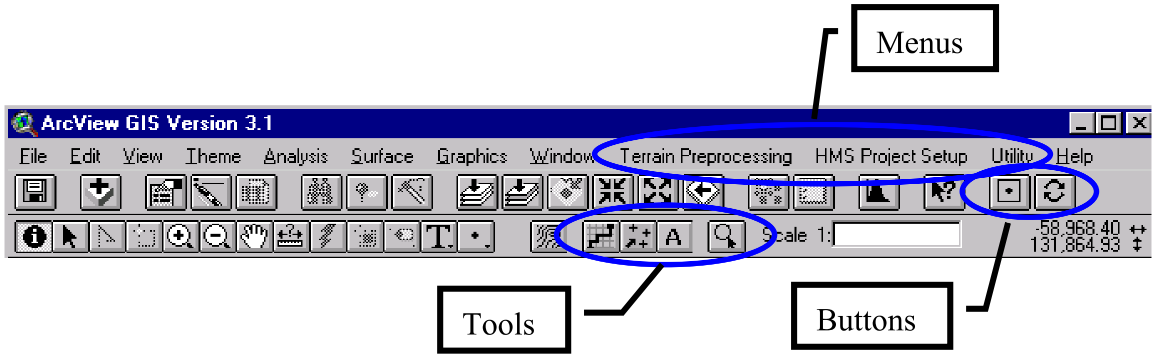


Figure 3–2. MainView GUI with GeoHMS extensions features.

Table 3-1. MainView Menus.

Menus	Descriptions
Terrain Preprocessing Data Management Terrain Reconditioning Fill Sinks Flow Direction Flow Accumulation Stream Definition Stream Segmentation Watershed Delineation Watershed Polygon Processing Stream Segment Processing Watershed Aggregation Full Preprocessing Setup	The **Terrain Preprocessing** menu is used to modify, process, and analyze the terrain. It has the capability of processing the terrain in two ways: step by step or batch processing. It also has a data management capability for tracking data sets as they are derived. (Chapter 6)
HMS Project Setup Start New Project Generate Project New Threshold for Selected Project Remove Selected Project	After the terrain has been processed, the **HMS Project Setup** menu is used to extract the processed terrain information from the ***MainView***. The extracted information will be placed in a separate view called the ***ProjView***. There are several options for extraction of terrain information. (Chapter 6)

	The **Utility** menu contains miscellaneous tools dealing with assigning roles for data sets and developing graphical output. Most users should not use this menu except for the graphic generation in the last two menu items.

Table 3-2. MainView Buttons.

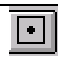
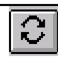
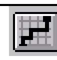
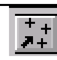
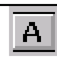
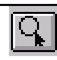
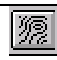
Buttons	Names	Descriptions
	Find Area	Find a number of locations that have the closest, but not exceeding, drainage area to the user-specified area. This tool provides many candidate points. In order to narrow the number of candidate points, the tool should be used when zoomed into the area of interest.
	Toggle GeoHMS	Toggle the HEC-GeoHMS tools ON/OFF. When it is in the ON position, HEC-GeoHMS tools are enabled. When it is in the OFF position, tools from other extensions are enabled.
	Help	Access context sensitive online help on any tools or menus. Select the tool and Press it on any tool for online help.

Table 3-3. MainView Tools.

Tools	Names	Descriptions
	Flow Trace	Trace the flow path downstream of a user-specified point (for visualization purposes).
	Point Delineate	Delineate the watershed contributing to a user-specified point.
	Identify Area	Identify contributing area in units as specified in the View's properties "distance unit" field.
	Specify Project Point	Specify the downstream outlet and/or upstream source point for extraction of terrain information.
	Contour	This is an ArcView tool that is useful in HEC-GeoHMS. This tool draws contours at the user-specified point.

Hydrologic Processing

Hydrologic processing is performed in the ***ProjView*** document, which is generally responsible for hydrologic model construction and setup. The menus, buttons, and tools available in the ***ProjView*** GUI are shown in Figure 3–3, Table 3-4, Table 3-5, and Table 3-6. Typically, the user proceeds from **Basin Processing** (Chapter 7) to **Basin Characteristics** (Chapter 8) to Hydrologic Parameters (Chapter 9) to **HMS** (Chapter 10) menus.

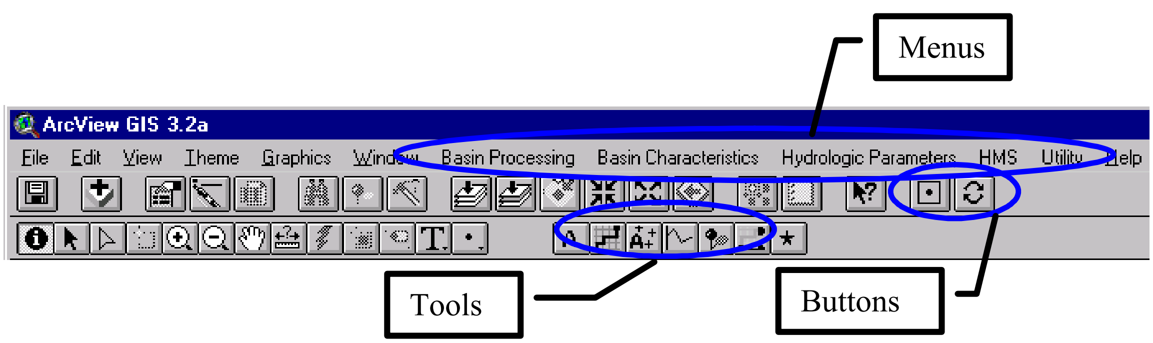


Figure 3–3. ProjView GUI with GeoHMS extensions features.

Table 3-4. ProjView Menus.

Menus	Descriptions
Basin Processing Basin Merge River Merge River Profile Split Basin at Confluences Import Batch Points Delineate at Batch Points	This menu provides the user with interactive and batch processing capabilities to modify existing subbasins and delineate new subbasins. There are also several tools available for subdividing basins and preparing batch points for delineation. (Chapter 7)
Basin Characteristics River Length River Slope Basin Centroid Centroid Elevation Update Longest Flow Path Centroidal Flow Path	After the user finalizes the basin delineation, this menu develops the physical characteristics for both the streams and subbasins based on the terrain model. The stream characteristics will be stored in the stream's attribute table. Similarly, the basin characteristics will be stored in the subbasin's attribute table. These two tables can be exported for external computations. (Chapter 8)
Hydrologic Parameters Subbasin Curve Number ModClark Processing ModClark Grid CN Muskingum-Cunge Parameters Rainfall 2 Year Design Rainfall TR55 Flow Path Segments TR55 Flow Segment Parameters TR55 Export Tt Parameters to Excel Basin Slope CN Lag Method	This menu facilitates a process for the user to estimate a number of hydrologic parameters, such as loss rate parameters and time of concentration. (Chapter 9)

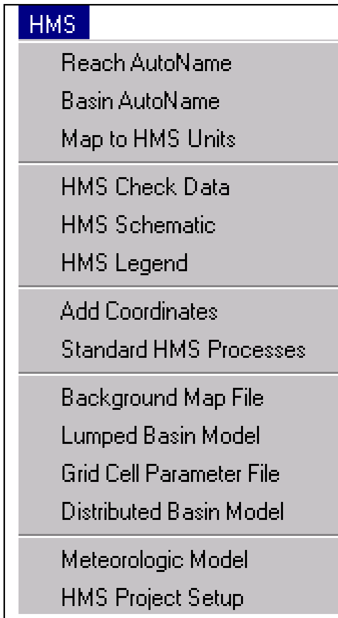
	This menu performs a number of tasks related to HMS. These tasks include assigning default names for the reaches and subbasins, unit conversion, checking and creation of the basin schematic, and HMS files generation. (Chapter 10)
	Similar to the menu in the MainView, this menu has a few new menu items that have been added to work soil and landuse databases. (Appendix E)

Table 3-5. ProjView Buttons.

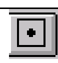
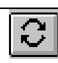
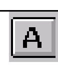
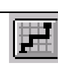
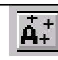
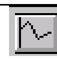
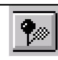
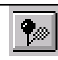
Buttons	Names	Descriptions
	Find Area	Same as those in the MainView
	Toggle GeoHMS	Same as those in the MainView

Table 3-6. ProjView Tools.

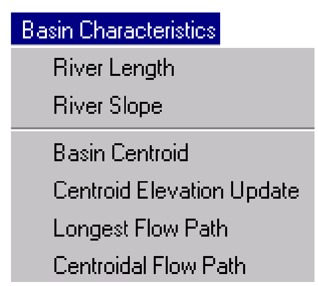
Tools	Names	Descriptions
	Identify Area	Same as those in the MainView
	Flow Trace	Same as those in the MainView

	Basin Subdivide	Subdivide existing basin or create new basin at user-specified point
	Profile	Extract the stream profile with elevation based on the terrain model
	Batch Point	Create a batch point shapefiles layer based on the user-specified point
	Profile Subdivide	While the stream profile chart is opened, this tool allows the user to subdivide existing basin at user-specified point along the stream profile.

Basin Processing

In this step, the user is provided with a variety of interactive and batch-mode tools to delineate subbasins. In the interactive mode, the tools allow the user to see the delineation results, assess outcomes, and accept or deny the resulting delineation. The interactive tools should work quickly. For example, the user sees the result of the merger of smaller basins or subdivision of a larger basin. When the user performs interactive basin processing, the program will prompt the user to confirm the results. A number of other interactive tools allow the user to delineate a basin from a stream profile, subdivide a basin at a stream confluence, and create a basin where a stream does not exist. In the batch mode, the user can supply the outlet locations and the program will delineate subbasins at those locations, but without interaction to view and revise.

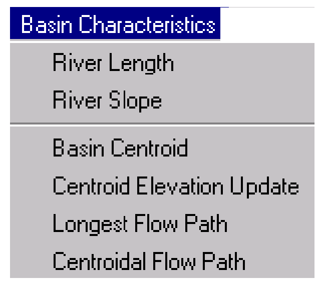
Basin processing is one of the responsibilities of the ***ProjView*** document and is discussed in greater detail in Chapter 7.



Stream and Watershed Characteristics

When the streams and subbasins delineation have been finalized, the user can extract their physical characteristics. The stream physical characteristics, such as length, upstream and downstream elevations, and slope, are extracted from the terrain data and stored as attributes in the stream table. Similarly, subbasin physical characteristics, such as longest flow lengths, centroidal flow lengths, and slopes, are extracted from terrain data and stored as attributes in the watershed table. The current version of the program focuses on the extraction of physical characteristics instead of hydrologic parameters. Physical characteristic tables can be exported and used externally to estimate hydrologic parameters. When more experience is gained with applying GIS generated parameters, it is anticipated that the program will suggest ranges for hydrologic parameters, as appropriate.

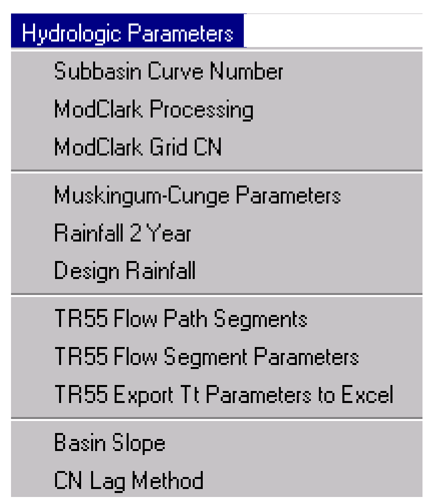
Computing stream and watershed physical characteristics under the **Basin Characteristics** menu is another responsibility of the ***ProjView*** document and is discussed in greater detail in Chapter 8.



Hydrologic Parameters

In addition to extracting stream and subbasin physical characteristics, the user has the option to estimate initial values of various hydrologic parameters. Hydrologic parameters, such as the curve number, can be extracted as lumped and grid-based quantities from the soil and landuse databases. Other hydrologic parameters, such as time of concentration, are computed from various data sets including terrain and precipitation data.

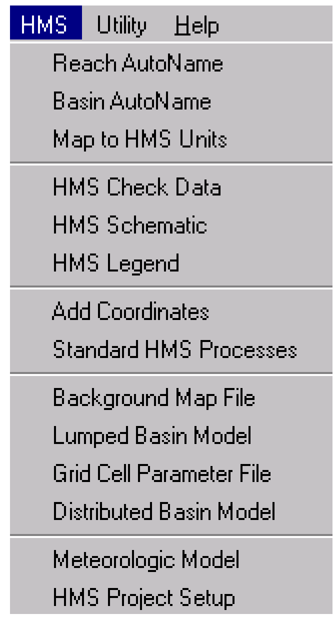
Estimating hydrologic parameters under the **Hydrologic Parameters** menu is another responsibility of the ***ProjView*** document and will be discussed in greater detail in Chapter 9.



HEC-HMS Model Files

GeoHMS produces four files that can be used directly with HMS. If the lumped modeling approach is used, then the user can generate the background-map file and the lumped-basin file. If the distributed modeling approach is used, then the user can generate the background-map file, the grid-cell parameter file, and the distributed basin file.

Generating HEC-HMS model files under the **HMS** menu is another responsibility of the ***ProjView*** document and is discussed in greater detail in Chapter 10.



Hydrologic Parameters and HEC-HMS

When the GeoHMS-generated files are brought into HMS, the user has a partially completed HMS model. To complete the HMS basin model, hydrologic parameters need to be estimated and entered using editors provided in HMS. In addition, the user can add or remove hydrologic elements and their connectivity to reflect difficult modeling areas. Finally, the user needs to develop a Meteorologic Component to represent the precipitation and a Control Specifications Component to define the time window and other time-related specifications. With these three model components completed, the user can refer to the HMS manual to make a simulation run and calibrate the hydrologic model.

CHAPTER 4

Data Collection

The purpose of this chapter is to illustrate some of the ways spatial data are used in hydrology. By understanding how the data sets are utilized, the user can focus adequate time, effort, and attention on the appropriate data set. When collecting data, the user can assess the quality of the data and its metadata and insure that they meet project specifications. This chapter also provides a list of data types, descriptions, and possible sources as a starting point for collecting data. Below is an outline of Chapter 4.

Contents

Data Usage

Spatial data are collected and used in a variety of ways. Understanding how data are used provides many important guidelines in data collection. When the data are intended as input in the program, they should be collected with attention given to accuracy, resolution, validity of data source, and quality of documentation. Oftentimes when the best available data are not adequate, the appropriate course of action will be to develop data that meets project specifications instead of putting efforts in collecting "bad" data. Terrain data is critical because GeoHMS uses it to determine drainage paths and physical characteristics. Other data often serve many useful roles, such as reference information, documentation, and visualization.

Reference Information for Results Validation

Reference data depicting known stream alignments, stream flow gage locations, and drainage boundaries are very helpful for comparing and validating the GIS delineated streams and subbasins.

Documentation of Field Conditions

GIS data can be collected and used with existing spatial data to document field conditions. For example, photographs of drainage structures as shown in Figure 4–1, and other field conditions can be photographed and geographically located with the street data to more effectively document these facilities and show their spatial relationships.

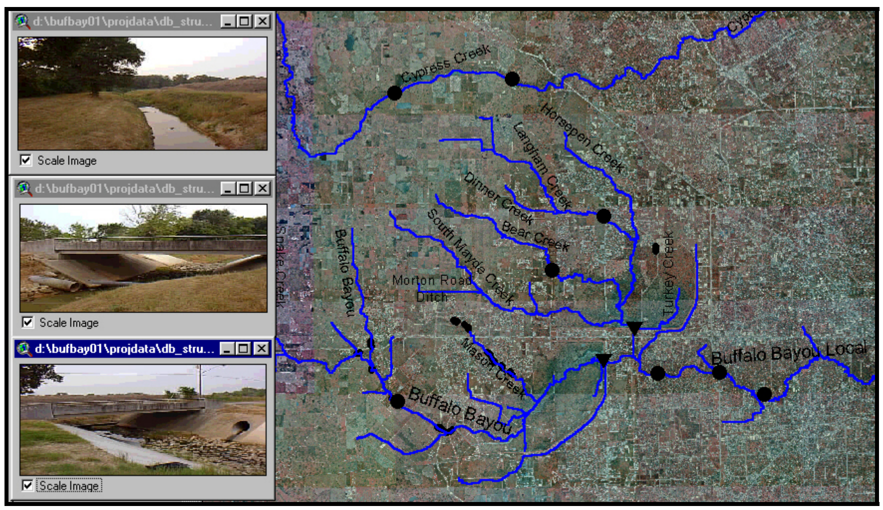


Figure 4–1. Field documentation with photographs.

Data Visualization

GIS data can be used to visualize multiple data sets. For example, aerial images can be overlaid with subbasin boundaries to see land use patterns and variability.

Data Types, Descriptions, and Sources

The amount of GIS data available through government institutions and data vendors has grown greatly over the years. Some of these data are available for free while others are provided for a fee. Table 4-1 provides a starting point for collecting and searching for GIS data. The list provides brief descriptions of the data used in hydrology and their sources. Additional information on the data sets can generally be found at the respective institution's web site. Although terrain data is the minimum data requirement to run HEC-GeoHMS, the other data sets are important information for constructing the hydrologic model. It is important to collect data for an area larger than your actual project region. Finally, metadata must also be collected for documentation.

Table 4-1. Data Types, Descriptions, and Sources.

Digital Elevation Model (DEM) DEMs are originally generated from USGS maps and are available for resolutions ranging from meters to kilometer cell size. The availability of the finer DEM data may be scarce at this time. The DEM at 30-by-30-meter resolution is generally used for modeling terrain because of their widespread availability. The most convenient source of seemless DEM data is the USGS's National Elevation Dataset (NED). Source http://gisdata.usgs.net/ned/default.asp www.usgs.gov www.water.usgs.gov
Hydrologic Unit Code (HUC) The HUC contains the major watershed boundaries as published by the USGS. The HUC shows watershed boundaries at 4 levels of detail ranging from local to regional drainage area. Source www.usgs.gov
Digital Line Graph (DLG) In addition to line representation of transportation data, such as streets and railroads, DLGs include water features, such as stream networks and irrigation ditches. DLGs are maintained by the United States Geological Survey (USGS). Source www.usgs.gov

Stream Networks

Stream networks are maintained by the Environmental Protection Agency (EPA). Many versions of stream networks are available as the River Reach File (RF1), the River Reach File (RF3), and the National Hydrography Data set (NHD).

Source

www.epa.com

http://nhd.usgs.gov

Streamflow Gage Data

Although streamflow gage data are natively non-spatial, the latitude and longitude coordinates of the gage are provided most of time. The streamflow gage locations can be converted into a GIS data set by using the coordinate information. The majority of streamflow gages are maintained by the USGS, state governments, and flood control districts.

The stream gages maintained by the USGS are organized by major basin names and the Hydrologic Unit Code. These gages often provide the historical daily peak flow values and/or annual peak flow values.

Source

www.usgs.gov

Digital Orthophoto Quarter Quads (DOQQ)

Digital aerial photos with colors are available at various resolutions can be used as a background base map.

Source

Various governmental authorities and commercial vendors

Drainage Facilities Photographs Photographs can be taken of key drainage structures. The photographs often include the areas looking upstream and downstream of the structures as well as the faces of the structures. Source Field observations conducted by the engineers.
Street Data Street level data that is provided by the US Census Bureau often needs format conversion before it can be accessed though GIS software. A number of data vendors have performed the format conversion as well as other value-added improvements. Source United States Census Bureau and commercial vendors
Soil Types Data The Soil Surveys Geographic Data Base (SSURGO) data contains good detail, but is limited in coverage. The State Soil Geographic Data Base (STATSGO) covers the entire USA, but in less detail. Source United States Department of Agriculture STATSGO and SSURGO CD- ROM http://www.ftw.nrcs.usda.gov/stat_data.html http://www.ftw.nrcs.usda.gov/ssur_data.html
Land Use/Land Cover The USGS Land Use Land Cover (LULC) provides good coverage but may be dated. Source http://mapping.usgs.gov http://edc.usgs.gov

CHAPTER 5

Data Assembly

The assembly of GIS data sets often requires conversion of file formats and coordinate systems, as well as geographical referencing of non-spatial data sets. For vector data, the industry-standard shapefile format is preferred when working with ArcView. Examples of vector data that require conversions are Digital Line Graphs for stream alignments and State Soil Geographic Data Base (STATSGO) data for the hydrologic soil types. For raster data, ESRI's ARC Grid format should be used. Examples of raster data that require conversions are the terrain and radar rainfall data. In addition to file formatting, data assembly often requires a number of map related transformations to ensure that vector and raster data are in proper alignment and map distortions are minimized. That is, they have the same datum, projection, and common coordinate system. These data sets can be overlaid for spatial analysis. In essence, a spot on the various data sets refers to the same point on the ground in all data sets. Some common map-related transformations are as follows.

- Projection
- Coordinate System
- Vertical and Horizontal Datum
- Units
- Resolution
- Accuracy
- Scales

When data are assembled with GIS software, the user should be aware of the distinctions between various spatial operations. For example, when the user joins various sized terrain tiles into a continuous terrain model, the ArcInfo grid "merge" and/or "mosaic" commands produce different results. The "merge" command will overwrite overlapping areas along the edges with the data that is merged last. However, the "mosaic" command will perform smoothing of data values along the overlapping areas. Recognizing the different approaches for combining terrain is crucial to prevent abrupt artificial changes in elevation along the edges of tiles that will affect drainage path determination. Other data assembly issues include combining various data sets of different resolution, filling data gaps as shown in Figure 5–1, and data re-sampling techniques.   Below is an outline of Chapter 5.

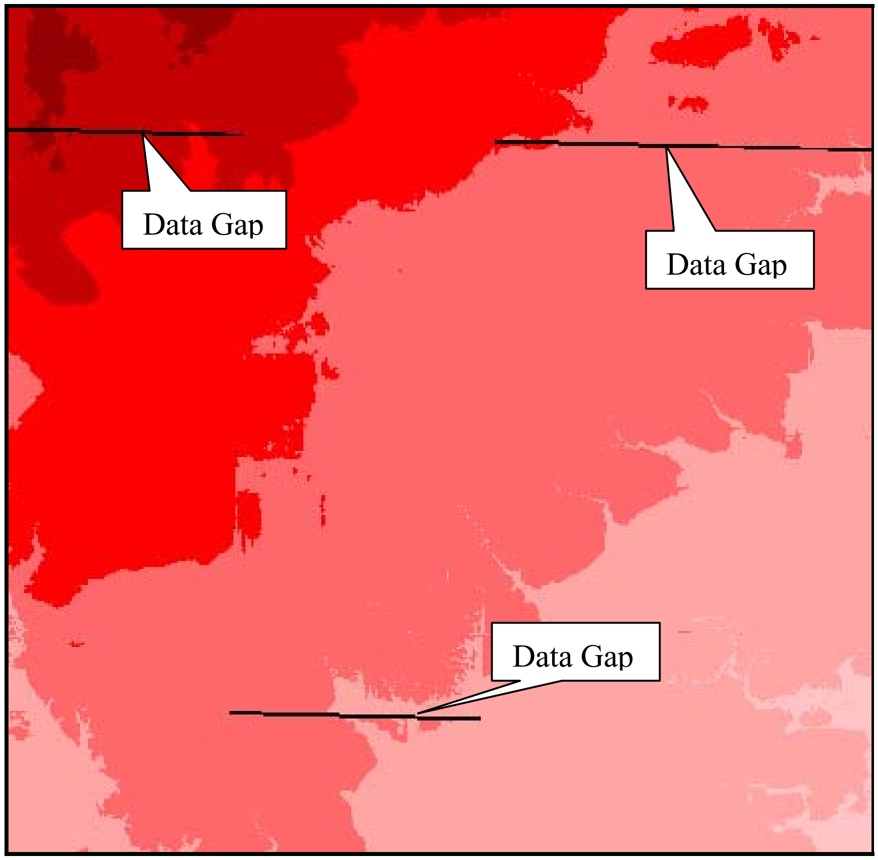


Figure 5–1. DEM model with data gaps.

Contents

- Terrain Data Assembly
- "Hydrologically Corrected" and "Depressionless" Terrain Model
- Data Issues
- Hydrologic Coordinate System Specifications

Terrain Data Assembly

The growth and availability in seemless terrain data in recent years has provided users with better quality data and minimized the need to manually assemble terrain data from small tiles of data. The seemless terrain data are available in larger potions than the tile data. Also, the seemless data has been edge-matched and contain the same coordinate system, datum, and units. However, in some cases where manual assembly of terrain data is required, the user should be aware of many important issues related to the data age, units, coordinate system, datum, etc. Ultimately, the quality of the results depends heavily on the terrain data. Traditionally, continuous terrain data was assembled manually from joining tiles of terrain information as shown in Figure 5–2. Then, data gaps were filled in with interpolated elevation values from neighboring elevation values to make a continuous DEM model as shown in Figure 5–3. However, when terrain data were assembled in this manner, they often contained errors and areas that were problematic for computing drainage patterns from a hydrologic standpoint. Often, terrain data undergoes extensive editing to correct problematic areas. Automated routines are available to fill depressions in the DEM. The “depressionless” DEM may still not have streams located properly when compared to other map and photo resources. Extensive editing is usually required to create a “hydrologically corrected or conditioned” DEM. There are many issues surrounding terrain data assembly as discussed below.

Waller NW	Magnolia West	Magnolia East	Oklahoma	Tamina	Outlaw Pond	Splendora	Plum Grove
Waller	Hockley	Rose Hill	Tomball	Spring	Maedan	Moonshine Hill	Huffman
Hockley Mound	Warren Lake	Cypress	Satsuma	Aldine	Humble	Harmaston	Crosby
Brookshire	Katy	Addicks	Hedwig Village	Houston Heights	Settegast	Jacinto City	Highlands
Fulshear	Richmond Northeast	Clodine	Alief	Bellaire	Park Place	Pasadena	La Porte
Orchard	Richmond	Sugar Land	Missouri City	Almeda	Pearland	Friends-wood	League City

Figure 5–2. DEM tile quad names.

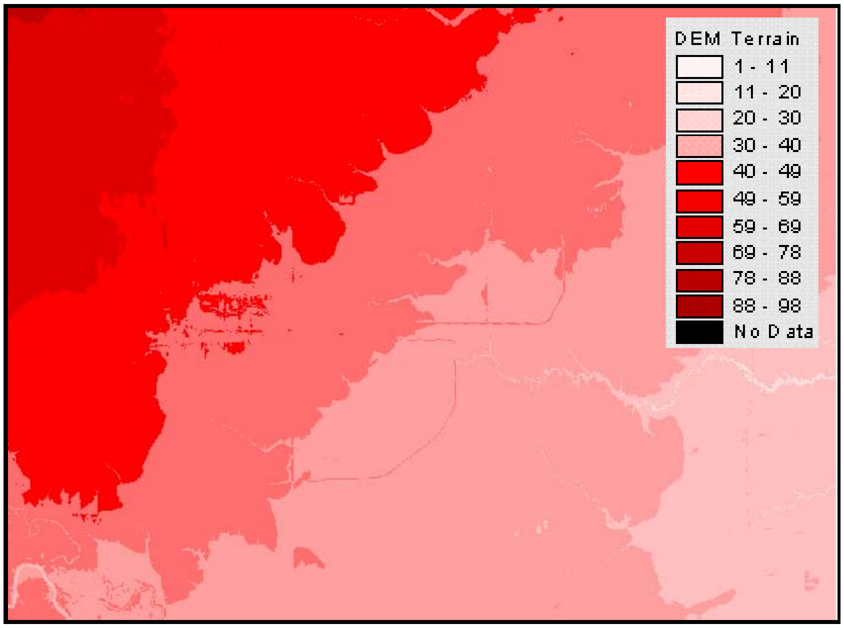


Figure 5–3. Continuous DEM.

"Hydrologically Corrected" and "Depressionless" Terrain Model

The preparation of "hydrologically corrected" terrain data often requires much iteration through drainage path computations. To represent the movement of water through the watershed, the "hydrologically corrected" DEM must have the proper accuracy and resolution to capture details of the stream alignments and watershed divides. The problems often arise when the watershed has low relief and the resolution is not fine enough to delineate the needed details.

Construction of a "hydrologically corrected" terrain model involves more complexity than combining tiled USGS's DEMs into a unified DEM grid. The DEM assembled from the USGS represented by elevation averages at regular intervals may not accurately represent stream locations and watershed boundaries. For example, stream and watershed delineation sometimes does not coincide with published data sources like the EPA's RF1 and the USGS's watershed in the Hydrologic Unit Code (HUC). A "hydrologically corrected" terrain model must represent accurate stream patterns across the landscape, stream alignments, topographic ridges, stream confluences, internal drainage areas, and drainage facilities. Many factors, such as cell resolution, accuracy, topographic relief, and drainage facilities deserve careful consideration because they often affect the quality of the terrain model. In theory, combining GIS data sets of different resolutions is generally not recommended because of the difficulty in assessing the accuracy and the precision of the resulting data set. In practice, however, combining data sets of various resolutions is necessary due to lack of uniform data and data coverage.

In contrast to the effort required for the "hydrologically corrected" DEM, the "depressionless" DEM is simply constructed using automated algorithms to fill in the sinks or depressions in the assembled DEM. In a "depressionless" DEM, all area is contributing to the most downstream outlet and therefore does not address closed basins or substantial non-contributing areas. Because of the complexity and effort required for constructing a "hydrologically corrected" terrain model, a "depressionless" terrain model often serves as a simpler substitute in the analysis. For study regions with moderate to high topographic relief, the "depressionless" terrain model may be adequate for the analysis. For low-relief regions, however, the "depressionless" terrain model often needs additional work to adequately represent the terrain. For example, a watershed with flat terrain often requires editing to force proper drainage location.

Until better data quality and editing techniques are available, users may struggle with terrain data assembly. It is important to identify the issues with the data so that the user can understand and fixes the problems. As an encouraging note, many governmental institutions, including the USGS and the EPA, are working to develop seamless terrain information and streams and watersheds information, which will ease the data assembly efforts.

Data Issues

A number of issues have been identified to increase awareness as a first step in formulating a solution. When assembling terrain data, the user should address the considerations shown in Table 5-1.

Table 5-1. Data Issues

Data Issues	Descriptions and Potential Solutions
1. Low-relief terrain	With low-relief terrain, it is often difficult to delineate reliable drainage paths from relative average elevations. Finer resolution terrain data should be considered for the flat region if it is available. However, finer resolution data has its tradeoffs with increased storage and longer computation times. Other possible approaches include imposing the

	published stream alignment onto the terrain.
2. Man-made structures	Man-made structures like dams often alter the flow direction because the water surface prevents the mapping of the reservoir bottom. In addition, when the terrain data get filled, the terrain is represented as a flat surface behind the dam. A potential way to deal with this situation would be to put an artificial notch at the dam and carve a stream on to the terrain.
3. Missing elevation data	Missing elevation data often exist along the edges and can be filled with interpolated values from neighboring elevations. Bad elevation data due to re-sampling effects and other causes can be fixed with spot elevation editing on a cell by cell basis or by region.
4. Subsidence and other Environmental Impacts	The ground surface may subside due to overdraft of groundwater. Recognizing when the terrain data were developed, the terrain data should be checked for subsidence.
5. Subsurface Flow	Volcanic soils, limestone formations, and canals/tunnels lead to drainage patterns that the terrain cannot reproduce. These difficult features must be handled in GeoHMS by delineating the subbasin downstream of the feature to avoid the problem areas or modifying the terrain to impose the correct drainage patterns.

Hydrologic Coordinate System Specifications

Transforming spatial data into a common coordinate system ensures proper alignment of various data sets for spatial analysis. Coordinate system transformation often leads to map distortions of direction, distance, shape, and area. From a hydrologic perspective where the terrain and precipitation are important, a suitable coordinate system should preserve area. The two possible coordinate systems are the Standard Hydrologic Grid (SHG) and the Hydrologic Rainfall Analysis Project (HRAP). The SHG is based on the Albers Equal Area projection, which preserves area. The SHG coordinate system is defined in Table 5-2. More information on both coordinate systems is in Appendix D.

Table 5-2. Standard Hydrologic Grid Definition

Projection:	Albers Equal-Area
Spheroid:	GRS1980
Datum:	North American Datum, 1983 (NAD83)
Central Meridian:	96 degrees 0 minutes 0 seconds West
Latitude of Origin:	23 degrees 0 minutes 0 seconds North
1st Standard Parallel:	29 degrees 30 minutes 0 seconds North
2nd Standard Parallel:	45 degrees 30 minutes 0 seconds North
False Easting:	0.0
False Northing:	0.0
Units:	Meters

Terrain Data Coordinate System and Projection Support

In HEC-GeoHMS version 1.1, users are allowed to analyze terrain data in a number of coordinate systems and projections, including Albers-Equal Area, Universal Transverse Mercator (UTM), Tranverse Mercator, Lambert, and the State Plane Coordinate System. The user should always verify that the projection file (prj.adf) exists and is saved as part of the terrain grid data. When the user wants to create a ModClark grid cell parameter file, the program will need this projection file.

The Earth is represented as a spheroid. For spheroid definition in the projection file, the units are assumed to be in meters. If the units are not meters, then FEET are the only other valid option and should be specified in the projection file with an explicit UNITS = FEET entry. The following spheroids are supported:

GRS1980

WGS84

WGS72

SPHERE

CLARKE1880

CLARKE1866

KRASOVSKY

INT1909

EVEREST

BESSEL

AUSTRALIAN

AIRY

CHAPTER 6

Terrain Preprocessing

Refering to the overview in Chapter 3, terrain preprocessing marks the first step to using HEC-GeoHMS. In this step, a terrain model is used as an input to derive eight additional data sets that collectively describe the drainage patterns of the watershed and allows for stream and subbasin delineation. The first five data sets in grid representation are the flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. The next two data sets are the vectorized representation of the watersheds and streams, and they are the watershed polygons and the stream segments. The last data set, the aggregated watersheds, is used primarily to improve the performance in watershed delineation. Terrain preprocessing is performed in the ***MainView***.

The objectives of terrain preprocessing ar:

- Terrain is processed and analyzed using the 8-pour point approach to determine flow paths. Terrain analysis is computer intensive and some steps may require several hours, depending on the amount of data and computer resources.
- After terrain preprocessing is completed, the resulting data sets serve as a spatial database for the study. With the information centralized in the spatial database, pertinent data sets can be extracted for subsequent work on building the hydrologic models.
- Preliminary watershed and stream delineation provides results that can be verified with published information to detect possible errors in the terrain model. If errors are detected in the terrain model, the DEM should be edited outside of GeoHMS. When the DEM has been revised to better represent field conditions, it should be processed again to update the spatial database.

This chapter will discuss terrain preprocessing features and functionality, HMS model setup, and related utilities. Below is an outline of Chapter 6.

<u>Contents</u>

Features and Functionality

The HEC-GeoHMS extension adds features and functionality to the standard ArcView program (**Terrain Preprocessing**, **HMS Project Setup**, and **Utility**), buttons, and tools are added to the standard ArcView GUI as shown in Figure 6–1. A number of capabilities related to terrain processing are under the **Terrain Preprocessing** menu. Once the terrain processing is complete, data can be extracted to support hydrologic model creation via the **HMS Model Setup** menu. The **Utility** menu allows users to perform some limited administrative tasks in assigning or changing a theme, which is to be identified and used by the program. Each theme will be assigned a unique name or "tag" by which it will be known to the program. The tags are names associated with themes that identify the role of the theme in the program. Buttons perform tasks after they are activated, tools execute the task after they are activated and the user applies an action.

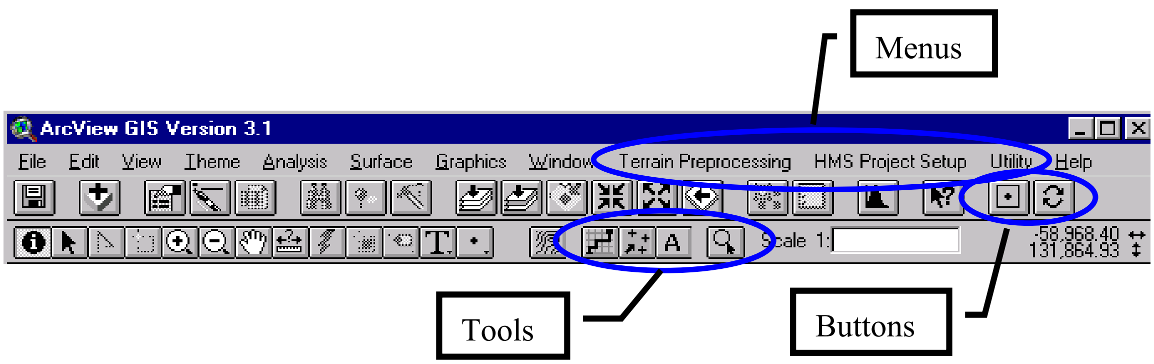


Figure 6–1. MainView GUI with GeoHMS extensions features.

Data Management

Data that are introduced or derived with the GeoHMS extension are managed through role association. For example, when a DEM is introduced, GeoHMS will associate it with "RawDEM", which is the original DEM. When a Fill command is issued, the program will automatically offer the RawDEM as default for creating a depressionless DEM. Aside from associating data sets with their intended roles as they are created, data management allows the user the ability to bring in other data sets and assign a role to them. For example, if the user has developed the flow direction and accumulation grid in another program, they can bring these data in as themes and assign their roles. This is a good way to keep track of data as they are generated. Another example are the flow tracing and area tools; GeoHMS knows which data layer should be operated on to provide the results. Figure 6–2 shows the data management of themes on the left-hand side and the assigned themes on the right-hand side. The "Null" entry for the assigned theme indicates that the appropriate theme has not been created and assigned. When the appropriate themes are created, their names replace the "Null" entry as shown in Figure 6–3.

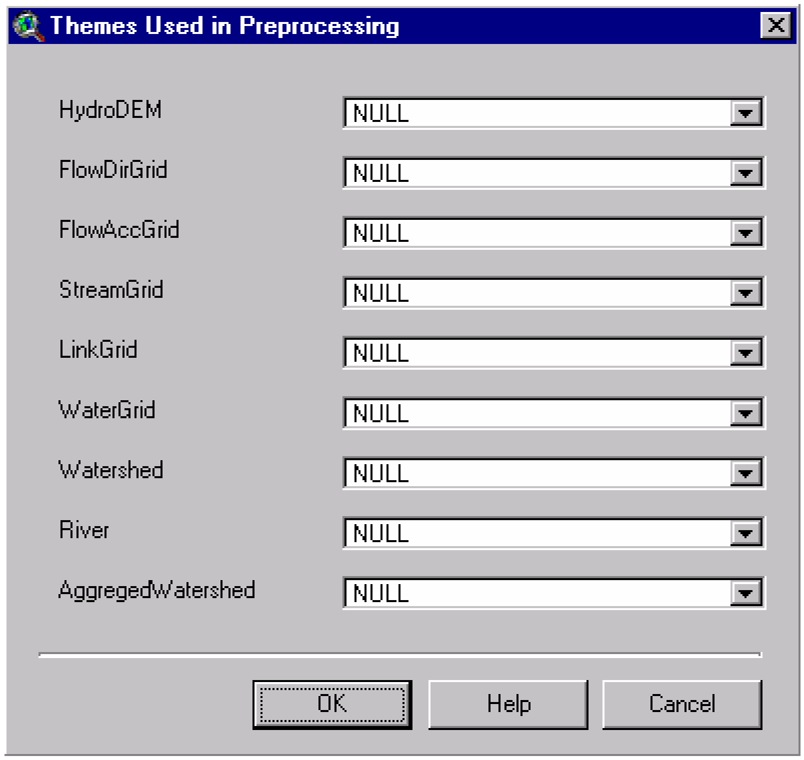


Figure 6–2. Data Management window.

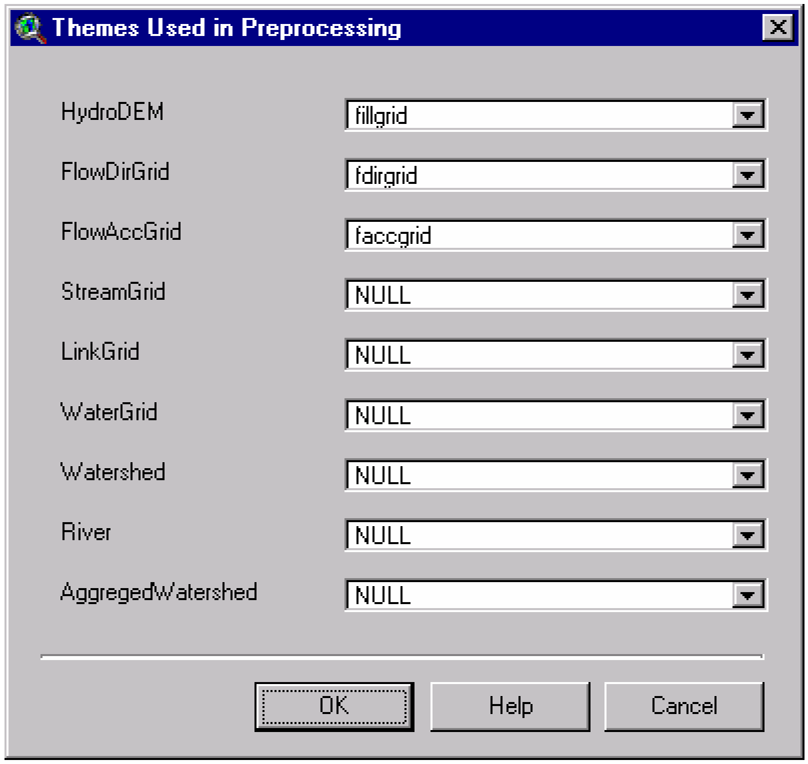


Figure 6–3. Data management with assigned themes.

Terrain Reconditioning

Many users in the past have used the simple "burning in" techniques to force a stream network on the DEM. This simple "burning in" technique allows the user to abruptly lower only the stream cell elevation by a fixed amount. Similar to the simple "burning in" technique, the new Terrain Reconditioning method, located under the **Terrain Preprocessing** menu, allows the user to lower the elevation of the stream cell and also provides an option to gradually lower the neighboring cells along the stream. This method creates a gradual transition from the overbank to the stream centerline in the DEM for water to enter the stream.

In many cases where the stream cells in the DEM and the stream vector line are not aligned, this method can be used to eliminate the undesirable side effects of fictitious islands near the stream centerline and parallel streams as shown in Figure 6–4.

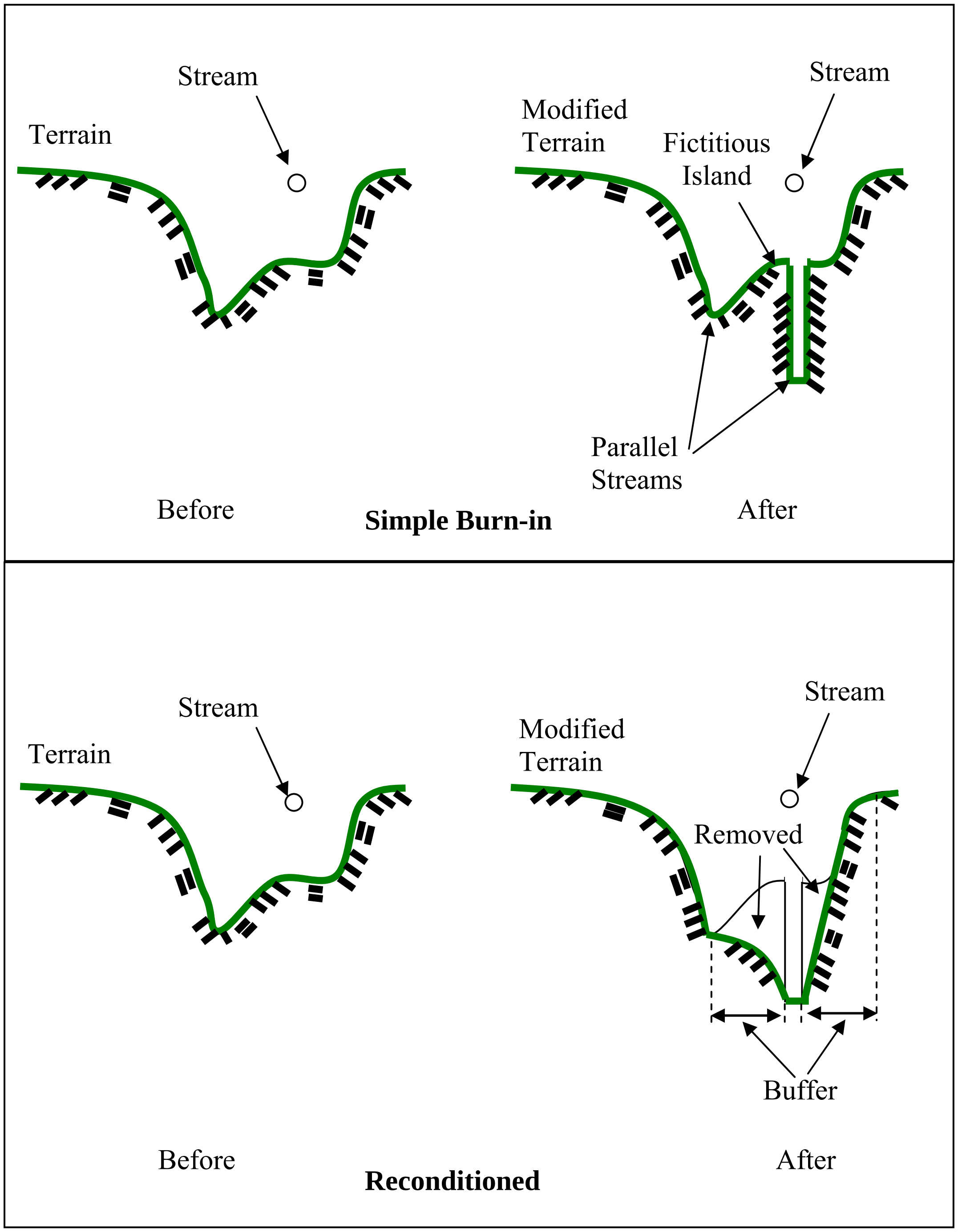


Figure 6–4. Cross-section views of simple burning-in (top) and reconditioned DEM (bottom).

The ***Terrain Reconditioning*** menu modifies terrain by imposing line features on a grid by lowering ("burning") and raising ("fencing") grid cell elevation along the line feature. This function requires two inputs, a grid and a line theme as shown in Figure 6-5, which must be present in the MainView to be accessible from the dropdown menu. The function outputs a reconditioned grid.

The original AGREE method was developed with Arc/Info by Ferdi Hellweger at the University of Texas at Austin in 1997. For a full reference to the procedure refer to the web link: http://www.ce.utexas.edu/prof/maidment/GISHYDRO/ferdi/research/agree/agree.html. This implementation of the AGREE method in HEC-GeoHMS is in the ArcView 3.x platform.

In addition, HEC is working on releasing an interactive tool in ArcGIS 8.x platform for reconditioning and editing the DEM. Further information is available in the Appendix H under the frequently asked question #8.

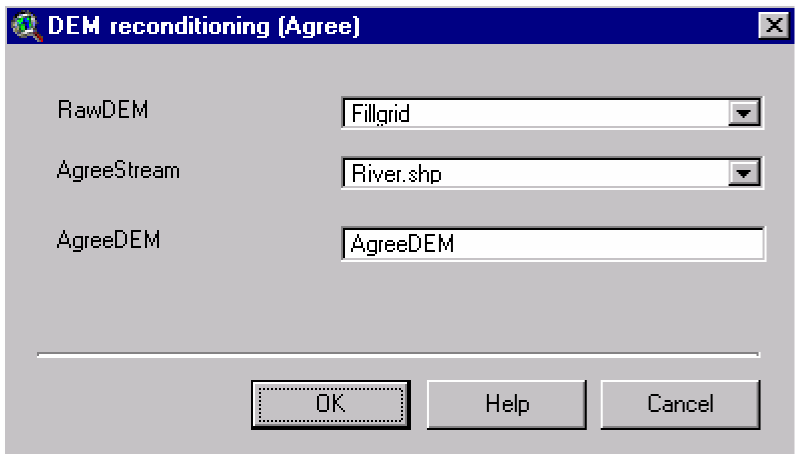


Figure 6–5. DEM reconditioning data requirements.

After initiating the function, the user needs to enter three reconditioning parameters as shown in Figure 6-6:

- Vector buffer (cells) – this is the number of cells around the vector line theme for which the smoothing will occur.
- Smooth drop/raise – this is the amount (in vertical units) that the river will be dropped if the number is positive or the fence will be extruded if the number is negative. This value will be used to interpolate the DEM into the buffered area between the boundary of the buffer and the dropped/raised vector feature.
- Sharp drop/raise – this is the additional amount (in vertical units) that the river will be dropped if the number is positive or the fence will be extruded if the number is negative. This amount of additional burning/fencing will be on top of the smooth buffer interpolation.

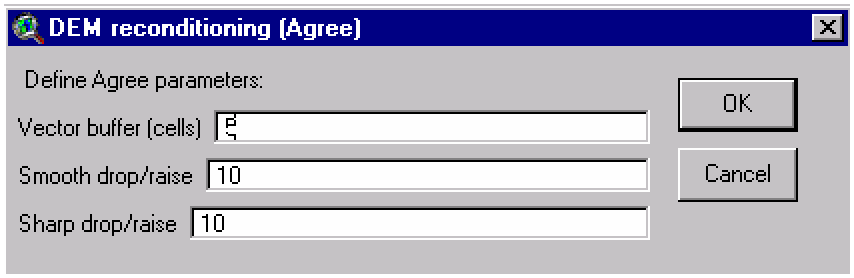


Figure 6–6. DEM reconditioning parameters.

For best results, users will often need to make iterative and multiple passes through this burning/fencing process. After the reconditioned DEM is obtained, users should perform the **Fill Sinks** menu to remove potential sinks generated from the reconditioning process. Use the filled reconditioned DEM to determine flow direction and flow accumulation. Prior to creating the **ProjView,** where basin characteristics will be extracted, use the dropdown menu to change the "HydroDEM" to the original DEM that was not modified by the reconditioning process to ensure that the correct elevations are extracted for slope calculations.

Terrain Preprocessing

By applying the GIS algorithms discussed below, the terrain can be processed in two ways: step-by-step or batch processing. With the step-by-step approach illustrated below, data sets are derived after each operation. Greater control over the results is obtained because the user verifies the results and makes decisions before proceeding. For example, prior to performing the stream definition, it is good practice to use the **Identify Area** tool and check the contributing area at several locations. This information on the area can help pick a threshold for adequate stream definition. In batch mode, all of the inputs like the threshold are entered up front, and then the program generates all of the data sets. In a few instances, the batch mode may pause and prompt for more input to complete the terrain process. For example, if there are too many outlets, the program will prompt for input to determine whether stream segments serve as an outlet. When using the batch mode, there are some safeguards for changing the threshold to vary the detail of the stream definition. After batch processing is complete, the user can use the **Identify Area** tool to estimate a good threshold and then specify that threshold when setting up a hydrologic model.

GIS Approach

GIS approaches toward hydrologic analysis require a terrain model that is “hydrologically corrected”. A “depressionless” terrain model is used in the analysis. The GIS analyzes the “depressionless” terrain model by applying the 8-point pour model, where water flows across the landscape from cell to cell based on the direction of the greatest elevation gradient. The process of analyzing the landscape characteristics and slopes for stream networks and subbasin boundaries is presented in Table 10. Steps in the analysis include filling depressions or pits, calculating flow direction and flow accumulation, delineating streams with an accumulation threshold, defining streams, segmenting streams, delineating watersheds, processing watershed polygons, processing streams, and aggregating watersheds.

Depressionless DEM

The depressionless DEM is created by filling the depressions or pits by increasing the elevation of the pit cells to the level of the surrounding terrain in order to determine flow directions. The pits are often considered as errors in the DEM due to re-sampling and interpolating the grid. For example, in a group of three-by-three cells, if the center cell has the lowest elevation compared to its eight neighboring cells, then the center cell's elevation will be increased equaling the next lowest cell. Filling the depressions allows water to flow across the landscape. This assumption is generally valid when a large event storm fills up the small depressions and any incremental amount of water that flows into the depression will displace the same amount of water from the depression.

The steps to fill the depressions are shown below.

- Add the unfilled DEM into the ***MainView*** using the **Add Theme** button, see Figure 6–7.

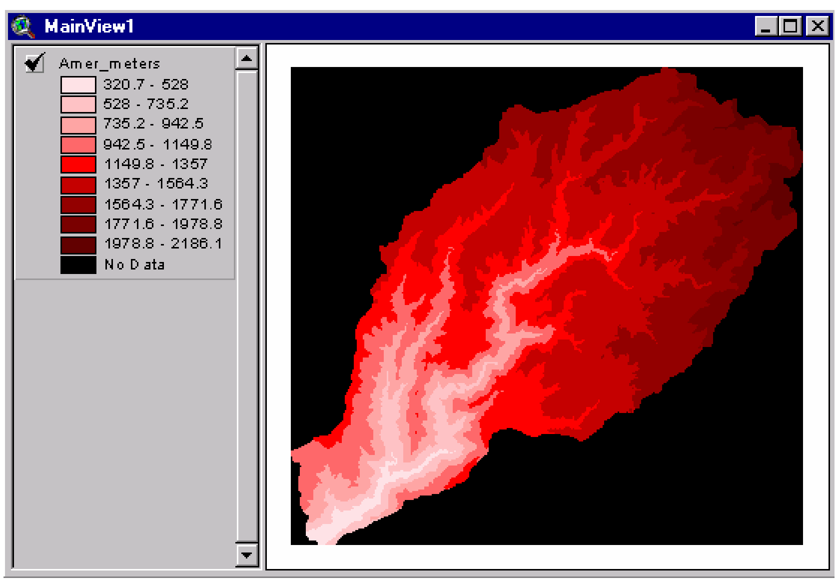


Figure 6–7. Depressionless DEM.

- Select **Terrain Preprocessing** ⇒ **Fill Sinks** when a "MainView" document is active.
- Confirm that the input of the RawDEM (also referred to as the unfilled DEM) is "Amer_meters". The output of the HydroDEM is "FillGrid", see Figure 6–8. "FillGrid" is a default name that can be edited by the user.
- Press OK

Figure 6–8. Fill Sinks operation.

The result of the Fill Sinks operation is the "Fillgrid" theme, as shown in Figure 6–9, where the lowest cell elevation is increased from 320.7 meters to 324.2 meters.

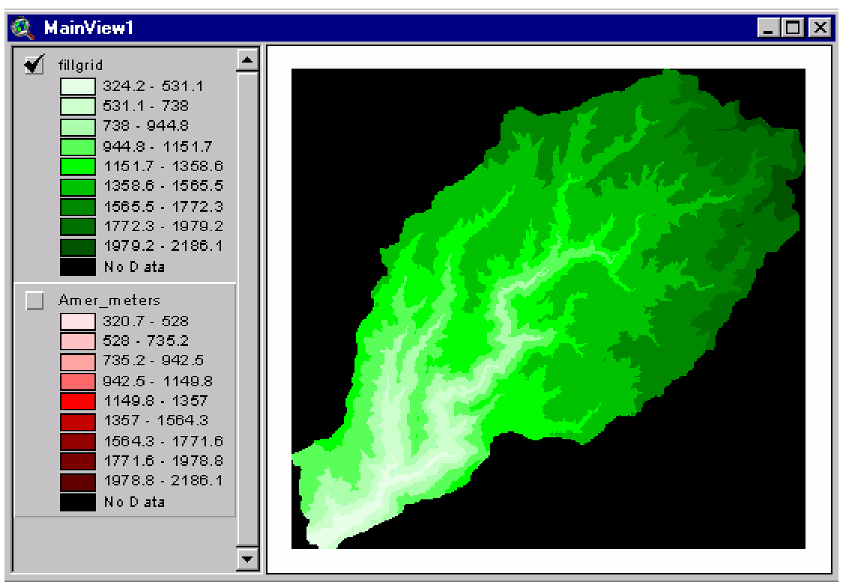


Figure 6–9. Fill Sinks operation result.

Step-by-Step Process

When performing this procedure, the user needs to bring in a "hydrologically corrected" or the "depresssionless" DEM from the previous step. With the step-by-step approach, each step starts with offering a list of inputs that will be used to produce the output grid. If the step-by-step procedure is performed in a sequential order, the program will be able to offer the correct data input for processing. In a few instances, when certain steps are repeated or performed out of order, it would be important to verify that the appropriate data sets are used.

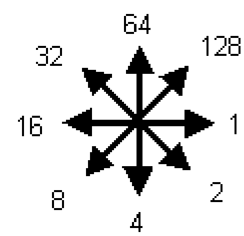
Flow Direction. This step defines the direction of the steepest descent for each terrain cell. Similar to a compass, the eight-point pour algorithm specifies the following eight possible directions:

1 = east, 2= southeast,

4 = south, 8 = southwest,

16= west, 32=northwest,

64 = north, 128=northeast.



The steps to compute flow directions are shown below.

- Select **Terrain Preprocessing ⇒ Flow Direction**.
- Confirm that the input of the HydroDEM is "fillgrid". The output of the FlowDirGrid is "FDirGrid", as shown in Figure 6–10. "FDirGrid" is a default name that can be edited by the user.
- Press **OK**

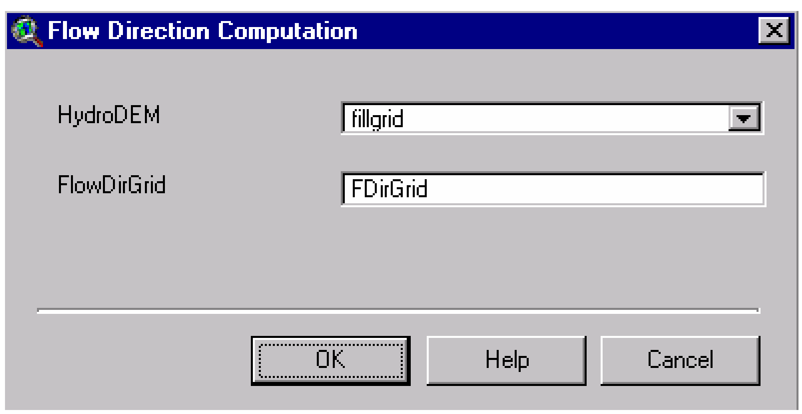


Figure 6–10. Flow Direction operation.

The result of the Flow Direction operation is the "FdirGrid" as shown in Figure 6–11.

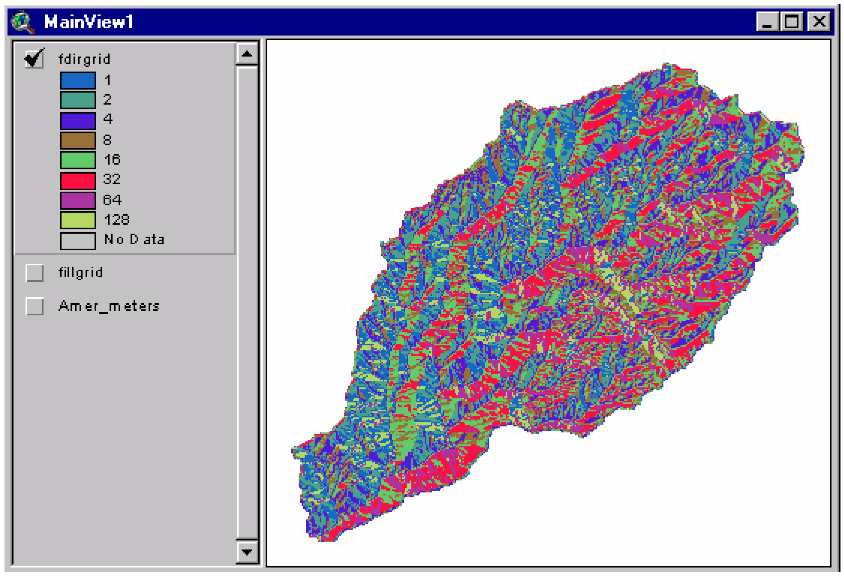


Figure 6–11. Flow Direction operation result.

Flow Accumulation. This step determines the number of upstream cells draining to a given cell. Upstream drainage area at a given cell can be calculated by multiplying the flow accumulation value by the cell area.

The steps to compute flow accumulation are shown below.

- Select **Terrain Preprocessing ⇒ Flow Accumulation**.
- Confirm that the input of the FlowDirGrid is "fdirgrid". The output of the FlowAccGrid is "FAccGrid", as shown in Figure 6–12. "FAccGrid" is a default name that can be edited by the user.
- Press **OK**

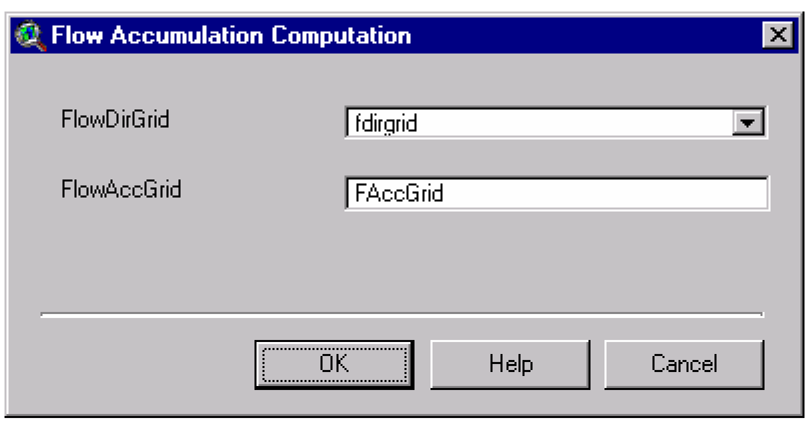


Figure 6–12. Flow Accumulation operation.

The result of the Flow Accumulation operation is the "faccGrid", as shown in Figure 6–13.

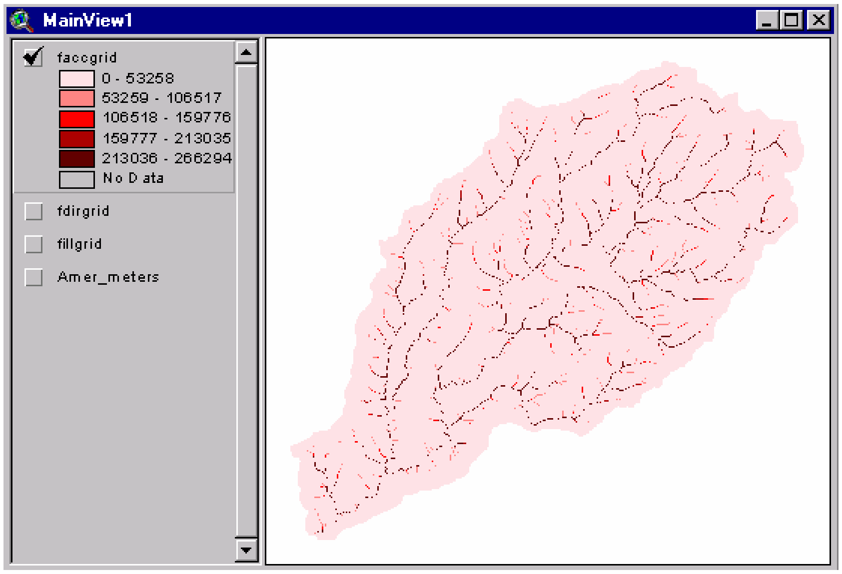


Figure 6–13. Flow Accumulation operation result.

Stream Definition. This step classifies all cells with flow accumulation greater than the user-defined threshold as cells belonging to the stream network. Typically, cells with high flow accumulation, greater than a user-defined threshold value, are considered part of a stream network. The user-specified threshold may be specified as an area in distance units squared, e.g., square miles, or as a number of cells. The flow accumulation for a particular cell must exceed the user-defined threshold for a stream to be initiated. The default is one percent (1%) of the largest drainage area in the entire basin. The smaller the threshold chosen, the greater the number of subbasins delineated by Geo-HMS.

The steps to compute stream definition are shown below.

- Select **View** ⇒ **Properties**; this opens the properties dialog shown in Figure 6–14.
- "Map Units" are the units in which the GIS themes are projected. In this example, the horizontal unit of the DEM is measured in meters. **Specify** the **Map Units** as **meters** from the dropdown menu.
- "Distance Units" are the reporting units in ArcView. In this example, "Distance Units" are chosen as miles so that the information generated from ArcView can be compared with the stream flow gage drainage area reported in square miles. **Specify** the **Distance Units** as **miles** from the dropdown menu.
- Press **OK** and then save the project.

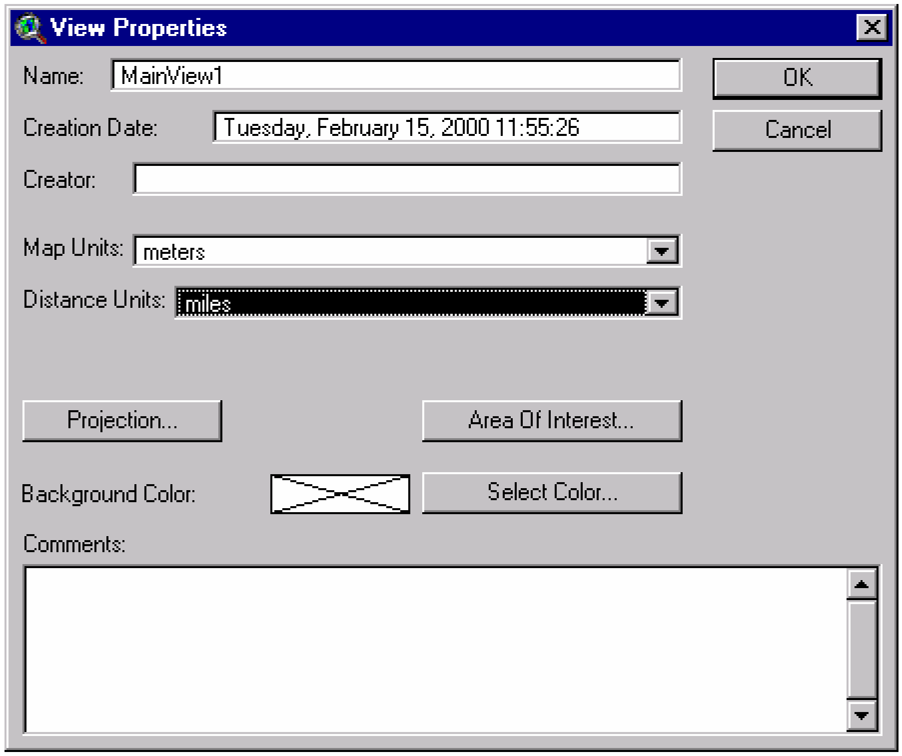


Figure 6–14. View Properties window.

- Select **Terrain Preprocessing ⇒ Stream Definition**.
- Confirm that the input of the FlowAccGrid is "faccGrid". The output of the StreamGrid is "StrGrid", see Figure 6–15. "StrGrid" is a default name that can be edited by the user.
- Press OK

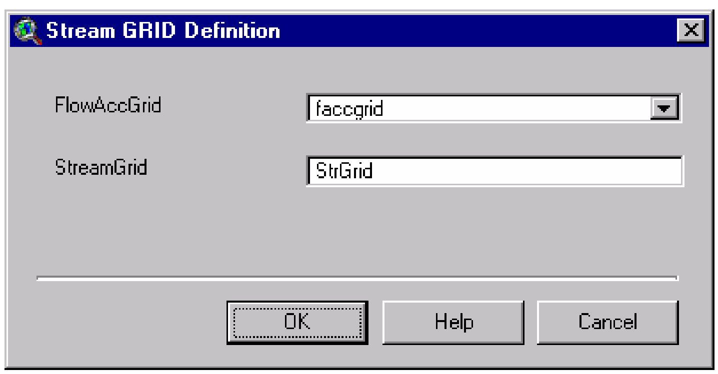


Figure 6–15. Stream definition operation.

- The threshold types available under the dropdown menu are "Area in Distance Units squared", or "Number of Cells" as shown in Figure 6–16.
- Select **Area in Distance Units squared**.

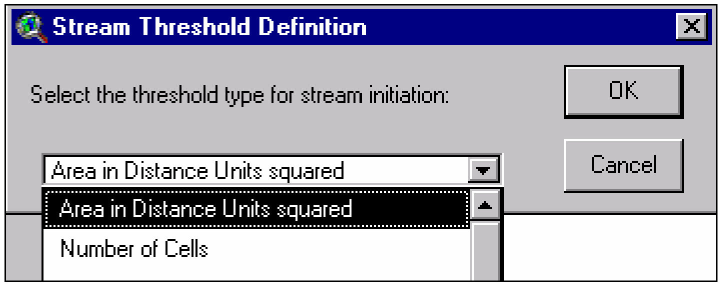


Figure 6–16. Stream threshold definition types.

- Enter the threshold as "5" square miles, as shown in Figure 6–17. Press **OK**.

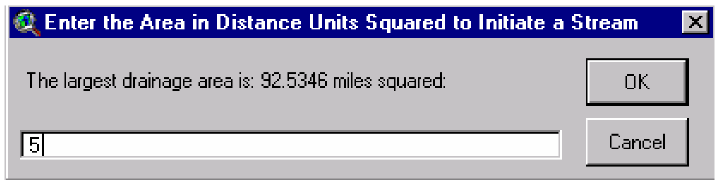


Figure 6–17. Stream threshold entry window.

The result of the Stream Definition operation is the "strgrid"as shown in Figure 6–18.

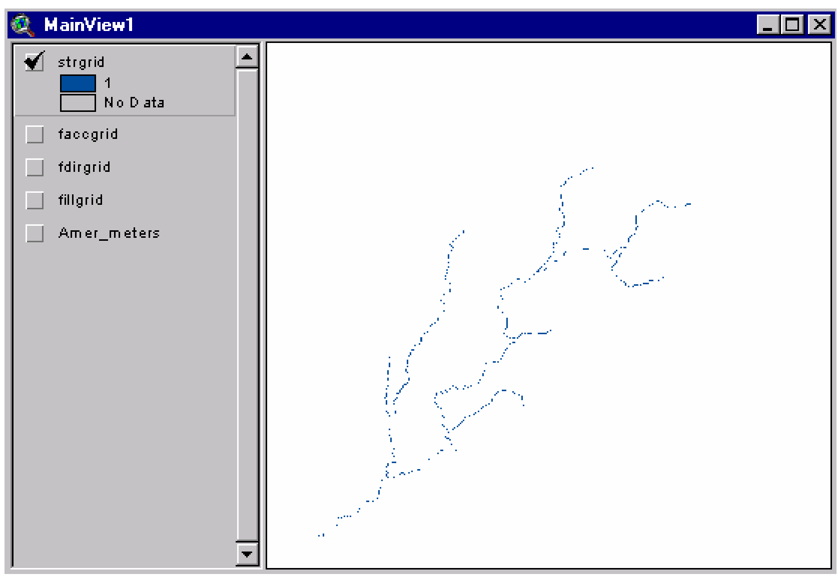


Figure 6–18. Stream definition operation result.

Stream Segmentation. This step divides the stream into segments. Stream segments or links are the sections of a stream that connect two successive junctions, a junction and an outlet, or a junction and the drainage divide.

The steps to compute flow segmentation are shown below.

- Select **Terrain Preprocessing ⇒ Stream Segmentation**.
- Confirm that the input of the FlowDirGrid is "fdirgrid" and StreamGrid is "strgrid". The output of the LinkGrid is "StrLnkGrid", see Figure 6–19. "StrLnkGrid" is a default name that can be edited by the user.
- Press **OK**

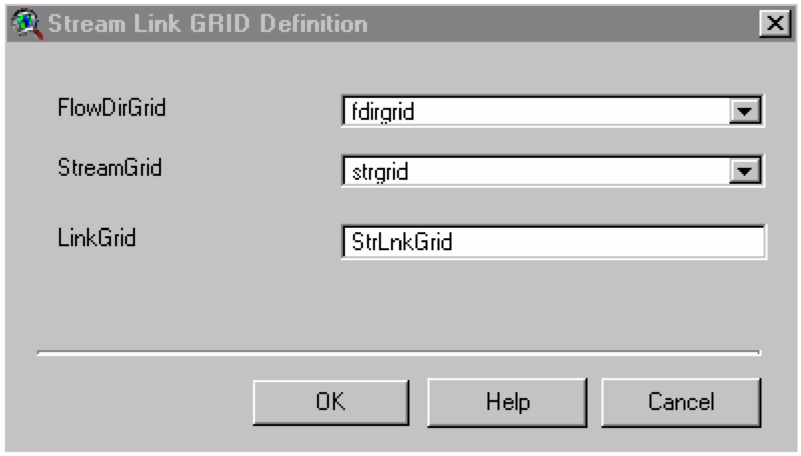


Figure 6–19. Stream Segmentation operation.

The stream segmentation operation results in 13 stream segments as shown in the "strlnkgrid" theme in Figure 6–20.

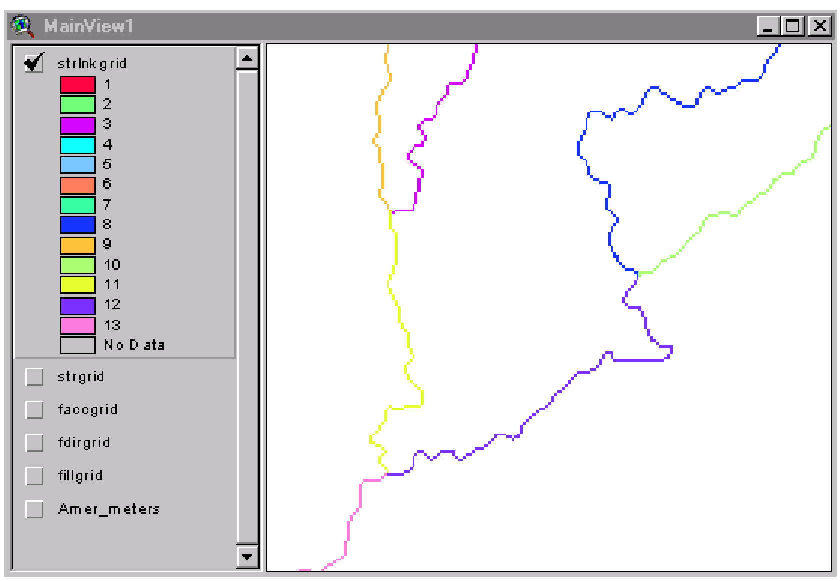


Figure 6–20. Stream Segmentation operation result.

Watershed Delineation. This step delineates a subbasin or watershed for every stream segment.

The steps to delineate watersheds are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Delineation**.
- Confirm that the input of the FlowDirGrid is "fdirgrid" and LinkGrid is "strlnkgrid". The output of the WaterGrid is "WShedGrid", see Figure 6–21. "WShedGrid" is a default name that can be edited by the user.
- Press **OK**

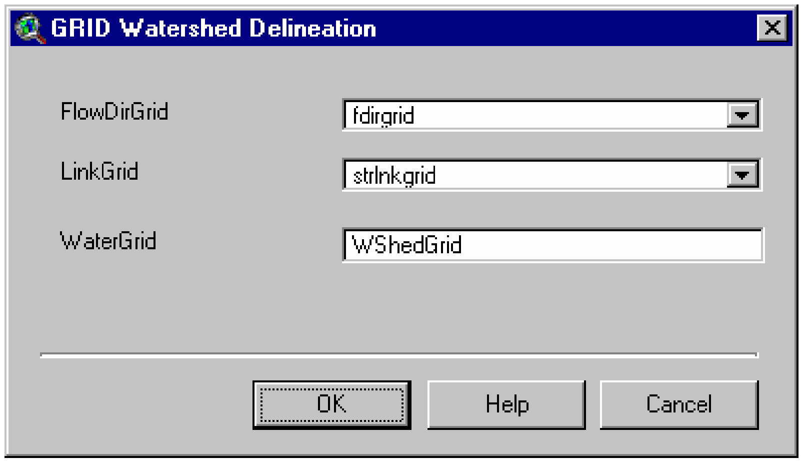


Figure 6–21. Watershed Delineation operation.

The watershed delineation operation results in 13 subbasins as shown in the "wshedgrid" theme in Figure 6–22.

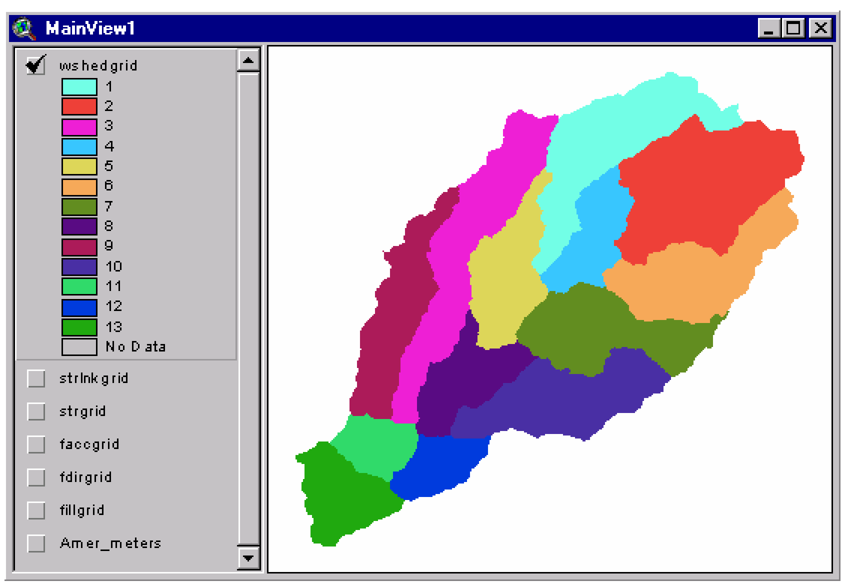


Figure 6–22. Watershed Delineation operation result.

Watershed Polygon Processing. This step converts subbasins in the grid representation into a vector representation.

The steps to vectorize a grid-based watershed are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Polygon Processing**.
- Confirm that the input of the WaterGrid is "wshedgrid" and the output of the Watershed is "Wshedshp.Shp", see Figure 6–23. "Wshedshp.Shp" is a default name that can be edited by the user.
- Press **OK**

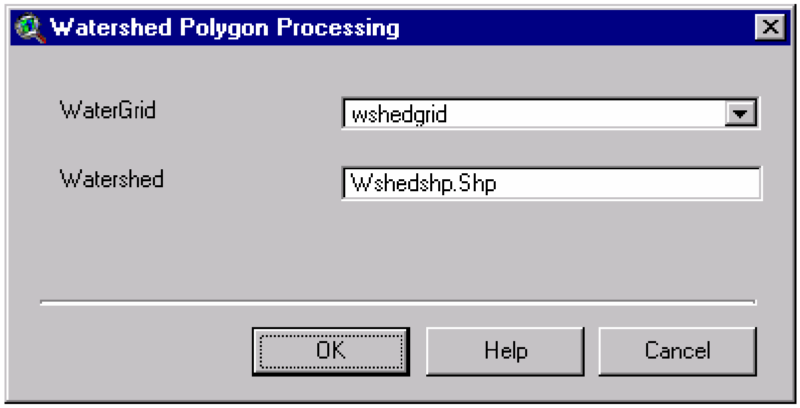


Figure 6–23. Watershed Polygon Processing operation.

The watershed polygon processing operation vectorized the grid-based subbasin into polygon vectors as shown in the "Wshedshp.Shp" theme in Figure 6–24.

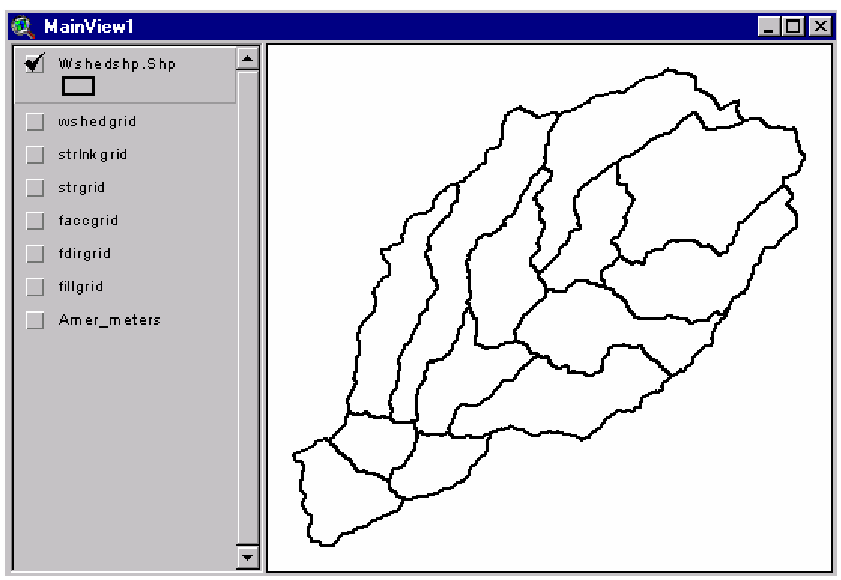


Figure 6–24. Watershed Polygon Processing operation result.

Stream Segment Processing. This step converts streams in the grid representation into a vector representation.

The steps to vectorize stream segments are shown below.

- Select **Terrain Preprocessing ⇒ Stream Segment Processing**.
- Confirm that the input of the LinkGrid is "strlnkgrid" and FlowDirGrid is "fdirgrid". The output of the River is "River", see Figure 6–25. "River" is a default name that can be edited by the user.
- Press **OK**

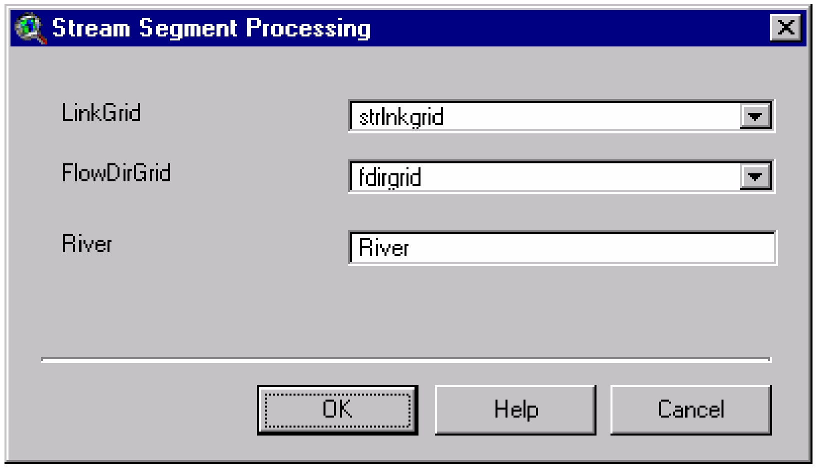


Figure 6–25. Stream Segment processing operation.

The stream processing operation vectorized the grid-based streams into line vectors as shown in the "River.shp" theme in Figure 6–26.

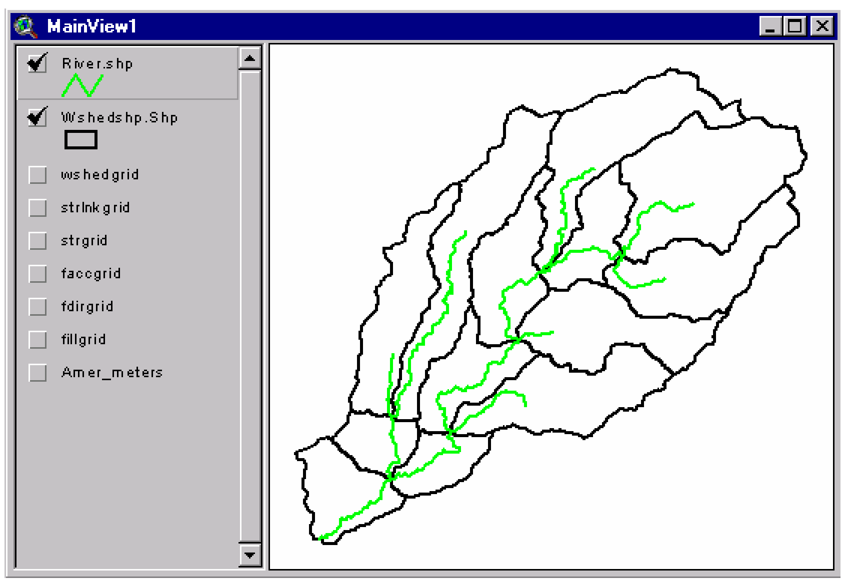


Figure 6–26. Stream Segment processing operation result.

Watershed Aggregation. This step aggregates the upstream subbasins at every stream confluence. This is a required step and is performed to improve computational performance for interactively delineating subbasins and to enhance data extraction. This step does not have any hydrologic significance.

The steps to aggregate watersheds are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Aggregation**.
- Confirm that the input of the River is "River.shp" and Watershed is "Wshedshp.Shp". The output of the AggregatedWatershed is "WshedMg.shp", a default name that can be edited by the user, see Figure 6–27.
- Press **OK**

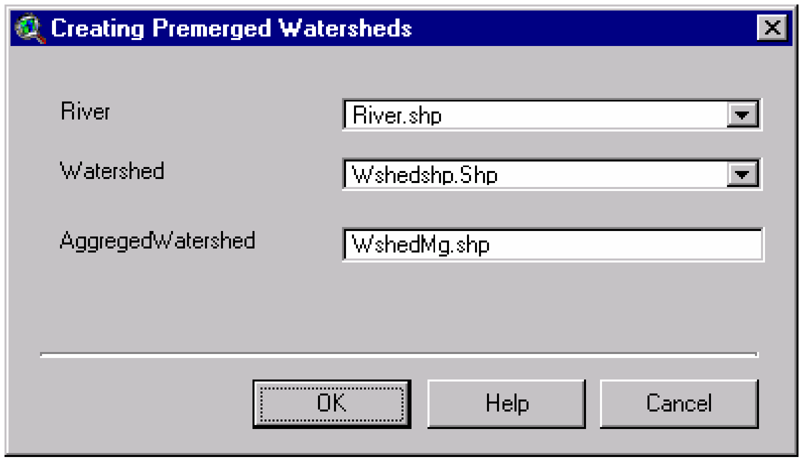


Figure 6–27. Watershed Aggregation operation.

The watershed aggregation operation results are shown in the "wshedmg.shp" theme in Figure 6–28.

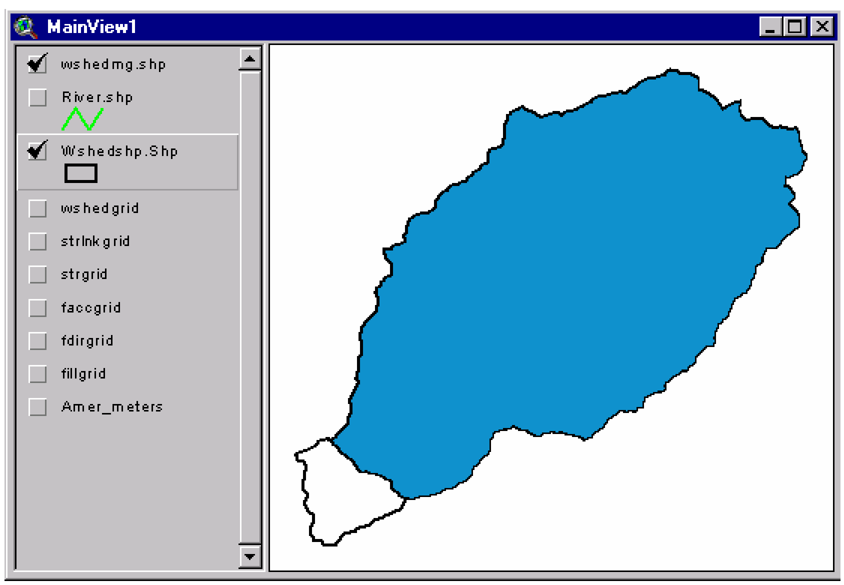


Figure 6–28. Watershed Aggregation operation result.

Full Processing Setup

When terrain processing is performed in batch mode, **Full Processing Setup** is used under the **Terrain Preprocessing** menu. The inputs are specified prior to processing, and a list of default names is presented. The full delineation accepts the depressionless DEM and derived drainage data sets. Therefore, the DEM must be filled first to prepare for full delineation setup. The inputs to the batch processing include the stream threshold for stream initiation.

The steps to perform full preprocessing are shown below.

- To preserve the content of ***MainView1***, create another view called ***MainView2***.
- Select **MainView** on the project window, and press **New**
- Add the "Amer_meters" DEM.
- Perform **Fill Sinks** and name the filled DEM as "Fillgrid2".
- Select the **Terrain Preprocessing ⇒ Full Preprocessing Setup**.

The default names are shown in Figure 6–29. These default names need to be changed to avoid naming conflicts with the MainView1.

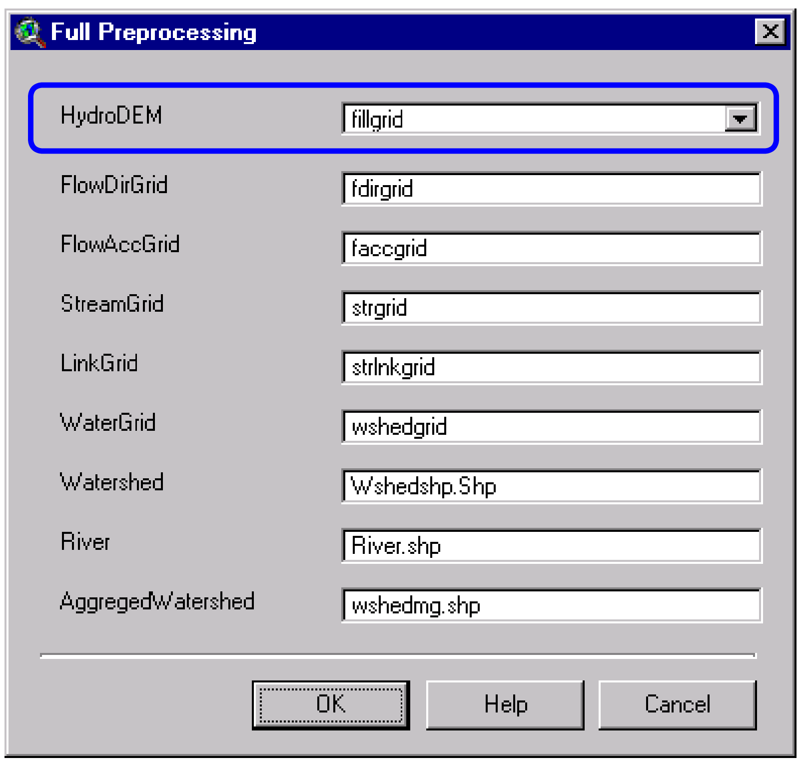


Figure 6–29. Full preprocessing setup with default theme names.

- From the **HydroDEM** dropdown menu, select the **fillgrid2**.
- Rename the default names by adding a "2" behind the default names as shown in Figure 6–30.
- Press **OK**

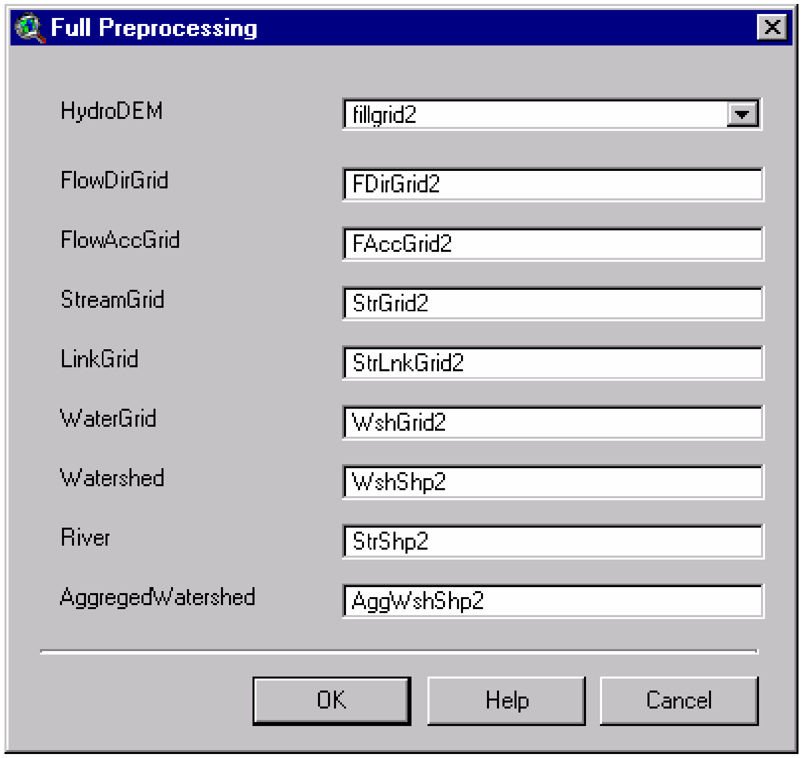
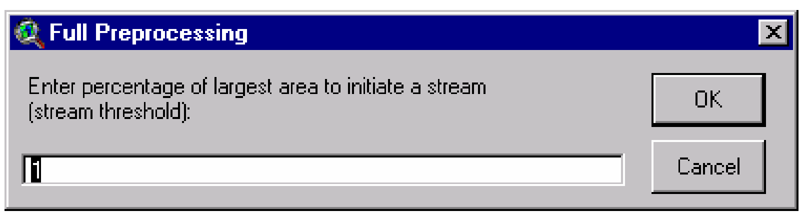


Figure 6–30. Full preprocessing setup with revised theme names.

- Enter the threshold to initiate a stream in terms of a percentage of the largest drainage area. In batch processing, the threshold must be defined as a percentage of the largest drainage area.
- Enter “`1`” to initiate the stream at 1%.



The full preprocessing operation creates the eight themes shown in Figure 6–31.

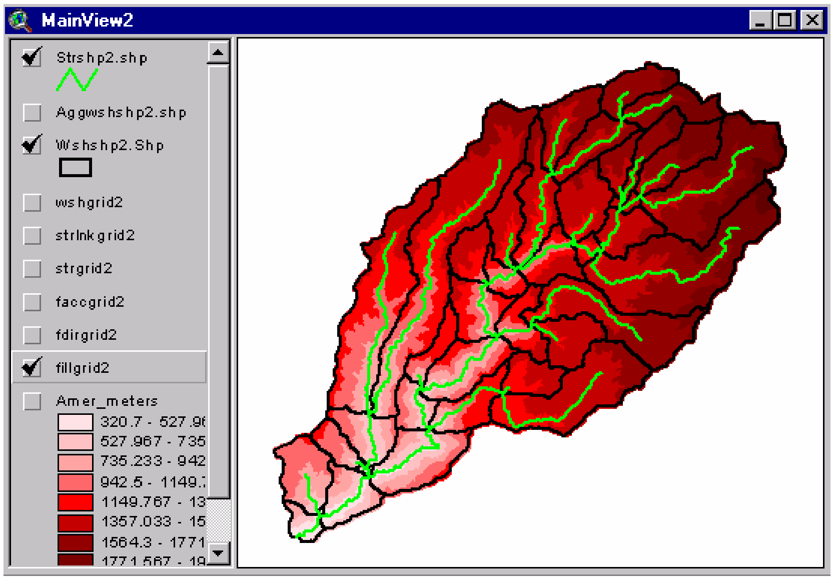


Figure 6–31. Full preprocessing setup results.

Data Exploration with Buttons and Tools

This section discusses the buttons and tools that the user may need to explore and derive data. The buttons and tools allow the user to find the drainage area at a point or find the point that has a specified drainage area. The tools also allow the user to draw a flow path from a specified point and delineate the area tributary to a point. This functionality allows the user to compare the GIS results with published results. In the following example, a streamflow gage with specified drainage area will serve as the published data source.

- Add the theme "gage.shp" with the  (**Add Theme**) button. There are four gages in this data set as displayed in Figure 6–32.

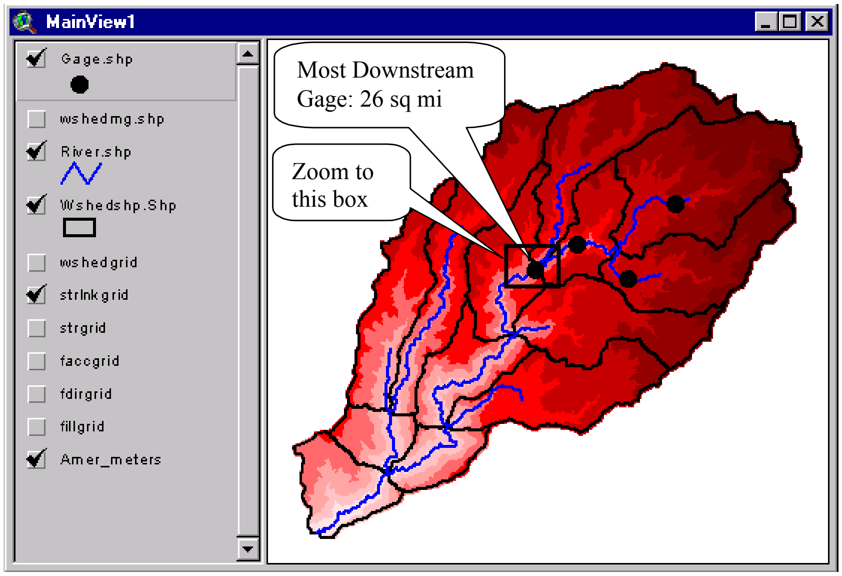


Figure 6–32. Gage locations.

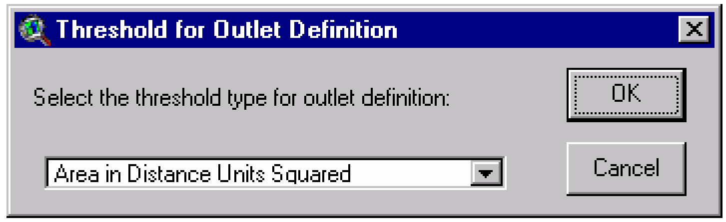
- Zoom in to the region of the most downstream gage whose reported drainage area is 26 square miles (sq mi).

The descriptions and procedures for using available buttons are explained in Table 6-1.

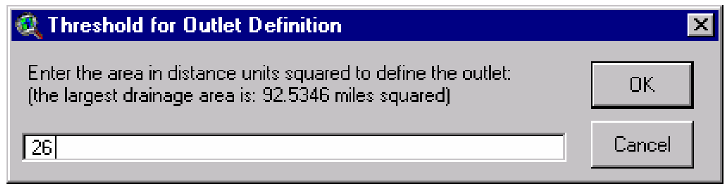
Table 6-1. MainView button descriptions and procedures.

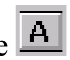
Button	Descriptions and Procedures
Find Area	<u>Description</u> This button allows the user to find possible locations on each stream that have the closest, but not exceeding, drainage area to a user-specified area. This tool provides many candidate points, with some points containing much smaller areas than the target area. In order to narrow the number of candidate points, the tool should be used when the user zooms to the area of interest. <u>Procedure</u> In this case, the downstream gage is close to three streams. The user knows that the downstream gage drains 26 sq mi. Using the (Find Area) button, the user searches within the zoomed-in region for the locations along the streams where the area does not exceed the specified 26 sq mi. With this information, the user can define the watershed of interest.

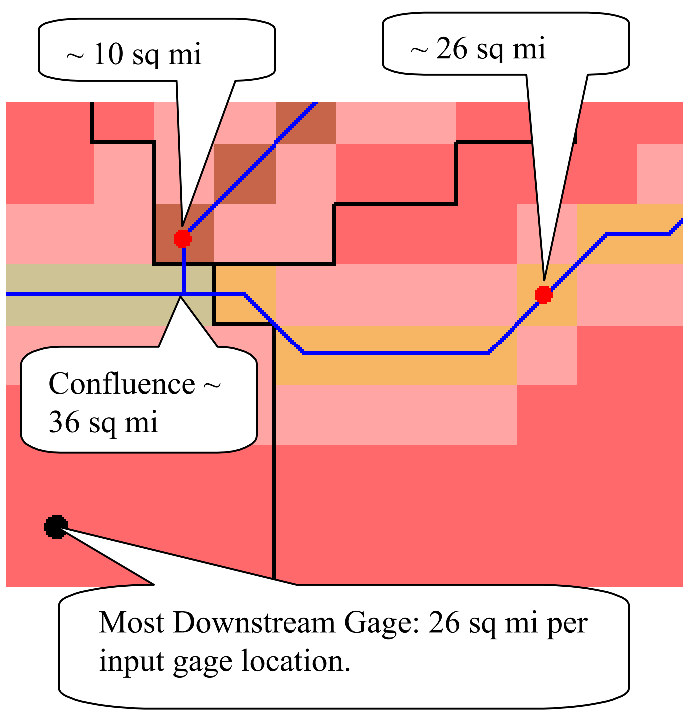
Select the threshold type and press **OK**.



Enter the Area as "`26`".

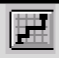
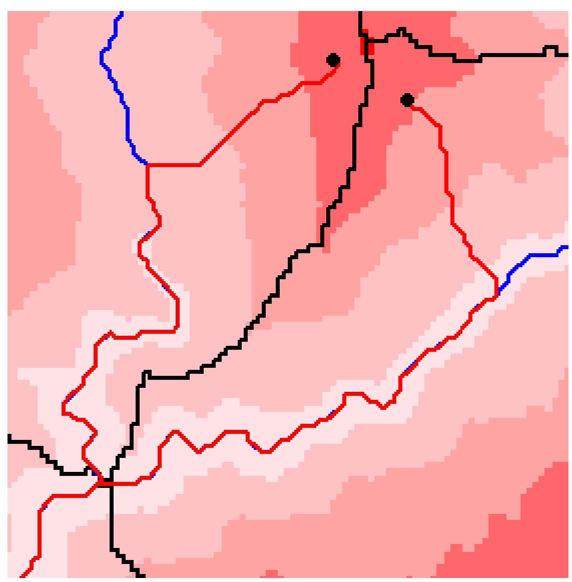
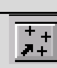


The results of the search provide two possible points that do not exceed the specified area. Using the  (Identify Area) tool, the user finds that one possible point drains about 10 sq. miles while the other point drains about 26 sq mi. From this analysis, the user understands that the downstream stream gage does not belong on the stream with 10 sq mi of drainage area or on the stream below the confluence. The applicable location of the downstream gage is on the stream with the 26 sq mi drainage area.



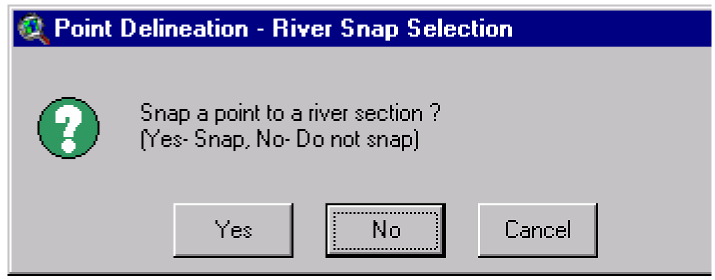
The descriptions and procedures for using available tools are explained in Table 6-2.

Table 6-2. MainView tools descriptions and procedures.

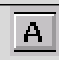
Tools	Descriptions and Procedures
 Flow Trace	<u>Description</u> This tool traces the flow path downstream of a user-specified point. <u>Procedure</u> To verify the drainage paths and watershed boundaries, the user can apply the flow-tracing tool and click on the display. The program draws a line representing the flow path from a user-specified point to the most downstream location. The flow path lines can be selected and deleted when the user is done examining them. To delete the lines, select the graphic with a standard ArcView  (Pointer) tool or Select **Edit** ⇒ **Select All Graphics**, and select **Edit** ⇒ **Delete Graphics.** 
 Point Delineate	<u>Description</u> This tool delineates the watershed tributary to a user-specified point.

Procedure

To use the tool, zoom in to the stream. Select the **Point Delineate** tool. Click **Yes** to enable snapping to a river or **No** to disable snapping.



The results of this operation are saved in point and polygon shapefiles.



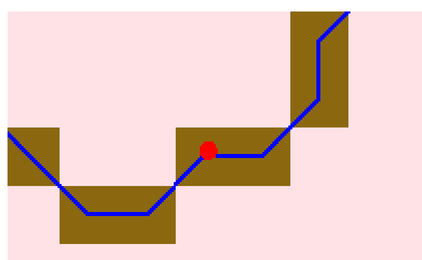
Identify Tool

Description

This tool allows te user to identify contributing area for any cell in distance units as specified in the View's properties.

Procedure

To identify contributing are for a cell, select the **Identify** tool and click on the cell in question.



The drainage area in distance units at the cell is displayed in the lower left-hand corner of the status bar as shown below.

Hydrologic Model Setup

The **HMS Project Setup** menu on the ***MainView*** GUI is responsible for extracting necessary information from the spatial database and creating an HMS project. The approach for extraction involves specifying control points at the downstream outlet, which defines the tributary of the HMS basin. As multiple HMS Basin models can be produced from the same spatial database, these models are managed through two shapefiles themes: project points "ProjPnts.shp" and project area "ProjArea.shp". The management of these models shows the regions that already have a project. In addition, management of these models allows re-creation of a study area with different thresholds or delete the project and related files easily and conveniently.

Start New Project

To define a new project name and create a directory to contain extracted data and related files, go to the **HMS Project Setup** menu.

- Select **HMS Project Setup ⇒ Start New Project**.
- Enter the project name as "AmerRiv1" as shown in Figure 6–33.

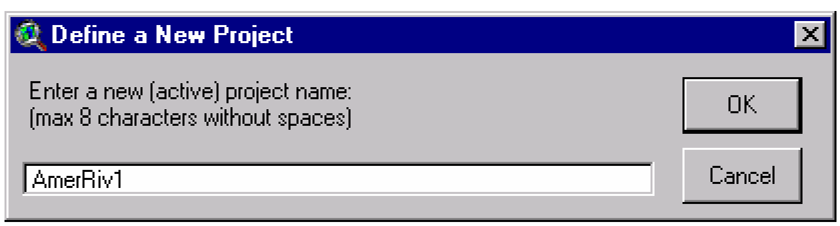
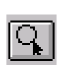


Figure 6–33. New project definition.

- Select the  (Specify Outlet Point) tool.
- Specify the outlet point for a tributary basin model as shown in Figure 6–34.

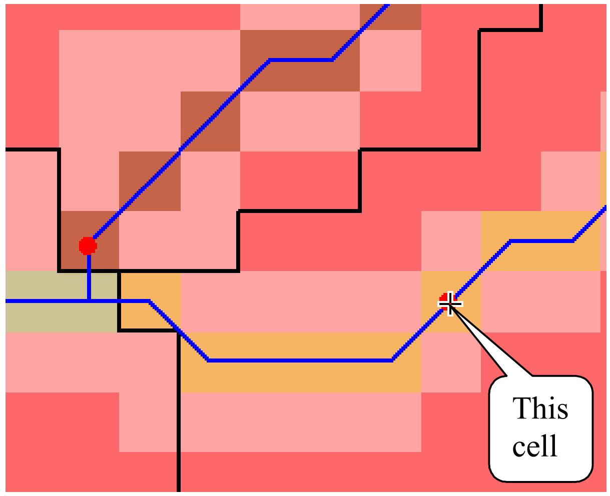


Figure 6–34. Specify outlet location.

- Select **HMS Project Setup ⇒ Generate Project.**
- Select the method of generating the project. Select **Original stream definition** from the dropdown menu as shown in Figure 6–35. The other two options are "A new threshold" and "Head basin area". The option "A new threshold" allows the user to specify a new threshold for the project. The option "Head basin area" allows the user to specify a threshold such that the head subbasins are approximately equal to the threshold.

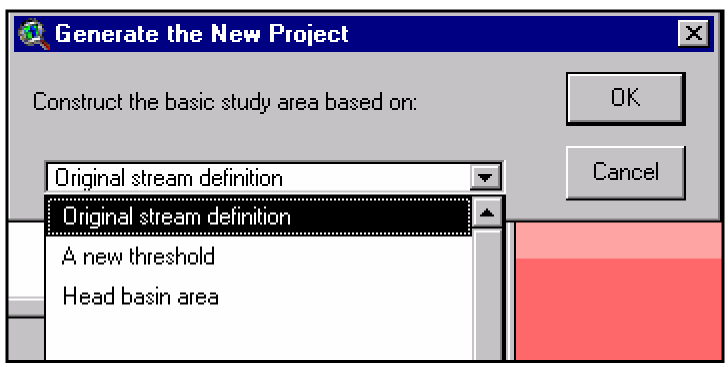


Figure 6–35. Generate project with options.

- Press **OK**
- Use the default name "ProjArea.SHP"as shown in Figure 6-36.

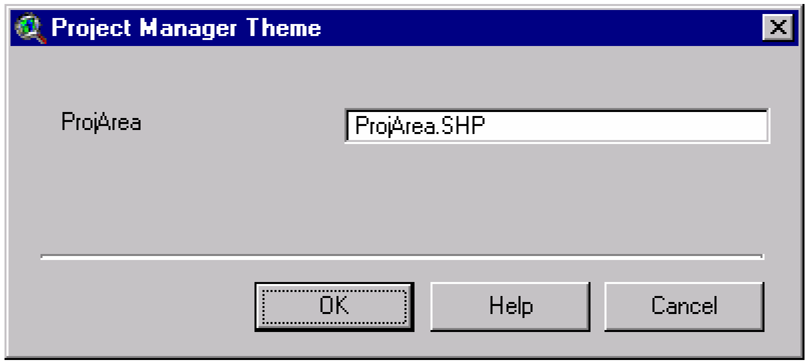


Figure 6–36. Project manager theme window.

- Press **OK** to generate a new project in the ***ProjView*** document type named "AmerRiv1" as shown in Figure 6–37.

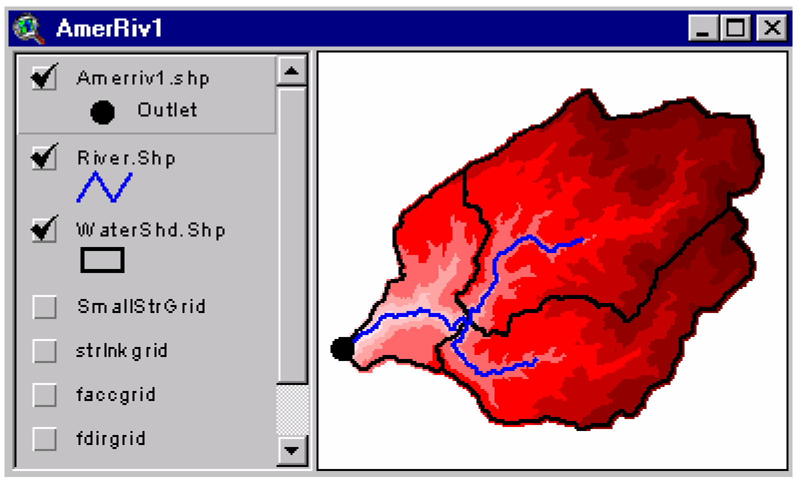


Figure 6–37. New project for hydrologic model.

In the ***ProjView*** named "AmerRiv1", the following data sets are extracted and created for the specified study area. The extracted area includes the buffer zone in order to deal with the boundary conditions. Data sets ending with "Grid" are raster data sets, and data sets with the "shp" extension are vector data sets in the industry standard shapefile format.

- "fillgrid" represents the extracted terrain for the study area.
- "fdirgrid" represents the extracted flow direction for the study area.
- "strlnkgrid" represents extracted stream segments for the study area.
- "SmallStrGrid" is an additional grid theme created using 10% of the specified threshold. It contains denser stream representation for visualization purposes.
- "WaterShp.Shp" represents the extracted subbasins for the study area.
- "River.Shp" represents the extracted stream segments for the study area.

- "Amerriv1.shp" contains project outlet and source point that defines the study area.

Additional HMS projects or Basin Models can be generated from the original set of preprocessed data. As illustrated in Figure 6–38 and Figure 6–39, the user can extract the pertinent data sets from the ***MainView*** to create another project. The benefit of this setup is that it allows the user to preserve the original data sets and work on multiple projects.

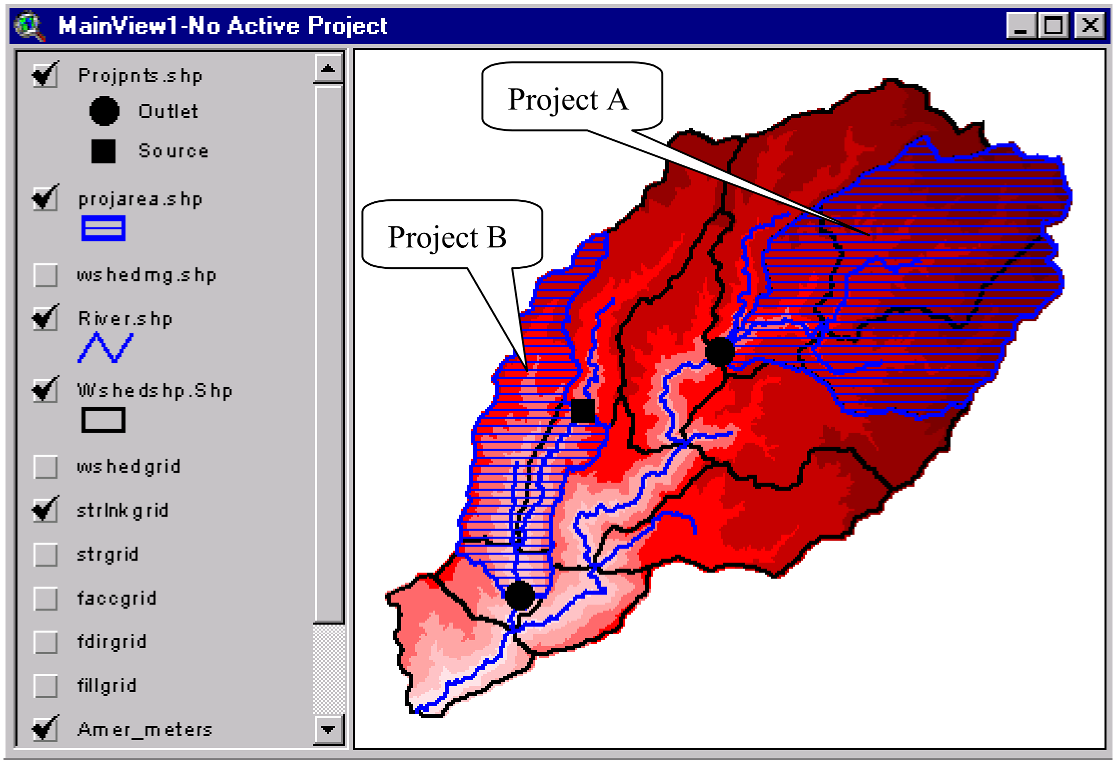


Figure 6–38. MainView with two projects.

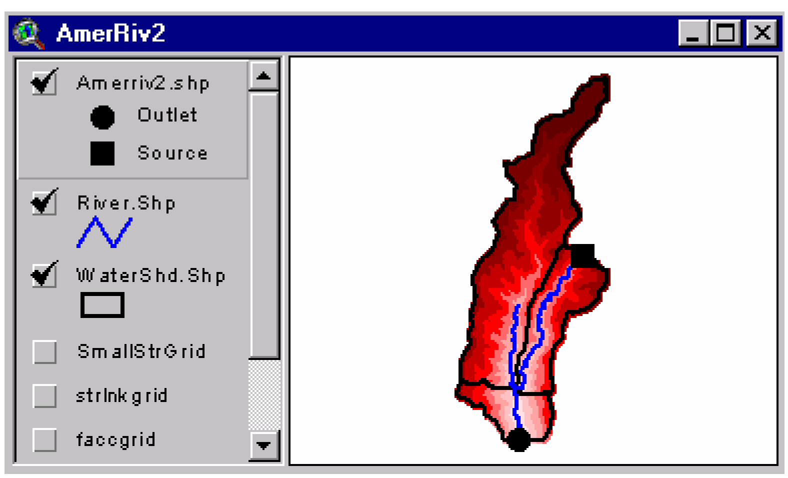


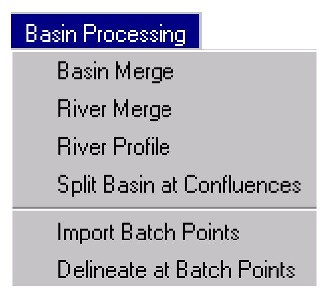
Figure 6–39. Generation of a separate project B from Figure 6–38.

CHAPTER 7

Basin Processing

After the terrain preprocessing is completed in the ***MainView*** window, the extracted data for the HMS model is generated and placed in the ***ProjView*** window, which allows the user to revise the subbasins delineation. Subbasin and routing reach delineations include points where information is needed, i.e., streamflow gage locations, flood damage centers, environmental concerns, and hydrologic and hydraulic controls. The tools described in this chapter will allow the user to interactively combine or subdivide subbasins as well as to delineate subbasins to a set of points.

This chapter will discuss the tools for subbasin delineation that are available in the ***ProjView*** GUI under the **Basin Processing** menu. Below is an outline of Chapter 7.



Contents

- Basin Merge
- Basin Subdivision
- River Merge
- River Profile
- Split Basins at Confluences
- Batch Subbasin Delineation

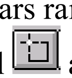
Basin Merge

Under the **Basin Processing** menu, the **Basin Merge** menu item merges multiple subbasins according to the following rules. This tool works interactively by presenting the result of the operation, allowing the user to examine the result, and giving the user options to accept or cancel the operation.

Rules!

- The subbasins must share a common confluence or
- The subbasins must be adjacent in an upstream and downstream manner.
- More than two subbasins are permitted.

Steps

- Make the "WaterShp.Shp" theme active by pressing on the theme with the  (**Pointer)** tool in the **View's** table of contents. The active theme appears raised.
- Use the **select** tool  and select the two subbasins as shown in Figure 7–1.

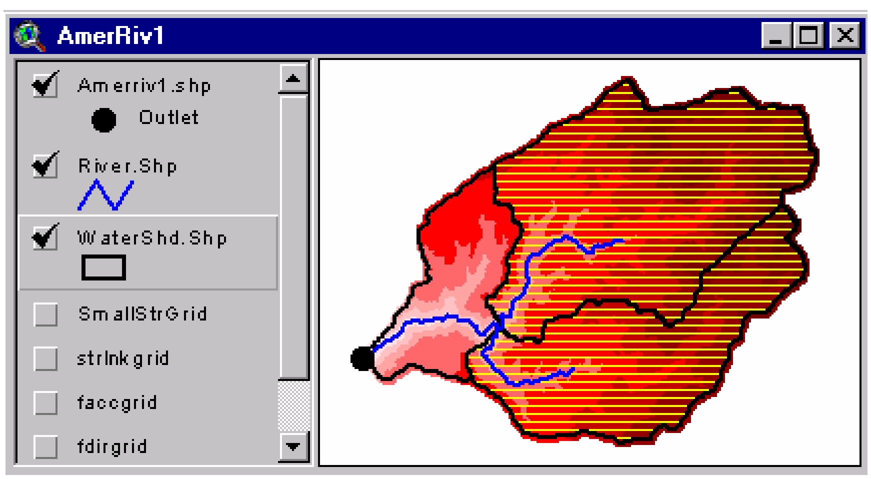


Figure 7–1. Basin merge.

- Select **Basin Processing** ⇒ **Basin Merge**, as shown in Figure 7–2.

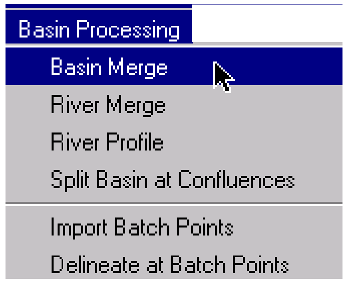


Figure 7–2. Basin merge menu item.

- The result of the merged subbasin is shown with a red outline. Press **Yes** to accept the resulting merged subbasin or **No** to cancel the merge operation.
- In this case, press **Yes** as shown in Figure 7–3.

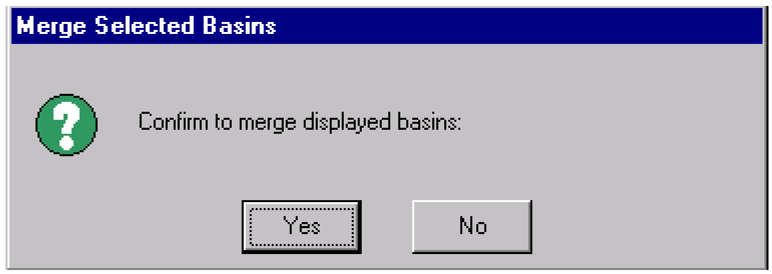


Figure 7–3. Basin merge confirmation.

The result of the merged basin is shown in Figure 7–4.

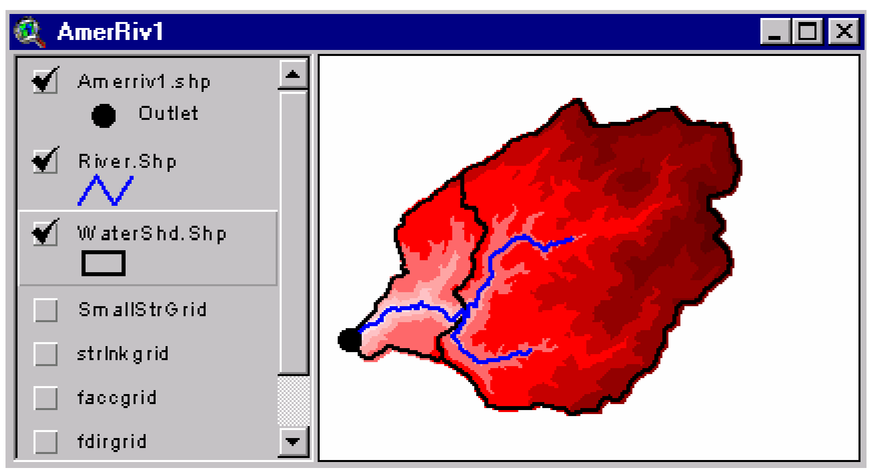


Figure 7–4. Basin merge result.

Basin Subdivision

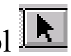
A basin can be subdivided with the  (**Basin Subdivide**) tool. The tool tip can be viewed by placing the pointer tool  over the  tool as shown in Figure 7–5. The tool tip indicates that the users can 1) Click on the stream to subdivide a basin or 2) Control key plus Click to remove an unnecessary point. The unnecessary point is often a residual from multiple basin subdivisions and merges. Basin subdivision can be completed using one of the methods described below.

Figure 7–5. Basin subdivision tool.

Method 1: Basin Subdivision on Existing Stream

An existing basin can be subdivided into two basins on an existing stream.

- Zoom in to the area of interest as shown in Figure 7–6. Make the “SmallStrGrid” theme visible by checking the box in the table of contents as shown in Figure 7–7. The “SmallStrGrid” theme represents the grid cells that compose the stream network. The existing streams are shown as blue lines according the “River.Shp” theme.

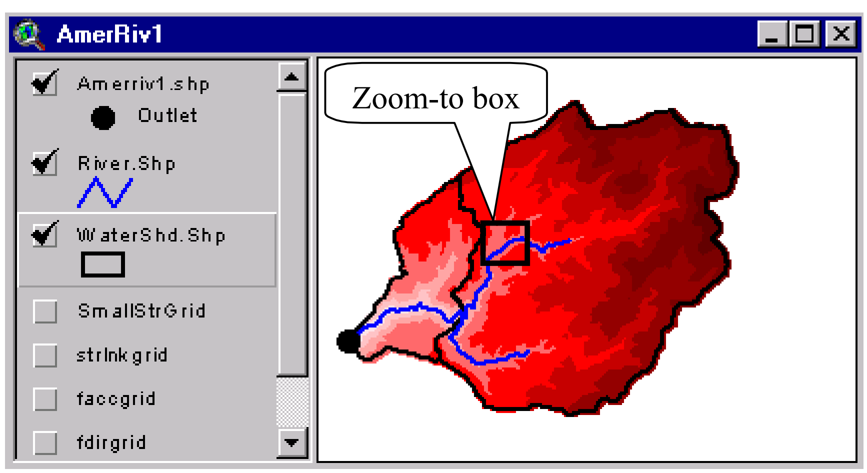
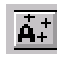


Figure 7–6. Zoom in prior to basin subdivision.

- Select the  tool.
- Click on the cell of interest as shown in Figure 7–7.

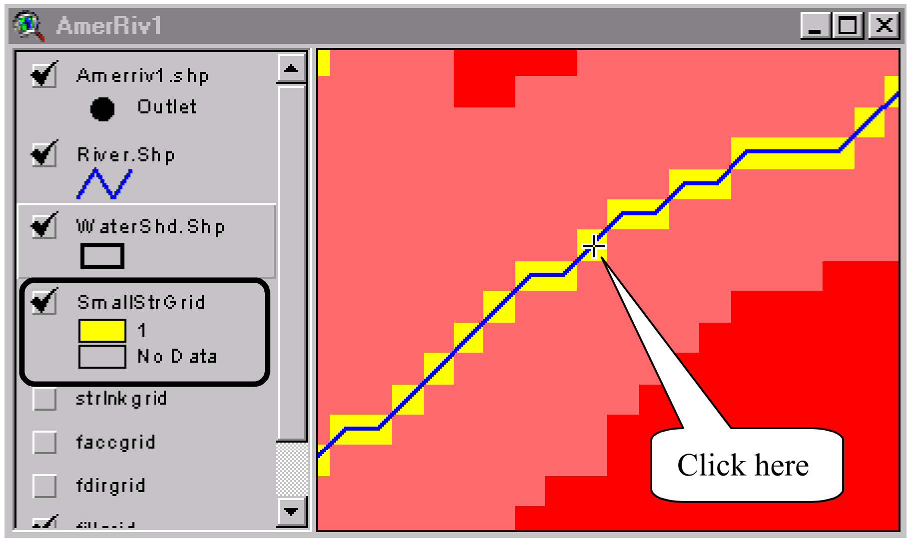


Figure 7–7. Click on the cell to subdivide basin.

- Accept the default name for the new basin outlet or overwrite it in the text box as shown in Figure 7–8.
- In this example, accept the default name. Press **OK**.

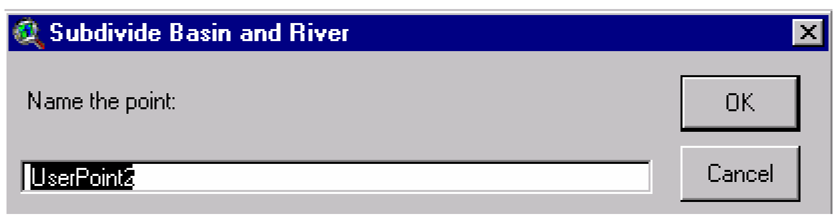


Figure 7–8. Default outlet name.

- A few seconds later, the result shown by the red outline is displayed. In this case, accept the result by pressing **Yes**.

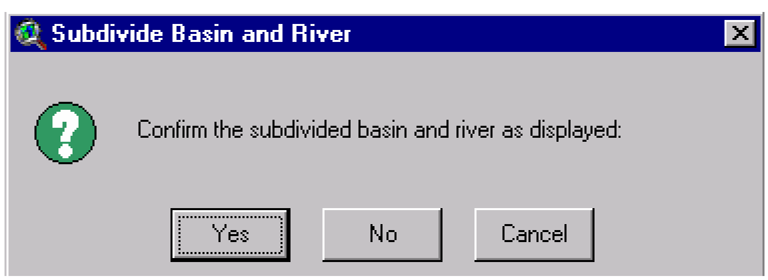


Figure 7–9. Basin subdivision confirmation.

The result of the operation is shown in Figure 7–10.

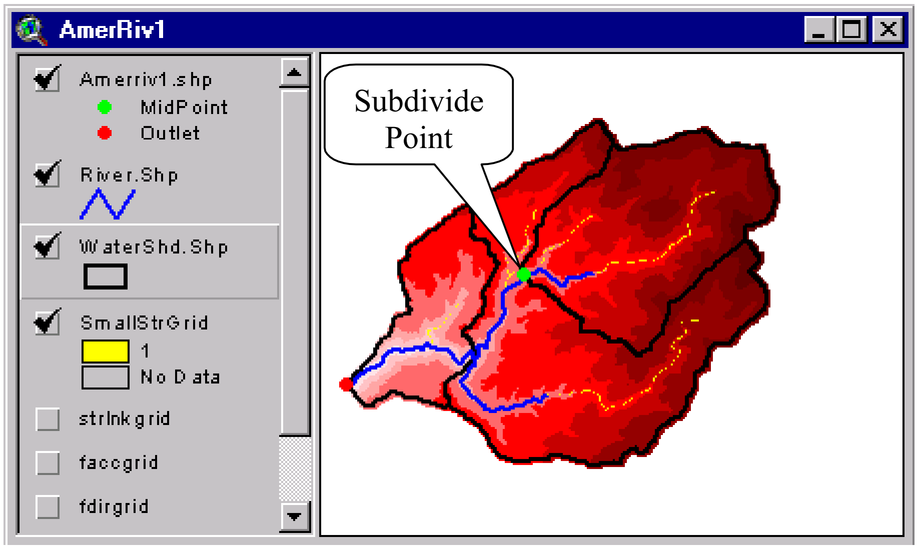


Figure 7–10. Basin subdivision result.

Method 2: Basin Subdivision without Existing Stream

When an existing stream does not extend upstream far enough, the user can use the same **Basin Subdivide** tool to delineate a new subbasin. For example, in Figure 7–11, the blue (if document is in color) or dark (if document is in black and white) stream does not extend up to the area of interest indicated by the box. The tool delineates a subbasin at the specified point that is not on the existing stream and traces a new stream segment downstream from the specified point to the existing stream.

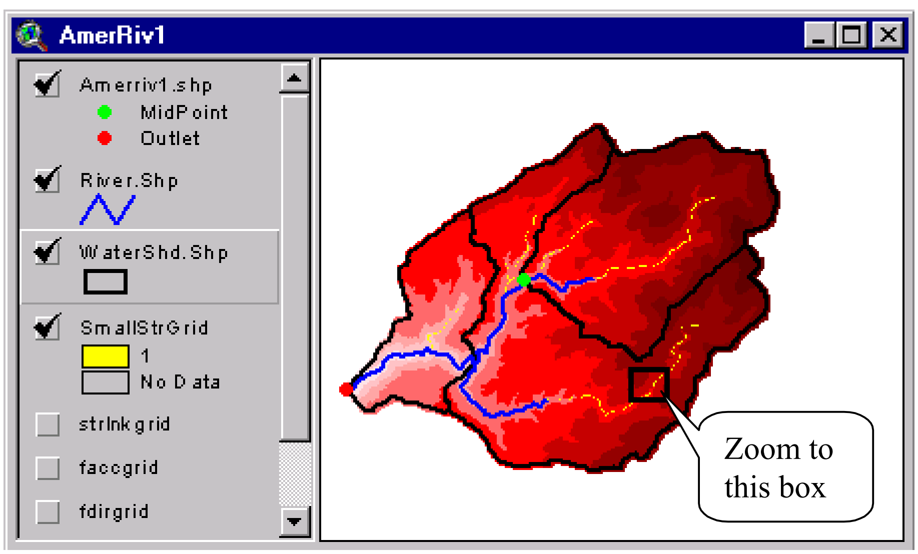


Figure 7–11. New subbasin delineation.

- Zoom in to the area of interest and make the “SmallStrGrid” theme visible.

- With the **Basin Subdivide** tool selected, click on the point shown below. Notice that the existing blue or dark stream does not exist in Figure 7–12.

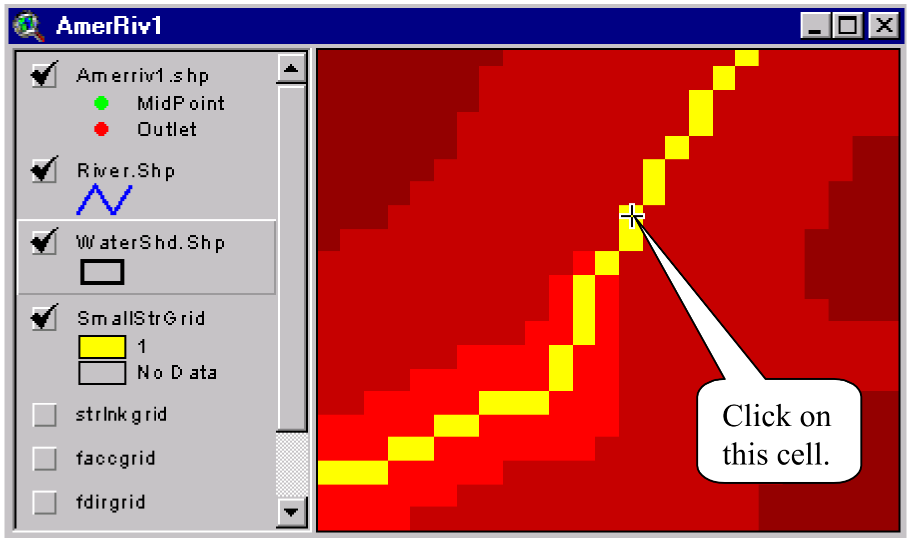


Figure 7–12. Zoom in prior to basin delineation.

- Accept the default name for the outlet and press **OK** as shown in Figure 7–13.

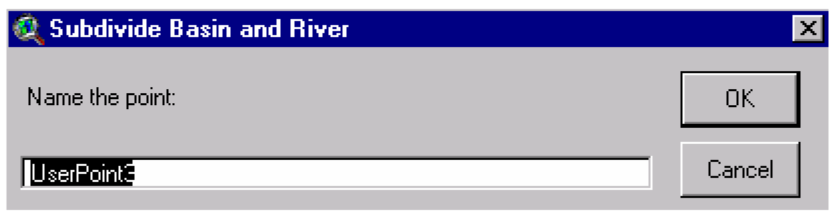


Figure 7–13. Default name of new outlet.

The result of the operation is shown in Figure 7–14. A new subbasin is created and a new blue or dark stream segment is also created from the specified point to the existing stream. Where the two streams meet, a point is created for reference information. The existing and new stream segments are not joined together.

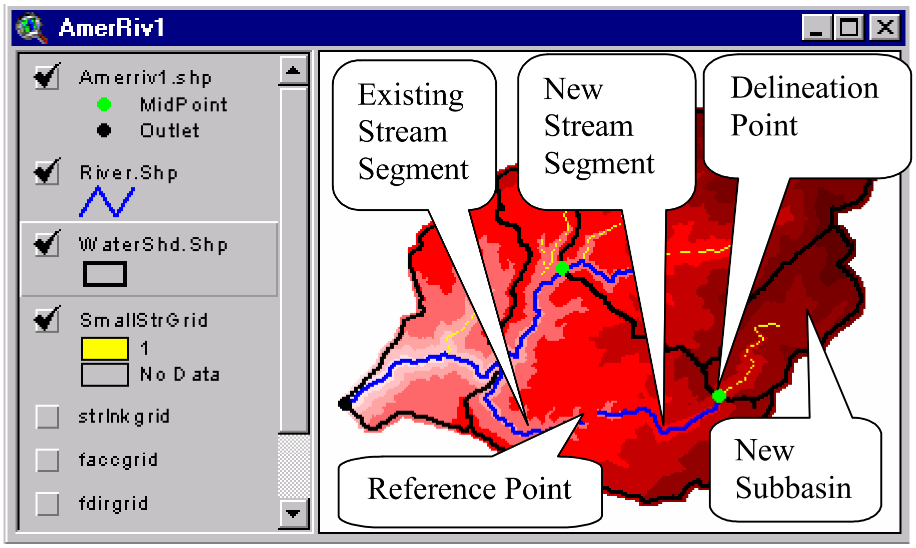


Figure 7–14. New subbasin delineation result.

Method 3: Basin Subdivision on Tributary

Similar to Method 2, the situation in Method 3 involves subbasin delineation on a tributary branch where the stream does not exist. For example in Figure 7–15, the blue or dark stream does not have a tributary stream extending up to the area of interest indicated by the delineation point. Clicking on the delineation point with the **Basin Subdivide** tool delineates a subbasin at the specified point not on the existing stream, traces a new stream segment downstream from the specified point to the existing stream, and splits the existing stream at the confluence.

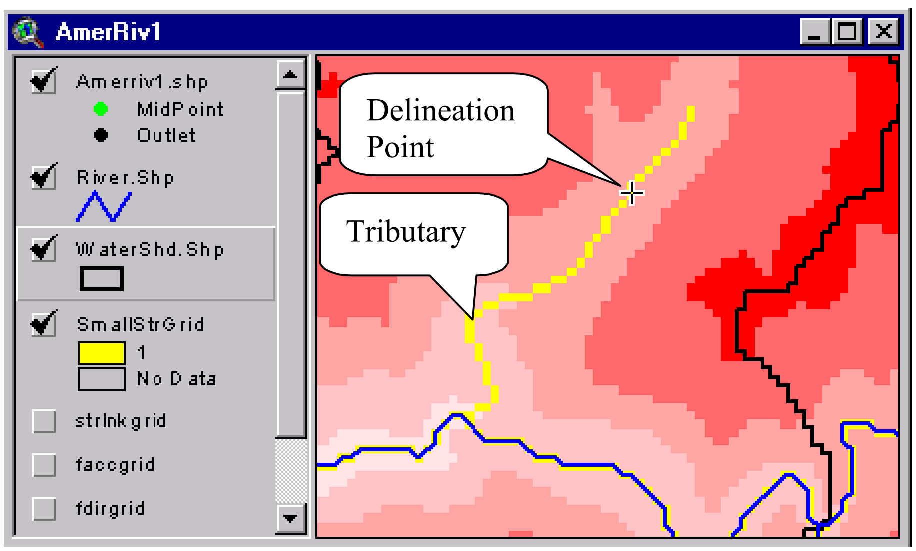


Figure 7–15. Subbasin delineation on a tributary.

- Accept the default name for the outlet and press **OK** as shown in Figure 7–16.

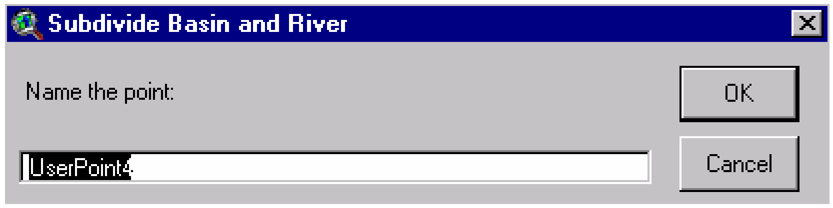


Figure 7–16. Default name for outlet.

The result of the operation is shown in Figure 7–17. A new subbasin is created with the outlet at the user-specified point; and a new stream segment is created from the user-specified point to the existing stream. Where the new stream segment meets the existing stream, a confluence is established by splitting the existing stream into two segments. At the confluence, there are two stream segments flowing in and one segment is flowing out. The existing and new stream segments are not joined.

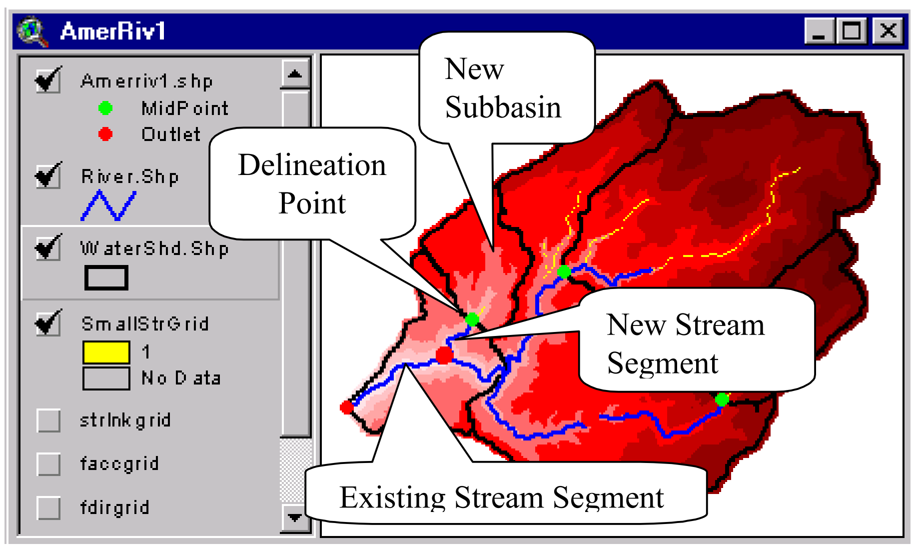


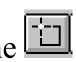
Figure 7–17. Subbasin delineation on a tributary result.

River Merge

When basin merges and subdivisions are performed, stream segments are often created. As an example, the basin subdivision with method 2 created a stream segment that extends from the existing stream to the user-specified basin outlet as shown in Figure 7–18. The point shown in the figure illustrates that the two segments are not joined together. From a hydrologic perspective, the two segments are considered as routing reaches.

If the user intends to model routing with multiple reaches, the user will need to develop routing parameters for both reaches. However, if the user intends to model the routing with a single reach, then the user will need to merge both stream segments. The capability to route the hydrograph through multiple reaches is supported in HMS. The issue here is to raise awareness on modeling techniques options.

Steps

- Activate the "River.Shp".
- Select the two stream segments with the  (**Select**) tool.
- Select **Basin Processing ⇒ River Merge**.
- The selected stream segments become one segment. The reference point is not deleted.

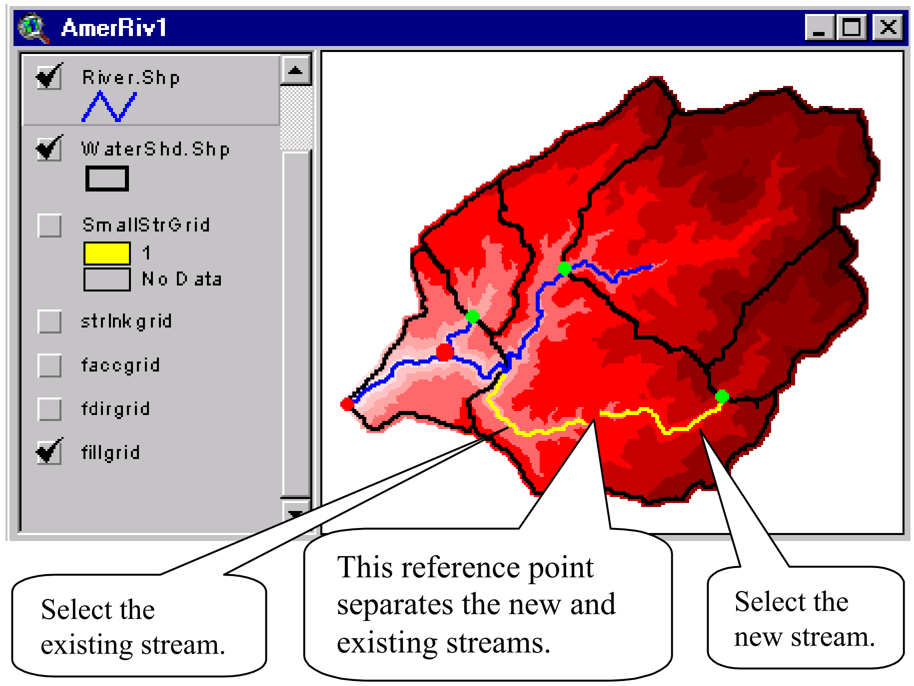


Figure 7–18. River merge.

River Profile

The river profile tool provides information on slopes and grade breaks that can be used to delineate subbasins. The river profile is created by extracting elevation values from the terrain model along the stream. Creating the river profile can be performed using two methods: **River Profile** menu item or the (**Profile**) tool.

Method 1: River Profile menu item

Steps

- While in the **ProjView** document, activate the "River.Shp" theme.
- Select one or several contiguous stream segments shown in Figure 7–18 with the (**Select**) tool.
- Select **Basin Processing** ⇒ **River Profile**.

Method 2: Profile Tool

Steps

- Activate the "River.Shp" theme.
- Select the (**Profile**) tool and view the tool tip for directions as shown in Figure 7–19.

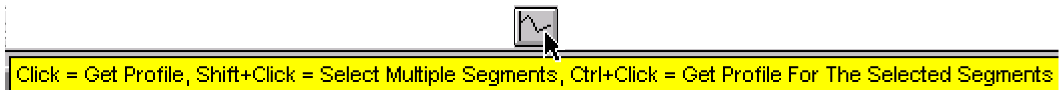


Figure 7–19. Profile tool.

- Click on the stream segment on the map to get the profile as shown in Figure 7–20.

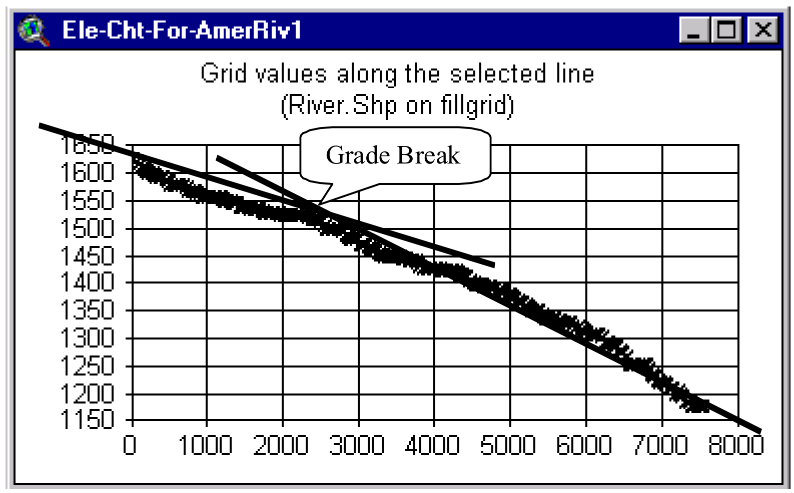


Figure 7–20. Stream profile.

The user can to subdivide a basin based on a grade break as shown in Figure 7–20.

Steps

- Select the  (**Profile Subdivide**) tool when the stream profile chart is active and view the tool tip for directions as shown in Figure 7–21.

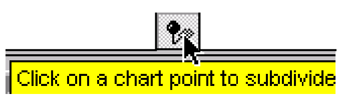


Figure 7–21. Profile subdivide tool.

- Click on the chart approximately at the grade break as shown in Figure 7–22.

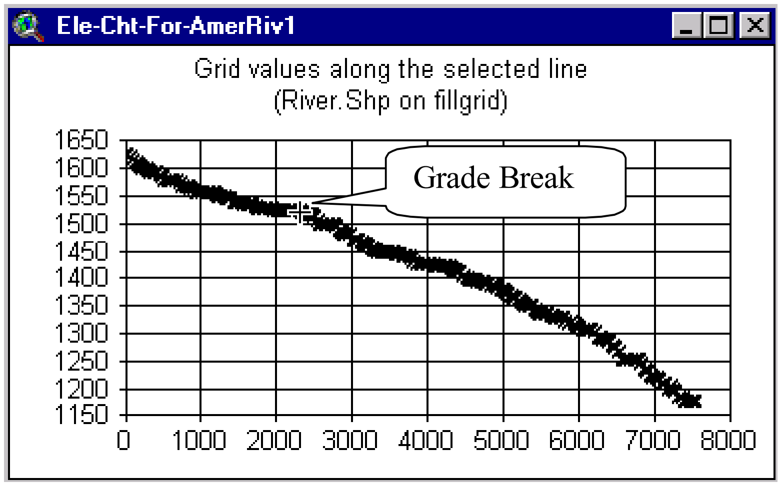
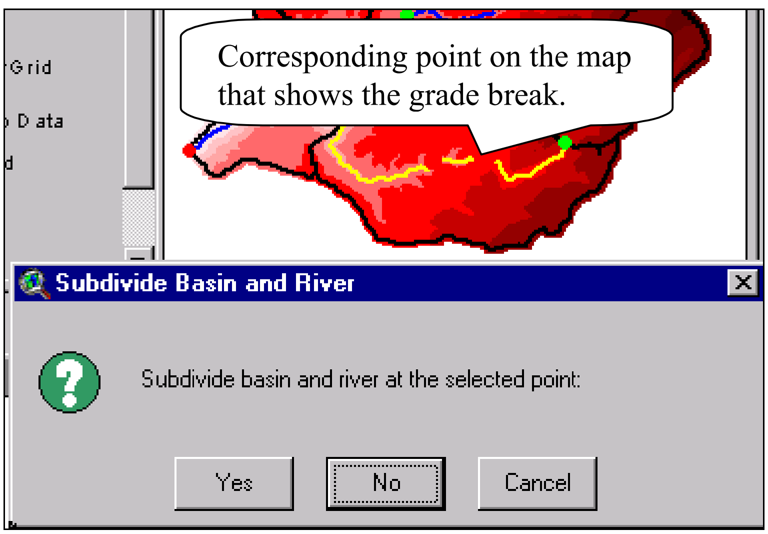


Figure 7–22. Stream profile base on a stream.

- Watch the corresponding point that the user clicked as it blinks on the map display.
- Inspect the result and accept it by clicking **Yes**.



- Press **OK** to accept the default name for the outlet as shown in Figure 7–23.

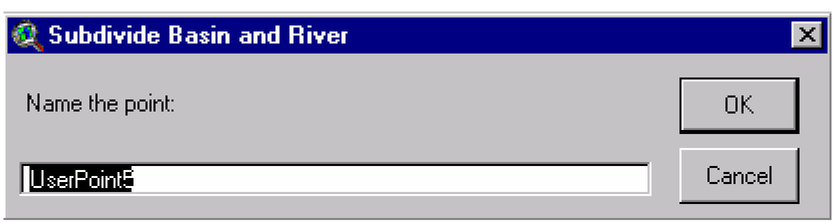


Figure 7–23. Default name for outlet.

The result of the basin subdivision is shown in Figure 7–24.

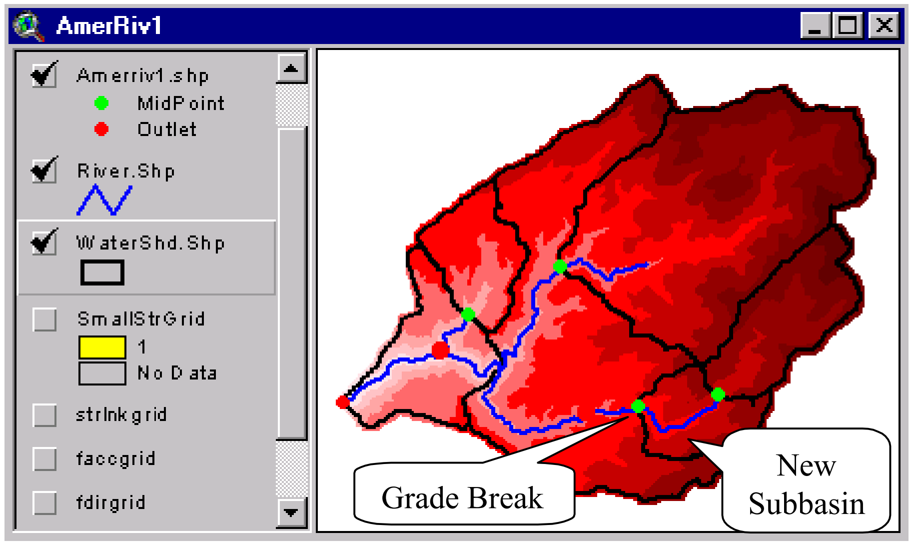
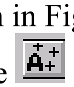


Figure 7–24. Basin subdivision from a profile.

Split Basins at Confluences

The **Split Basins at Confluences** menu item allows the user to subdivide a basin at a confluence. For the situation shown in Figure 7–25, the menu item should be used instead of the interactive  (**Basin Subdivide**) tool.

Rules!

- Only one basin can be selected for each operation.
- This menu item can be used with a basin having multiple confluences.

Steps

- Activate the “WaterShp.shp” theme on the ***ProjView*** document.
- Select the basin containing the confluence as shown in Figure 7–25.

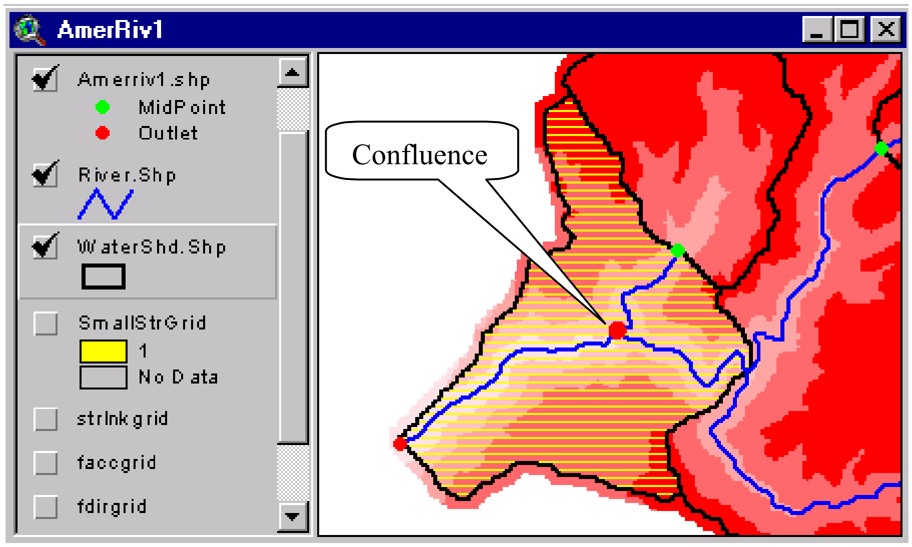


Figure 7–25. Subdivide basin at confluences.

- Select **Basin Processing** ⇒ **Split Basin at Confluences** as shown in Figure 7–26.

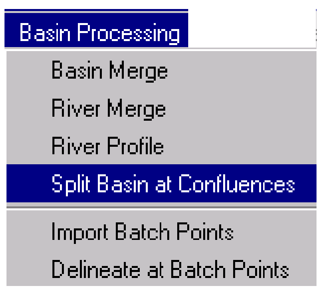


Figure 7–26. Split Basin at Confluences menu item.

The operation creates three subbasins as shown in Figure 7–27. One basin for each stream segments.

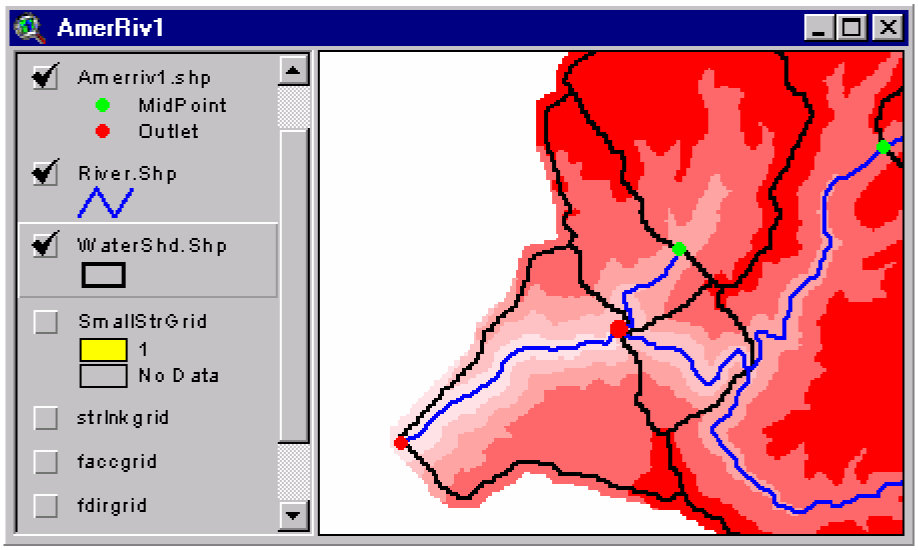
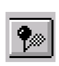


Figure 7–27. Basin subdivided at confluence.

Batch Subbasin Delineation

Subbasin delineation may also be accomplished through batch processing; this requires that a point shapefile be created which contains the desired outlet locations. It is important to recognize that the batch subbasin delineation operates on the existing delineations by further delineating with the new outlet points in the shapefile. To abandon the existing delineation, the user can batch process the outlet locations and follow with subbasin revisions to remove existing delineations. There are two methods for creating to create a point shapefile for batch subbasin delineation.

Method 1: Batch Point Tool

Apply the  (**Batch Point**) tool to place points on the map display and a point shapefile named “Batchpnt.shp” is created. To use this tool effectively, turn on the StrLnkGrid or SmallStrGrid themes, zoom in until the grid cell is visible, and place the point within the grid cell.

Rules!

- The point should be located within the grid cell that has an existing stream.

Steps

- Place four batch points in the order shown in Figure 7–28.
- Zoom in to the batch points to specify the batch points on the existing stream cells.

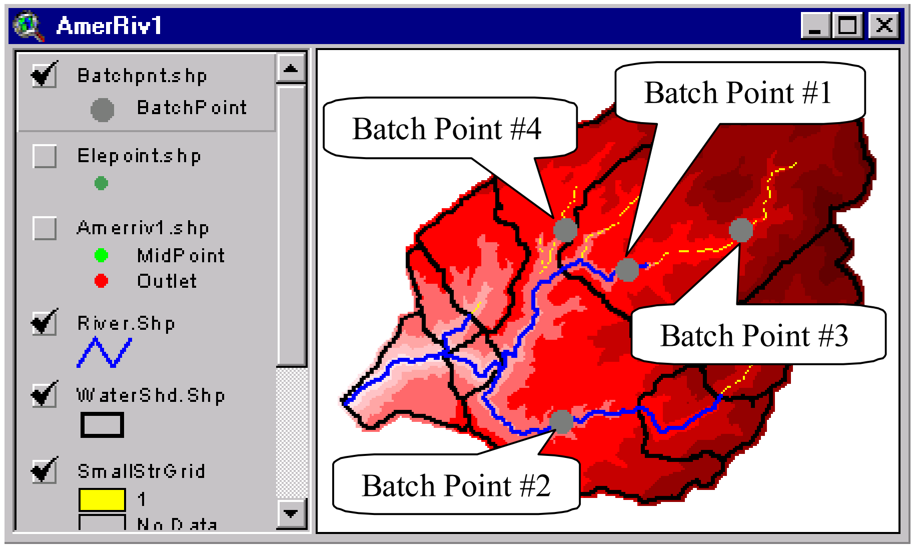


Figure 7–28. Subbasin delineation at batch points.

- Click on the grid cell to specify batch point #1 as shown in Figure 7–29. Notice that batch point #1 follows the rule concerning the presence of the existing stream.

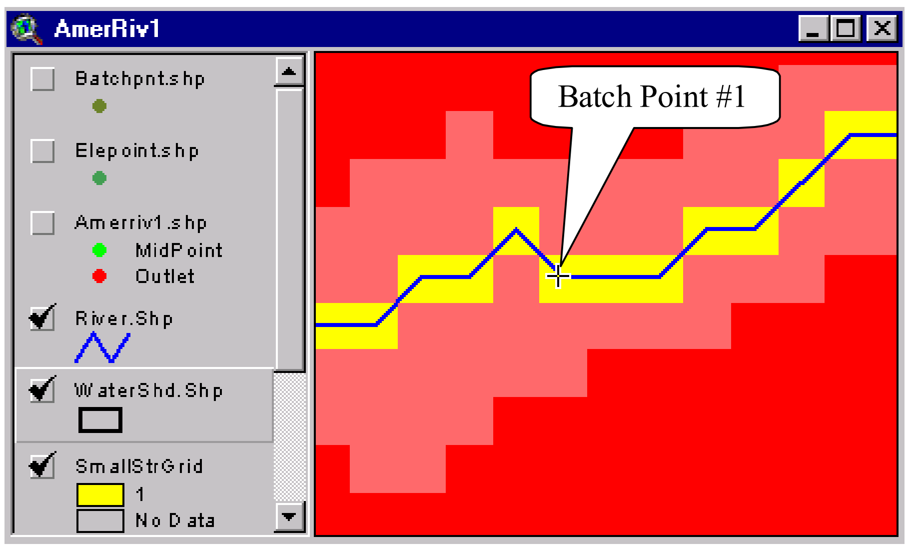


Figure 7–29. Batch Point #1 specification.

- Accept the default name as “BatchPoint1” as shown Figure 7–30 by clicking **OK**.

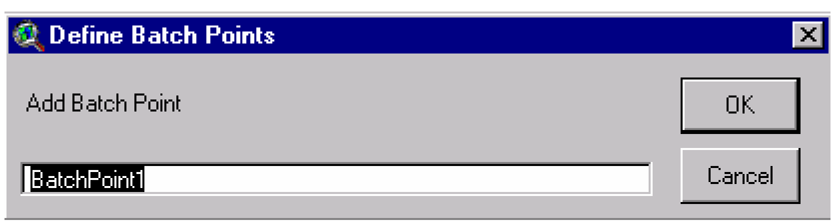


Figure 7–30. Default name for Batch Point #1 outlet.

- Locate Batch Point #2 as shown in Figure 7–32 with same procedure as before.

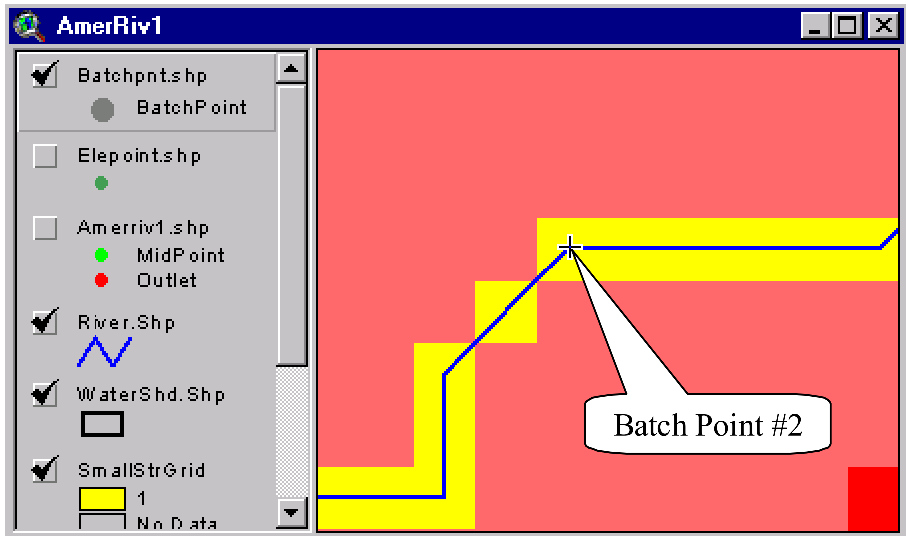


Figure 7–31. Batch Point #2 specification.

- Accept the default name as BatchPoint2 as shown in Figure 7–32. Press **OK**.

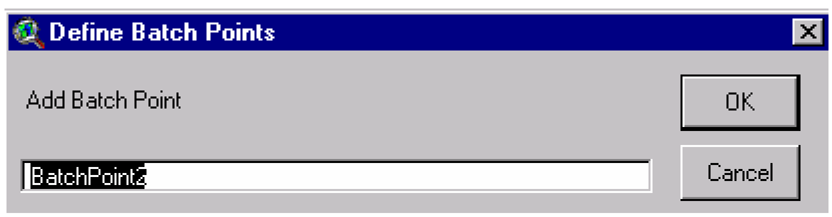
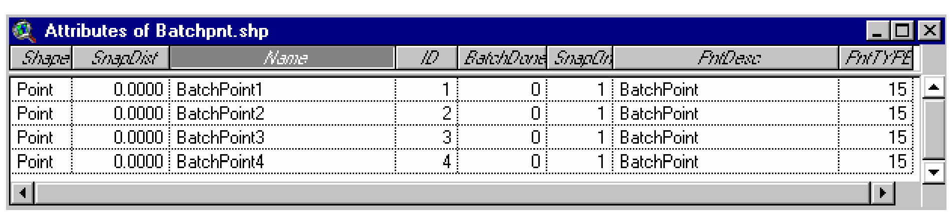


Figure 7–32. Default name for Batch Point #2 outlet.

- Locate Batch Point #3 and #4. *Notice that Batch Point #3 and #4 violate the rule concerning the presence of the existing stream.*

The batch-point shapefile contains the essential fields shown in Figure 7–33. These fields provide instructions and information for the programs to perform batch subbasin delineation. The field headings and values are discussed in Table 7-1.


Attributes of Batchpnt.shp

Shape	SnapDist	Name	ID	BatchDone	SnapOn	PntDesc	PntTYPE
Point	0.0000	BatchPoint1	1	0	1	BatchPoint	15
Point	0.0000	BatchPoint2	2	0	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	0	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	0	1	BatchPoint	15

Figure 7–33. Batch-Point attribute table.

Table 7-1. Batch Point Fields, Descriptions, and Values.

Field Headings	Descriptions	Possible Values
Shape	Standard ArcView requirement for noting the types (point, line, polygon) of shapefiles.	Point
SnapDist	The distance between the user-specified point to the final outlet point for subbasin delineation.	Real values in map units.
Name	The name of the outlet location (can be edited by the user).	Text
ID	An identifier for tracking the number of points generated.	Integer values
BatchDone	An indicator if batch processing has been performed for the points.	"0" indicates that batch processing has not been performed. "1" indicates that batch processing has been performed. "-1" indicates that batch processing has been performed unsuccessfully.
SnapOn	A flag that can be set to enable snapping of the user-specified point to the stream.	"1" enables snapping as a default. "0" can be entered by the user to disable snapping.
PntDesc	A text description for the user-specified point.	"Batchpoint"
PntTYPE	A numerical value that corresponds to the PntDesc.	"15" corresponds to the batch point type.

- To process the batch points in the "Batchpnt.shp", select **Basin Process ⇒ Delineate at Batch Points** as shown in Figure 7–34.

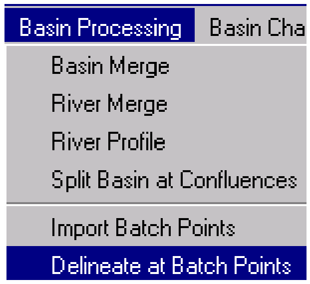


Figure 7–34. Delineate at Batch Points menu item.

The result of the batch delineation is shown in Figure 7–35. Notice that BatchPoint #1 and #2 have been successfully delineated. However, BatchPoint #3 and #4 did not result in subbasin delineation because their placements do not comply with the rules.

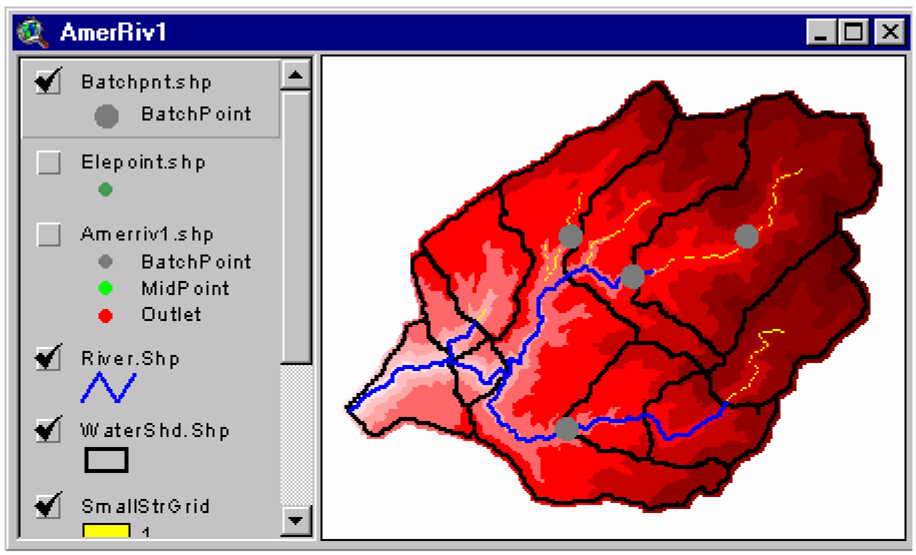
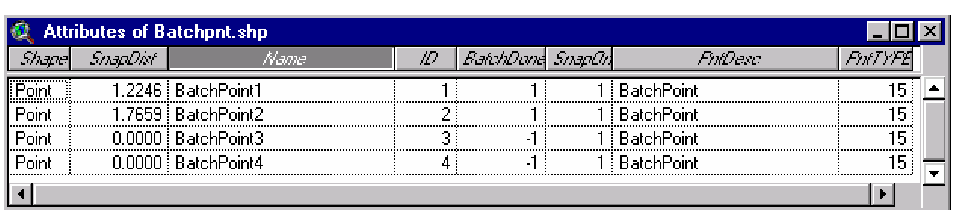


Figure 7–35. Batch points delineation results.

The attribute table of the "Batchpnt.shp" also shows a negative confirmation for subbasin delineation at Batch Points #3 and #4. Notice the "-1" under the BatchDone field heading in Figure 7–36.



Attributes of Batchpnt.shp

Shape	SnapDist	Name	ID	BatchDone	SnapOn	PntDesc	PntTYPE
Point	1.2246	BatchPoint1	1	1	1	BatchPoint	15
Point	1.7659	BatchPoint2	2	1	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	-1	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	-1	1	BatchPoint	15

Figure 7–36. Batch point attribute table after subbasin delineation.

Method 2: Import Batch Points

This method is useful when the user has existing point shapefiles containing points of interest, streamflow gage locations, and/or previous hydrologic model outlet specifications. The user can import the existing point shapefile to prepare a batch point shapefile.

As an example, the streamflow gage locations contained in “Gage.shp” as shown in Figure 7–37 can be imported into “Batchpnt.Shp”.

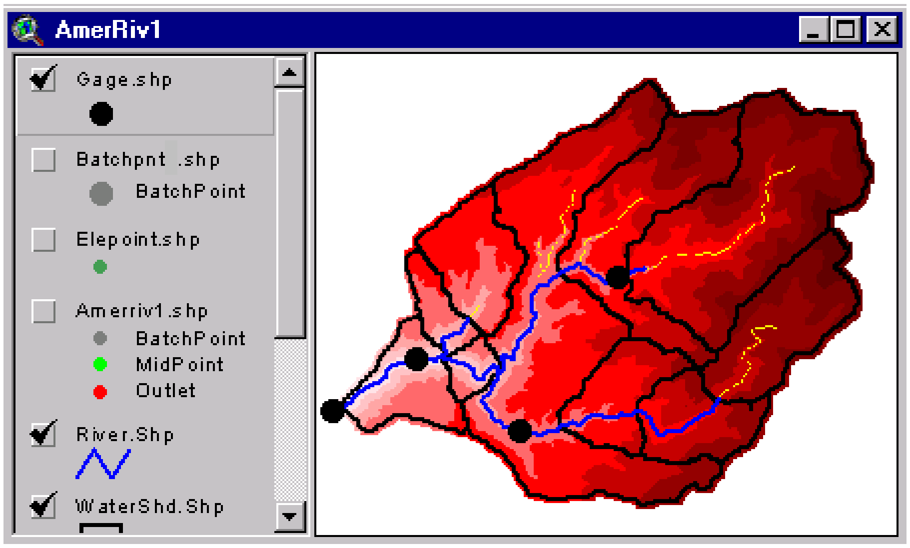


Figure 7–37. Import batch points.

Steps

- Select the **Basin Processing ⇒ Import Batch Points** as shown in Figure 7–38.

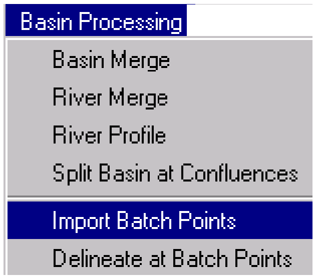


Figure 7–38. Import batch points menu item.

- Select the “Gage.shp” theme as the input from the drop down menu as shown in Figure 7–39. Press **OK**.

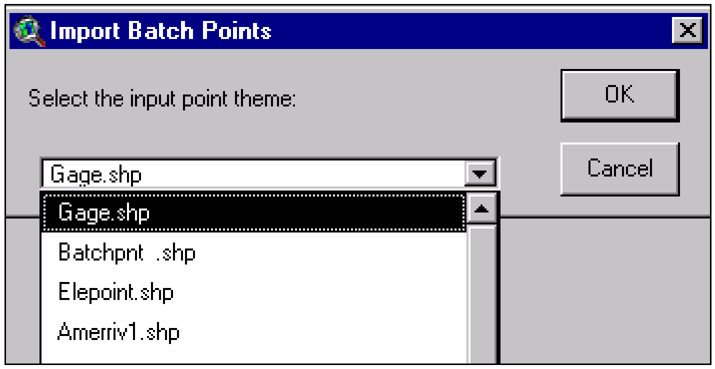


Figure 7–39. Input point theme selection.

- With the field names available in the “Gage.shp” theme, select the gage number (“Gage_no”) field to be imported in for the “Name” field in the “Batchpnt.shp” theme as shown in Figure 7–40. The “Gage_no” field is a suitable choice because it has unique values. Press **OK**.

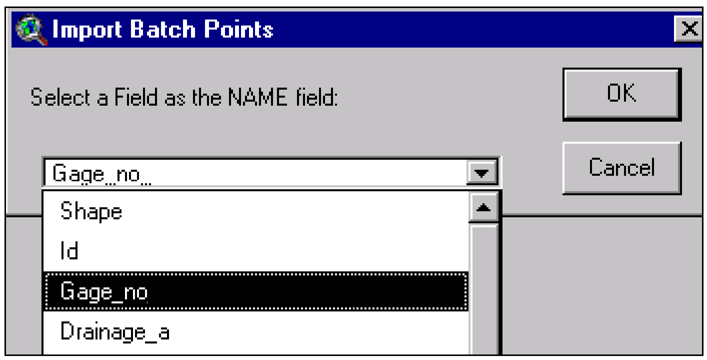


Figure 7–40. Field selection as name field.

- Press **Yes** on Figure 7–41 to enable snapping.

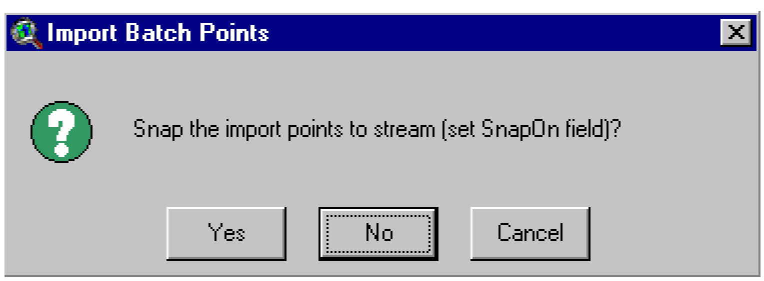


Figure 7–41. Snap options.

The result indicates that the four gages in the “Gage.shp” theme have been imported into the “Batchpnt.shp” theme as shown in Figure 7–42. Press **OK**.

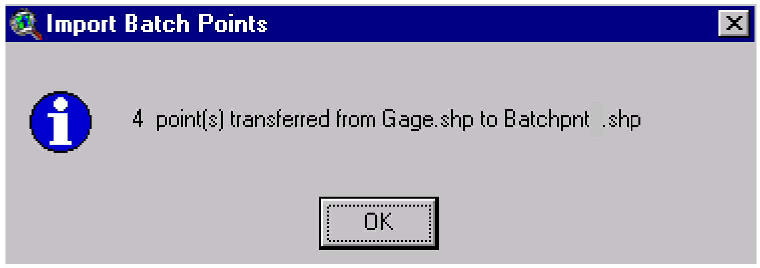


Figure 7–42. Import batch points confirmation.

The "Batchpnt.shp" theme now contains 8 batch points as shown in Figure 7–43. The four recently added batch points are shown in yellow (if this document is in color) or white (if this document is in black and white) in Figure 7–44.

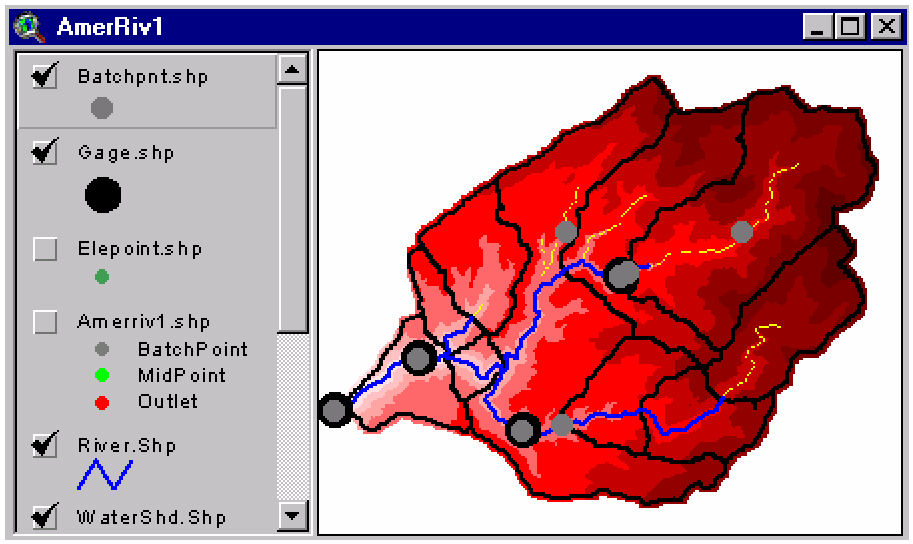


Figure 7–43. Import batch points result.

.

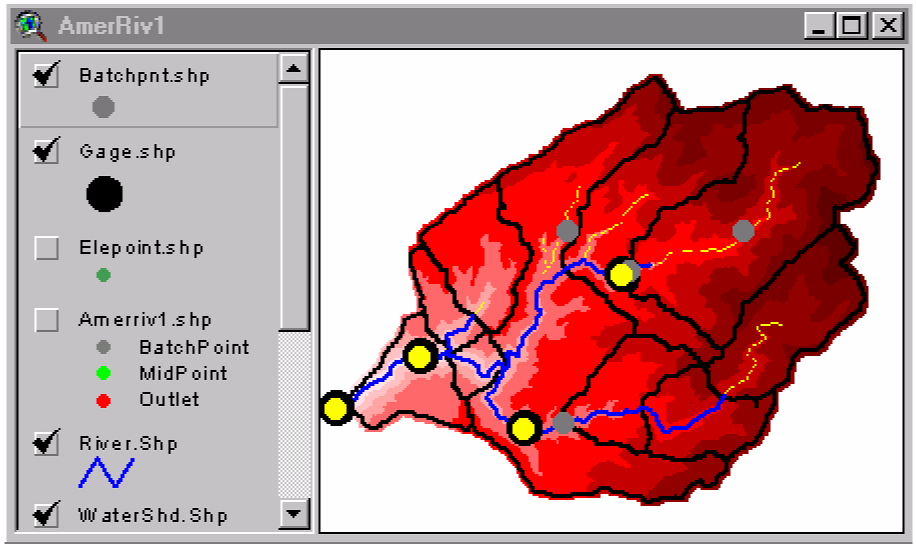


Figure 7–44. Imported batch points in yellow or white.

As shown in Figure 7–45, the “BatchDone” flags are set to “0” to indicate that the user can re-run the **Delineate at Batch Points** menu item to delineate subbasins at the four newly added batch points.

Attributes of Batchpnt.shp

Shape	Snapdist	Name	Id	Batchdone	Snapon	Pntdesc	Pnttype
Point	1.2246	BatchPoint1	1	1	1	BatchPoint	15
Point	1.7659	BatchPoint2	2	1	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	-1	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	-1	1	BatchPoint	15
Point	0.0000	Lower Trib # 1	0	0	1	BatchPoint	15
Point	0.0000	South Trib #1	0	0	1	BatchPoint	15
Point	0.0000	North Trib #1	0	0	1	BatchPoint	15
Point	0.0000	Lower Trib #2	0	0	1	BatchPoint	15

These batch points will be processed if batch delineation is performed.

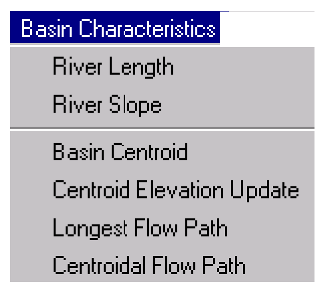
Figure 7–45. Batch-Points attribute table.

CHAPTER 8

Stream and Watershed Characteristics

HEC-GeoHMS computes several topographic characteristics of streams and watersheds. These characteristics are useful for comparing of basins and for estimating hydrologic parameters. The user should compare and verify the physical characteristics with published information prior to estimating the hydrologic parameters. The stream and watershed physical characteristics are stored in attribute tables, which can be exported for use with a spreadsheet and other programs. When more experience is gained from working with GIS data, initial estimates of hydrologic parameters will be provided in addition to the physical characteristics.

This chapter will discuss the tools for extracting topographic characteristics of the watershed and river that are available in the ***ProjView*** GUI under the **Basin Characteristics** menu.



The physical characteristics extracted for the streams and subbasins are summarized in Table 8-1. Below is an outline of Chapter 8.

Contents

- River Length
- River Slope
- Basin Centroid
- Longest Flow Path
- Centroidal Flow Path

Table 8-1. Physical Characteristics of streams and subbasins.

	Physical Characteristics	**Attribute Table Heading**
Stream ***(River.Shp)***	Length	Riv_Length
	Upstream elevation	US_Elv
	Downstream elevation	DS_Elv
	Slope	Slp_Endpt
	Stream Profile	N/A (See Chart)
Watershed ***(WaterShd.shp)***	Area	Area
	Centroid Location	N/A (See WshCentroid.shp)
	Centroid Elevation	Elevation
	Longest Flow Path	N/A (See LongestFP.shp)
	Longest Flow Length	Longest_FL
	Upstream elevation	USElv
	Downstream elevation	DSElv
	Slope between endpoints	Slp_Endpt
	Slope between 10% - 85%	Slp_1085
	Centroidal Path	N/A (See CentoidalFP.shp)
	Centroidal Length	CentroidalFL

The following sections illustrate the process outlined under the **Basin Characteristics** menu on the ***ProjView*** GUI to extract the stream and subbasin characteristics.

River Length

This step computes the river length for all subbains and routing reaches in the “River.shp” file as shown in Figure 8–1. The initial attribute table the “River.shp” theme is shown in Figure 8–2. The computed river length is added as an attribute to the existing “River.shp” attribute table as shown in Figure 8–2. The length column in the attribute table is computed roughly from the raster representation of the stream. This step will compute the river length more accurately with the vector representation of the stream.

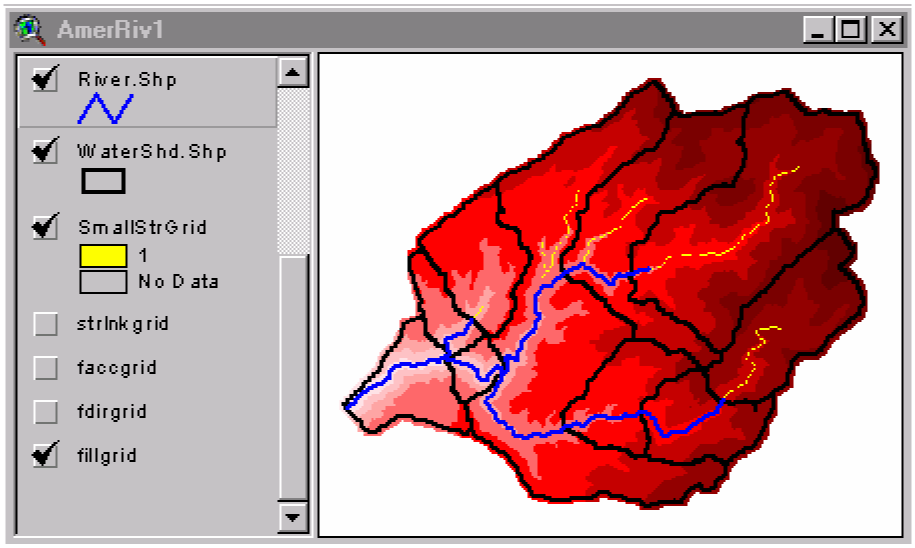


Figure 8–1. River shapefile.

Attributes of River.Shp

Shape	Arcid	Grid_code	From_node	To_node	Wshld	Rivid	Length
PolyLine	1	2	1	2	2	2	3190
PolyLine	2	4	2	3	9	4	2749
PolyLine	3	2	4	2	2	6	3089
PolyLine	0	2	0	0	5	7	1913
PolyLine	0	0	0	0	6	8	64
PolyLine	0	0	0	0	11	12	1853
PolyLine	0	0	0	0	7	11	45
PolyLine	0	0	0	0	10	13	1261
PolyLine	0	2	0	0	8	14	2480
PolyLine	0	2	0	0	12	15	455
PolyLine	0	2	0	0	13	16	1953

Figure 8–2. Initial attribute table for the river shapefile.

Steps

- Select **Basin Charateristics** ⇒ **River Length** as shown in Figure 8–3.

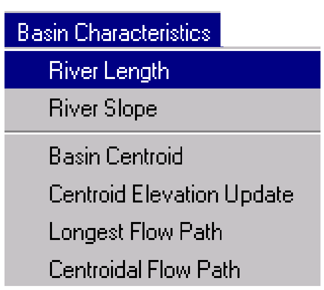
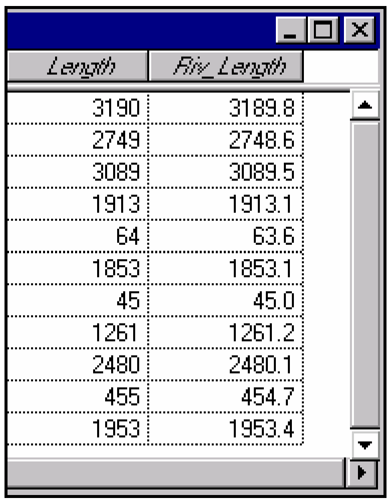


Figure 8–3. River Length menu item.

- Press **OK** at the message box shown in Figure 8–4.

Figure 8–4. River length confirmation.

The river length computation results in the "Riv_Length" column being added to the attribute table, as shown in Figure 8–5. "Riv_Length" is in the map units, which are meters in this example.



Length	Riv_Length
3190	3189.8
2749	2748.6
3089	3089.5
1913	1913.1
64	63.6
1853	1853.1
45	45.0
1261	1261.2
2480	2480.1
455	454.7
1953	1953.4

Figure 8–5. Populated attribute table with river length.

River Slope

This step extracts the upstream and downstream elevation of a river reach and computes the slope. The upstream and downstream elevation and slope are added as columns to the "River.shp" attribute table with the column headings: "us_Elv", "ds_Elv", and "Slp_Endpt".

Steps

- Select **Basin Characteristics ⇒ River Slope** as shown in Figure 8–6.

Figure 8–6. River Slope menu item

- Select **meters** for the **DEM Vertical Units** as shown Figure 8–7 because this terrain data has vertical units in meters. Sometimes, the terrain data has the horizontal units of meters and the vertical units in feet or decimeters. Press **OK**.

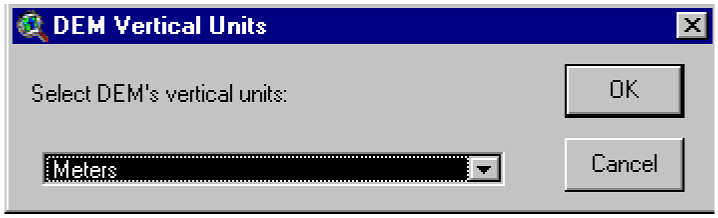


Figure 8–7. DEM's vertical units.

- Press **OK** at the confirmation as shown in Figure 8–8.

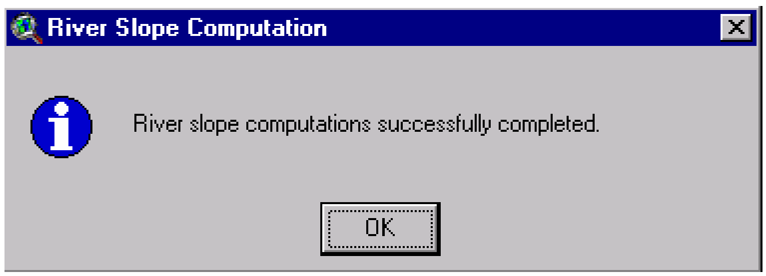
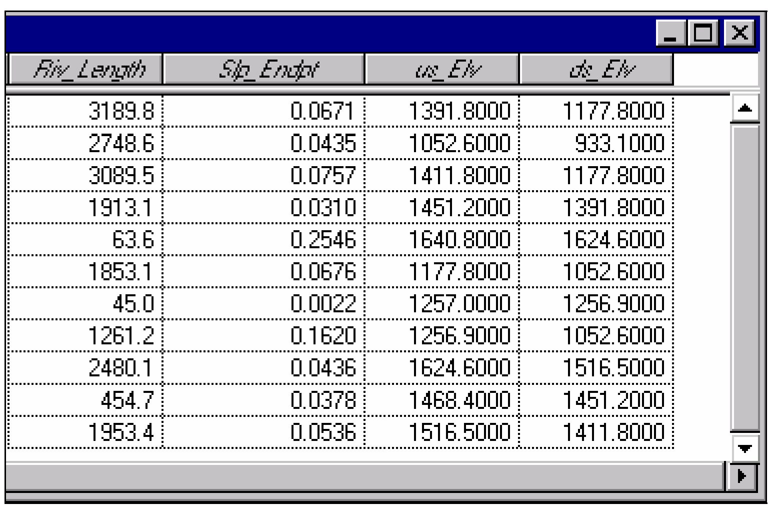


Figure 8–8. River slope confirmation.

The river slope computation adds the upstream and downstream elevations and slope to the existing attribute table as shown in Figure 8–9.



Riv_Length	Slp_Endpt	us_Elv	ds_Elv
3189.8	0.0671	1391.8000	1177.8000
2748.6	0.0435	1052.6000	933.1000
3089.5	0.0757	1411.8000	1177.8000
1913.1	0.0310	1451.2000	1391.8000
63.6	0.2546	1640.8000	1624.6000
1853.1	0.0676	1177.8000	1052.6000
45.0	0.0022	1257.0000	1256.9000
1261.2	0.1620	1256.9000	1052.6000
2480.1	0.0436	1624.6000	1516.5000
454.7	0.0378	1468.4000	1451.2000
1953.4	0.0536	1516.5000	1411.8000

Figure 8–9. Populated attribute table with river slope.

Basin Centroid

The basin centroid location can be estimated in four ways. The engineering approach to locating the centroid with momentum calculations around the X- and Y-axis is not implemented here because the centroid may be outside of U-shaped and other odd-shaped subbasins. The four methods of estimating the centroid are the bounding box, ellipse, flow path, and user-specified. The basin centroid menu item can operate on all of the subbasins or on selected subbasin.

Steps

- Select **Basin Charateristics ⇒ Basin Centroid,** as shown in Figure 8–10.

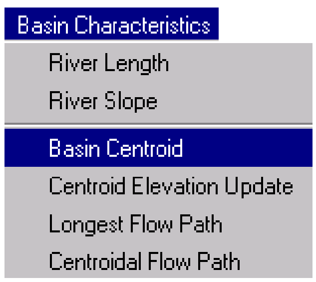


Figure 8–10. Basin Centroid menu item.

- Confirm the three inputs and one output in the operation as shown in Figure 8–11. Press **OK**.

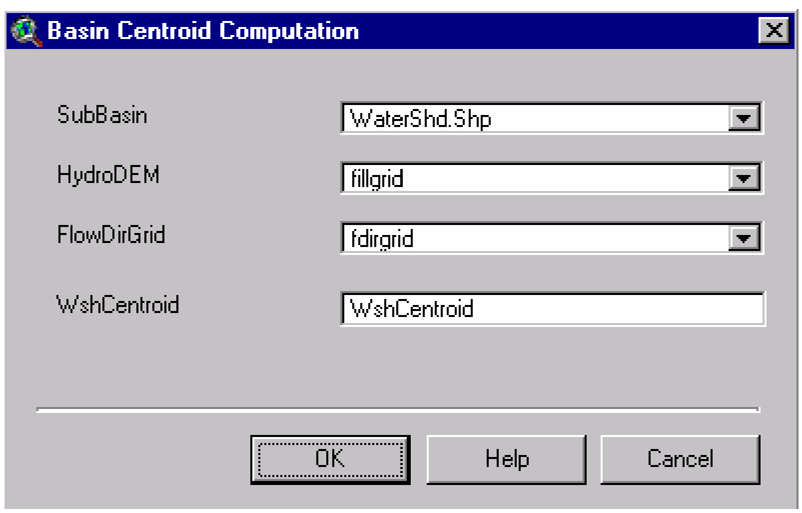


Figure 8–11. Basin centroid input and output files.

Method 1: Bounding Box

The Bounding Box method encompasses a subbasin with a rectangular box and approximates the centroid as the box center. This method works really fast but may not be applicable with many basin shapes.

- Select **Bounding Box Method** from the dropdown menu. Press **OK**.

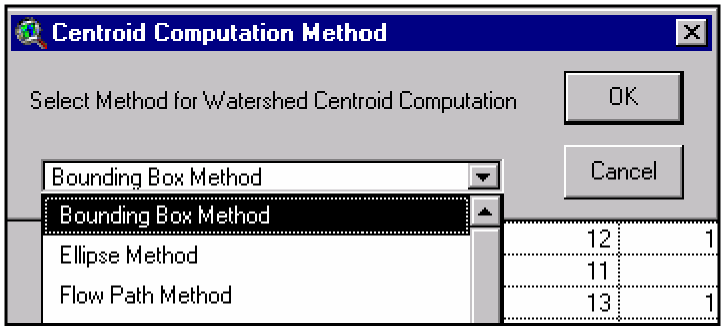


Figure 8–12. Centroid computation methods.

- Press OK at the confirmation as shown in Figure 8–13.

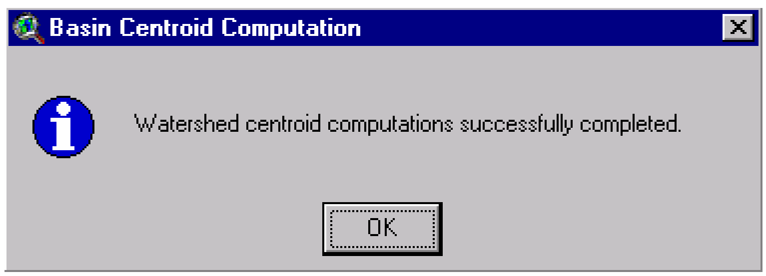


Figure 8–13. Centroid confirmation.

The result of the operation is a point shapefile, "WshCentroid.Shp", showing the basin centroids as shown in Figure 8–14.

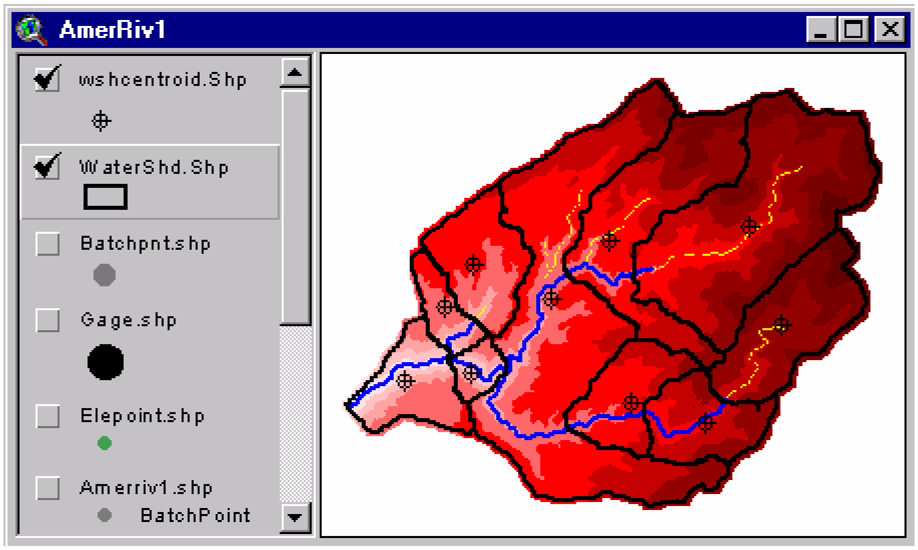


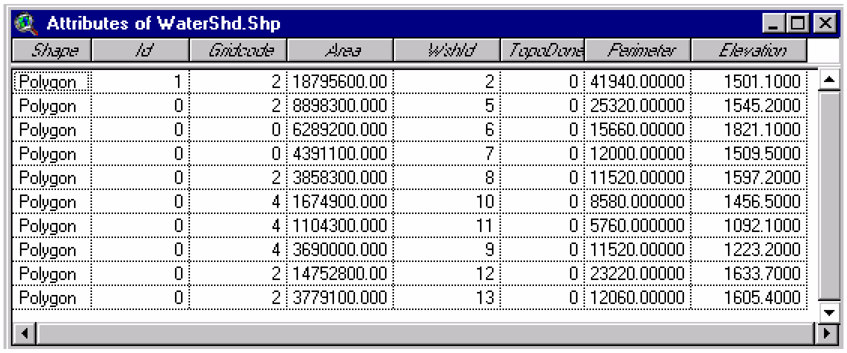
Figure 8–14. Basin centroid results.

The basin centroid elevation is computed and stored in the attribute table as shown in Figure 8–15. In addition, the basin centroid elevation is also stored in the "WaterShd.shp" attribute table as shown in Figure 8–16.

Attributes of wshcentroid.Shp

Shape	Wshld	Elevation
Point	2	1501.1000
Point	5	1545.2000
Point	6	1821.1000
Point	7	1509.5000
Point	8	1597.2000
Point	10	1456.5000
Point	11	1092.1000
Point	9	1223.2000
Point	12	1633.7000
Point	13	1605.4000

Figure 8–15. Basin centroid attribute table.



Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1633.7000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–16. Watershed attribute table with centroidal elevation.

Method 2: Ellipse Method

The Ellipse method encompasses a subbasin with an ellipse and approximates the centroid as the ellipse center. This method is slower than the bounding box, but it generally produces more desirable estimates of the basin centroids.

Rules!

- This method works only on subbasins of 2,000,000 cells or less.

Steps

- Activate the “WaterShd.Shp” theme.
- Select the subbasin as shown in Figure 8–17.

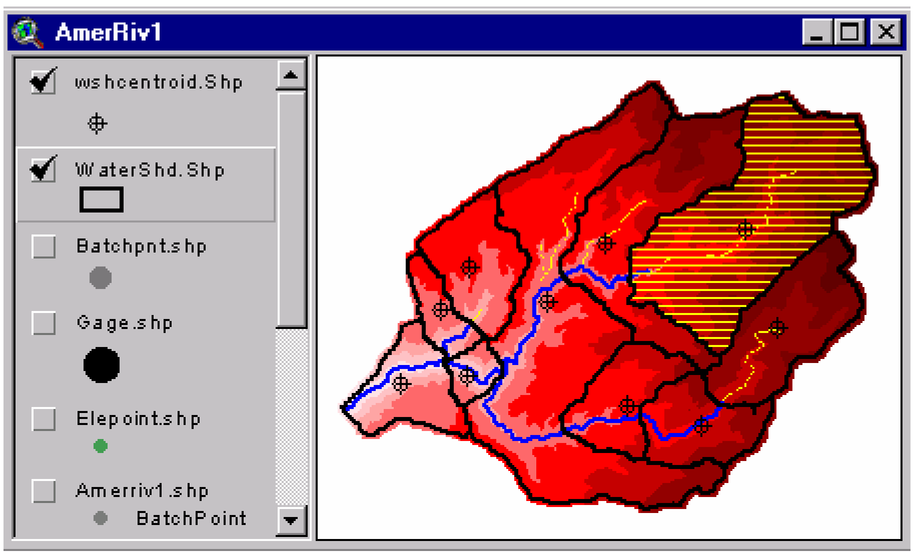
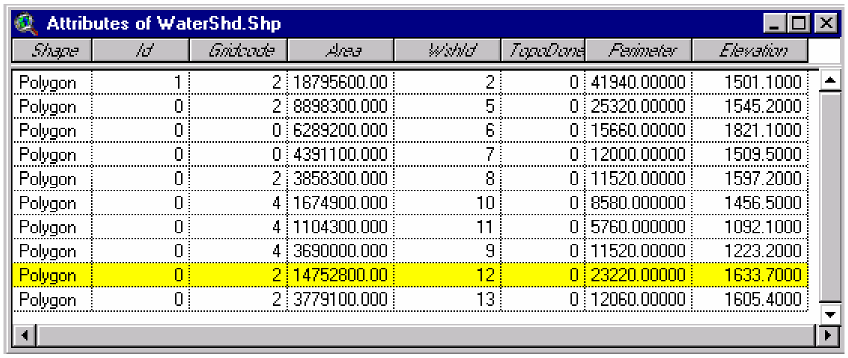


Figure 8–17. Basin centroid with ellipse method.

- Open the “WaterShd.Shp” attribute table. The highlighted row belongs to the selected subbasin. Notice that the centroid elevation is 1633.7.



Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1633.7000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–18. Watershed attribute table with one subbasin selected.

- Select the **Basin Charateristics ⇒ Basin Centroid**
- Select the **Ellipse Method** from the dropdown menu as shown in Figure 8–19. Press **OK**.

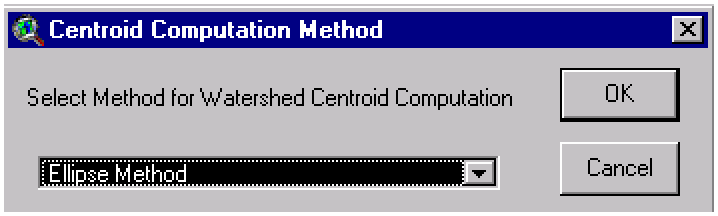


Figure 8–19. Basin centroid with ellipse method selected.

A new centroid is re-computed for the selected subbasin as shown in Figure 8–20. The ellipse method produces a centroid that is adjusted slightly compared to the bounding box method. The elevation of the centroid is automatically updated in the “Wshcentroid.shp” and “WaterShd.shp” theme attribute tables. The “Watershd.shp” and the attribute table are shown in Figure 8–20 and Figure 8–21.

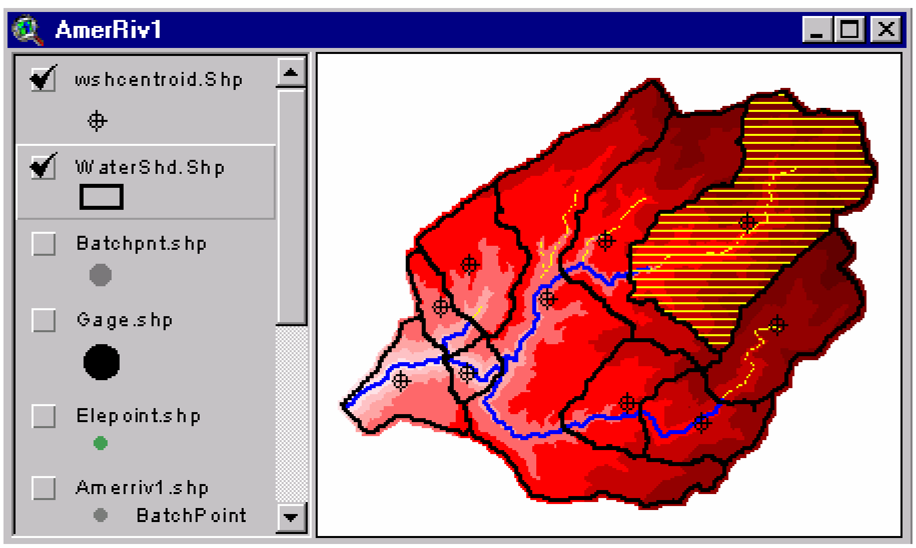


Figure 8–20. Ellipse method basin centroid result.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–21. Centroidal elevation updated in watershed attribute table.

Method 3: Flow Path

The Flow Path method draws the longest flow length for the subbasin and approximates the centroid as the midpoint on the longest flow length.

Steps

- Activate the “WaterShd.Shp” theme.
- Select the subbasin as shown in Figure 8–22.

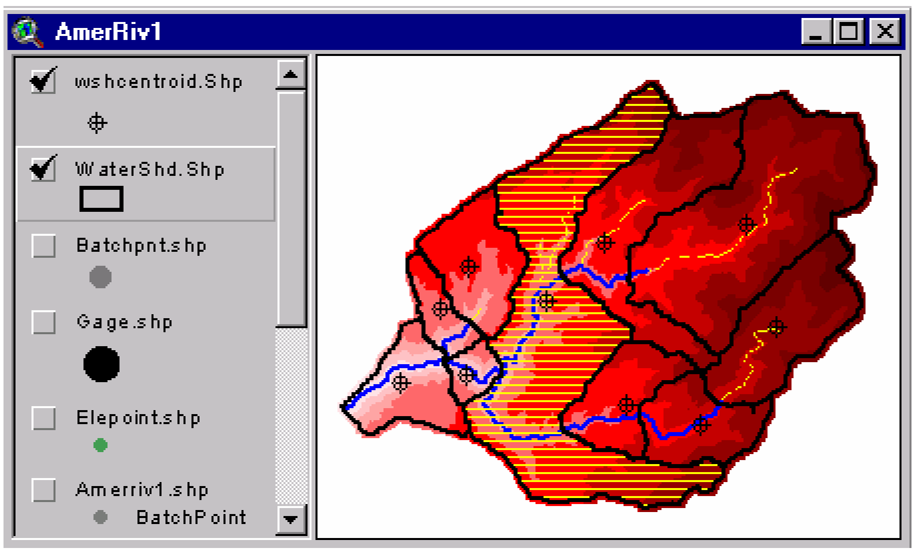


Figure 8–22. Basin centroid with flow path method.

- Select the **Basin Characteristics ⇒ Basin Centroid**
- Select the **Flow Path Method** from the dropdown menu as shown in Figure 8–23. Press **OK**.

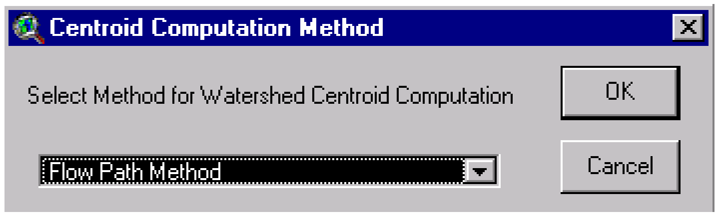


Figure 8–23. Basin centroid with flow path method selected.

Confirm the three inputs and one output in the operation as shown in Figure 8–24. The longest flow path, stored in the "Longestfp.shp" theme, is computed for the selected subbasin. Press **OK**.

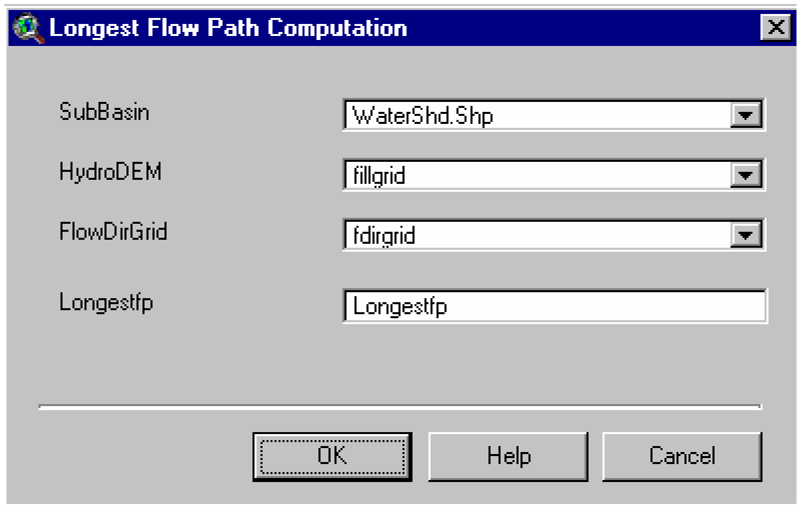


Figure 8–24. Flow path method input and output files.

The results are shown in Figure 8–25. A new centroid is re-computed for the selected subbasin. The elevation of the centroid is automatically updated in the "Wshcentroid.shp" and "Watershd.shp" attribute tables.

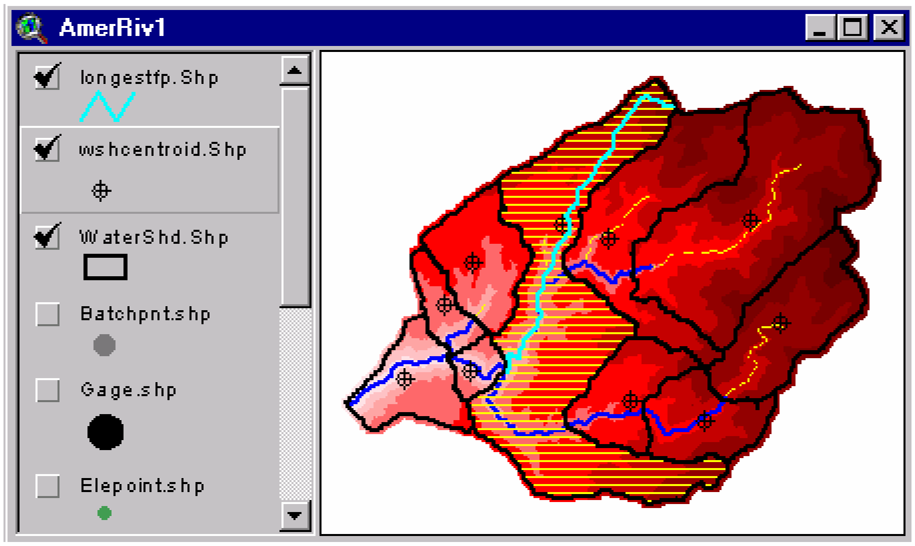


Figure 8–25. Flow Path method basin centroid result.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshid	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–26. Centroidal elevation updated with the Flow Path method.

Method 4: User-Specified Centroid Location

When the three previous methods do not produce satisfactory estimates of the centroid, this method allows to user to move the centroid to any location within the subbasin.

Steps

- Select the subbasin as shown in Figure 8–27.

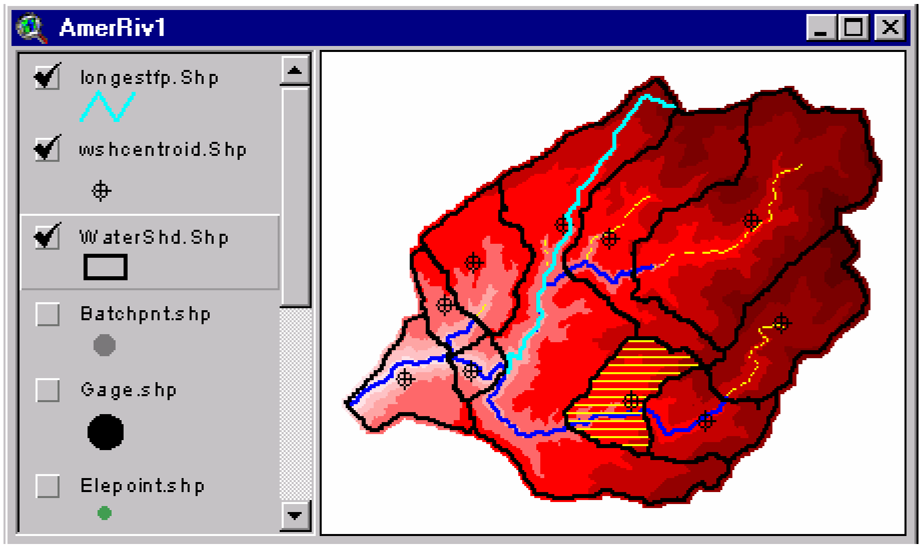


Figure 8–27. Selected subbasin for User-Specified method.

- Zoom in to the selected subbasin as shown in Figure 8–28.
- Open the “WaterShd.Shp” attribute table as shown in Figure 8–29.

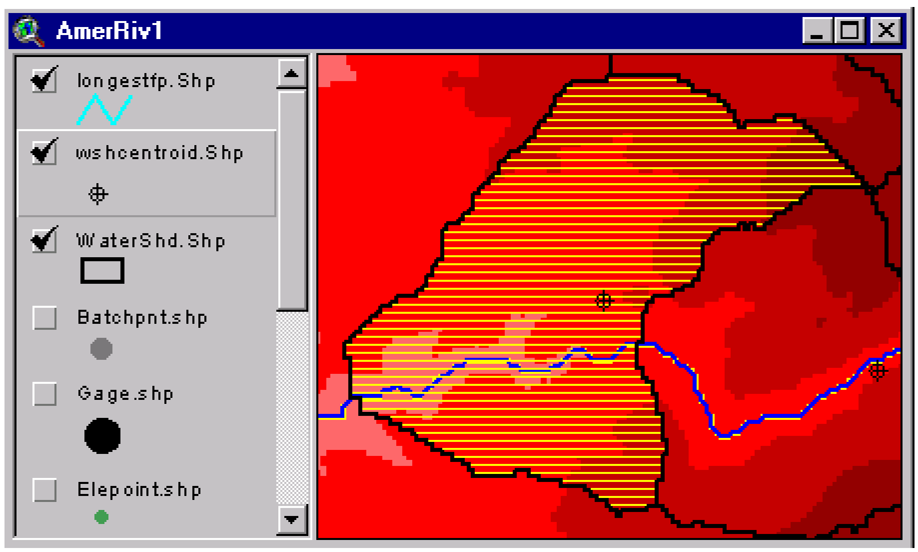
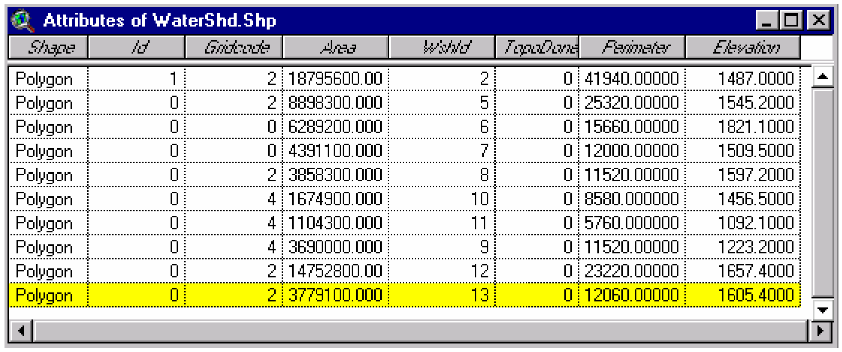


Figure 8–28. Zoom in to the selected subbasin.



Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–29. Watershed attribute table with the selected subbasin.

- Activate the “wshcentroid.shp” theme.
- Select **Theme ⇒ Starting Editing** from the standard ArcView interface as shown in Figure 8–30.

Figure 8–30. Start Editing menu item.

- When the “WshCentroid.Shp” is under editing mode, a dashed box is visible around the check box as shown in Figure 8–31.
- Use the pointer tool and click on the existing centroid.
- The pointer turns into a double arrow.
- Click and drag the centroid to another location as shown in Figure 8–31.

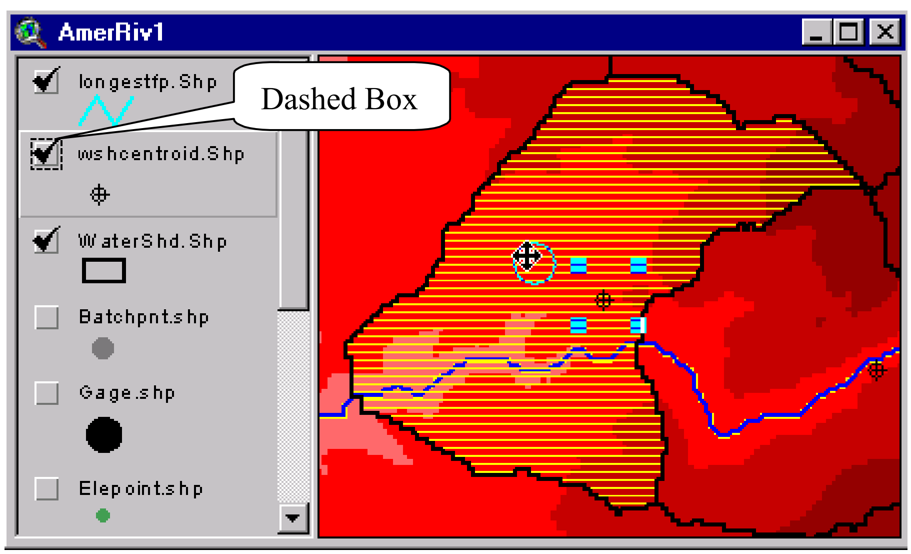


Figure 8–31. User-Specified new basin centroid location.

- To stop editing and save the changes, select **Theme ⇒ Stop Editing** as shown in Figure 8–32.

Figure 8–32. Stop Editing menu item.

After a centroid is moved, the centroid elevation in the “WshCentroid.Shp” and “WaterShd.shp” attribute tables must be updated as shown in Figure 8–33.

- Select **Basin Characteristics ⇒ Centroid Elevation Update**

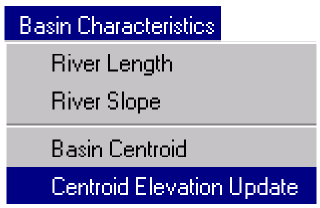


Figure 8–33. Centroid Elevation Update menu item.

The result of the user-specified centroid is shown in Figure 8–34 and elevation updates to the attribute tables of the “WshCentroid.Shp” and “WaterShd.shp” themes are shown in Figure 8–35 and Figure 8–36.

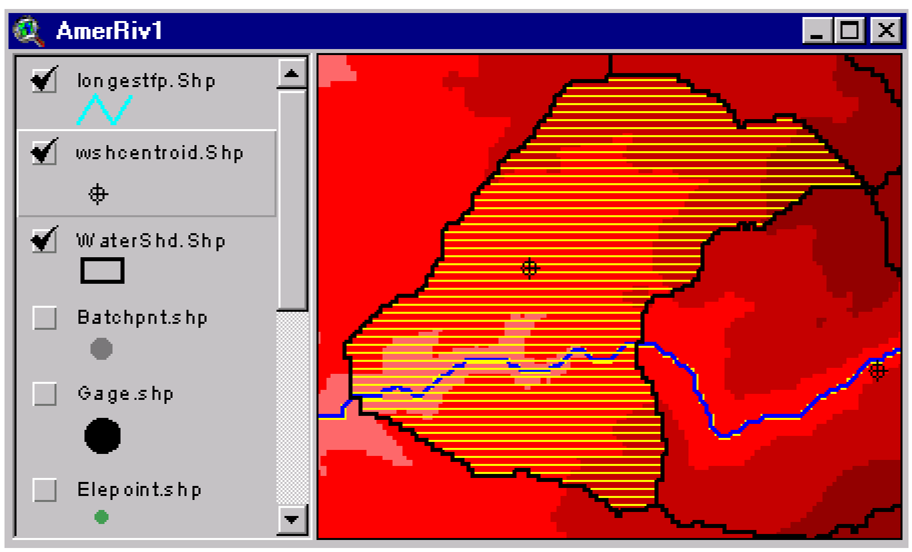


Figure 8–34. Moved basin centroid result.

Attributes of wshcentroid.Shp

Shape	WshId	Elevation
Point	5	1545.2000
Point	6	1821.1000
Point	7	1509.5000
Point	8	1597.2000
Point	10	1456.5000
Point	11	1092.1000
Point	9	1223.2000
Point	13	1534.9000
Point	12	1657.4000
Point	2	1487.0000

Figure 8–35. Centroid elevation updated in the centroid attribute table.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	WshId	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1534.9000

Figure 8–36. Centroid elevation updated in the watershed attribute table.

Longest Flow Path

The **Longest Flow Path** operation computes a number of basin physical characteristics: the longest flow length, upstream elevation, downstream elevation, slope between the endpoints, and slope between 10% and 85% of the longest flow length. These characteristics are stored in the "WaterShd.shp" theme.

Steps

- Select **Basin Characteristics ⇒ Longest Flow Path** as shown in Figure 8–37. The program will not prompt the user to verify the data input and output because that confirmation was already made before in Figure 8–24.

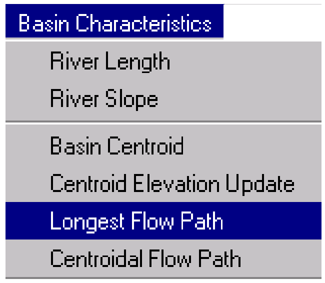


Figure 8–37. Longest Flow Path menu item.

- Press **OK** in the confirmation message box as shown in Figure 8–38.

Figure 8–38. Longest flow path confirmation.

The result of the longest flow path operation is shown in Figure 8–39.

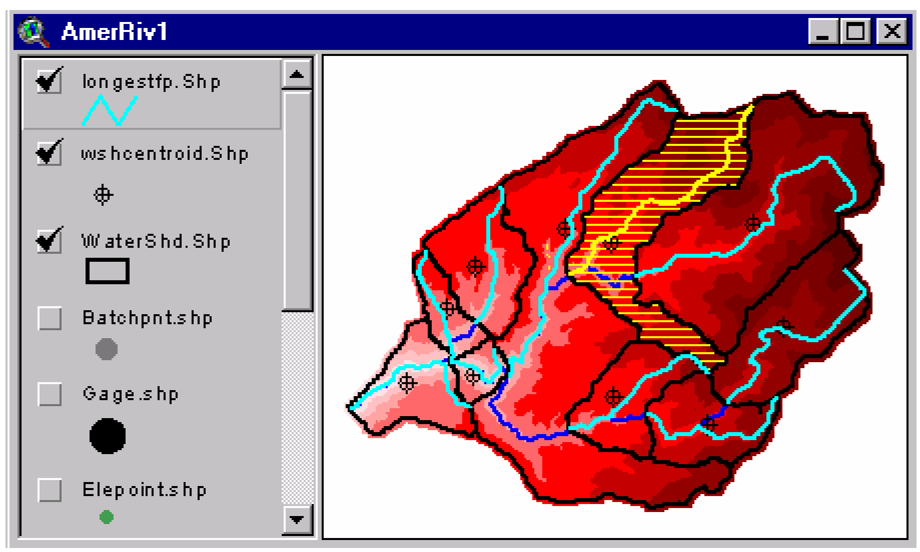


Figure 8–39. Longest flow path result.

The flow path attributes are written to both attribute tables for the "Longestfp.shp" and "WaterShd.shp" theme as shown in Figure 8–40 and Figure 8–41, respectively.

Attributes of longestfp.Shp

Shape	Wshld	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
PolyLine	2	1186.5000	0.093	0.081	8449.037	1971.0000
PolyLine	5	1391.8000	0.099	0.092	6563.818	2044.0000
PolyLine	6	1624.6000	0.094	0.067	5890.509	2181.0000
PolyLine	7	1256.9000	0.118	0.117	3434.924	1661.0000
PolyLine	8	1516.5000	0.087	0.096	4108.600	1873.0000
PolyLine	10	1056.2000	0.181	0.187	2792.498	1563.0000
PolyLine	11	1059.8000	0.214	0.189	2020.660	1493.0000
PolyLine	9	925.9000	0.147	0.186	3839.483	1491.0000
PolyLine	12	1451.2000	0.089	0.078	7618.082	2130.0000
PolyLine	13	1411.8000	0.121	0.125	3998.011	1896.0000

Figure 8–40. Longest flow path attribute table.

Attributes of WaterShd.Shp

Perimeter	Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
41940.00000	1487.0000	1186.5000	0.093	0.081	8449.037	1971.0000
25320.00000	1545.2000	1391.8000	0.099	0.092	6563.818	2044.0000
15660.00000	1821.1000	1624.6000	0.094	0.067	5890.509	2181.0000
12000.00000	1509.5000	1256.9000	0.118	0.117	3434.924	1661.0000
11520.00000	1597.2000	1516.5000	0.087	0.096	4108.600	1873.0000
8580.000000	1456.5000	1056.2000	0.181	0.187	2792.498	1563.0000
5760.000000	1092.1000	1059.8000	0.214	0.189	2020.660	1493.0000
11520.00000	1223.2000	925.9000	0.147	0.186	3839.483	1491.0000
23220.00000	1657.4000	1451.2000	0.089	0.078	7618.082	2130.0000
12060.00000	1534.9000	1411.8000	0.121	0.125	3998.011	1896.0000

Figure 8–41. Longest flow path results populated in watershed attribute table.

Centroidal Flow Path

This operation computes the centroidal flow path length by projecting the centroid onto the longest flow path. The centroidal flow path is measured from the projected point on the longest flow path to the subbasin outlet as shown in Figure 8–42.

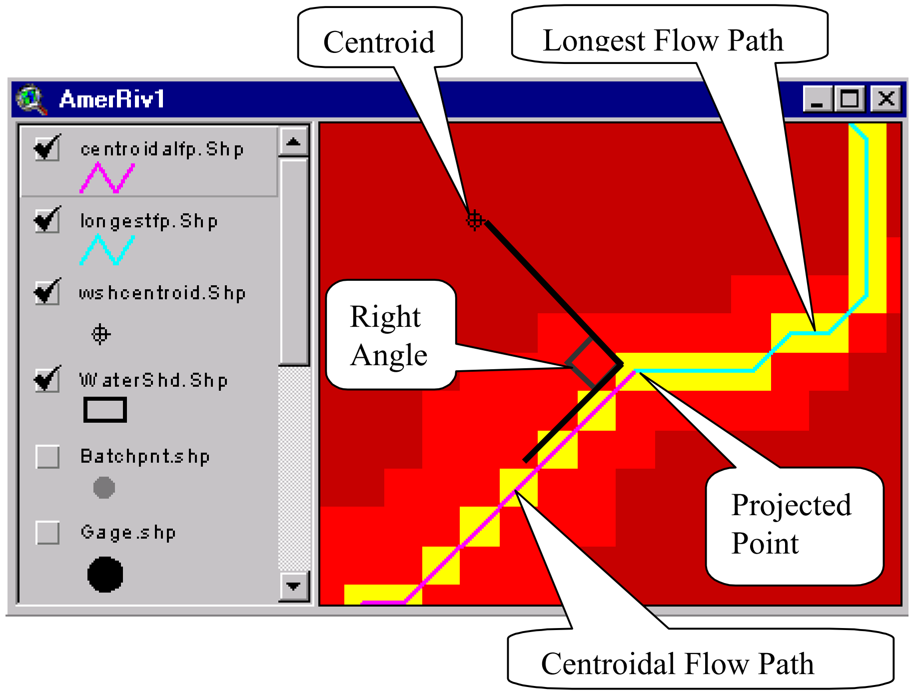


Figure 8–42. Centroidal flow path.

Steps

- Select **Basin Characteristics ⇒ Centroidal Flow Path** as shown in Figure 8–43.

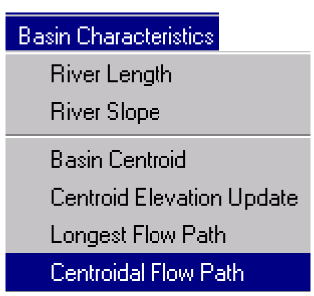


Figure 8–43. Centroidal Flow Path menu item.

- The program prompts the user to verify five data inputs and one output, see Figure 8–44. Press **OK**.

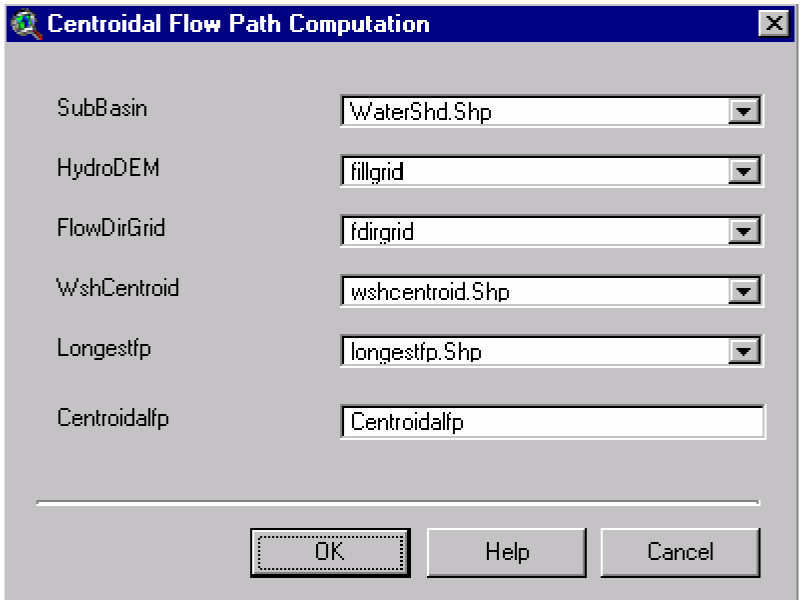


Figure 8–44. Centroidal flow path input and output files.

- Press **OK** at the confirmation message box as shown in Figure 8–45.

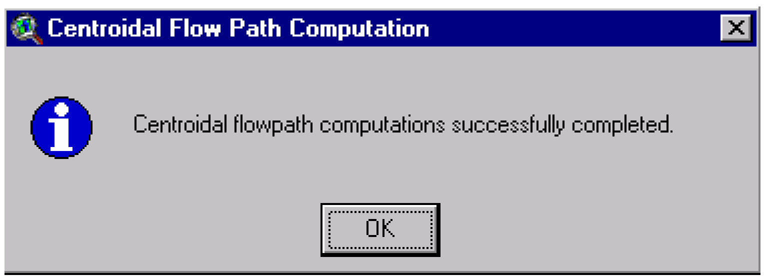


Figure 8–45. Centroidal flow path confirmation.

The result of the centroidal flow path operation is a line shapefile named "centroidalfp.Shp" and its attribute table as shown in Figure 8–46 and Figure 8–47, respectively. The centroidal flow length in the "CentroidalFL" column is also stored in the "WaterShd.shp" attribute table as shown in Figure 8–48.

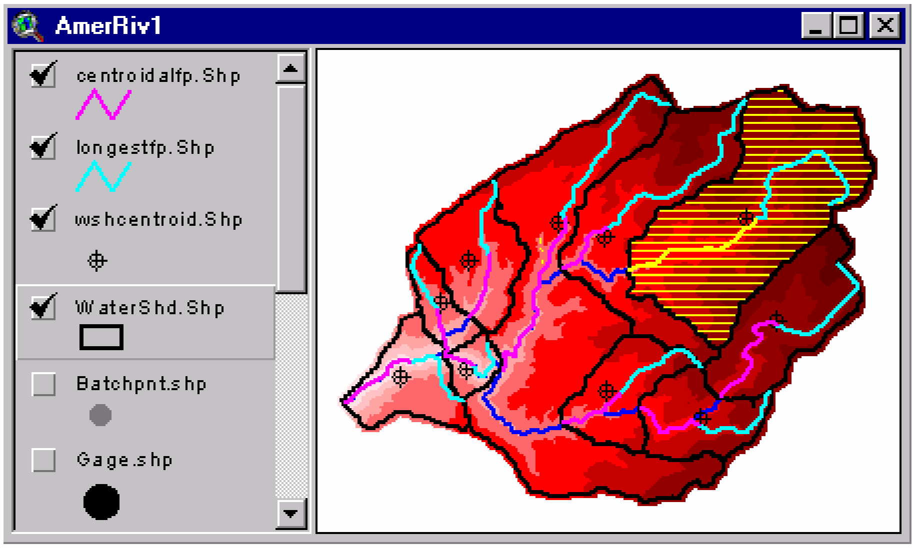


Figure 8–46. Centroidal flow path result.

Attributes of centroidalfp.Shp

Shape	Wshld	CentroidalFL
PolyLine	2	4224.518
PolyLine	5	1580.955
PolyLine	6	2909.483
PolyLine	7	1561.249
PolyLine	8	1785.807
PolyLine	10	1114.264
PolyLine	11	740.018
PolyLine	9	1907.939
PolyLine	12	3352.203
PolyLine	13	1653.381

Figure 8–47. Centroidal flow path attribute table.

Attributes of WaterShd.Shp

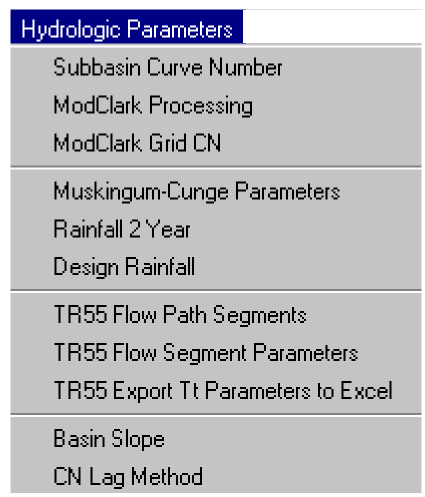
Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv	CentroidalFL
1487.0000	1186.5000	0.093	0.081	8449.037	1971.0000	4224.518
1545.2000	1391.8000	0.099	0.092	6563.818	2044.0000	1580.955
1821.1000	1624.6000	0.094	0.067	5890.509	2181.0000	2909.483
1509.5000	1256.9000	0.118	0.117	3434.924	1661.0000	1561.249
1597.2000	1516.5000	0.087	0.096	4108.600	1873.0000	1785.807
1456.5000	1056.2000	0.181	0.187	2792.498	1563.0000	1114.264
1092.1000	1059.8000	0.214	0.189	2020.660	1493.0000	740.018
1223.2000	925.9000	0.147	0.186	3839.483	1491.0000	1907.939
1657.4000	1451.2000	0.089	0.078	7618.082	2130.0000	3352.203
1534.9000	1411.8000	0.121	0.125	3998.011	1896.0000	1653.381

Figure 8–48. Centroidal flow path results populated in watershed attribute table.

CHAPTER 9

Hydrologic Parameters Estimation

When the stream and subbasin physical characteristics have been extracted, users have the option to estimate a number of hydrologic parameters in GeoHMS Version 1.1. Infiltration loss rates, in terms of curve numbers, can be estimated as lumped and grid-based quantities that are based on soil and landuse databases. Other hydrologic parameters, such as time of concentration and Muskingum-Cunge routing parameters can be obtained from the terrain, surveyed data, and precipitation data.



The estimated hydrologic parameters are subbasin curve number, ModClark grid curve number, Muskingun-Cunge routing parameters, subbasin time of concentration, and subbasin lag time. The other steps and parameters, such as ModClark Processing, Rainfall 2 Year, TR55 Flow Path Segments, TR55 Flow Path Segment Parameters, TR55 Export Tt Parameters to Excel, and Basin Slope, are intermediate steps for computing hydrologic parameters. The Design Rainfall is only used for setting up a Meteorologic model as discussed in Chapter 10.

The user should compare and verify these estimated hydrologic parameters against published information. These hydrologic parameters are stored in attribute tables, which can be exported for use with a spreadsheet and other programs. When more experience is gained working with GIS data, more initial estimates of hydrologic parameters will be provided.

This chapter will discuss the tools for estimating hydrologic parameters that are available in the ***ProjView*** GUI under the **Hydrologic Parameters** menu. Below is an outline of Chapter 9.

Contents

- Subbasin curve number
- ModClark gridded subbasin processing

- Muskingum-Cunge routing parameters
- Time of concentration
- Basin lag time
- Subbasin index precipitation

Subbasin Curve Number

This function overlays the subbasin boundaries over a curve number grid and computes the average curve number for the selected set of subbasins as shown in Figure 9-1. The construction of a curve number grid is covered in Appendices E, F, and G. If no subbasin has been selected, the function will process all subbasins. This function also stores the curve number statistics in the table, Cnstat.dbf, saved in the project workspace.

This function creates or updates one field in the subbasin shapefile theme: bcn: Average curve number value for the subbasin.

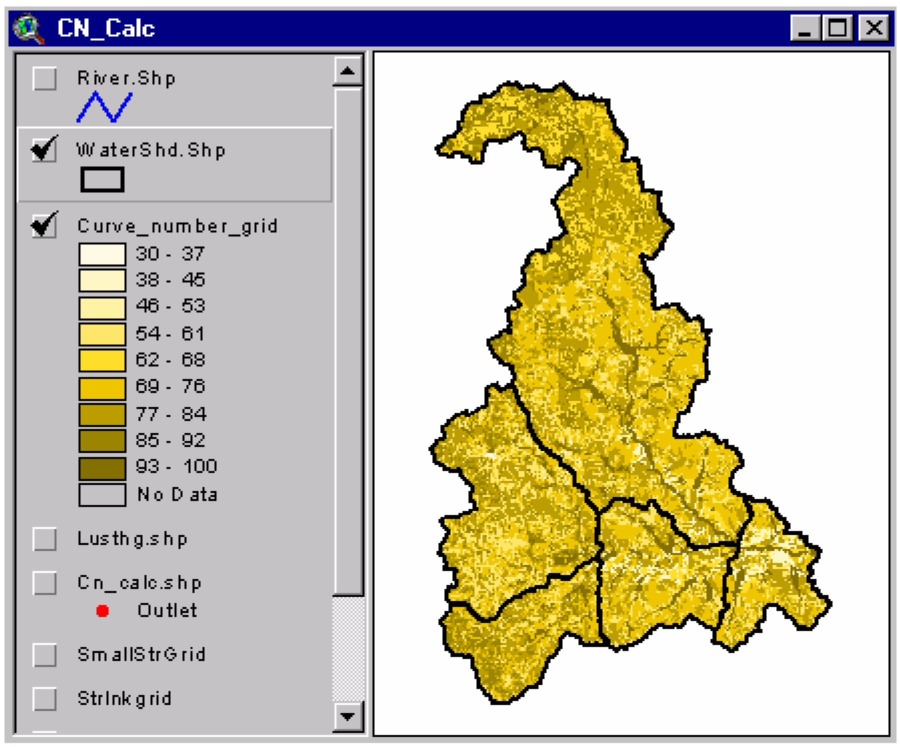


Figure 9–1. Subbasin boundaries overlay with curve number grid.

Steps

- Select **Hydrologic Parameters ⇒ Subbasin Curve Number**
- Select the subbasin and curve number theme from the dropdown menus as shown in Figure 9-2.

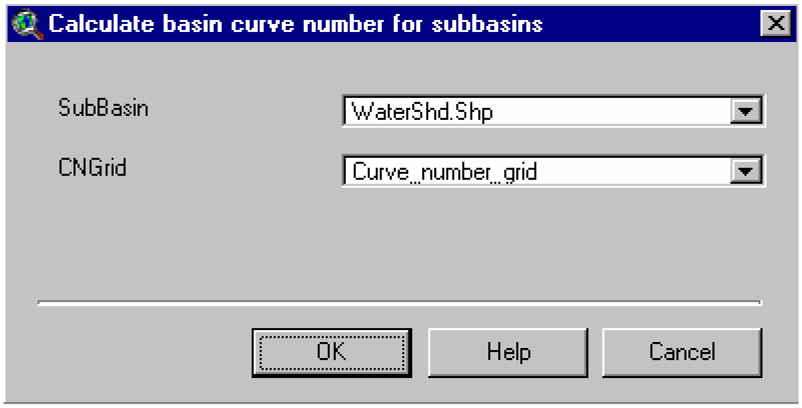
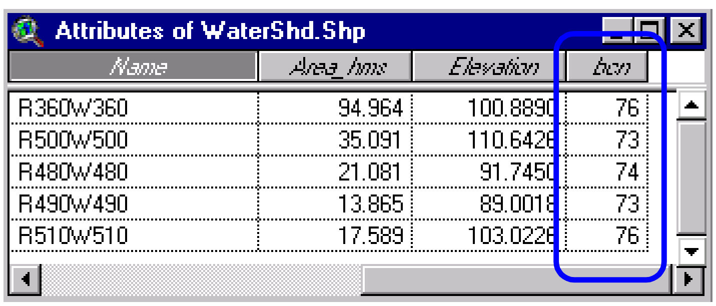


Figure 9–2. Input themes for curve number estimation.

The resulting average lumped curve number for each subbasin is shown in Figure 9-3.


Attributes of WaterShd.Shp

Name	Area_hms	Elevation	bcn
R360W360	94.964	100.8890	76
R500W500	35.091	110.6428	73
R480W480	21.081	91.7450	74
R490W490	13.865	89.0018	73
R510W510	17.589	103.0228	76

Figure 9–3. Lumped curve numbers for subbasins.

ModClark Gridded Subbasin Processing

This section applies to the distributive modeling approach using the ModClark transform method. The first function, **ModClark Processing**, creates a grid-based representation of the subbasin. The second function, **ModClark Grid CN**, computes grid-based curve numbers for each of the ModClark grid cells. These steps should be performed after the user has revised the subbasin and reach names and built the HMS schematic.

ModClark Processing

This function creates a ModClark grid cell polygon theme, which divides the subbasins into grid cells for the distributed-modeling approach. It is produced by intersecting the subbasin polygons with the boundaries of cells in the precipitation-reporting grid. GeoHMS supports two pre-defined precipitation grid geometries: the Standard Hydrologic Grid (SHG) and the Hydrologic Rainfall Analysis Project (HRAP). However, it is recommended that the user select the SHG or the HRAP option instead of the “User Defined” option. The “User Defined” option uses the SHG and the user can type in any cell size in meters. With the radar rainfall reported in the HRAP grid format, the use of SHG or HRAP grids can ensure better alignment and compatibility between radar rainfall and a gridded subbasin. More details on the selection of a grid format are available in the Appendix D.

Irrespective of the selected unit system in HMS, the ModClark grid cell size is always in SI units to maintain alignment and compatibility with radar rainfall.

There are three methods for creating the ModClark grid cell polygon theme:

1. SHG Method: the user will be prompted to select the SHG cell size in meters.
2. HRAP Method.
3. User Defined: same as SHG, but the user can type in any cell size in meters.

This function requires three inputs:

- Flow direction grid
- Subbasin shapefile
- Input projection file (e.g. prj.adf file associated with the DEM).

The operation creates the ModClark grid cell polygon theme, named by appending “ModClark” to the cell size. The ModClark grid cell polygon theme contains the following fields:

- Area: Area of the cell.
- WshId: Unique identifier for each polygon in the ModClark theme.
- Name: Name of the subbasin the cell is in.
- Shg_x: x SHG coordinate of the cell (or HRAP_x: x HRAP coordinate of the cell).
- Shg_y: y SHG coordinate of the cell (or HRAP_y: y HRAP coordinate of the cell).

- Mod_Area: Area in square kilometers
- Flowlength: Average distance in kilometers of all the DEM cells in the ModClark polygon from the subbasin's outlet. This is in effect the average distance of the ModClark polygon from the sub basin outlet.

Steps

- Select **Hydrologic Parameters ⇒ ModClark Processing**.
- Select **SHG Method** from the dropdown menu as shown in Figure 9-4.
- Press **OK**.

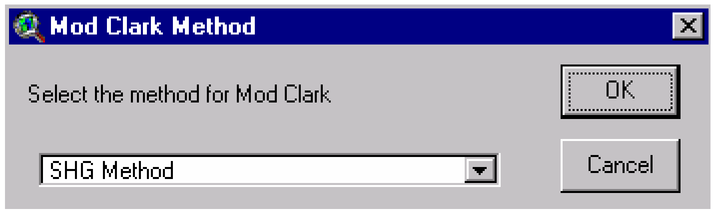


Figure 9–4. Precipitation grid types.

- The SHG grid uses the Albers Equal-Area projection as shown in Figure 9-5. Press **Yes**.

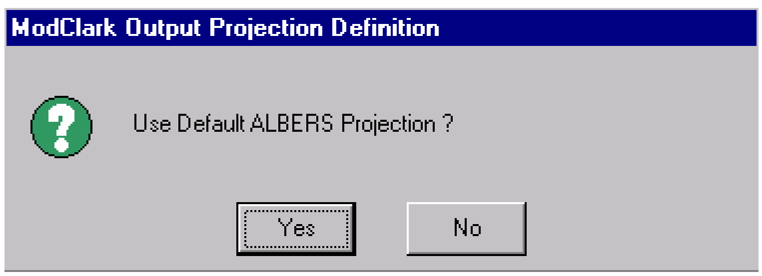


Figure 9–5. Default Albers projection.

- Select the cell resolution for the SHG grid. 2000 (meters implied) is selected as shown in Figure 9-6. A grid-cell resolution of 2000 meters is often suggested when working with radar rainfall. At that resolution, a grid cell has an area of four square kilometers if it resides entirely within a subbasin. Along the subbasin boundaries, however, a grid cell is often broken into several pieces, which belong to several subbasins. Press **OK**.

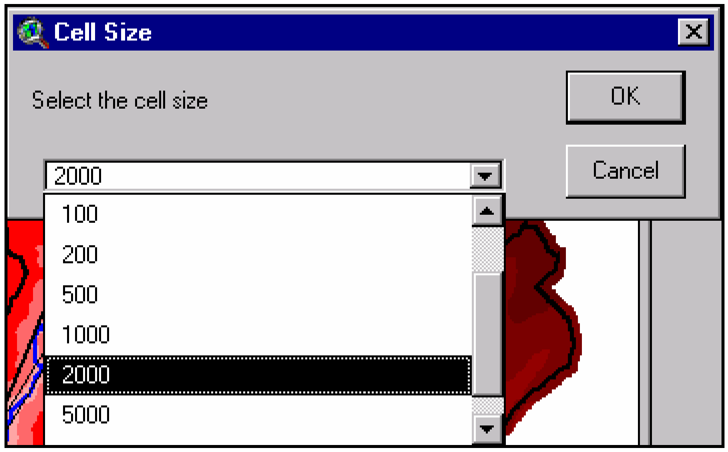


Figure 9–6. Grid-cell resolution for SHG.

A separate view is created to overlay the subbasin and the SHG grid (see Figure 9-7) and perform the intersection.

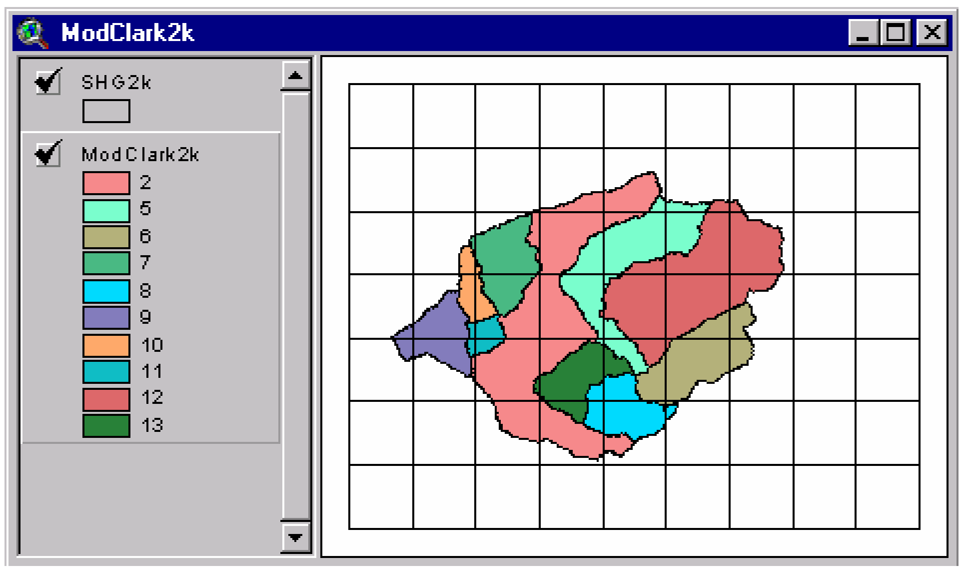


Figure 9–7. Intersection between subbasins and SHG grid.

This operation creates a ModClark grid cell shapefile, “ModClark2K.shp”, with grid-cell travel distances to the subbasin outlet as shown in Figure 9-8.

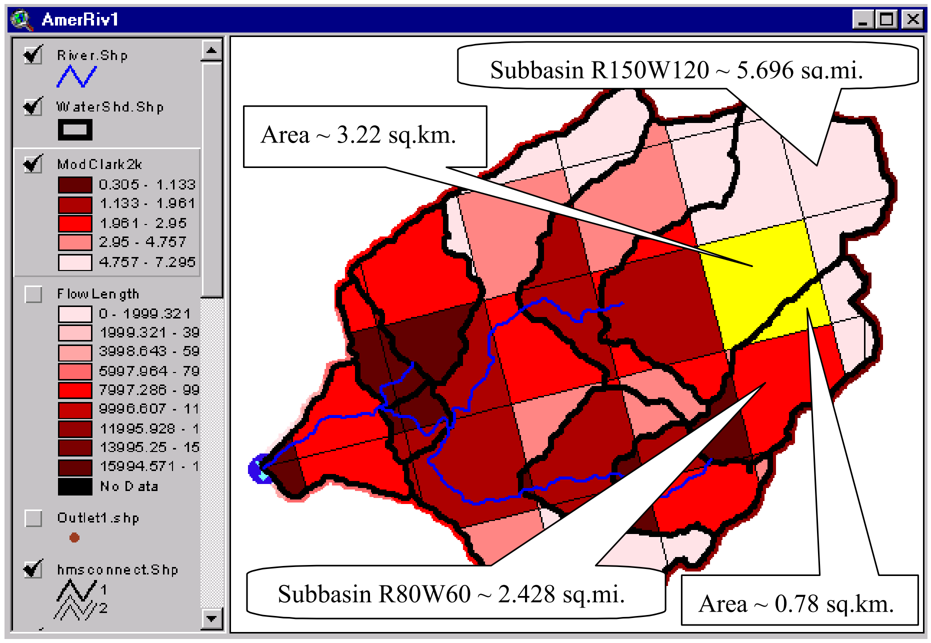


Figure 9–8. Grid-cell parameter file result.

The attribute table shown in Figure 9-9 displays the results for the selected cell.

Attributes of ModClark2k

Name	Area_HMS	Shg_x	Shg_y	Cell_id	Mod_Area	WshShdId	FlowLength
R80W60	2.428	-1039	1030	39	0.77614900000	34	4.26129931641
R150W120	5.696	-1039	1030	39	3.22360800000	66	3.52641894531
R20W20	7.257	-1043	1029	10	0.10599500000	0	1.37444274902
R20W20	7.257	-1042	1028	16	1.48070900000	1	3.45396728516
R20W20	7.257	-1042	1029	17	3.44594500000	2	1.82714331055
R20W20	7.257	-1042	1030	18	1.55452400000	3	1.70208093262
R20W20	7.257	-1042	1031	19	0.00465800000	4	3.25946362305

Figure 9–9. ModClark grid cell polygon theme attribute table.

ModClark Grid CN

This optinal function computes the average curve number for each ModClark grid cell. It will save the curve number statistics in the file Cnstat.dbf stored in the project workspace.

Two input themes are required:

- ModClark grid cell polygon theme
- Curve number grid

The function creates or updates the following field in the ModClark theme:

- bcn: Average curve number value for the ModClark grid cell as shown in Figure 9-10.

Attributes of ModClark2k

Shape	Area	Wshld	Shg_x	Shg_y	Mod_Area	WshShgId	FlowLength	bcn
Polygon	109038.9386	36	146	1240	0.10903900000	0	48.64328125000	82
Polygon	229924.8844	36	146	1241	0.22992500000	1	48.28168359375	80
Polygon	684169.5754	36	147	1240	0.68417000000	2	48.05998437500	77
Polygon	3208487.423	36	147	1241	3.20848700000	3	46.89892187500	79
Polygon	1064699.929	36	147	1242	1.06470000000	4	44.87976562500	81

Figure 9–10. ModClark grid cell polygon theme with gridded curve number.

Muskingum-Cunge Parameters

This function facilitates a process for entering Muskingum-Cunge standard routing parameters for prismatic shaped channels in the stream attribute table. The user will not be able to get accurate channel geometry because the DEM is often too coarse. However, the users are allowed to link as-built drawings, photos, survey data, and other information that show channel shape and geometry as shown in Figure 9-11. This information can provide a basis for the user to specify channel dimension, shape, and other parameters.

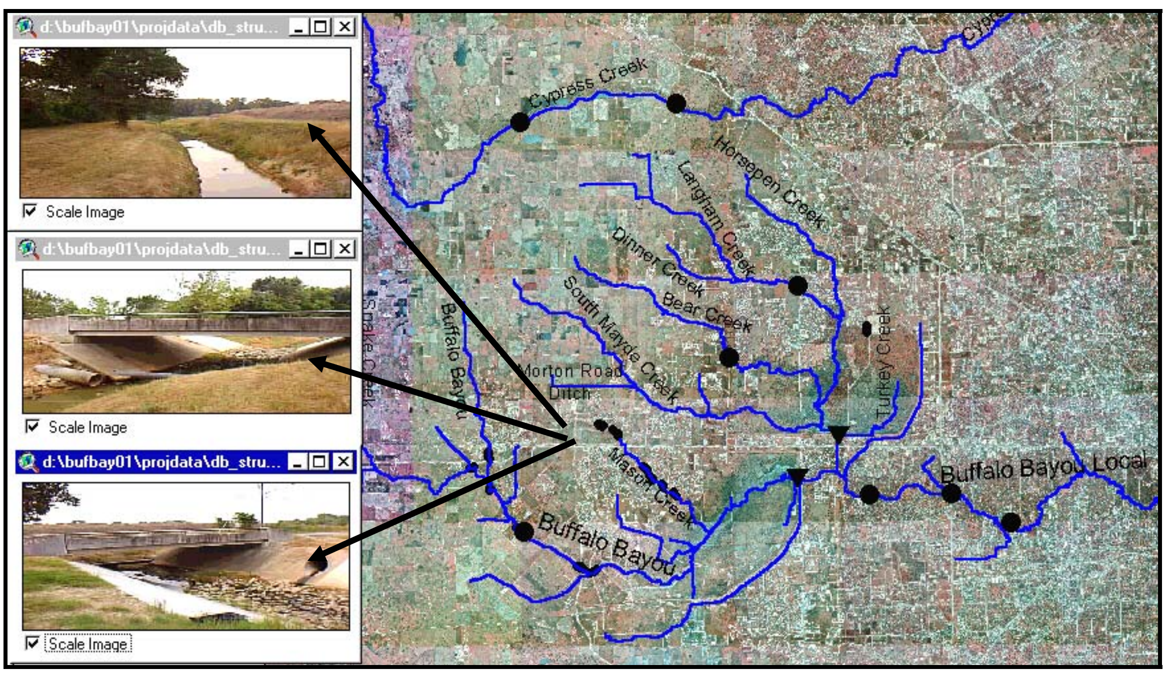


Figure 9–11. Field survey data and photographs.

Steps

- Select at least one river segment as shown in Figure 9-12.

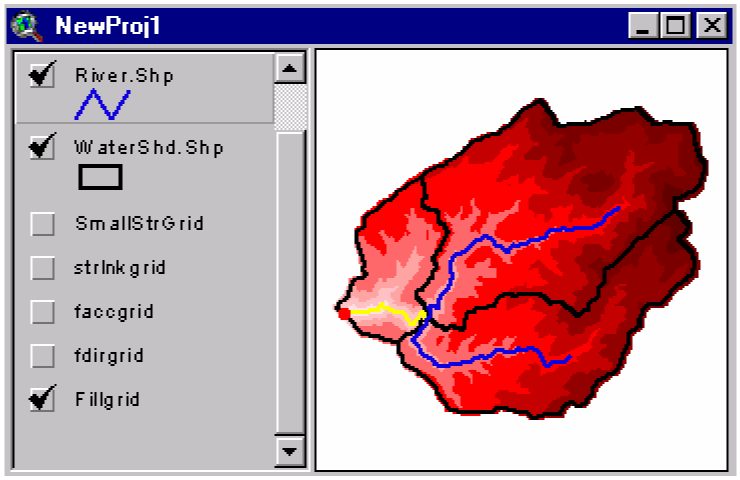


Figure 9–12. River segment selection.

- Select **Hydrologic Parameters** ⇒ **Muskingum-Cunge Parameter**
- Enter the bottom width of the channel, channel side slopes, and the channel's roughness coefficient (Manning's n) as shown in Figure 9-13. Only the prismatic channel type can be defined through this function.

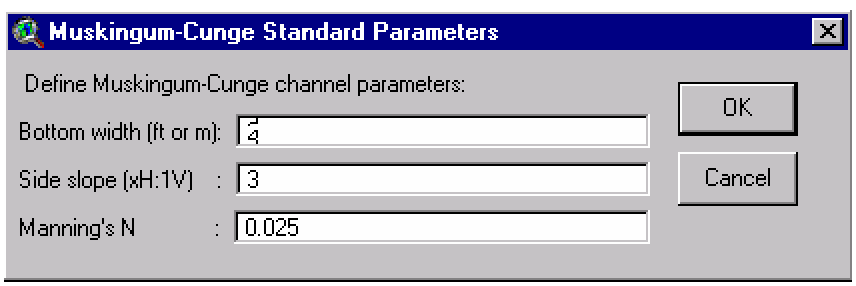
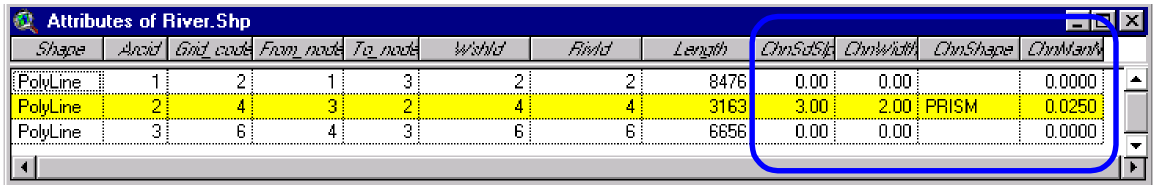


Figure 9–13. Muskingum-Cunge standard parameters entry.

This function creates or updates the following fields in the River shapefile theme as shown in Figure 9-14:

- ChnSdSlp: Channel side slope.
- ChnWidth: Channel width.
- ChnShape: Channel shape.
- ChnManN: Channel Manning's number.



Attributes of River.Shp

Shape	Arcid	Grid_code	From_node	To_node	Wshid	Rivid	Length	ChnSdSlp	ChnWidth	ChnShape	ChnManN
PolyLine	1	2	1	3	2	2	8476	0.00	0.00		0.0000
PolyLine	2	4	3	2	4	4	3163	3.00	2.00	PRISM	0.0250
PolyLine	3	6	4	3	6	6	6656	0.00	0.00		0.0000

Figure 9–14. Muskingum-Cunge standard parameters.

Time of Concentration

The time of concentration is estimated in accordance to the Natural Resources Conservation Service (NRCS) TR-55 methodology. The following information is required to estimate travel time, 2-year 24-hour rainfall amount, slopes, flow distance of precipitation excess on the land's surface for the three NRCS flow regimes - sheet flow, shallow concentrated flow, and channel flow. These inputs are used to populate a Microsoft Excel template spreadsheet. Users are encouraged to check and overwrite these GIS derived parameters as well as provide additional inputs, such as Manning's roughness coefficient, channel cross-sectional area, and wetted perimeter. Users have full control over the spreadsheet to make changes to parameters and even equations, as appropriate.

The spreadsheet is launched from a GeoHMS menu. Oftentimes, GeoHMS is unable to locate Excel because the various directories that Excel can be installed on depends on the operating systems. The user can help GeoHMS locate Excel by opening the Excel template (tc.xls file located in the \$AVHOME\etc folder) and then select the GeoHMS menu.

Rainfall Two-Year

This function computes the two-year rainfall for each subbasin needed for the calculation of travel time in accordance to the Natural Resources Conservation Service (NRCS) TR-55 methodology. To be consistent with the TR-55 method for time of concentration computation, the precipitation intensity value should be in inches. The two-year rainfall value is extracted at the subbasin centroid location from the precipitation intensity grid. The function operates on a selected set of subbasins. If no subbasin has been selected, the function processes all subbasins. The function does not perform unit conversion; therefore the value for the precipitation intensity grid should be in inches.

If the user has the 2-year, 24-hour precipitation intensity grid, then the function requires three input themes: subbasin theme, precipitation intensity grid, and the centroid theme.

If the user does not have the necessary precipitation intensity grid, then the user can click the **Cancel** button on Figure 9-15. The function will offer to have the required field created (but not populated). The user can then manually enter the precipitation intensity for each subbasin by editing the “Precip2Yr” field in the “watershed.shp” attribute table.

Steps

- Select **Hydrologic Parameters** ⇒ **Rainfall 2 Yr**
- Select the subbasin shapefile, 2-year 24-hour precipitation intensity grid, and watershed centroid shapefile from the dropdown menus as shown below.

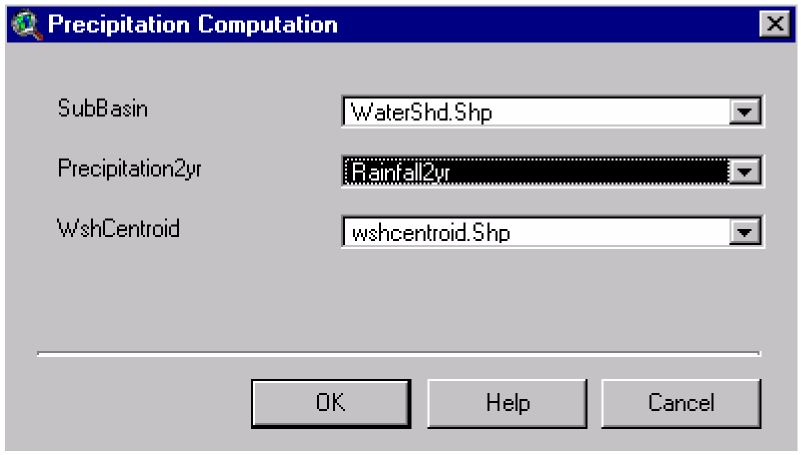


Figure 9–15. Precipitation intensity computation.

The function creates or updates one field in the subbasin theme as shown in Figure 9-16:

- Precip2Yr: The precipitation in inches is extracted from the precipitation intensity grid at the location of the watershed centroid. If the grid is not in inches, the user needs to convert the unit manually.

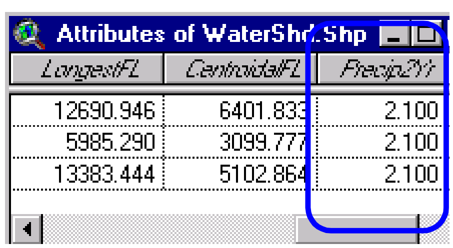


Figure 9–16. Precipitation intensity computation result.

TR55 Flow Path Segments

This function creates a point theme showing the flow regimes along the longest flow path for the computation of time of concentration in accordance to the Natural Resources Conservation Service's TR55 methodology. The function places two points along the longest flow path for each subbasin. If no subbasin has been selected, the function processes all the subbasins. The first point, AA, marks the break between sheet flow and shallow concentrated flow. Point AA is by default located about 300 feet from the watershed divide along the longest flow path. The second point, BB, marks the break between shallow concentrated flow and the channel flow. Point BB is by default located where the longest flow path first encounters or intersects the channel.

Steps

- Select **Hydrologic Parameters ⇒ TR55 Flow Path Segments**
- Select the subbasin shapefile, TR55 channel line shapefile (by default, the program uses the centroidal flow path), longest flow path shapefile, and flow accumulation grid from the dropdown menus as shown in Figure 9-17.

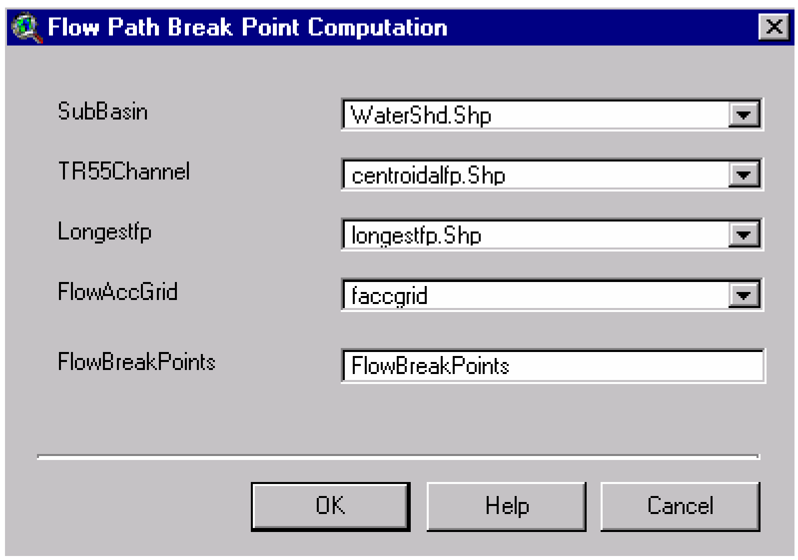


Figure 9–17. Flow path break point computation.

The function creates or updates the flow break point theme as shown in Figure 9-18. This theme contains the following fields:

- Name: Indicate whether the point is an "AA" or a "BB" point.
- WshID: Subbasin identifier.

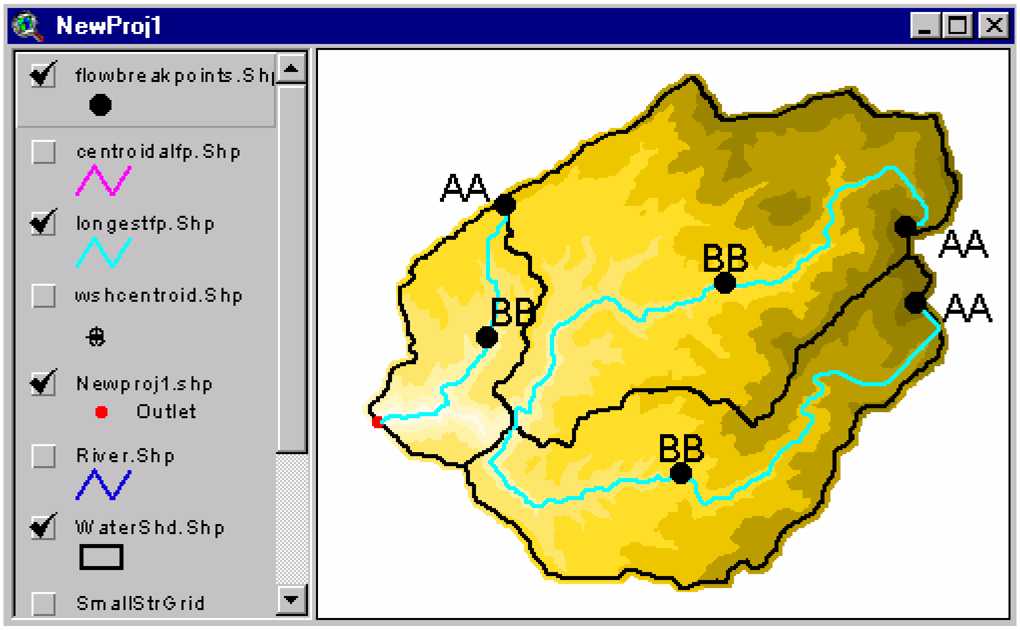
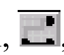


Figure 9–18. Flow path break point computation result.

Once these points are placed by the program, the user has the flexibility to move them using ArcView standard editing tools to drag those points to a new location. The user can use the custom tool (**Define TR55 Points**), , to specify new AA or BB points and delete the old ones, see following section.

The user can also apply the **Interactive Flow Path** tool, , to specify a different longest flow path by clicking on a different most remote point in the subbasin, see subsequent section.

Define TR55 Points

This tool modifies the location of the AA and BB points that define the TR55 flow path types obtained using the "**TR55 Flow Path Segments**" function. When the tool is active as shown in Figure 9-19, click to add an AA point, Ctrl+Click to add a BB Point, or Shift+Click to remove an AA or BB point. When a point is added, the old point of that type in the watershed is NOT removed automatically, so it must be removed manually or the functions for parameter extraction will not operate correctly. There should be only one AA and one BB point in each watershed. The result of using the **Define TR55 Points** tool is shown in Figure 9-20.

Figure 9–19. Define TR55 points tool.

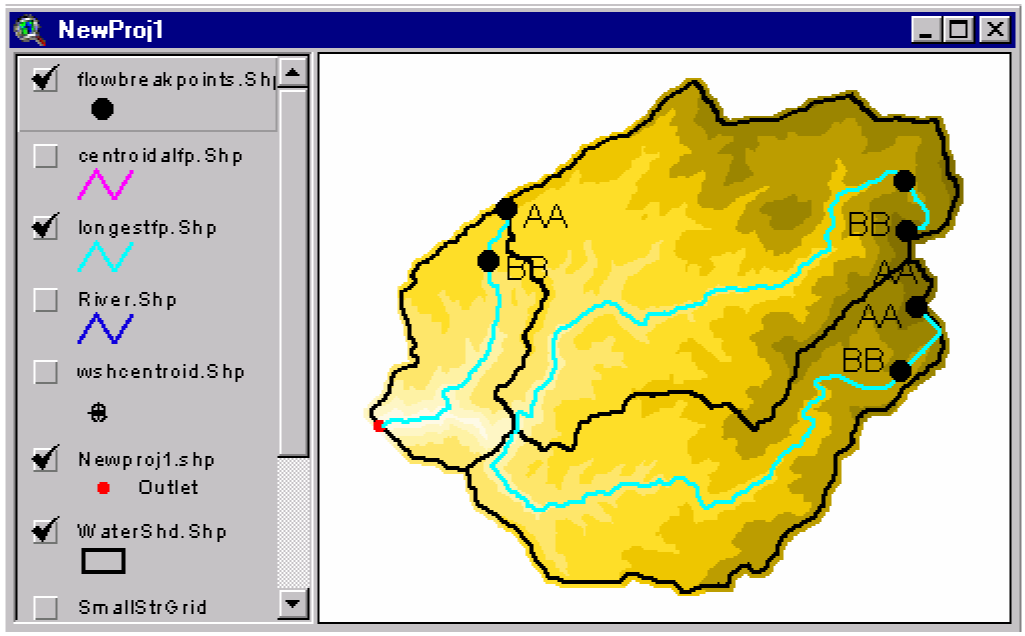


Figure 9–20. Define TR55 points results.

Interactive Flowpath

By secifying a different most remote point in the watershed, the user can use this tool to generate a different longest flow path than the one generated by the program.

Steps

- Select the **Interactive Flowpath** tool, .
- Click on the location of the most hydraulically remote point in the subbasin

The tool creates or updates the two following themes:

- Longest flow path shapefile
- Slope points10%-85% shapefile

The user clicks on the desired flow path starting point in the watershed: the function will generate the flow path downstream to the outlet of the watershed. The user will then be prompted whether to replace the existing flow path in this subbasin. If the flow path is replaced, then the tool will identify the new locations of the 10% and 85% points and calculate the new slope parameters (see 10-85 LF Slope in the subbasin attribute table).

TR55 Flow Segment Parameters

This function calculates the length and slope for the TR55 flow paths. It operates on a selected set of subbasins in the subbasin theme. If no subbasin has been selected, the function processes all the subbasins.

The function extracts the elevations from the terrain at the starting and ending points of the longest flow paths and at the AA and BB flow break points. The lengths are measured along the longest flow paths between the four points of interest.

The function creates or updates the following fields in the longest flow path theme as shown in Figure 9-21:

- ChSlp: Slope for the TR55 channel flow segment (ft/ft) between point BB and the end of the channel.
- ChLength: Length of the TR55 channel flow segment (between the BB flow break point and the outlet of the sub basin) (ft).
- ShSlp: Slope for the TR55 shallow flow (overland flow) segment (ft/ft) between most remote point and AA.
- ConShLength: Length of the TR55 concentrated shallow flow segment (between AA and BB flow break points) (ft).
- ConShSlp: Slope for the TR55 concentrated shallow flow segment (ft/ft) between point AA and BB.
- ShLength: Length of the TR55 shallow flow (overland flow) segment (between start of the longest flow path and the AA flow break point) (ft).

Attributes of longestfp.Shp

USElv	ChSlp	ChLength	ShSlp	ConShLength	ConShSlp	ShLength
2130.8999	0.06199	37026.98996	0.03390	4309.88830	0.18635	300.00000
1661.2000	0.10783	15656.68720	0.12358	3680.05187	0.14336	300.00000
2181.8999	0.05907	38359.75790	0.36308	5249.09034	0.19588	300.00000

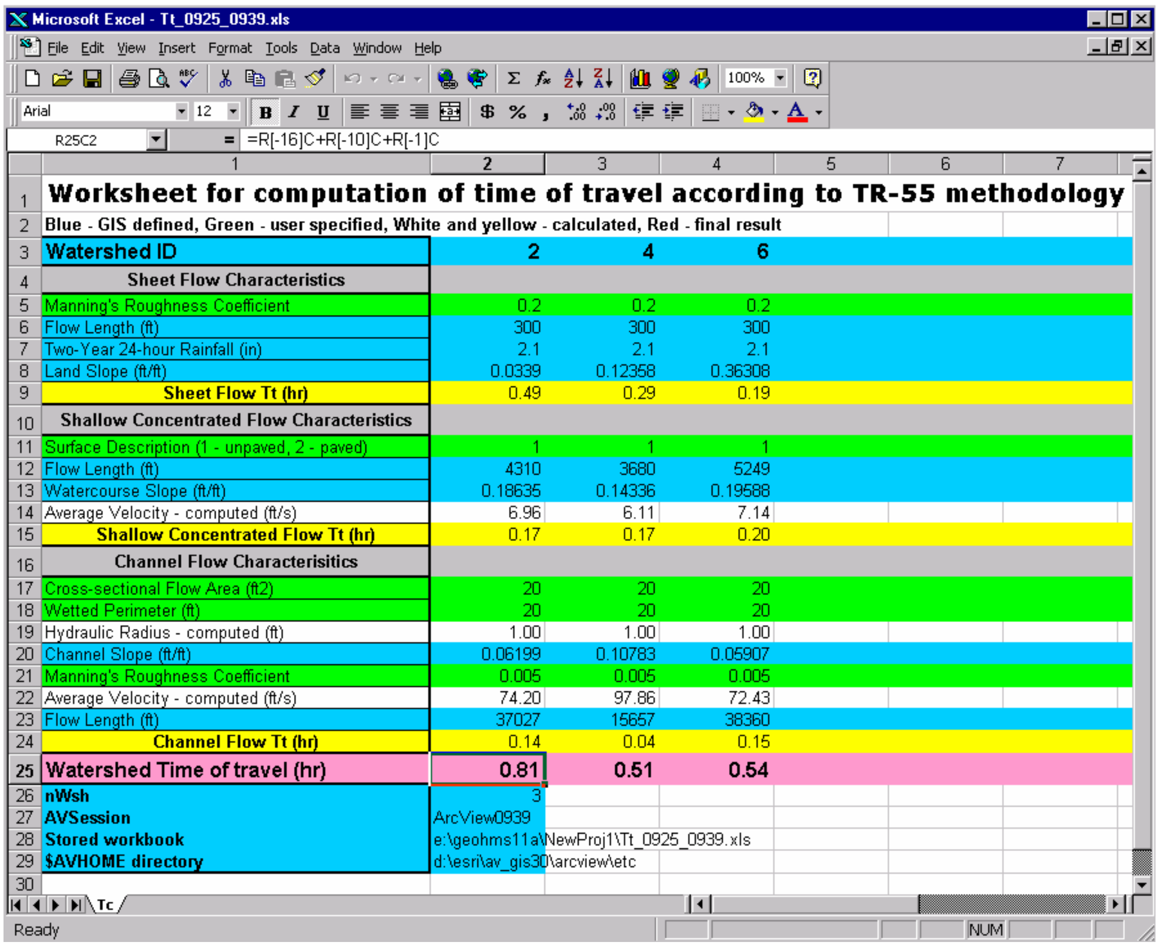
Figure 9–21. Flow segment parameters results.

Export TR55 Data

This function exports the data about the TR55 flow segments to a Microsoft Excel template workbook. The function operates on a selected set of subbasins in the subbasin theme. If no subbasin has been selected, the function processes all the subbasins.

In the Excel spreadsheet as shown in Figure 9-22, the blue (darkest shading) areas contain the data brought in from GeoHMS. The user can overwrite them if necessary, but those changes will not be transferred back to GeoHMS. The green areas contain the data that the user inputs. Default values are provided and they should be revised to better reflect field conditions and project needs. The white and yellow areas contain computed values; therefore they should not be modified in any way. They will be recomputed whenever there are changes to the blue and green areas.

The Excel spreadsheet will be stored automatically in the project directory. The full file name and its path are displayed in the cell B28 or next to the cell entitled "Stored Workbook." The file name is concatenated with the "Tt" prefix and the date and time the file was created. The file can be renamed using the standard Excel "Save as" capability.



	1	2	3	4
1	Worksheet for computation of time of travel according to TR-55 methodology			
2	Blue - GIS defined, Green - user specified, White and yellow - calculated, Red - final result			
3	Watershed ID	2	4	6
4	Sheet Flow Characteristics			
5	Manning's Roughness Coefficient	0.2	0.2	0.2
6	Flow Length (ft)	300	300	300
7	Two-Year 24-hour Rainfall (in)	2.1	2.1	2.1
8	Land Slope (ft/ft)	0.0339	0.12358	0.36308
9	Sheet Flow Tt (hr)	0.49	0.29	0.19
10	Shallow Concentrated Flow Characteristics			
11	Surface Description (1 - unpaved, 2 - paved)	1	1	1
12	Flow Length (ft)	4310	3680	5249
13	Watercourse Slope (ft/ft)	0.18635	0.14336	0.19588
14	Average Velocity - computed (ft/s)	6.96	6.11	7.14
15	Shallow Concentrated Flow Tt (hr)	0.17	0.17	0.20
16	Channel Flow Characterisitics			
17	Cross-sectional Flow Area (ft2)	20	20	20
18	Wetted Perimeter (ft)	20	20	20
19	Hydraulic Radius - computed (ft)	1.00	1.00	1.00
20	Channel Slope (ft/ft)	0.06199	0.10783	0.05907
21	Manning's Roughness Coefficient	0.005	0.005	0.005
22	Average Velocity - computed (ft/s)	74.20	97.86	72.43
23	Flow Length (ft)	37027	15657	38360
24	Channel Flow Tt (hr)	0.14	0.04	0.15
25	Watershed Time of travel (hr)	0.81	0.51	0.54
26	nWsh	3		
27	AVSession	ArcView0939		
28	Stored workbook	e:\geohms11a\NewProj1\Tt_0925_0939.xls		
29	$AVHOME directory	d:\esri\av_gis30\arcview\etc		
30				

Figure 9–22. TR55 travel time computation results.

Once the travel time of each subbasin is estimated, the user can press the calculator button, TR55 Export, to transfer the travel times back to GeoHMS as shown in Figure 9-23.

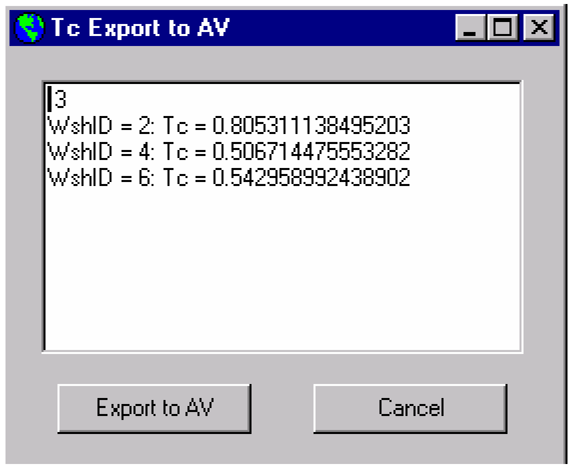


Figure 9–23. Travel time results exported to GeoHMS.

The function creates or updates the following fields in the subbasin theme as shown in Figure 9-24:

- BasinLag: Basin lag (hours), computed as 0.6*Tc.
- LagMethod: Method used for lag computations. For basins for which the TR55 method was used the entry will be "TR55".
- Tc: Basin time of concentration (hours).

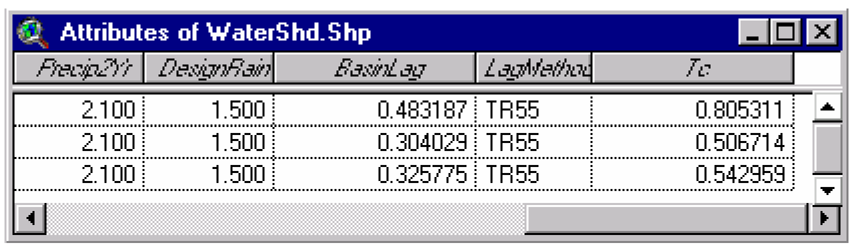


Figure 9–24. Time of concentration results.

Basin Lag Time

In this section, the basin lag time is estimated with a two step process. The first step is used to estimate the basin or watershed slope. In the second step, the basin lag time is estimated using the curve number method described in the NRCS National Engineering Handbook, 1972.

Basin Slope

This function computes the average basin slope in the watershed, which is used as an input for the computation of the CN Lag time. The function operates on a selected set of subbasins from the subbasin theme. If no subbasin has been selected, the function processes all the subbasins. The basin slope is determined by averaging the values of slope in the subbasin as defined by the slope grid. If the slope grid does not exist, it will be computed using the ESRI **ArcView Spatial Analyst** slope operator.

Steps

- Select **Hydrologic Parameters** ⇒ **Basin Slope**
- Select the terrain grid from the dropdown menu as shown in Figure 9-25.
- Specify the slope grid by typing its name in the text box.

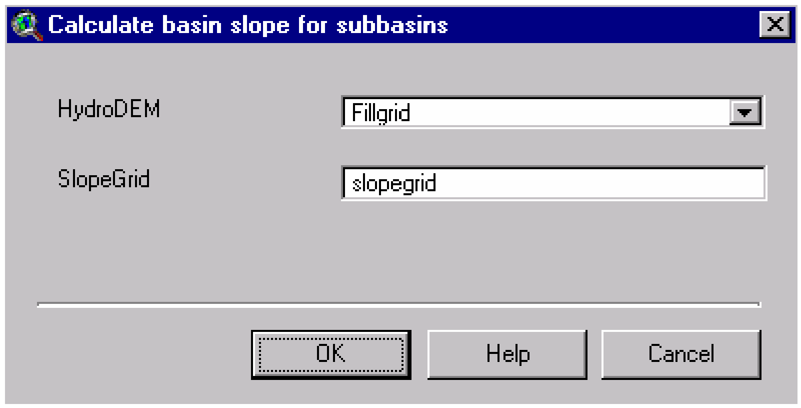


Figure 9–25. Basin slope theme selection.

The function may create a slope grid if one is needed as shown in Figure 9-26. It also creates or updates the following field in the subbasin theme as shown in Figure 9-27:

- BasinSlp: Average subbasin slope.

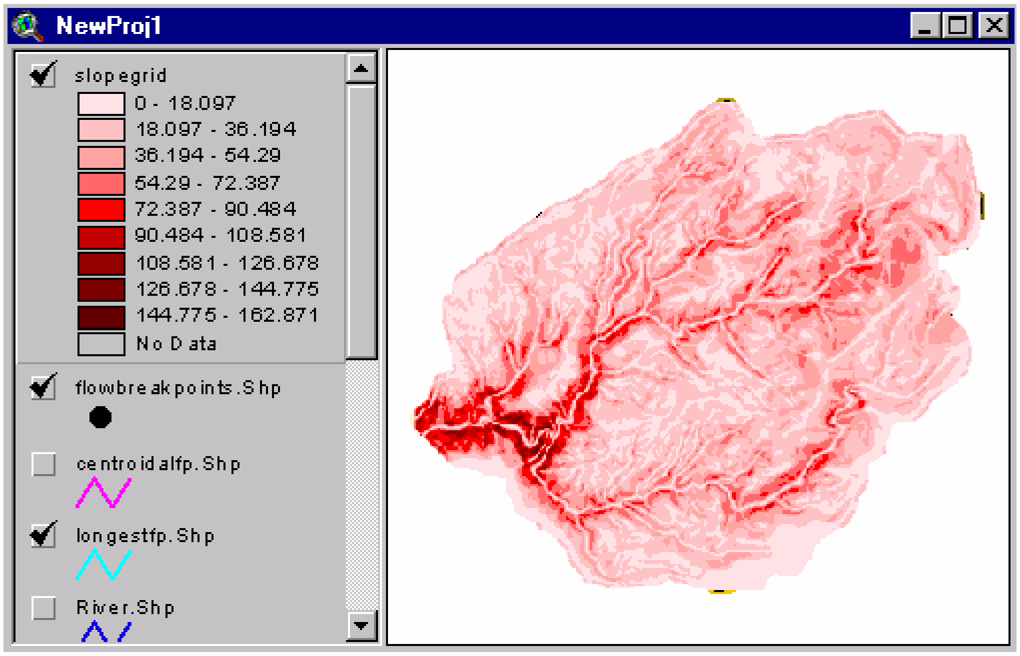
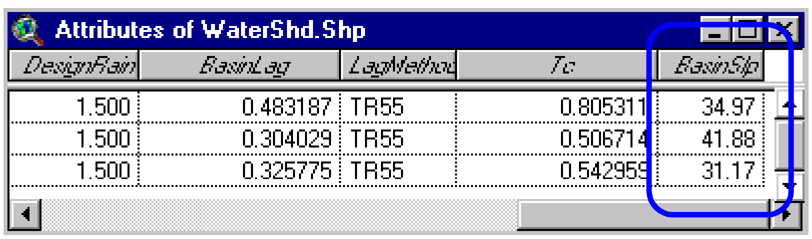


Figure 9–26. Basin slope grid.



DesignRain	BasinLag	LagMetho	Tc	BasinSlp
1.500	0.483187	TR55	0.805311	34.97
1.500	0.304029	TR55	0.506714	41.88
1.500	0.325775	TR55	0.54295	31.17

Figure 9–27. Basin slope computation results.

CN Lag Method

This function computes the basin lag time according to the equation below based on the curve number method described in the NRCS National Engineering Handbook, 1972. This method was developed for watersheds of less than 2000 acres. The function operates on a selected set of subbasins in the subbasin theme. If no subbasin has been selected, the function processes all the subbasins.

$$\text{Lag} = \frac{(L^{0.8} * (S+1)^{0.7})}{(1900 * Y^{0.5})}$$

Where: Lag = basin lag time (hours)

L = hydraulic length of the watershed (feet)

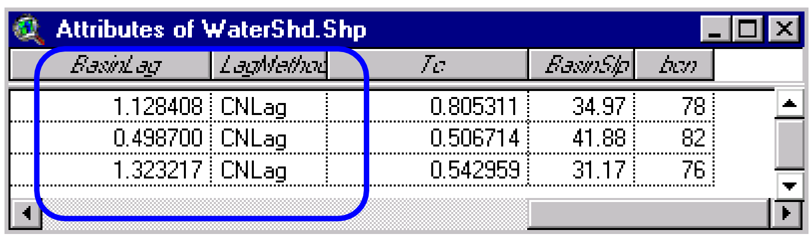
$S = \frac{1000}{CN'} - 10$; where CN’ is approximately equal to the curve number. CN’ values between 50 to 95 are appropriate to this equation.

Y = watershed slope (%)

The watershed slope (Y) value is determined in the previous step, Basin Slope, by averaging the values of slope in the watershed as defined by the slope grid. If the slope grid does not exist, it will be computed using the ESRI **ArcView Spatial Analyst** slope operator.

The function creates or updates the following fields in the watershed theme as shown in Figure 9-28:

- BasinLag: Basin lag (hours).
- LagMethod: Method used for lag computations. For basins for which the CN lag method was used, the entry will be "CNLag".


Attributes of WaterShd.Shp

BasinLag	LagMethod	Tc	BasinSlp	bcn
1.128408	CNLag	0.805311	34.97	78
0.498700	CNLag	0.506714	41.88	82
1.323217	CNLag	0.542959	31.17	76

Figure 9–28. Curve number lag computation results.

Subbasin Index Precipitation

This function calculates the subbasin index precipitation used for the User-Specified Gage Weights method in the HMS Meteorologic Component. The function operates on a selected set of subbasins in the watershed theme. If no subbasin has been selected, the function processes all the subbasins. The value is determined by selecting the amount from the rainfall grid located at the subbasin centroid. There is no unit conversion, so the units of the grid will be used. These units should match the units defined for the meteorologic model defined in the "Unit" entry in the "HMSMetDesign.txt" file (in $AVHOME\etc directory). They should be in millimeters if the units are "SI" and in inches if the units are "English".

This function requires three input themes: subbasin theme, precipitation intensity grid, and the centroid theme.

If the user does not have the necessary precipitation intensity grid, then the user can click the **Cancel** button as shown in Figure 9-29. The function will offer to have the required field created (but not populated). The user can then manually enter the precipitation intensity for each subbasin by editing the "DesignRain" field. The "design" rain here refers to a subbasin index precipitation used in the User Gage Weighting Meteorologic model. The result of this function is only used for setting up a Meteorologic model as discussed in Chapter 10.

Steps

- Select **Hydrologic Parameters** ⇒ **Design Rainfall**
- Select the subbasin, design rainfall grid theme, centroid theme from the dropdown menus as shown in Figure 9-29.

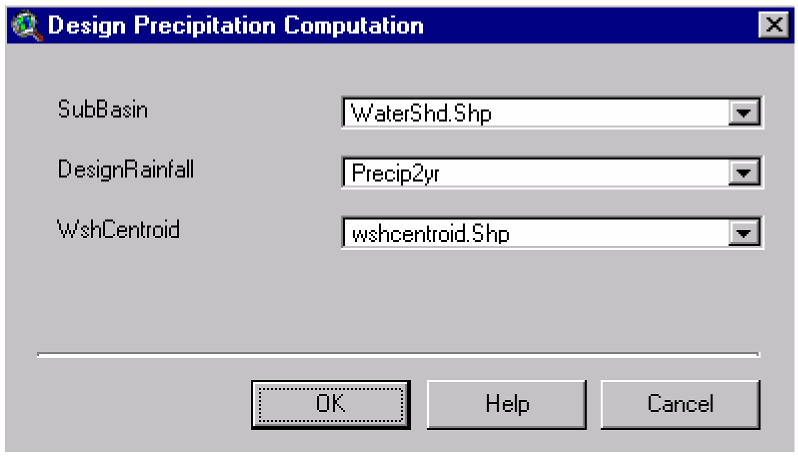
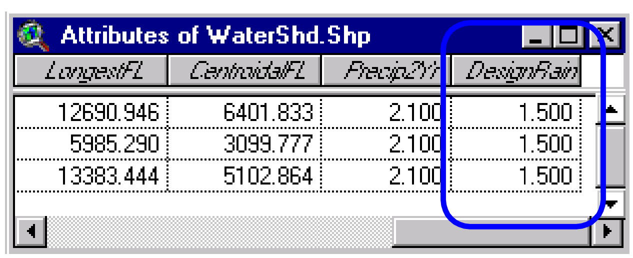


Figure 9–29. Design precipitation computation.

The function creates or updates one field in the subbasin theme as shown in Figure 9-30.

- DesignRain: Precipitation in inches is extracted from the precipitation grid at the location of the watershed centroid. If the precipitation grid contains units that are not in millimeters or inches, then the user will need to do the unit conversion manually.



LongestFL	CentroidalFL	Precip2Yr	DesignRain
12690.946	6401.833	2.100	1.500
5985.290	3099.777	2.100	1.500
13383.444	5102.864	2.100	1.500

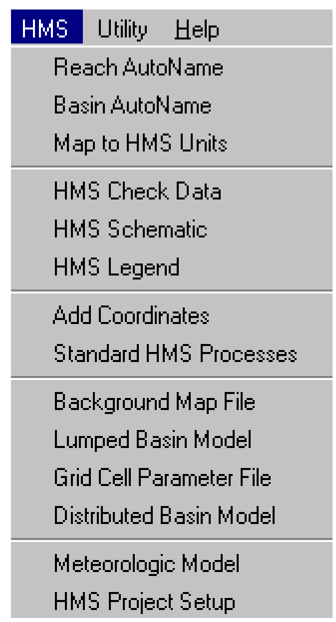
Figure 9–30. Precipitation intensity computation result.

CHAPTER 10

Hydrologic Modeling System

HEC-GeoHMS develops a number of hydrologic inputs for HEC-HMS: background-map file, lumped-basin schematic model file, grid-cell parameter file, and distributed-basin schematic model file. The steps GeoHMS follows to create these files includes automatic naming of reaches and subbasins, checking for errors in the basin and stream connectivity, and producing an HMS schematic. The hydrologic parameter data is then entered through HMS menus.

This chapter will discuss the tools for generating HMS model files that are available in the ***ProjView*** GUI under the **HMS** menu. Below is an outline of Chapter 10.



Contents

Reach AutoName

This process names reaches in sequence from upstream to downstream. The naming convention combines the letter "R" and a number. For example, the upstream reach starts with R10 and then R20, R30, R40, etc. are the reach names proceeding downstream. The intent of this tool is to quickly name the reaches; the user can change the default names to something more descriptive.

Steps

- Select **HMS ⇒ River AutoName** as shown in Figure 10–1.

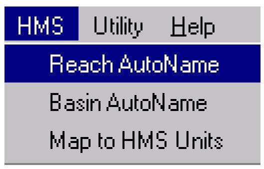
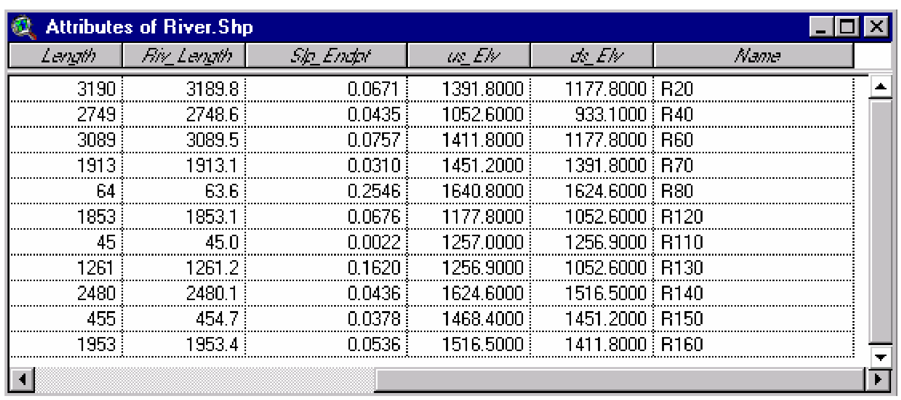


Figure 10–1. Reach autoname menu item.

- Press **OK** on the confirmation message box.

The Reach Autoname operation creates a "Name" column in the stream's attribute table as shown in Figure 10–2.



Attributes of River.Shp

Length	Riv_Length	Slp_Endpt	us_Elv	ds_Elv	Name
3190	3189.8	0.0671	1391.8000	1177.8000	R20
2749	2748.6	0.0435	1052.6000	933.1000	R40
3089	3089.5	0.0757	1411.8000	1177.8000	R60
1913	1913.1	0.0310	1451.2000	1391.8000	R70
64	63.6	0.2546	1640.8000	1624.6000	R80
1853	1853.1	0.0676	1177.8000	1052.6000	R120
45	45.0	0.0022	1257.0000	1256.9000	R110
1261	1261.2	0.1620	1256.9000	1052.6000	R130
2480	2480.1	0.0436	1624.6000	1516.5000	R140
455	454.7	0.0378	1468.4000	1451.2000	R150
1953	1953.4	0.0536	1516.5000	1411.8000	R160

Figure 10–2. Reach autoname result.

The following steps can be used to edit the names in the attribute table.

- Open and activate the attribute table of "River.shp".
- Select **Table ⇒ Start Editing** as shown in Figure 10–3.

Figure 10–3. Edit reach name.

- Select the  (**Edit**) tool.
- Press on a name-field entry and revise it.
- When the revision is done, select **Table** ⇒ **Stop Editing** as shown in Figure 10–4.
- The user is prompted to **Save Edits?** Press **Yes** to save and **No** to cancel the edit.

Figure 10–4. Stop and save revised reach name.

Basin AutoName

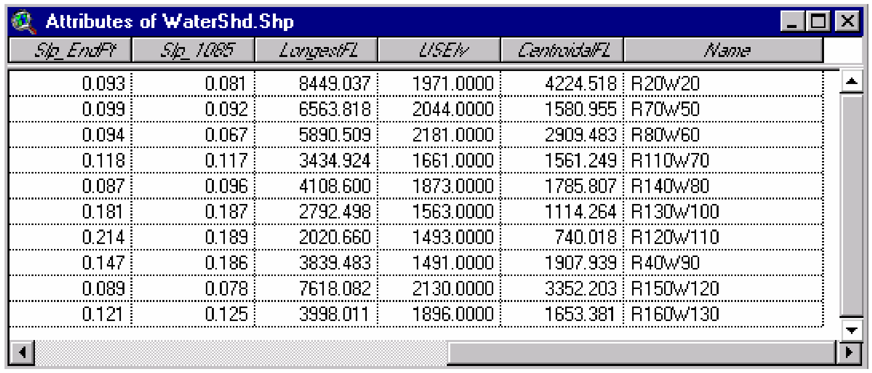
This process names the subbasins in sequence from upstream to downstream. The naming convention adds "W + 10, 20, and etc." to the receiving reach name to form the subbasin name. e.g., R20W20. The intent of this tool is to quickly name the subbasin, and the user can edit the default names to something more descriptive.

Steps

- Select **HMS** ⇒ **Basin AutoName** as shown in Figure 10–5.

Figure 10–5. Basin AutoName menu item.

- The **Basin Autoname** operation creates a "Name" column in the "WaterShd.shp" attribute table as shown in Figure 10–6.



Attributes of WaterShd.Shp

Slp_EndFt	Slp_1085	LongestFL	USElv	CentroidalFL	Name
0.093	0.081	8449.037	1971.0000	4224.518	R20W20
0.099	0.092	6563.818	2044.0000	1580.955	R70W50
0.094	0.067	5890.509	2181.0000	2909.483	R80W60
0.118	0.117	3434.924	1661.0000	1561.249	R110W70
0.087	0.096	4108.600	1873.0000	1785.807	R140W80
0.181	0.187	2792.498	1563.0000	1114.264	R130W100
0.214	0.189	2020.660	1493.0000	740.018	R120W110
0.147	0.186	3839.483	1491.0000	1907.939	R40W90
0.089	0.078	7618.082	2130.0000	3352.203	R150W120
0.121	0.125	3998.011	1896.0000	1653.381	R160W130

Figure 10–6. Subbasin autoname result.

Map to HMS Units

This step converts the physical characteristics of the reaches and subbasins from the map units to the HMS units. The map unit is the unit of the ArcView data; the terrain data is typically in meters. The user has the option to convert the map units to English or the International System (SI) units supported by HMS. HEC-HMS only uses the subbasin area at this time; the other characteristics can be used for regional parameter estimation.

The Table 10-1 shows the HMS units in the English and International System.

Table 10-1. HMS unit systems.

	Physical Characteristics (Table Heading)	HMS EnglishUnits (Table Heading)	HMS SI Units (Table Heading)
Stream (River.Shp)	Length (Riv_Length)	Feet (Riv_Length_HMS)	Meters (Riv_Length_HMS)
	Upstream elevation (US_Elv)	Feet (US_Elv_HMS)	Meters (US_Elv_HMS)
	Downstream elevation (DS_Elv)	Feet (DS_Elv_HMS)	Meters (DS_Elv_HMS)
Watershed (WaterShd.shp)	Area (Area)	Square miles (Area_HMS)	Square kilometers (Area_HMS)
	Centroid Elevation (Elevation)	Feet (Elevation_HMS)	Meters (Elevation_HMS)
	Longest Flow Length (LongestFL)	Feet (Longest_FL)	Meters (LongestFL_HMS)
	Upstream elevation (US_Elv)	Feet (USElv_HMS)	Meters (USElv_HMS)
	Downstream elevation (US_Elv)	Feet (DSElv_HMS)	Meters (DSElv_HMS)
	Centroidal Length (CentroidalFL)	Feet (CentroidalFL_HMS)	Meters (CentroidalFL_HMS)

Steps

- Select **HMS ⇒ Map to HMS Units.**
- Select English from dropdown menu as shown in Figure 10–7. Press **OK**.

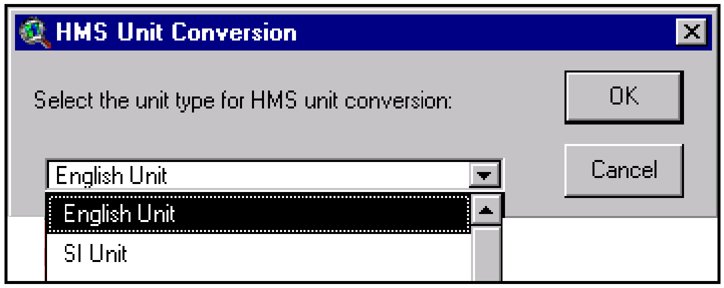
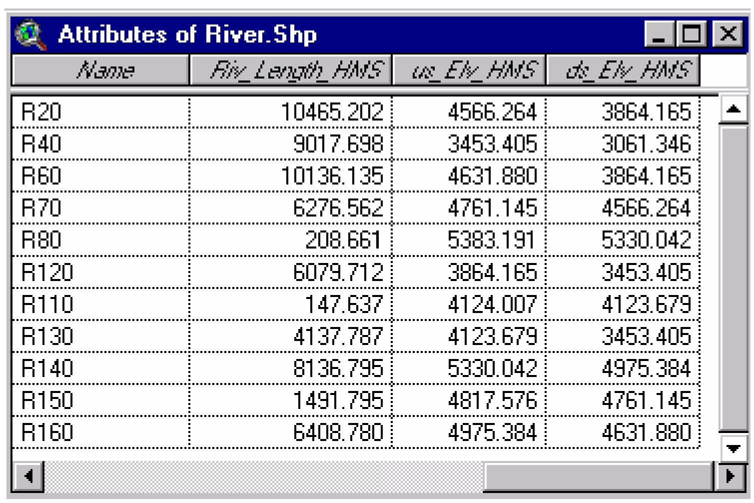


Figure 10–7. HMS unit conversion options.

- Press **OK** in confirmation message box.

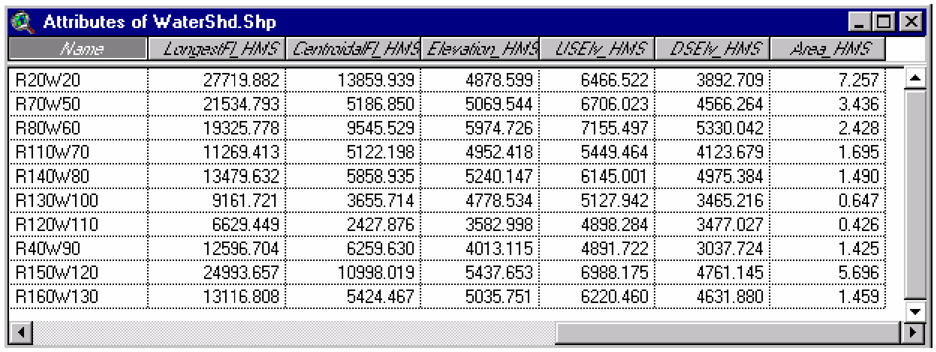
The unit conversion operation results in three added columns for the stream attribute table as shown in Figure 10–8 and six added columns for the subbasin attribute table as shown in Figure 10–9. The units of the added columns are specified in Table 10-1 for the selected unit system.



Attributes of River.Shp

Name	Riv_Length_HMS	us_Elv_HMS	ds_Elv_HMS
R20	10465.202	4566.264	3864.165
R40	9017.698	3453.405	3061.346
R60	10136.135	4631.880	3864.165
R70	6276.562	4761.145	4566.264
R80	208.661	5383.191	5330.042
R120	6079.712	3864.165	3453.405
R110	147.637	4124.007	4123.679
R130	4137.787	4123.679	3453.405
R140	8136.795	5330.042	4975.384
R150	1491.795	4817.576	4761.145
R160	6408.780	4975.384	4631.880

Figure 10–8. River attribute table populated with HMS units fields.



Attributes of WaterShd.Shp

Name	LongestFl_HMS	CentroidalFl_HMS	Elevation_HMS	USElv_HMS	DSElv_HMS	Area_HMS
R20W20	27719.882	13859.939	4878.599	6466.522	3892.709	7.257
R70W50	21534.793	5186.850	5069.544	6706.023	4566.264	3.436
R80W60	19325.778	9545.529	5974.726	7155.497	5330.042	2.428
R110W70	11269.413	5122.198	4952.418	5449.464	4123.679	1.695
R140W80	13479.632	5858.935	5240.147	6145.001	4975.384	1.490
R130W100	9161.721	3655.714	4778.534	5127.942	3465.216	0.647
R120W110	6629.449	2427.876	3582.998	4898.284	3477.027	0.426
R40W90	12596.704	6259.630	4013.115	4891.722	3037.724	1.425
R150W120	24993.657	10998.019	5437.653	6988.175	4761.145	5.696
R160W130	13116.808	5424.467	5035.751	6220.460	4631.880	1.459

Figure 10–9. Watershed attribute table populated with HMS units fields.

HMS Data Check

This step checks the data sets for consistency in describing the hydrologic structure of the model. For example, the program checks for unique names for the reaches, subbasins, and outlet points. In addition, the program checks that the rivers and centroids are contained within the subbasins and that rivers are connected with relevant points created in the basin processing step. This is desirable for placement of the hydrologic elements' names and connectivities on the HMS basin schematic. In general, the program keeps track of the relationship between the stream segments, subbasins, outlet points, and other entities. These checks are necessary because the relationships between hydrologic elements may have been broken by unintentional use of the tools.

The program checks every spatial feature in the "River.shp", "WaterShd.shp", "Amerriv1.shp", and "wshcentroid.shp" data files. It produces a text file, "SkelConsChk.txt", that presents the results on each feature and summarizes the results. This step does not fix any of the problems. However, the user can view the result and fix the problems manually using HEC-GeoHMS or HMS.

Steps

- Select **HMS ⇒ HMS Check Data**.
- Review the input data sets as shown in Figure 10–10. Press **OK**.

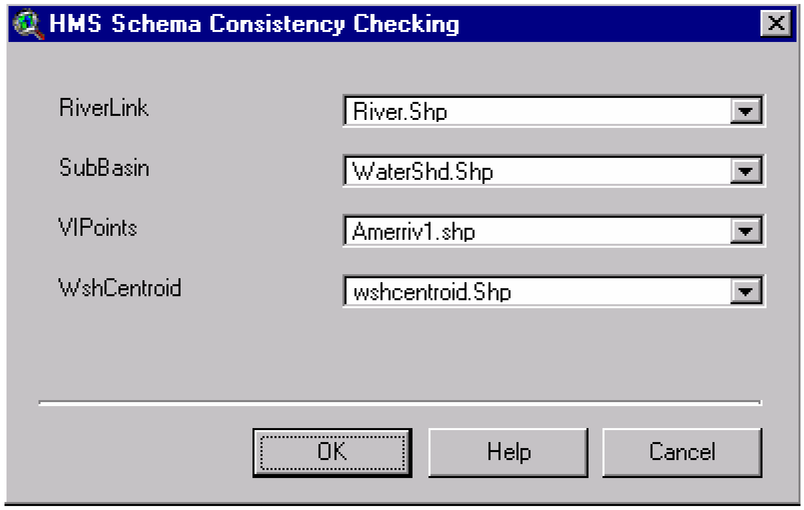


Figure 10–10. HMS check data input and output files.

- Make a note of the filename and its location as shown in Figure 10–11. Press **OK**.

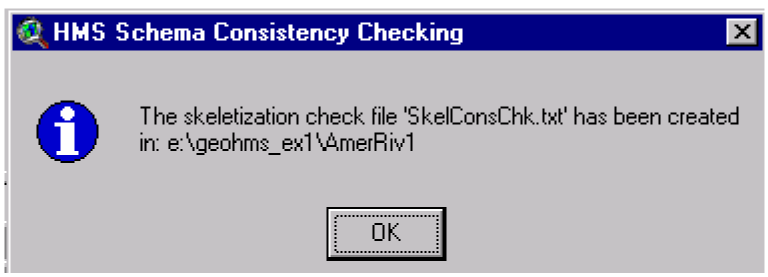


Figure 10–11. HMS check data result file location.

- Open the results file with a text editor and review the results.

The "Checking Summary" at the end of the file shows that 4 of the 5 items checked have no problems, see Figure 10–12. The "VIP Relevance" check shows two problems. The VIPs (very important points) represent locations of basin subdivision, outlets, centroids, etc. Sometimes, a few VIPs are no longer relevant or needed because the basin outlets may have changed as a result of basin processing.

```
CHECKING SUMMARY
****************

Unique names        - no problems.
River Containment   - no problems.
Center Containment  - no problems.
River Connectivity  - no problems.
VIP Relevance       - total of 2 problems.
```

Figure 10–12. HMS check data result summary.

- Scroll up the file and find that problems exist with BatchPoint1 and BatchPoint2 as shown in Figure 10–13.

After examining the subbasin delineation, Batch Points 1 and 2 appear to be relevant because they serve as basin outlets. Keep these problems in mind and fix them in HMS, if necessary. These problems can also be fixed with some effort using HEC-GeoHMS by editing various tables. Currently, the types of problems that can be easily fixed are reach and subbasin name revisions.

```
Checking VIP point:BatchPoint1
End of checking VIP point: BatchPoint1 - PROBLEM: the status could not be determined

Checking VIP point:BatchPoint2
End of checking VIP point: BatchPoint2 - PROBLEM: the status could not be determined
```

Figure 10–13. HMS check data problems.

HEC-HMS Basin Schematic

The HMS basin schematic is the GIS representation of the hydrologic basin model with basin elements and their connectivity. This step creates a point shapefile, "HMSPoint.shp", and a line shapefile, "HMSConnect.shp". The "HMSPoint.shp" contains point features, such as subbasin icon locations, outlets, and junctions. Subbasin icons are placed at the centroid of the area. The "HMSConnect.shp" contains line features, such as subbasin connectors and reaches. The subbasin connector joins a subbasin icon to the basin outlet.

Steps

- Select **HMS ⇒ HMS Schematic**.
- Review the input and output data sets as shown in Figure 10–14. Press **OK**.

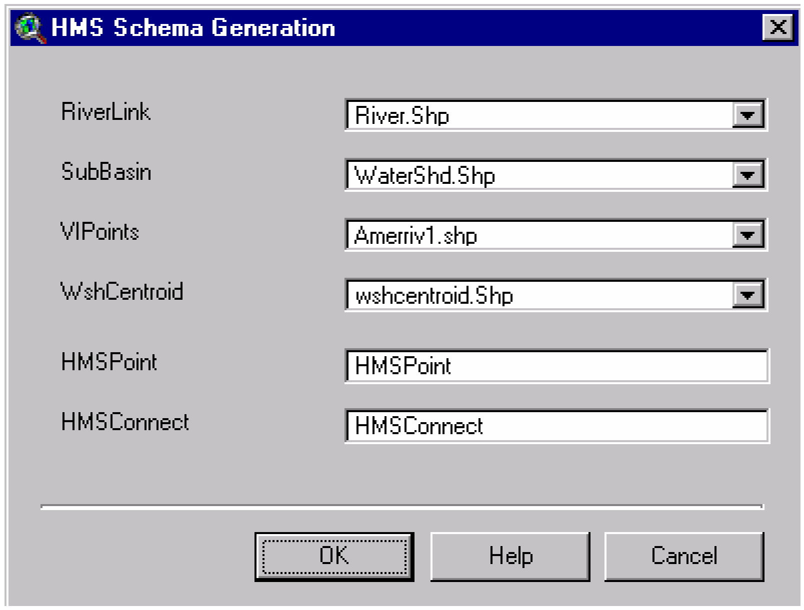


Figure 10–14. HMS schematic input and output files.

- Press **OK** at the confirmation message box.

The HMS schematic with ArcView symbols is shown in Figure 10–15.

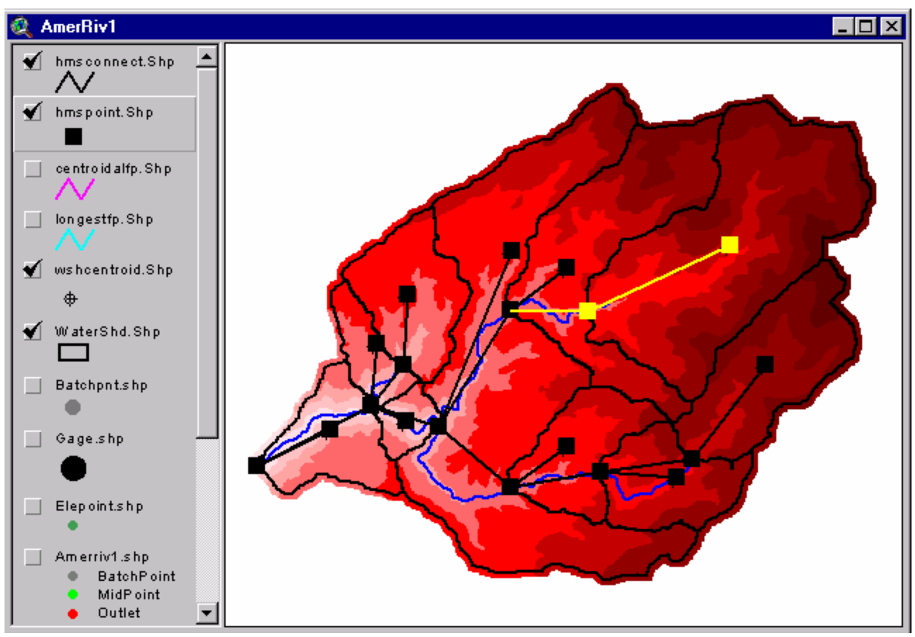


Figure 10–15. Initial HMS schematic result.

The attribute tables of the “hmspoint.shp” and “hmsconnect.shp” shapefiles are shown in Figure 10–16 and Figure 10–17. The highlighted features are shown on the tables to display how the program uses the downstream element name, “Dstr_Name”, in both tables to establish element connectivity.

Attributes of hmspoint.Shp

Shape	Numid	Dstr_Name	Name	Type
Point	1		OutletAR	0
Point	2	R20	UserPoint2	2
Point	3	R140	UserPoint3	2
Point	4	R130	UserPoint4	2
Point	5	R160	UserPoint5	2
Point	6	R70	BatchPoint1	15
Point	7	R60	BatchPoint2	15
Point	8	R120	JR120	7
Point	2	JR120	R20W20	8
Point	5	UserPoint2	R70W50	8
Point	6	UserPoint3	R80W60	8
Point	7	UserPoint4	R110W70	8
Point	8	UserPoint5	R140W80	8
Point	9	R40	JR40	7
Point	10	JR40	R130W100	8
Point	11	JR40	R120W110	8
Point	9	OutletAR	R40W90	8
Point	12	BatchPoint1	R150W120	8
Point	13	BatchPoint2	R160W130	8

Figure 10–16. HMS schematic point attribute table.

Attributes of hmsconnect.Shp

Shape	Numid	Dstr_Name	Name	Type
PolyLine	2	JR120	R20W20	1
PolyLine	5	UserPoint2	R70W50	1
PolyLine	6	UserPoint3	R80W60	1
PolyLine	7	UserPoint4	R110W70	1
PolyLine	8	UserPoint5	R140W80	1
PolyLine	10	JR40	R130W100	1
PolyLine	11	JR40	R120W110	1
PolyLine	9	OutletAR	R40W90	1
PolyLine	12	BatchPoint1	R150W120	1
PolyLine	13	BatchPoint2	R160W130	1
PolyLine	2	JR120	R20	2
PolyLine	4	OutletAR	R40	2
PolyLine	6	JR120	R60	2
PolyLine	7	UserPoint2	R70	2
PolyLine	12	JR40	R120	2
PolyLine	13	JR40	R130	2
PolyLine	14	UserPoint5	R140	2
PolyLine	16	BatchPoint2	R160	2

Figure 10–17. HMS schematic line attribute table.

HMS Legend

This process implements HMS symbology to represent point and line features more descriptively as hydrologic elements, such as junctions, subbasins, sources, and others. The user has the option to toggle between **HMS Legend** and **Regular Legend**.

Steps

- Select **HMS** ⇒ **HMS Legend**.
- The user can toggle between **HMS Legend** and **Regular Legend** by selecting **HMS** ⇒ **HMS Legend** or **Regular Legend**.

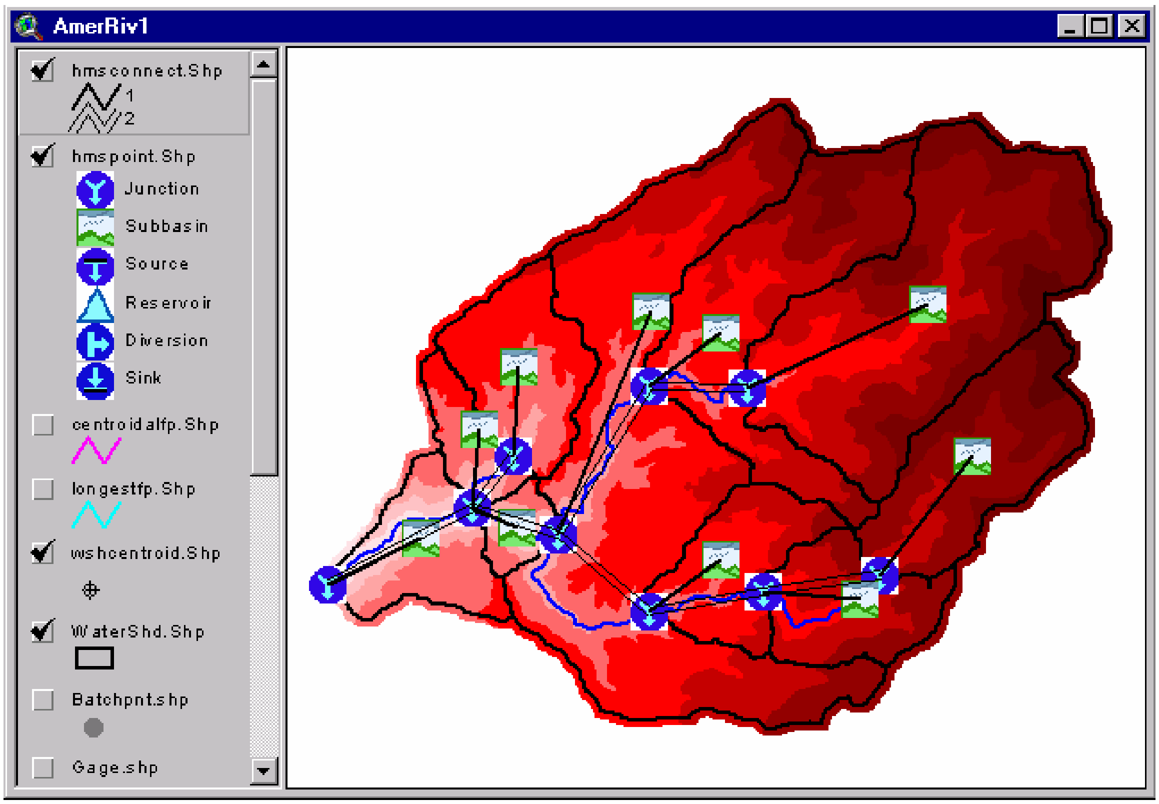


Figure 10–18. HMS schematic with symbols.

Add Coordinates

This step attaches geographic coordinates to hydrologic elements in the attribute tables of “HMSPoint.shp” and “HMSConnect.shp”. The attachment of coordinates allows GIS data to be exported to a non-proprietary ASCII format and still preserves the geospatial information.

Steps

- Select **HMS ⇒ Add Coordinates**. Press **OK**.

The results are shown in Figure 10–19 and Figure 10–20. For a point feature in Figure 10–19, the “CanvasX”, “CanvasY”, “Elevation” columns describe an outlet in 3-dimensional space. For a line feature in Figure 10–20, the coordinate pair (“FromCanvasX”, “FromCanvasY”) and (“CanvasX, CanvasY”) describe a reach orientation with flow direction.

Attributes of hmspoint.Shp

Name	Type	CanvasX	CanvasY	Elevation
OutletAR	0	-54690.000	122400.000	933.100
UserPoint2	2	-49935.000	125325.000	1391.800
UserPoint3	2	-46515.000	122535.000	1624.600
UserPoint4	2	-51945.000	124305.000	1256.900
UserPoint5	2	-48255.000	122295.000	1516.500
BatchPoint1	15	-48495.000	125295.000	1451.200
BatchPoint2	15	-49935.000	121995.000	1411.800
JR120	7	-51285.000	123135.000	1177.800
R20W20	8	-49903.622	126433.622	1487.000
R70W50	8	-48885.000	126105.000	1545.200
R80W60	8	-45165.000	124305.000	1821.100
R110W70	8	-51870.000	125610.000	1509.500
R140W80	8	-46830.000	122175.000	1597.200
JR40	7	-52545.000	123525.000	1052.600
R130W100	8	-52455.000	124680.000	1456.500
R120W110	8	-51885.000	123240.000	1092.100
R40W90	8	-53325.000	123090.000	1223.200
R150W120	8	-45825.000	126525.000	1657.400
R160W130	8	-48868.909	122767.636	1534.900

Figure 10–19. Point attribute table populated with coordinates.

Attributes of hmsconnect.Shp

Name	Type	FromCanvasX	FromCanvasY	CanvasX	CanvasY
R20W20	1	-49903.622	126433.622	-51285.000	123135.000
R70W50	1	-48885.000	126105.000	-49935.000	125325.000
R80W60	1	-45165.000	124305.000	-46515.000	122535.000
R110W70	1	-51870.000	125610.000	-51945.000	124305.000
R140W80	1	-46830.000	122175.000	-48255.000	122295.000
R130W100	1	-52455.000	124680.000	-52545.000	123525.000
R120W110	1	-51885.000	123240.000	-52545.000	123525.000
R40W90	1	-53325.000	123090.000	-54690.000	122400.000
R150W120	1	-45825.000	126525.000	-48495.000	125295.000
R160W130	1	-48868.909	122767.636	-49935.000	121995.000
R20	2	-49935.000	125325.000	-51285.000	123135.000
R40	2	-52545.000	123525.000	-54690.000	122400.000
R60	2	-49935.000	121995.000	-51285.000	123135.000
R70	2	-48495.000	125295.000	-49935.000	125325.000
R120	2	-51285.000	123135.000	-52545.000	123525.000
R130	2	-51945.000	124305.000	-52545.000	123525.000
R140	2	-46515.000	122535.000	-48255.000	122295.000
R160	2	-48255.000	122295.000	-49935.000	121995.000

Figure 10–20. Line attribute table populated with coordinates.

Standard HMS Processes

An HMS basin model file contains the hydrologic data structure, which includes the hydrologic elements, their connectivities, and related parameters. GeoHMS can export some of the hydrologic parameters to the HMS basin model file. For those parameters that do not have a GIS input at this time, but are required to complete the HMS project, this function populates a series of fields with default values needed for setting up the HEC-HMS input files. In GeoHMS Version 1.1, only one method for modeling is definable. If changes to these modeling methods and parameters are required, they can be done after the basin model is imported into HMS.

Changes to these modeling methods and parameters can also be made manually in GeoHMS by editing the "fieldmap.fmf" file located in the project file directory.   This file contains the default fields to be used for basin file generation. If this file already exists, the user will be prompted whether to replace it. If the file is replaced or overwritten, it will contain only default fields. Any user customizations will be lost and will require manual editing of the 'fieldmap.fmf' file. Additional information can be added to this file as more parameters can be extracted using GeoHMS. For further information review the help section on **GeoHMS Field Specification** for HMS Object Definition.

This operation creates an ASCII file named 'fieldmap.fmf' in the project directory. Table 10-2 presents the fields in the "fieldmap.fmf" file and the default values set by this function.

Table 10-2. Default HMS modeling methods.

Theme	Field (function)	Default value
HMSPoint	TransMet (transformation method)	"SCS"
	LossMet (loss method)	"SCS"
HMSConnect	RouteMet (routing method)	"Muskingum Cunge Standard"
SubBasin	InitAbst (initial abstraction)	0
	PctImp (percent impervious)	0

Background-Map File

The background-map file captures the geographic information of the subbasin boundaries and stream alignments in an ASCII text file that can be read by HMS. The format specifications of the background map file are given in Appendix B.

Steps

- Select **HMS ⇒ Background Map File**.
- Make a note of the filename and its location as shown in Figure 10–21. Press **OK**.

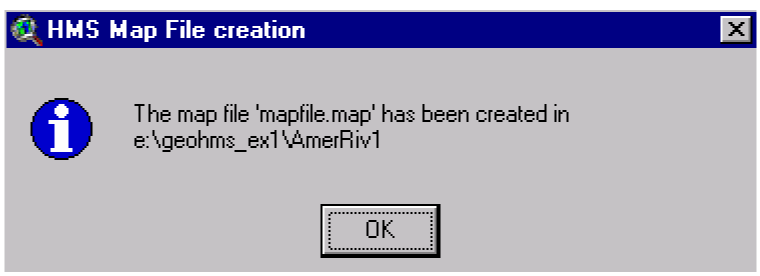


Figure 10–21. Background map file location.

The resulting background map file in ASCII format looks similar to Figure 10–22.

```
MapGeo:  BoundaryMap
MapSegment:  closed
     -48150, 121350
     -48120, 121350
     -48120, 121320
     -48090, 121320
     -48090, 121290
```

…many lines omitted …

```
MapGeo:  RiverMap
MapSegment:  open
    -49935, 125325
    -49965, 125295
    -49995, 125295
    -50145, 125145
    -50175, 125145
```

…many lines omitted …

Figure 10–22. HMS background map file example.

Lumped-Basin Model

The lumped-basin model captures the hydrologic elements, their connectivity, and related geographic information in an ASCII text file that can be input to HMS. This basin model should be used for a hydrologic model with lumped, not distributed, basin parameters. Lumped-basin models do not use gridded precipitation or the ModClark transform method.

Steps

- Select **HMS ⇒ Lumped Basin Model**.
- Make a note of the filename and its location as shown in Figure 10–23. Press **OK**.

Figure 10–23. Lumped basin model file location.

The resulting lumped-basin model file in ASCII format looks similar to Figure 10–24.

```
Basin:  AmerRiv1
Description:  Basin model created with HEC-GeoHMS v1.0
Last Modified date:  27 February 2000
Last Modified Time:  17:19:13
Unit System:  English Unit
End:

Junction:  OutletAR
CanvasX:  -54690.000000
CanvasY:  122400.000000
Label X:  16
Label Y:  0
End:

Junction:  UserPoint2
CanvasX:  -49935.000000
CanvasY:  125325.000000
Label X:  16
Label Y:  0
Downstream:  R20
End:
```

Figure 10–24. HMS lumped-basin model example.

Grid-Cell Parameter File

This function generates the ModClark grid cell parameter file. The grid-cell parameter file represents subbasins as grid cells for the distributed-modeling approach. An ASCII file with name ProjectName.mod, which contains gridded subbasin information, will be created in the project directory. The ModClark grid cell parameter file has been extended to include a gridded curve number. The grid-cell parameter file contains the parameters and units as shown in Table 10-3.

This function requires one input theme:

ModClark grid cell polygon shapefile

Table 10-3. Grid-Cell Parameters Units

	Physical Characteristics ***(Table Heading)***	***Units***
Grid Cell Parameter ***(ModClark2K.Shp)***	X Coordinates (Shg_X)	N/A
	Y Coordinates (Shg_Y)	N/A
	Grid-Cell Travel Distance (FlowLength)	Kilometers
	Grid-Cell Area (Mod_Area)	Square kilometers
	Curve Number (SCSCN)	N/A (Value between 0 and 100)

Steps

- Select **HMS ⇒ Grid Cell Parameter File**.
- Make a note of the filename and its location as shown in Figure 10–25. Press **OK**.

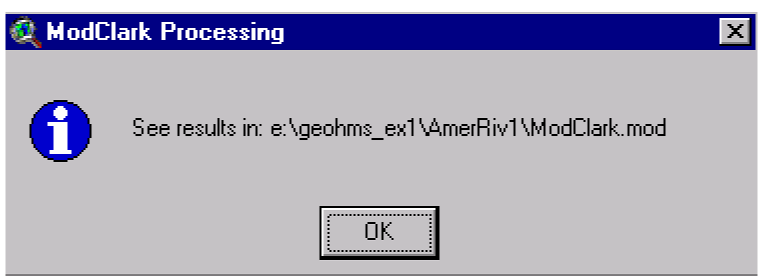


Figure 10–25. Grid-cell parameter file location.

The resulting grid-cell parameter file in ASCII format looks similar to Figure 10–26.

```
PARAMETER ORDER: Xcoord Ycoord TravelLength Area  SCSCN
END:
SUBBASIN:  R20W20
GRIDCELL:  -1043  1029  1.374443  0.105995
GRIDCELL:  -1042  1028  3.453967  1.480709
GRIDCELL:  -1042  1029  1.827143  3.445945
GRIDCELL:  -1042  1030  1.702081  1.554524
GRIDCELL:  -1042  1031  3.259464  0.004658
GRIDCELL:  -1042  1031  4.946023  0.399514
GRIDCELL:  -1042  1032  5.651498  0.007268
GRIDCELL:  -1041  1028  5.022047  2.119920
GRIDCELL:  -1041  1029  4.106799  1.067283
GRIDCELL:  -1041  1029  3.417962  0.019840
GRIDCELL:  -1041  1030  2.949917  2.369097
GRIDCELL:  -1041  1031  4.757159  3.010195
GRIDCELL:  -1041  1032  6.097099  0.675054
GRIDCELL:  -1040  1028  6.561974  0.506599
GRIDCELL:  -1040  1031  6.570029  0.444512
GRIDCELL:  -1040  1032  7.295388  1.584486
END:
```

… Many lines omitted …

Figure 10–26. HMS grid-cell parameter file in ASCII format.

Distributed-Basin Model

Similar to the lumped-basin model, the distributed-basin model has additional labeling that references the grid-based subbasin in conjunction with the grid-cell parameter file. The ModClark transform method and gridded precipitation must be used with distributed basin models.

Steps

- Select **HMS ⇒ Distributed-Basin Model**.
- Make a note of the filename and its location as shown in Figure 10–27. Press **OK**.

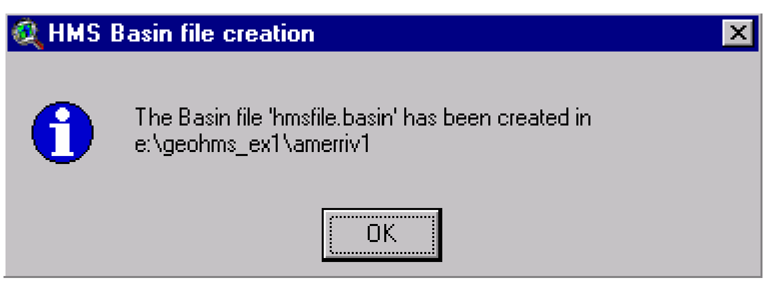


Figure 10–27. Distributed-basin model file location.

The resulting distributed-basin model file in ASCII format looks similar to Figure 10–28.

```
Basin:  AmerRiv1
Description:  Basin model created with HEC-GeoHMS v1.0 Beta
Last Modified date:  27 February 2000
Last Modified Time:  17:22:52
Unit System:  English Unit
End:

... many lines omitted ...

Gridded Subbasin:  R20W20
CanvasX:  -49903.622000
CanvasY:  126433.622000
Area:  7.257000
Label X:  16
Label Y:  0
Downstream:  JR120
End:

... many lines omitted ...
```

Figure 10–28. HMS distributed-basin model file example.

Meteorologic Model File

This function generates the HMS meteorological model file (*.met). The user will be prompted to specify the name of the meteorologic station whose temporal distribution will be used for the basins with the User-Specified Gage Weights method in HMS. This is currently the only supported meteorologic model in GeoHMS. Other meteorologic models can be specified through HMS.

The "DesignRain" field in the subbasin theme contains the values that will be associated with each subbasin/gaging station. The effect of this precipitation modeling approach is the following:

1. All subbasins are assigned the same, user selected, gaging station. This gaging station (as defined in the dss file) should contain temporal distribution of one unit of precipitation (cumulative value = 1).

2. "DesignRain" field contains the average design rainfall for each subbasin that will be used to adjust (scale/index) the unit precipitation defined by the gaging station. It is important to match the duration of the event defined by the gaging station with the values stored in the "DesignRain" field. For example, if the gaging station refers to a design rainfall pattern for a 100-year event of 24-

hour duration, then the values in the "DesignRain" field should match those design criteria.

3. The final effect is that each subbasin has the same temporal distribution pattern but the overall volume and peak rainfall is scaled using the individual values for each subbasin (as defined in DesignRain field).

The list of available gages is defined in the HMSMetDesign.txt file. These gages need to have an entry in the hmsdesign.gage file pointing to the rainfall distribution pattern stored in the hmsdesign.dss file. The three mentioned files should reside in the $AVHOME\etc directory. For customization of the available meteorological station, review the Rainfall Gage Specification help topic.

It is important to note that the "Unit" entry in the "HMSMetDesign.txt" file ($AVHOME\etc directory) must be consistent with the units in the “DesignRain” field. If the unit entry is "SI", than the DesignRain values must be in millimeters. If the unit entry is "English", than the DesignRain values must be in inches. GeoHMS does not provide functionality to convert different precipitation units into the HMS precipitation units, so it is user’s responsibility to insure that the precipitation units are correct (conversion can be easily performed using standard ArcView table editing operations – e.g. table calculator).

HMS Project Setup

This function generates a project subdirectory in the HMS project directory. It copies all project specific and standard GeoHMS files into that directory. If the directory exists, the files in there will be replaced. The location of the HMS project directory is specified in the HMSMetDesign.txt file (in $AVHOME\etc directory) as "HMSDataDirectory". By modifying that entry, GeoHMS can be instructed to generate project subdirectories in a different parent directory.

The following files are copied ("Project" identifies the name of the project in GeoHMS):

"Project".basin copied from the GeoHMS project subdirectory.

"Project".hms copied from the GeoHMS project subdirectory.

"Project".met copied from the GeoHMS project subdirectory.

"Project".map copied from the GeoHMS project subdirectory.

"Project".mod copied from the GeoHMS project subdirectory.

"Project".dss renamed from hmsdesign.dss in $AVHOME\etc directory.

"Project".control renamed from hmsdesign.control in $AVHOME\etc directory.

"Project".gage renamed from hmsdesign.gage in $AVHOME\etc directory.

This set of files completely defines an HMS project and can be directly loaded and executed from HMS without any further data manipulation. In general, quality control on the data input should be performed before actually performing the HMS run.

Once created, the files in the HMS directory are not related to the files in the GeoHMS project directory, so any changes in one set of files will NOT be reflected in the other.

Hydrologic Modeling System Connection

The purpose of this section is to illustrate the procedure for interfacing the inputs developed in HEC-GeoHMS within HEC-HMS models.

HEC-GeoHMS develops many components of an HMS model. GeoHMS capabilities extend from processing the terrain model to performing spatially intensive analysis for development of grid-based parameters. The results produced can be controlled somewhat by focusing on the spatial description of the landscape characteristics and stream networks. However, from a modeling standpoint, greater control over the model is often necessary to address difficult situations. HMS is powerful in that it offers full control over the model to address hydrologic connectivity, methodology, and parameters. For example, HMS can be used to change the connectivity and eliminate, add, and revise hydrologic elements and their properties.

The HMS project definition requires Basin, Meteorologic, and Control Specifications components (HEC, 2000). The steps for setting up these three HMS components are discussed below.

Directory Setup

- Create the HMS project first, and then copy the background-map file, basin-model file, and grid-cell parameter file, if appropriate, into “**D:\hmsproj\ GeoHMS_Ex1**”.

HMS Use

- Start HMS.

- Select **File ⇒ New Project** on the **HMS*PROJECT DEFINITION** screen.
- Enter the **Project** as "GeoHMS_Ex1" and **Description** as "GIS Application from HEC-GeoHMS" as shown in Figure 10–29.
- Press **OK**.

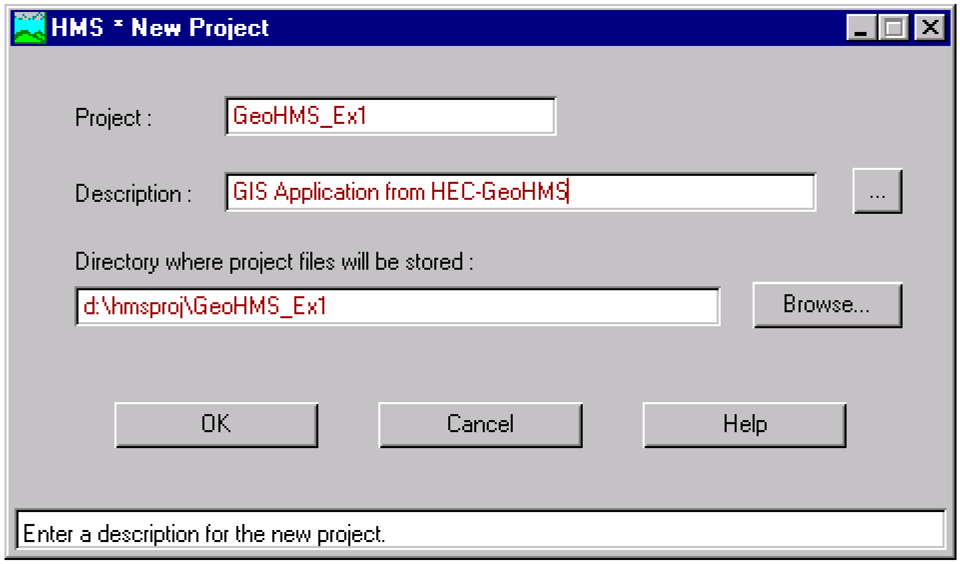


Figure 10–29. New HMS project definition window.

Basin Model

Import the Basin Model with the following steps.

- On the **HMS*PROJECT DEFINITION** screen, select **Component ⇒ Basin Model ⇒ Import** as shown in Figure 10–30.

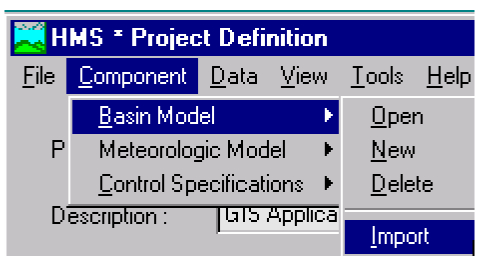


Figure 10–30. Basin model import.

- Navigate to "D:\hmsproj\ GeoHMS_Ex1".
- Select and import the "AmerRiv1" Basin Model.
- Press **Import** as shown in Figure 10–31.

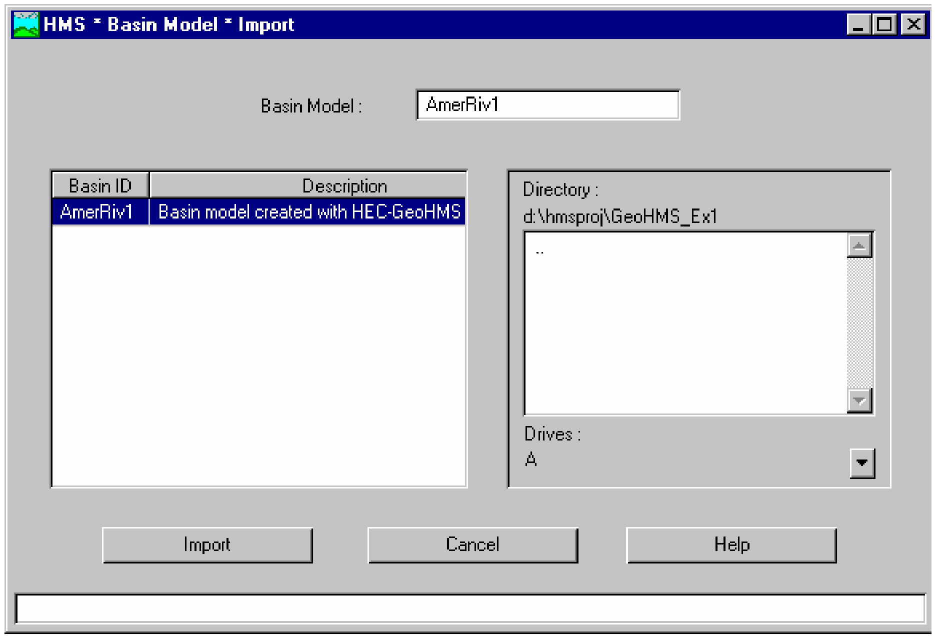


Figure 10–31. HMS basin model import window.

The following errors, shown in Figure 10–32 and Figure 10–33, warn the user that Batch Points 1 and 2 do not have a downstream element connection. Press **OK** in both message boxes and make note to fix the downstream connections later with HMS.

Figure 10–32. Critical error on batch point 2.

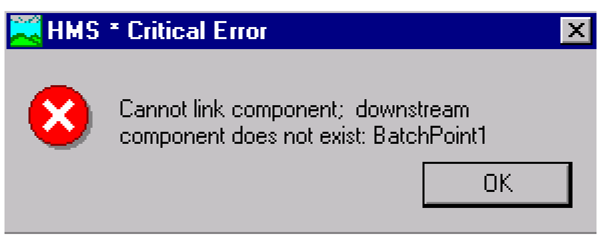


Figure 10–33. Critical error on batch point 1.

Background-Map File and Grid-Cell Parameter File

Specify the background-map file and grid-cell parameter file with the following steps.

- Specify the background-map file and grid-cell parameter file by selecting the **File ⇒ Basin Model Attributes** menu item as shown in Figure 10–34. This produces the Basin Model Attributes screen shown in Figure 10–35.

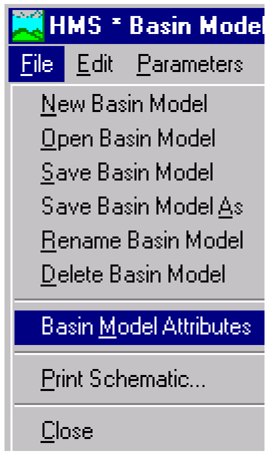


Figure 10–34. HMS basin model attributes menu item.

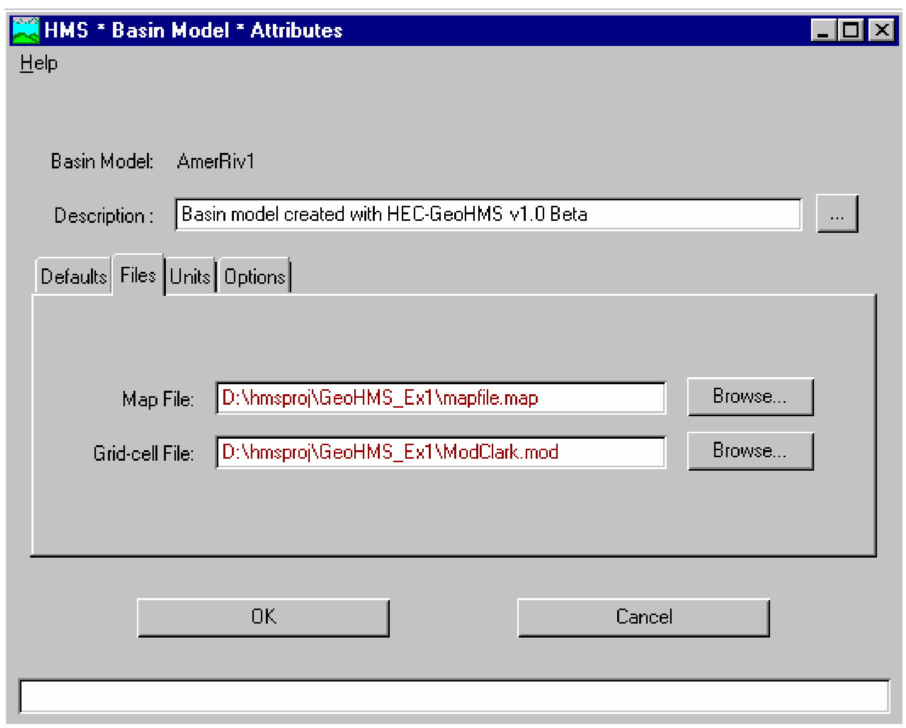


Figure 10–35. HMS basin model attributes specifications.

- Select the **Files** tab.
- To specify the Map File, press **Browse**.
- Navigate to the D:\hmsproj\ GeoHMS_Ex1 and select the file "mapfile.map" as shown in Figure 10–35.

- To specify the Grid-cell File, press **Browse**.
- Navigate to the D:\hmsproj\ GeoHMS_Ex1 and select the file "ModClark.mod" as shown in Figure 10–35.

- To specify the default methods, select the **Default** tab. Then select a loss rate, ModClark for transform (this is the grid-cell based unit graph), baseflow, and a routing method. Press **OK**.

The resulting basin model with the background map is shown in Figure 10–36. Notice that subbasins R150W120 and R160W130 are not connected to junctions (these were the problems noted for Batch Points 1 and 2 in the previous data checking).

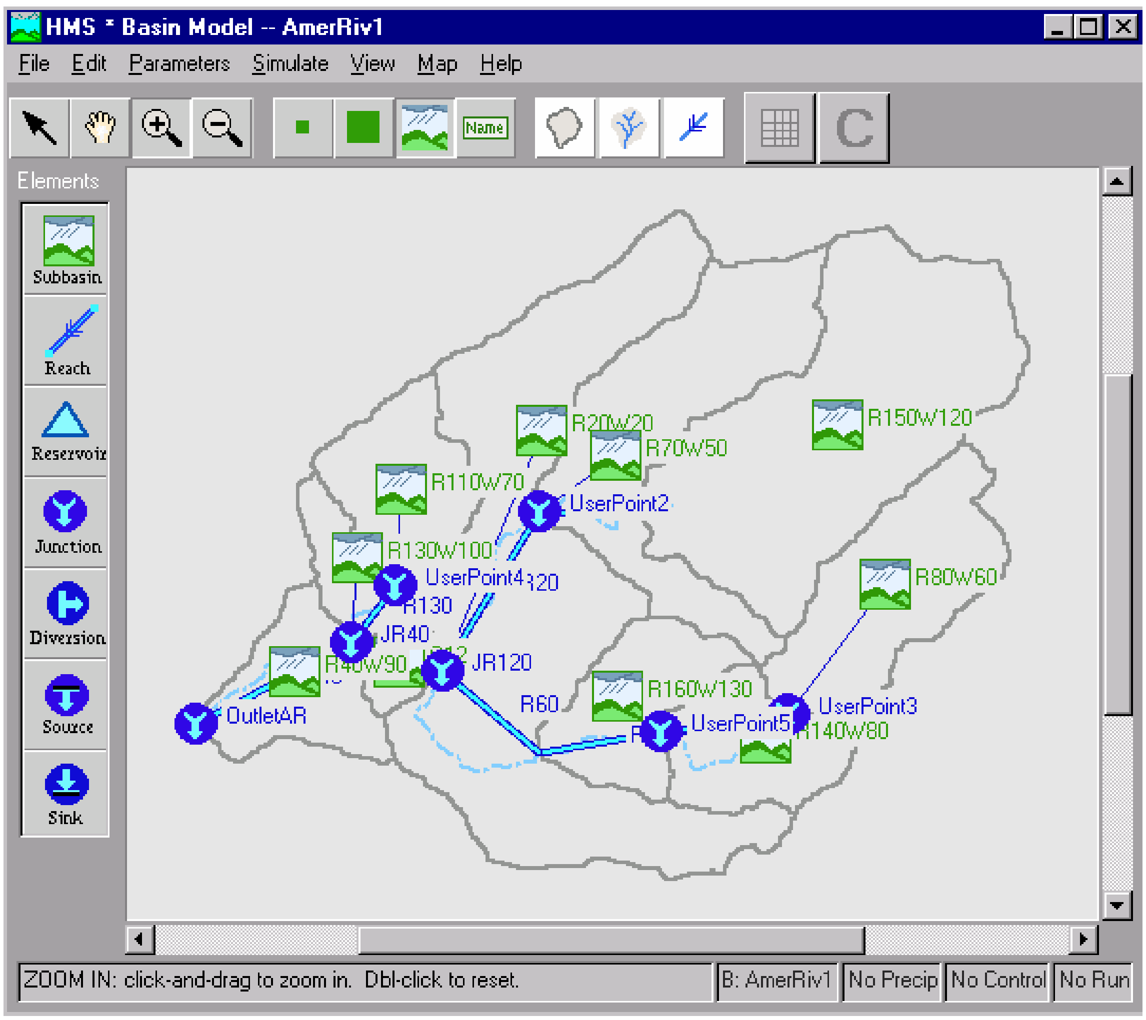


Figure 10–36. HMS basin model schematic.

To fix the missing junction, select the **Junction** element on the left side palette of the HMS Schematic screen and drag it onto the canvas and drop it at the outlet of subbasin R150W120.

Use HMS to connect subbasin R150W120 to Junction-1. Add routing reach R70 to connect Junction-1 to UserPoint2 as shown in Figure 10–37.

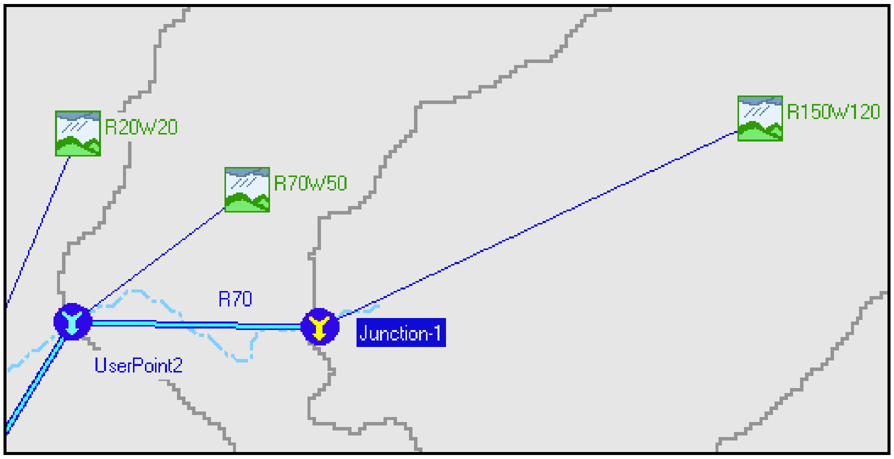


Figure 10–37. Revision to basin connectivity with junction-1.

To connect subbasin R160W130, first break the connection of R160 and R60. Then insert the **Junction** element on the left side palette by dragging and dropping it at the outlet of subbasin R160W130. Use HMS to connect subbasin R160W130 to Junction-2, then connect reach R160 to Junction-2, and finally Junction-2 to reach R60 as shown in Figure 10–38.

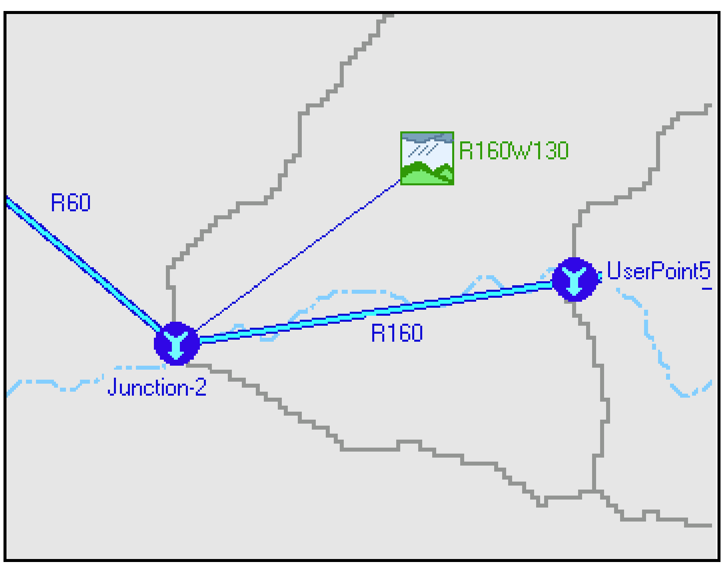


Figure 10–38. Revision to basin connectivity with junction-2.

The corrected basin model is shown in Figure 10–39.

- Select the **Parameters** menu to enter additional hydrologic parameters per menu items. Save and close the **HMS * Basin Model – AmerRiv1** window.

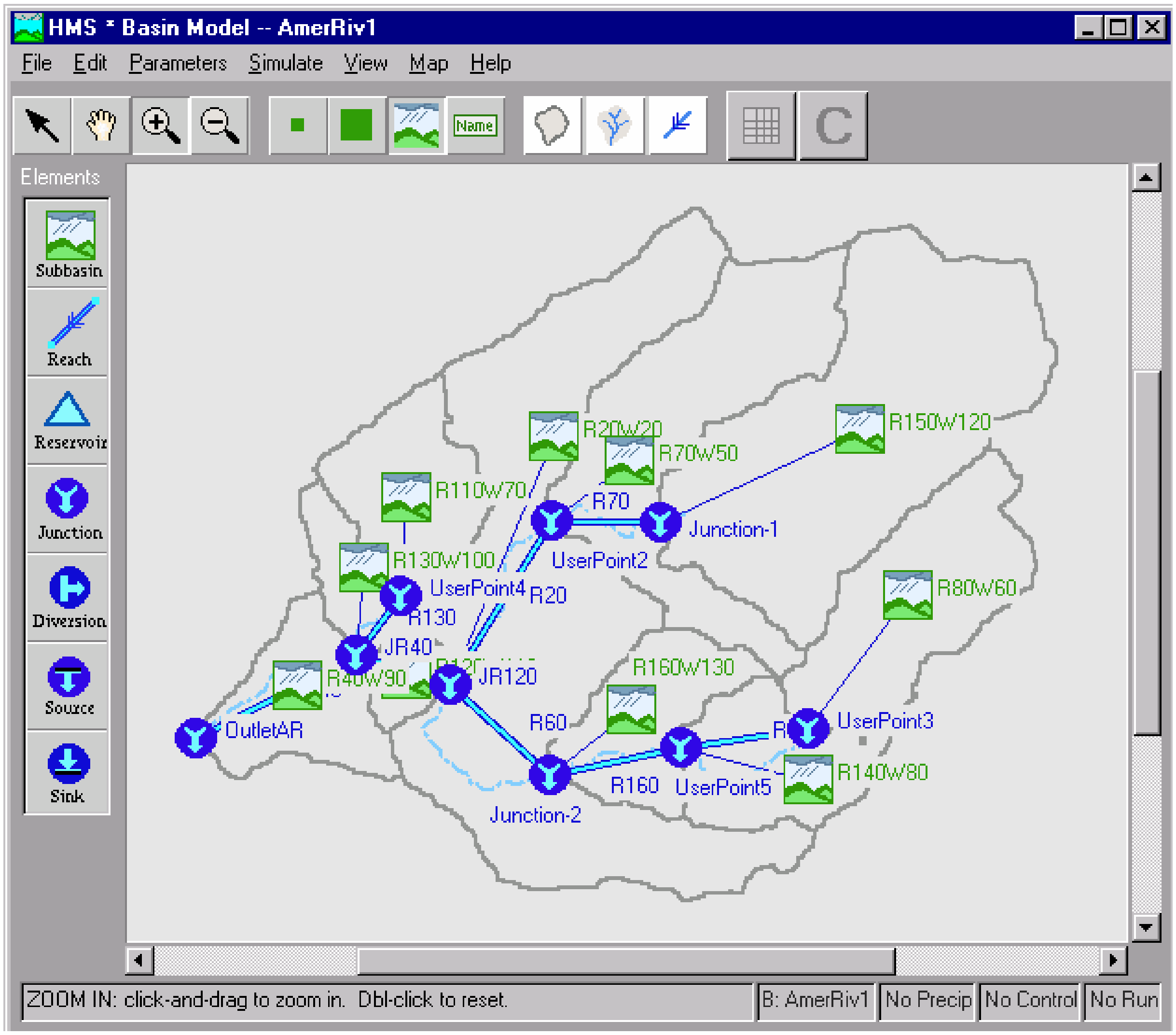


Figure 10–39. HMS basin model with correct connectivity.

Meteorologic Model

A number of methods are available to model the precipitation. The following steps illustrate the grid-based precipitation method that is often used in conjunction with the grid-cell parameter file. Gridded precipitation must be used with the ModClark transform method. The grid-based precipitation for this example has been developed in SHG at 2000-meter resolution. The rainfall is stored as a series of grids at 1-hour intervals in the Data Storage System, HEC-DSS (HEC, 1994 and

2000). The rainfall may be directly from the National Weather Service (NWS) NexRad if the Hydrologic Rainfall Analysis Project (HRAP) cell format is used, modified to the HEC Standard Hydrologic Grid (SHG) format, or interpreted from point gages with another program, called GageInterp (HEC, 1999). The precipitation grid format is aligned with the grid-cell parameter file. The steps for developing the meteorologic model follow.

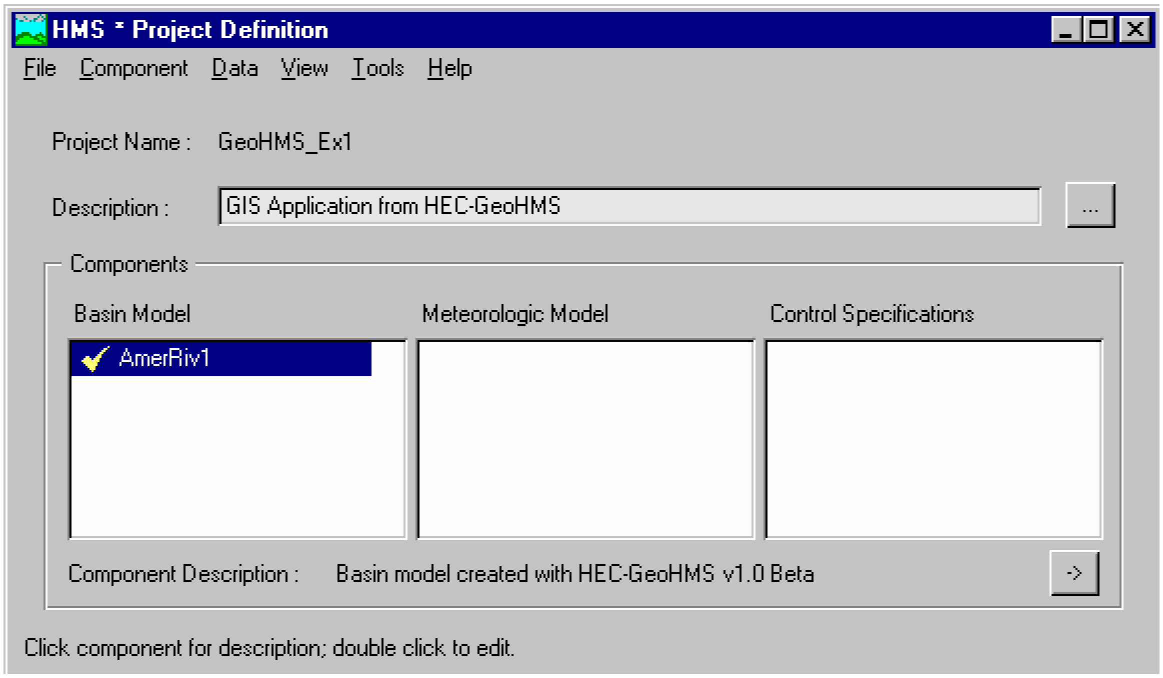


Figure 10–40. HMS Project with Basin Model.

- From the **HMS * Project Definition** window as shown in Figure 10–40, select **Component ⇒ Meteorologic Model ⇒ New** as shown in Figure 10–41. The result is shown in Figure 10–42.

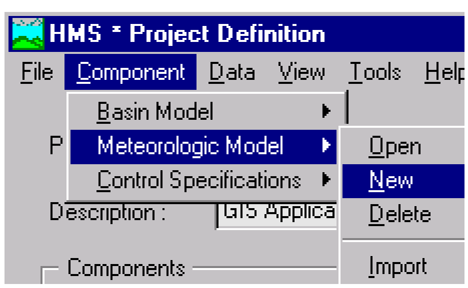


Figure 10–41. Met Model menu item.

- Enter the **Meteorologic Model** name as “Radar” and the **Description** as “Grid-based precipitation,” see Figure 10–42. Press **OK**.

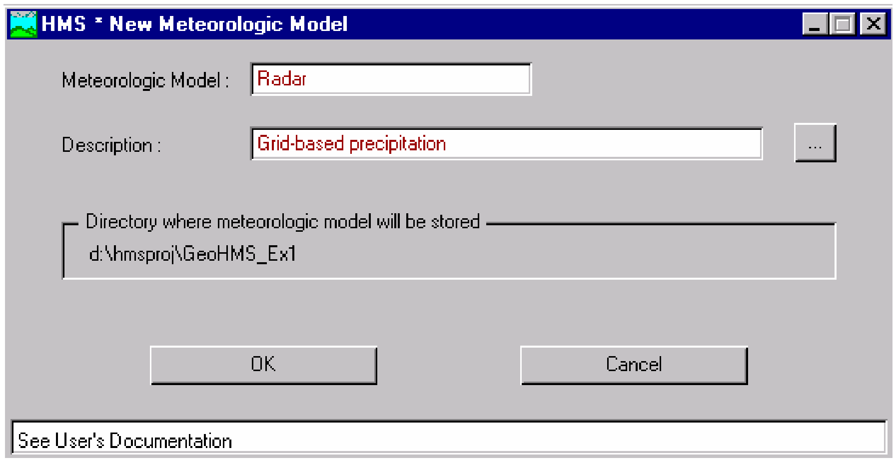


Figure 10–42. New meteorologic model.

- From the "Add subbasins from basin model:" dropdown menu, select "AmerRiv1". Press the **Add** button and the subbasins in the "AmerRiv1" basin model are added to the "Subbasin" heading as shown in Figure 10–43. Press **OK**.

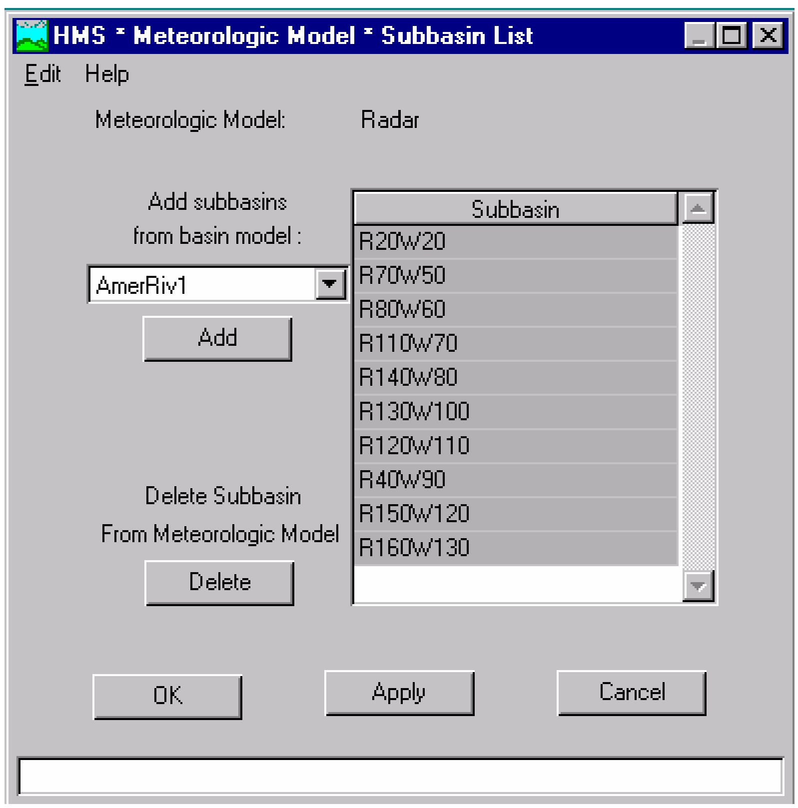


Figure 10–43. Meteorologic model subbasin list.

- With the “Precipitation” tab active, select “***Gridded Precipitation***” from the “***Method***:” dropdown list as shown in Figure 10–44.

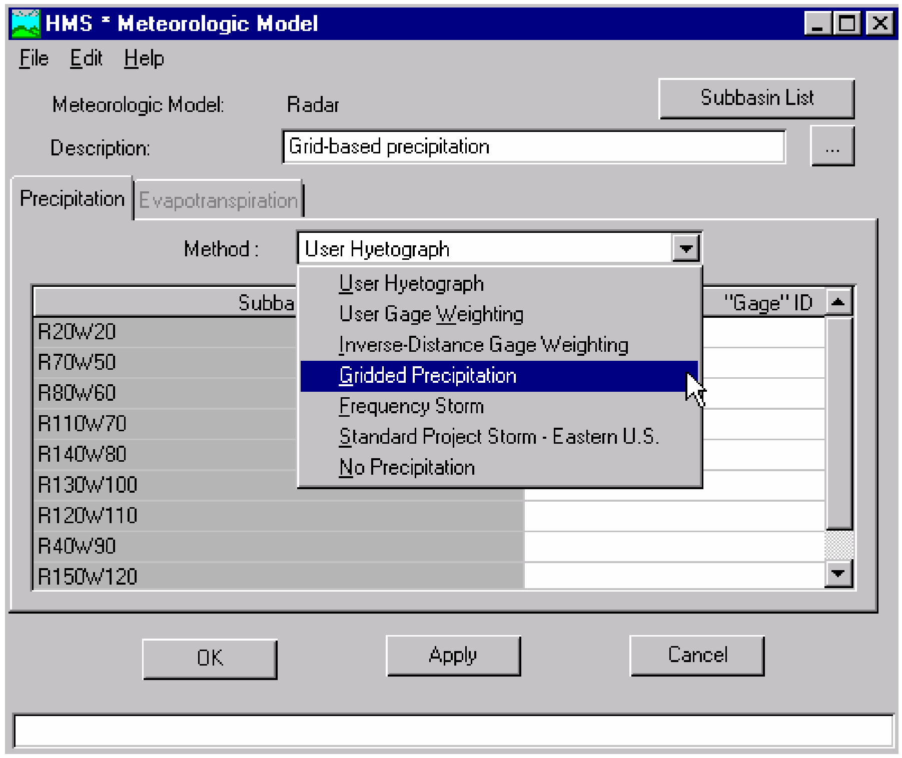


Figure 10–44. Meteorologic model methods.

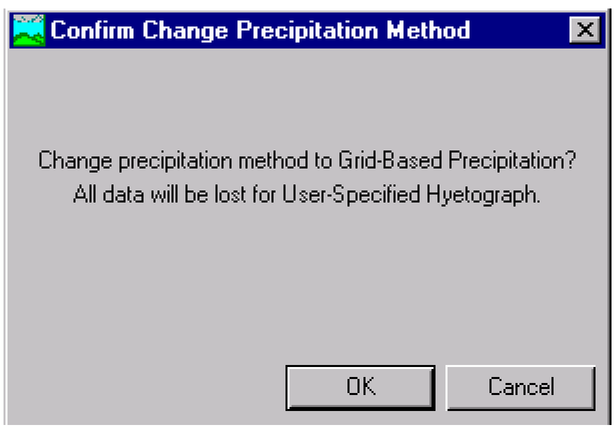


Figure 10–45. Confirmation of precipitation method.

- Press **OK** to the confirmation of precipitation method as shown in Figure 10–45.

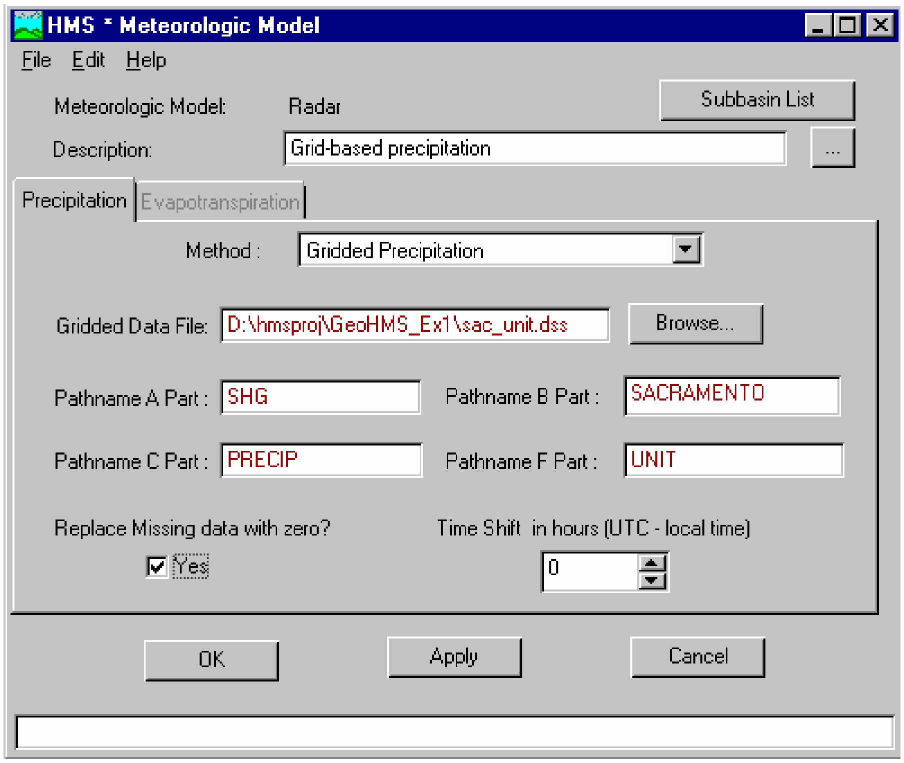


Figure 10–46. Gridded precipitation model options.

- To specify the "Gridded Data File:", Figure 10–46, press the **Browse…** button and navigate to and select the "D:\hmsproj\GeoHMS_EX1\sac_unit.dss".
- Enter the following pathname parts that are applicable to the "sac_unit.dss" file. For "Pathname A Part:", enter "`SHG`", for "Pathname B Part:", enter "`SACRAMENTO`", for "Pathname C Part:", enter "`PRECIP`", and for "Pathname F Part:", enter "`UNIT`".
- Check **Yes** to "Replace Missing data with zero?" as shown in Figure 10–46.

Control Specifications

The control specifications component contains time-related data (HEC, 2000). The following steps illustrate the creation of control specifications component with the time window and interval that are compatible with the precipitation. HMS does not currently interpolate gridded precipitation to other time intervals; the simulation must be performed at the same 1-hour interval as the gridded rainfall. The Control Specifications Component identifies a time window from 29 February to 3 March 2000. The computational time interval is set at 1 hour.

- From the **HMS * Project Definition** window, select **Component** ⇒ **Control Specifications** ⇒ **New** as shown in Figure 10–47.

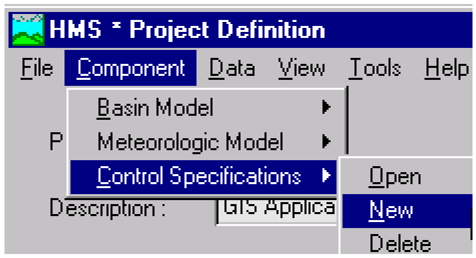


Figure 10–47. Control Specifications menu item.

- Enter "`Control Feb 2000`" for "Control Specs:" and "`Time related specifications for Feb 2000 storm`" for the "Description:" as shown in Figure 10–48. Press **OK**.

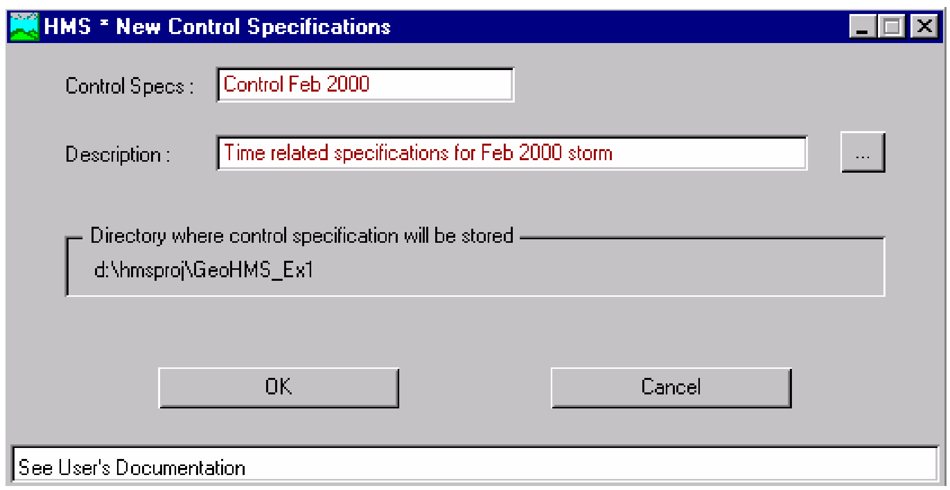


Figure 10–48. New Control Specifications.

- Enter the Starting Date as "`29Feb2000`", the Starting Time as "`0000`", the Ending Date as "`03Mar2000`", and the Ending Time as "`0000`". The time interval is 1 hour, which matches with the grid-based precipitation interval as shown in Figure 10–49. Press **OK**.

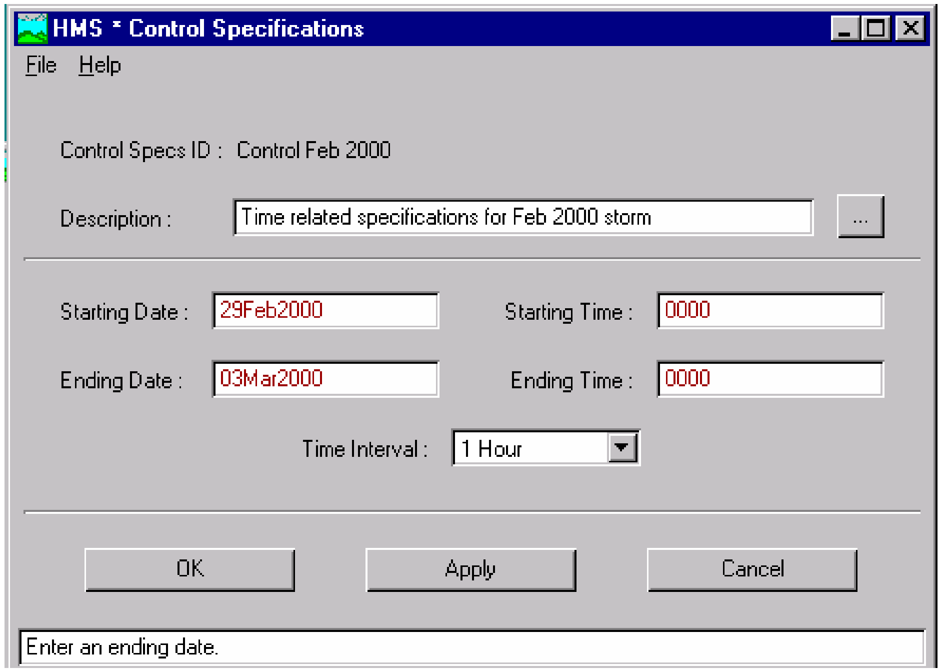


Figure 10–49. Control specifications time window.

HEC-HMS Simulation

An HMS run consists of **Basin Model, Meteorologic Model, and Control Specifications** components (HEC/, 2000) as shown in Figure 10–50. With these three components completed, HMS can compute flow. The HMS parameter optimization capability can also be used with gridded models. Refer to the HMS User's Manual for examples of gridded basin simulations.

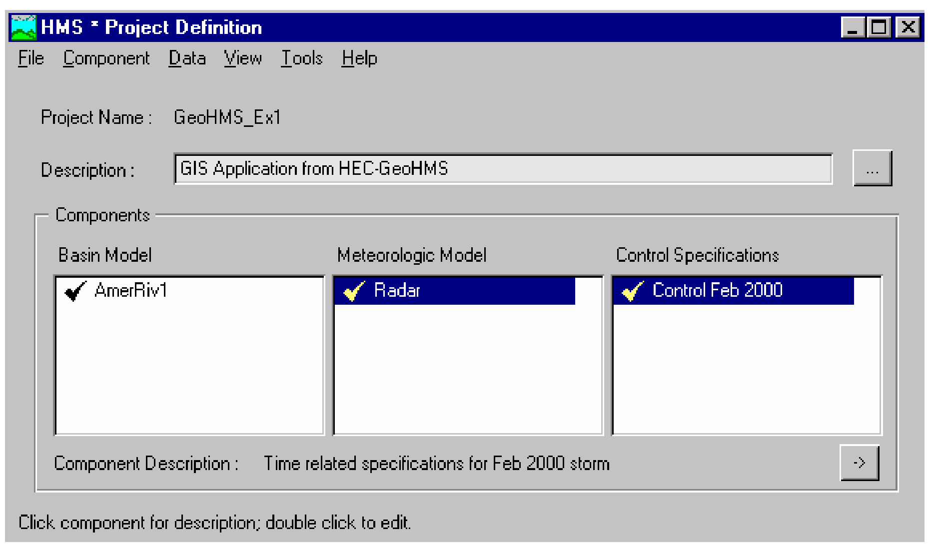


Figure 10–50. HMS components for simulation.

CHAPTER 11

Example Application - American River Basin

The purpose of this chapter is to illustrate the major steps in the development a hydrologic model using GeoHMS Version 1.0. The study watershed is the American River Basin tributary to Folsom Dam, just east of Sacramento, California. The watershed consists of 4,817 square kilometers (1,860 square miles). The digital elevation model has been assembled to represent the watershed terrain. In addition, streamflow gages have been compiled into a data layer of gage locations, names, drainage areas, and other attributes.

Overview

This chapter provides a detailed example of how to perform drainage analysis on a digital terrain model for development of an HEC-HMS model. Eight additional data sets are derived that collectively describe the drainage patterns of the watershed. This information will be used to perform a preliminary delineation of the streams and subbasins. The first five data sets in the grid representation are the flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation grids. The next two data sets are the vectorized representation of the watersheds and streams, and they are the watershed polygons and the stream segments. The last data set, the aggregated watersheds, is used primarily to improve the performance in watershed delineation.

The following tasks will be performed in the presentation of this example. Figures and tables numbers are not used as the information follows in the direct order of when the tasks and results are described. Processing times for most tasks are shown based on a Pentium III 500 MHz with 256 MB of memory. Besides the hardware specifications, the terrain grid size is the most important factor in determining the time required to perform most of the operation.

The sample data for this exercise includes the DEM ("AmerRiver_dem") and gage outlet locations ("hec1ga.shp"). The sample data is stored under the "AmerRiverData" directory on the CD-ROM.

The completed ArcView project ("AmerRiver.apr") with the HMS model files illustrating the results of Tasks I to III is saved under the "AmerRiver" directory on the CD-ROM.

Task I. Preprocess the Terrain Model

1. Open ArcView and load HEC-GeoHMS.
2. Setup the working directory with terrain and stream flow gage data.
3. Perform drainage analysis by processing the terrain using the 8-pour point approach.
4. Extract pertinent spatial data and setup a hydrologic model.

Task II. Basin Processing

5. Revise subbasin delineation.
6. Extract physical characteristics of streams and subbasins.
7. Develop HMS inputs.

Task III. Hydrologic Modeling System

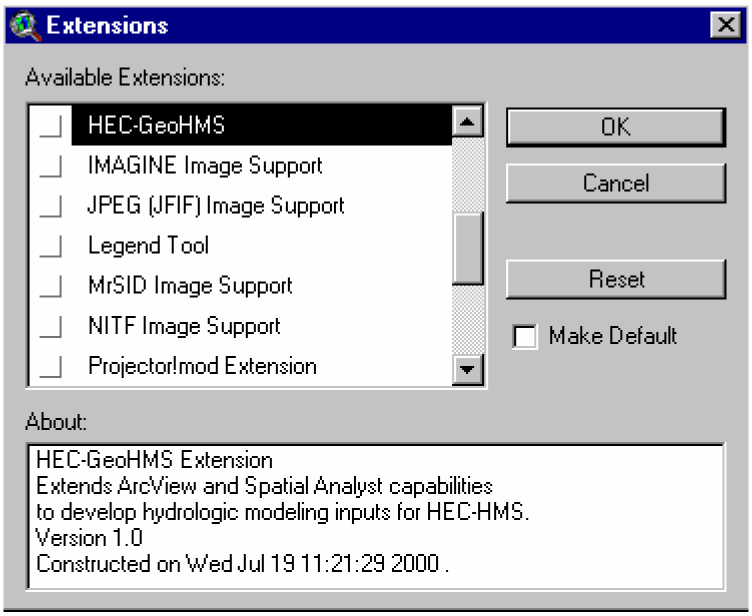
8. Setup an HMS model with inputs from HEC-GeoHMS.

Tasks

Task I. Preprocess the Terrain Model

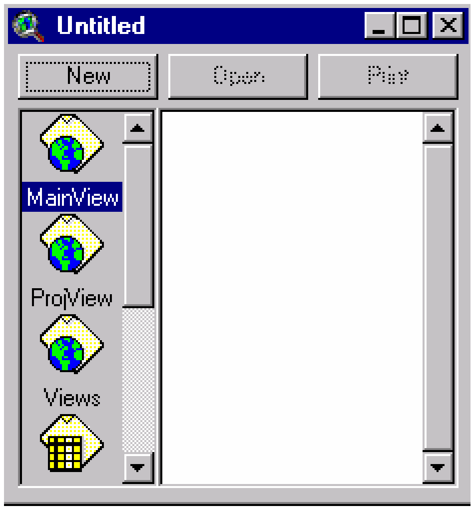
1. Open ArcView and load HEC-GeoHMS

- Create an empty folder called "\AmerRiver" on the hard drive. This folder serves as the working directory for your project. In this case E:\AmerRiver.
- Open ArcView and create a new project as **a Blank Project**.
- Select **File ⇒ Extensions…**
- When the Extensions dialog appears, scroll down until **HEC-GeoH**MS is visible.



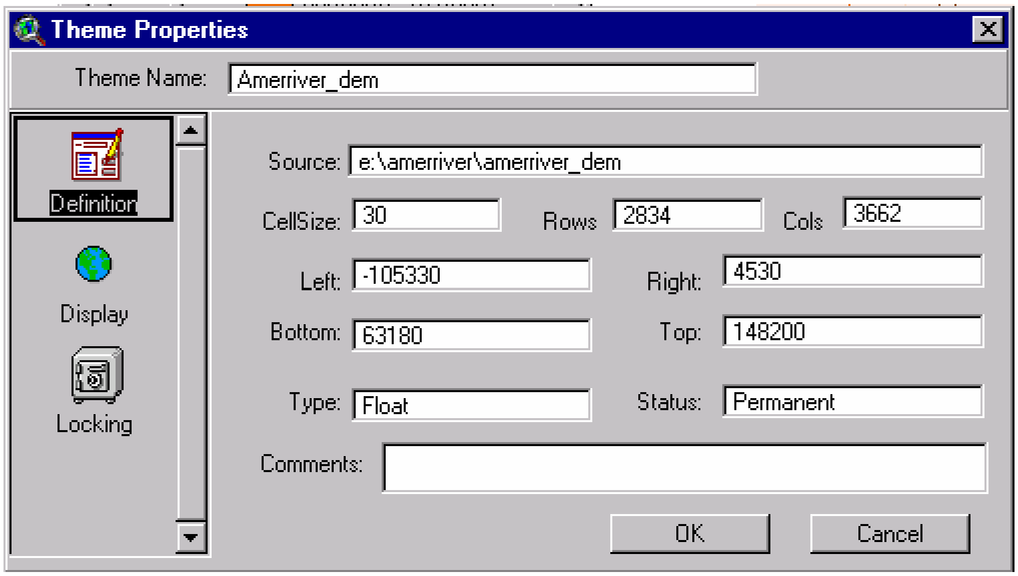
- Press on the name label (HEC-GeoHMS) to access the **About** information.
- Check the box next to it to turn it on.
- Press **OK** to close the dialog and watch the status bar in the lower left-hand corner for the loading messages.

It is not necessary to load the Spatial Analyst extension because GeoHMS will automatically load it. When properly installed and loaded, HEC-GeoHMS will create two custom views, "MainView" and "ProjView" as shown below.



2. Setup the working directory with terrain and streamflow gage data

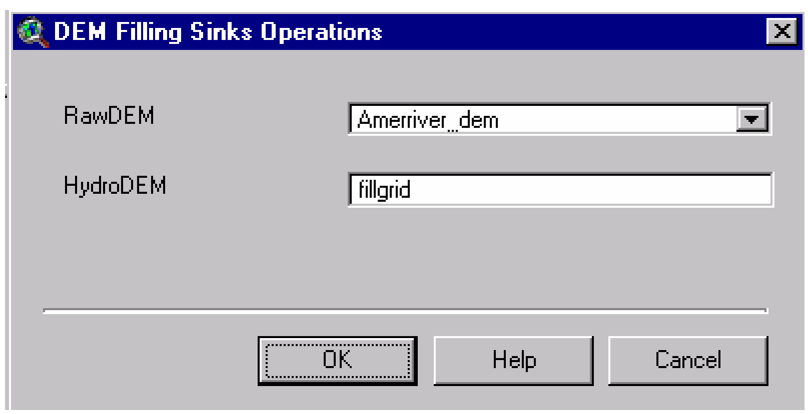
- Open a New MainView
- Select the **File ⇒ Manage Data Sources**…
- Navigate to the "CD-ROM\AmerRiverData"
- Copy the DEM called "AmerRiver_dem" to your working directory
- Add the "AmerRiver_dem" as a grid theme in the MainView
- Select **Theme ⇒ Properties**. Note that there are about 10 million (2834 rows * 3662 columns) cells at 30 meters resolution that cover a rectangular area of 9340 sq km (3606 sq mi), which encompasses this study watershed of 4817 sq km (1860 sq mi).
- Save the project as "AmerRiver.apr" in the working directory "E:\AmerRiver". The location of the project is important because subsequent derived data sets are stored relative to the project location.



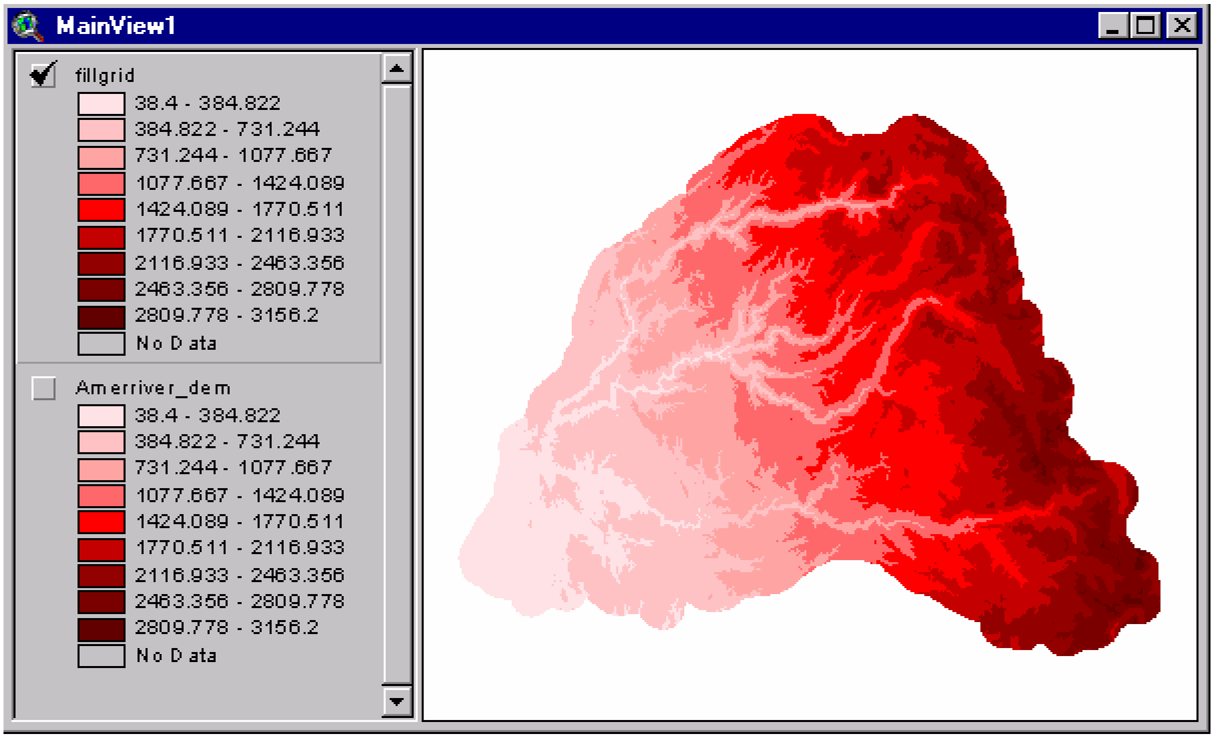
3. Perform drainage analysis by processing the terrain using the 8-point pour-down approach

A. Fill Sinks

- Select **Terrain Preprocessing ⇒ Fill Sinks**.
- Confirm that the input of the **RawDEM** (also refer to as the unfilled DEM) is "AmerRiver_dem". The output of the **HydroDEM** is "FillGrid". "FillGrid" is a default name that can be edited by the user.

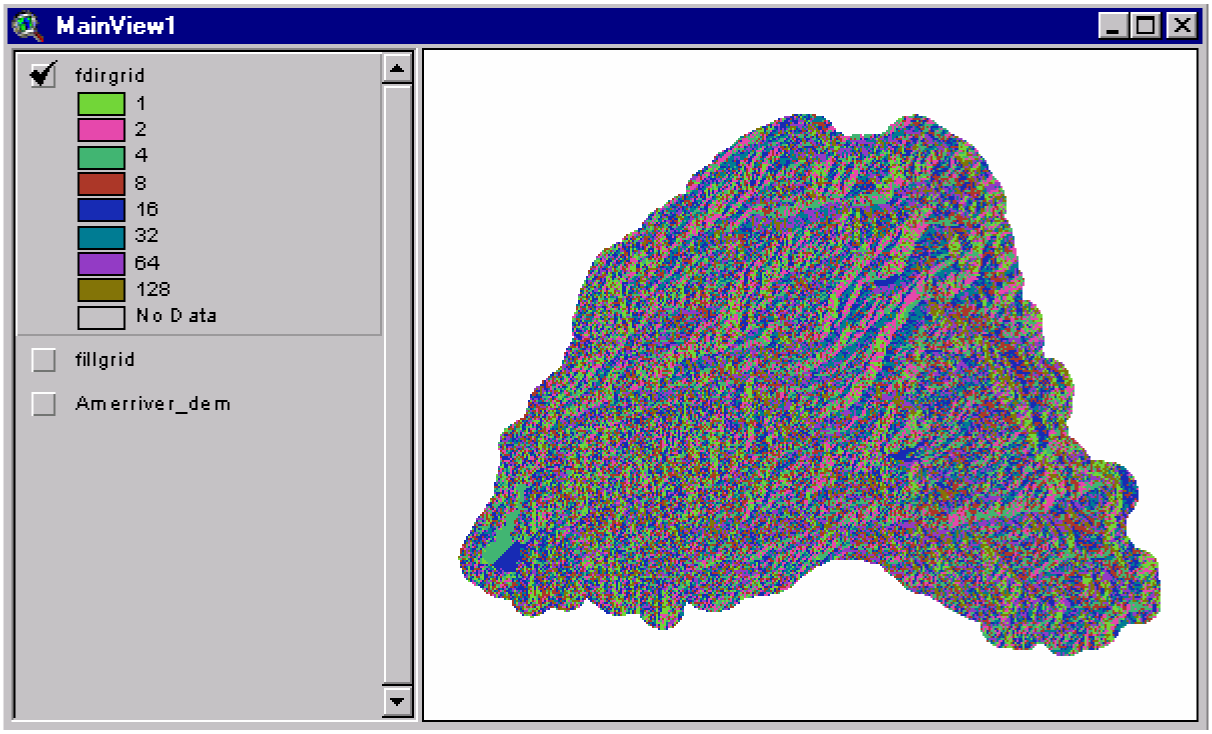


- Press **OK**. (This step takes about 45 minutes.)



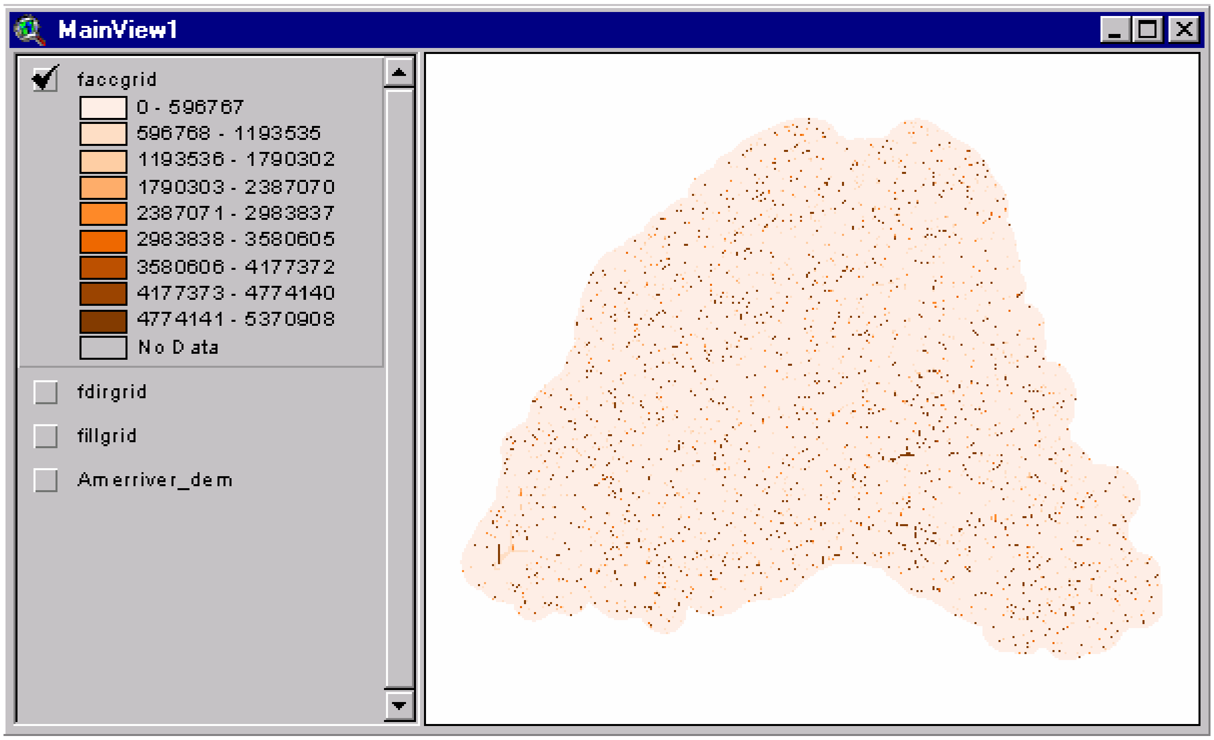
B. Flow Direction

- Select **Terrain Preprocessing ⇒ Flow Direction**.
- Confirm that the input of the **HydroDEM** is “Fillgrid”. The output of the **FlowDirGrid** is “FdirGrid”. “FdirGrid” is a default name that can be edited by the user.
- Press **OK**. (This step takes about 2 minutes.)

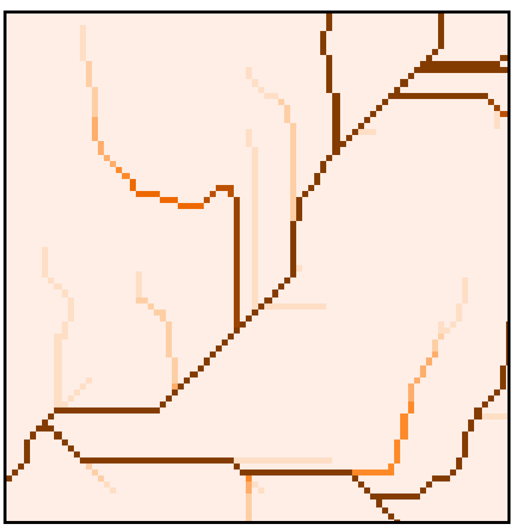


C. Flow Accumulation

- Select **Terrain Preprocessing ⇒ Flow Accumulation**.
- Confirm that the input of the **FlowDirGrid** is "FdirGrid". The output of the **FlowAccGrid** is "FaccGrid". "FaccGrid" is a default name that can be edited by the user.
- Press **OK**. (This step takes about 21 minutes.)

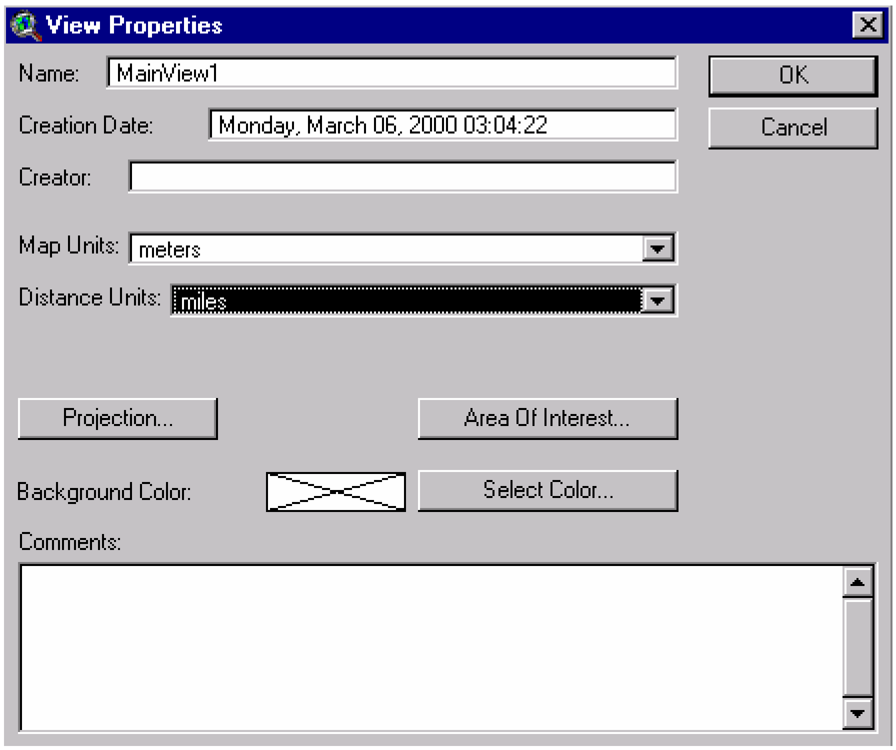


The above screen does not appear complete, but it is. Zoom-in to a part of the basin to display the details of the grid cells that make up the flow accumulation grid as shown below.



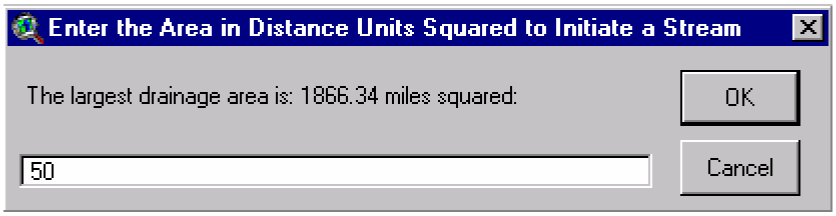
D. Stream Definition

- Select **View ⇒ Properties**.
- The **Map Units** are the data units. In this case, the DEM data units are measured in meters.
- Specify the **Map Units** as "meters".
- The **Distance Units** are the reporting units in ArcView. In this case, the **Distance Units** are chosen as miles so that the information reported from ArcView can be compared with the streamflow gage drainage area reported in square miles.
- Specify the **Distance Units** as miles.
- Press **OK**.

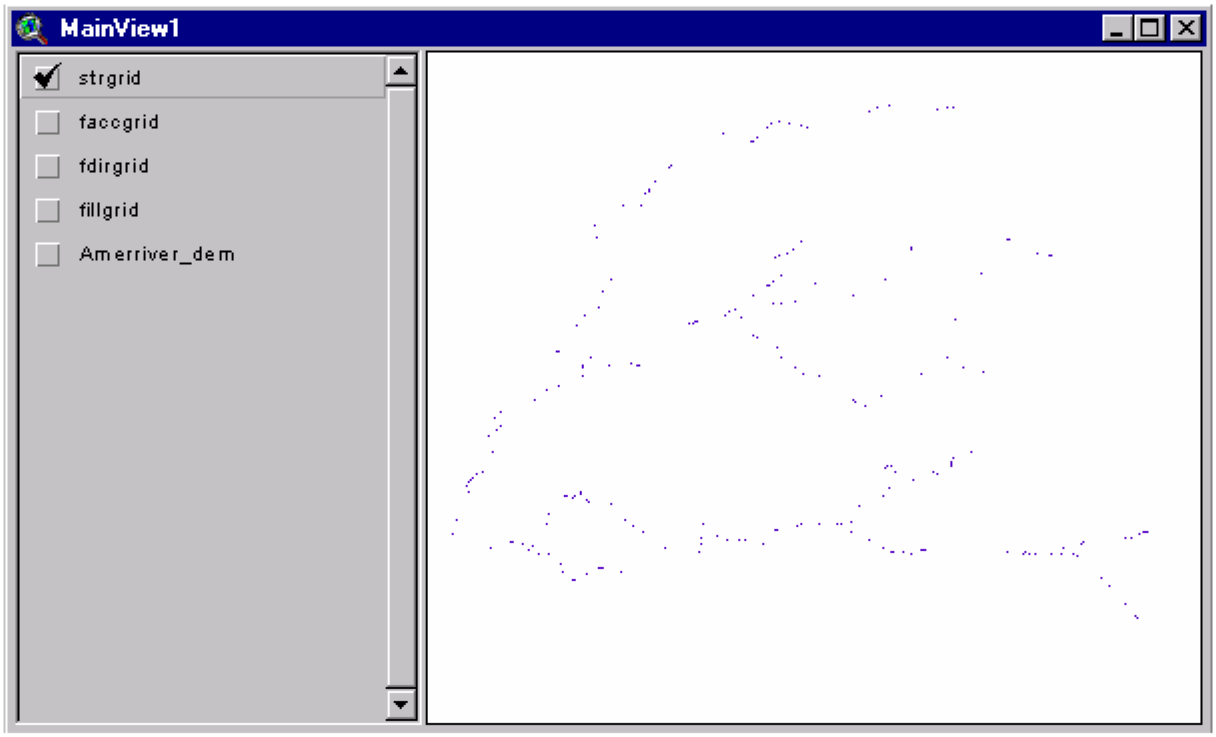


- Save the project as "AmerRiver.apr" in the working directory "E:\AmerRiver".
- Select **Terrain Preprocessing ⇒ Stream Definition**.
- Confirm that the input of the **FlowAccGrid** is "FaccGrid". The output of the **StreamGrid** is "StrGrid". "StrGrid" is a default name that can be edited by the user.
- Press **OK**.
- Select the threshold type as "Area in Distance Units squared".
- Enter the threshold for stream initiation at "50" square miles.

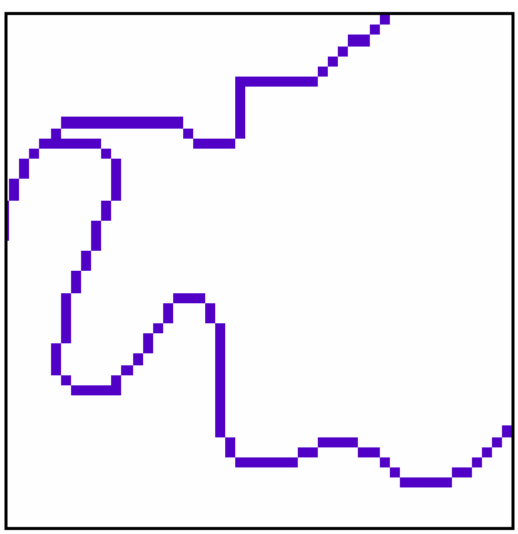
- Press **OK**. (This step takes about 30 seconds.)



The result of the Stream Definition operation is the "StrGrid" shown below.

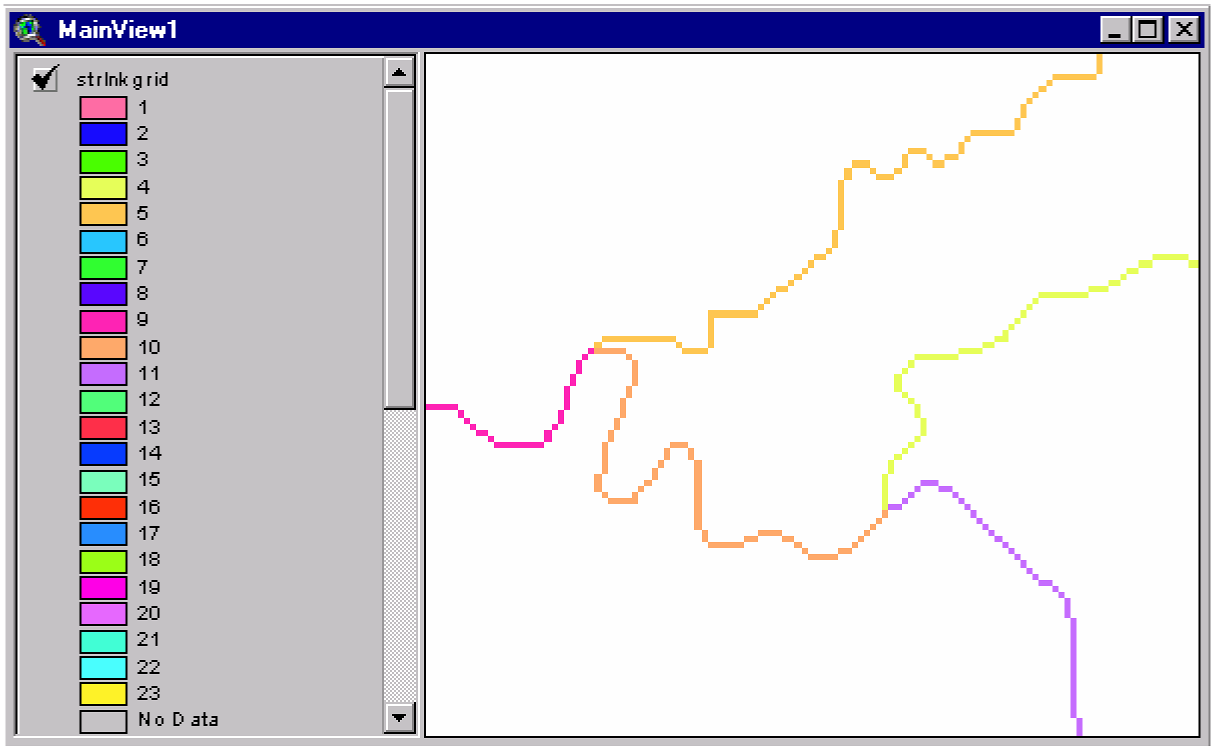


Zoom-in to display the details of the grid cells that make up the stream definition grid.



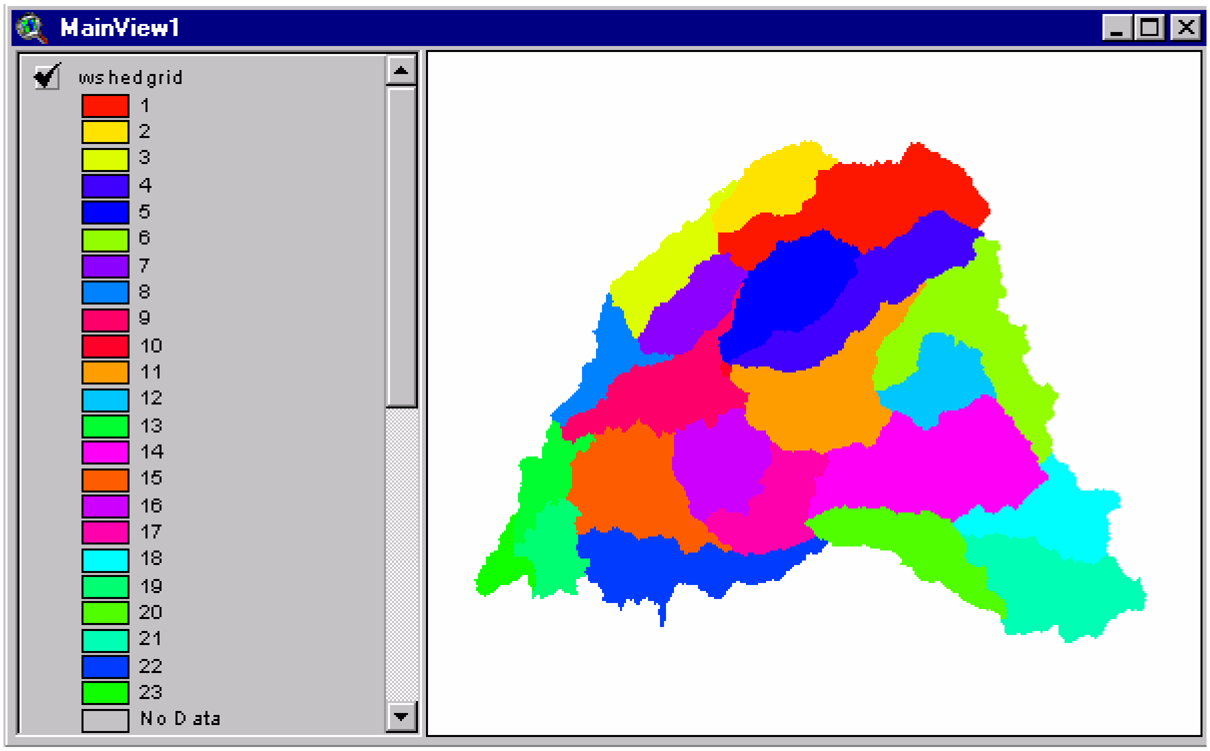
E. Stream Segmentation

- Select **Terrain Preprocessing ⇒ Stream Segmentation**.
- Confirm that the input of the **FlowDirGrid** is “FdirGrid” and **StreamGrid** is “StrGrid”. The output of the **LinkGrid** is “StrLnkGrid”. “StrLnkGrid” is a default name that can be edited by the user.
- Press **OK**. (This step takes about 30 seconds.)



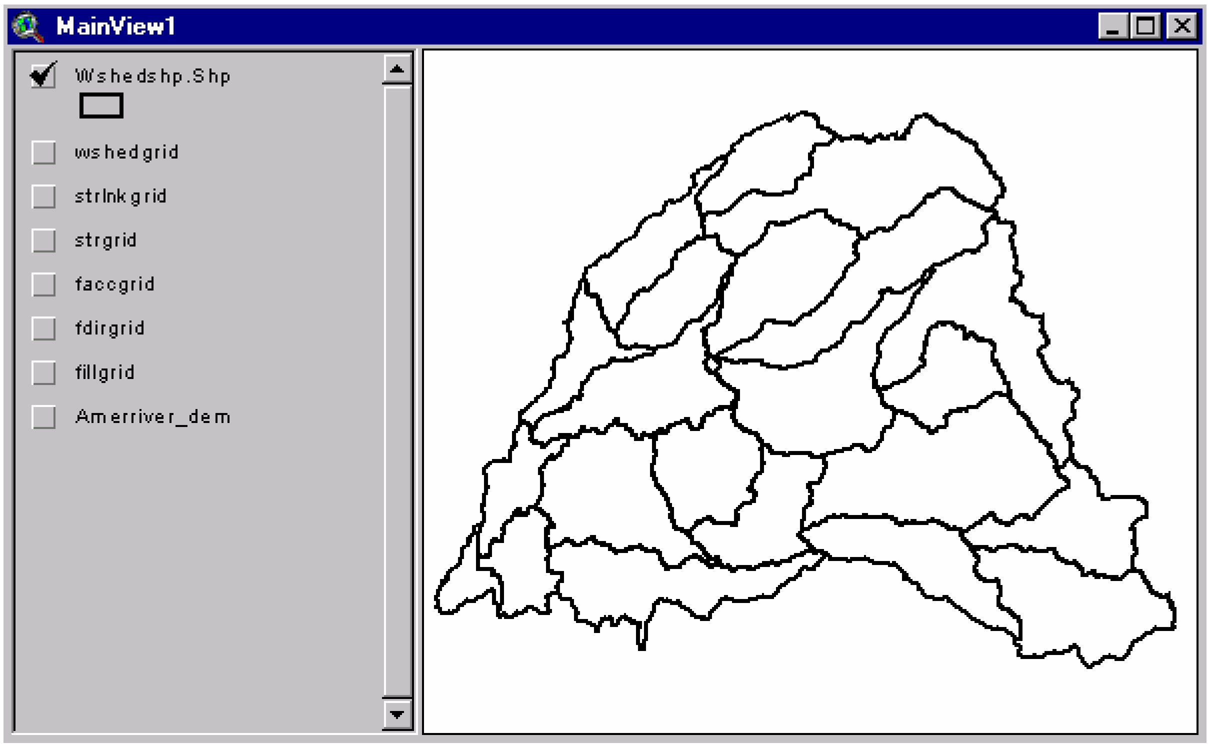
F. Watershed Delineation

- Select **Terrain Preprocessing ⇒ Watershed Delineation**.
- Confirm that the input of the **FlowDirGrid** is "FdirGrid" and **LinkGrid** is "StrLnkGrid". The output of the **WaterGrid** is "WshedGrid". "WshedGrid" is a default name that can be edited by the user.
- Press **OK**. (This step takes about 6 minutes.)



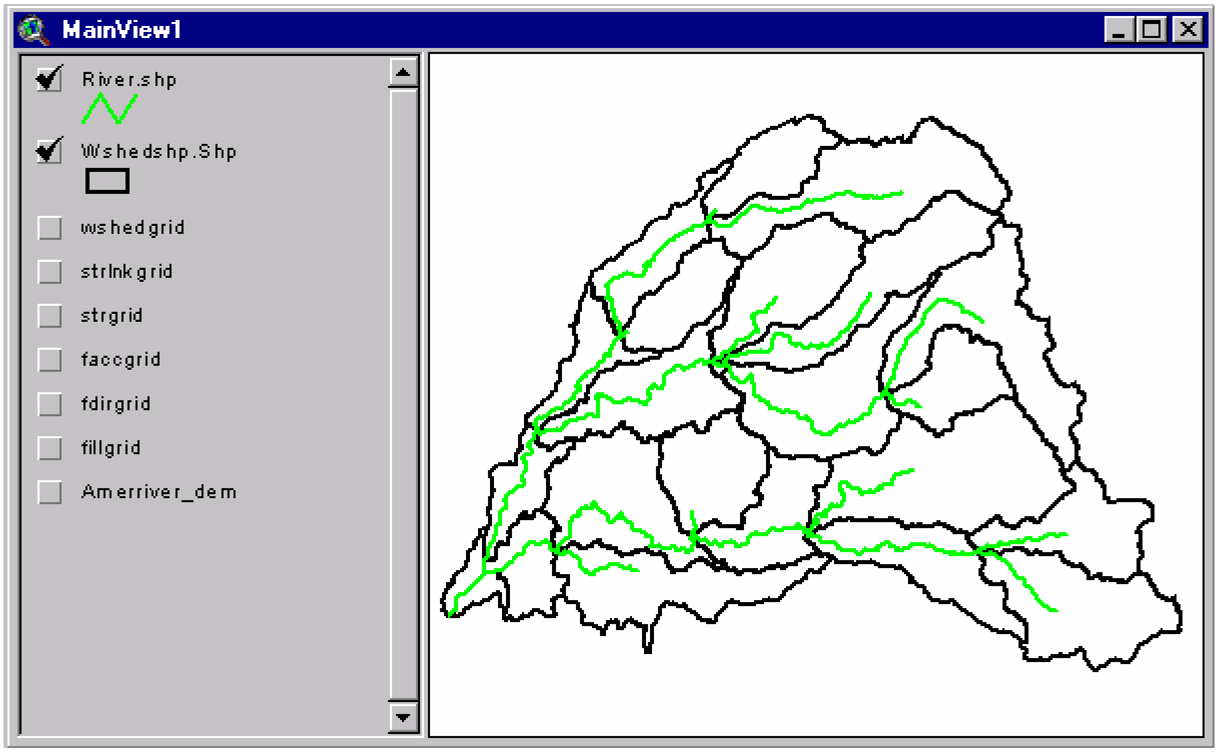
G. Watershed Polygon Processing

- Select **Terrain Preprocessing** ⇒ **Watershed Polygon Processing**.
- Confirm that the input of the **WaterGrid** is "WshedGrid". The output of the **Watershed** is "Wshedshp.Shp". "Wshedshp.Shp" is a default name that can be edited by the user.
- Press **OK**. (This step takes about 10 seconds.)



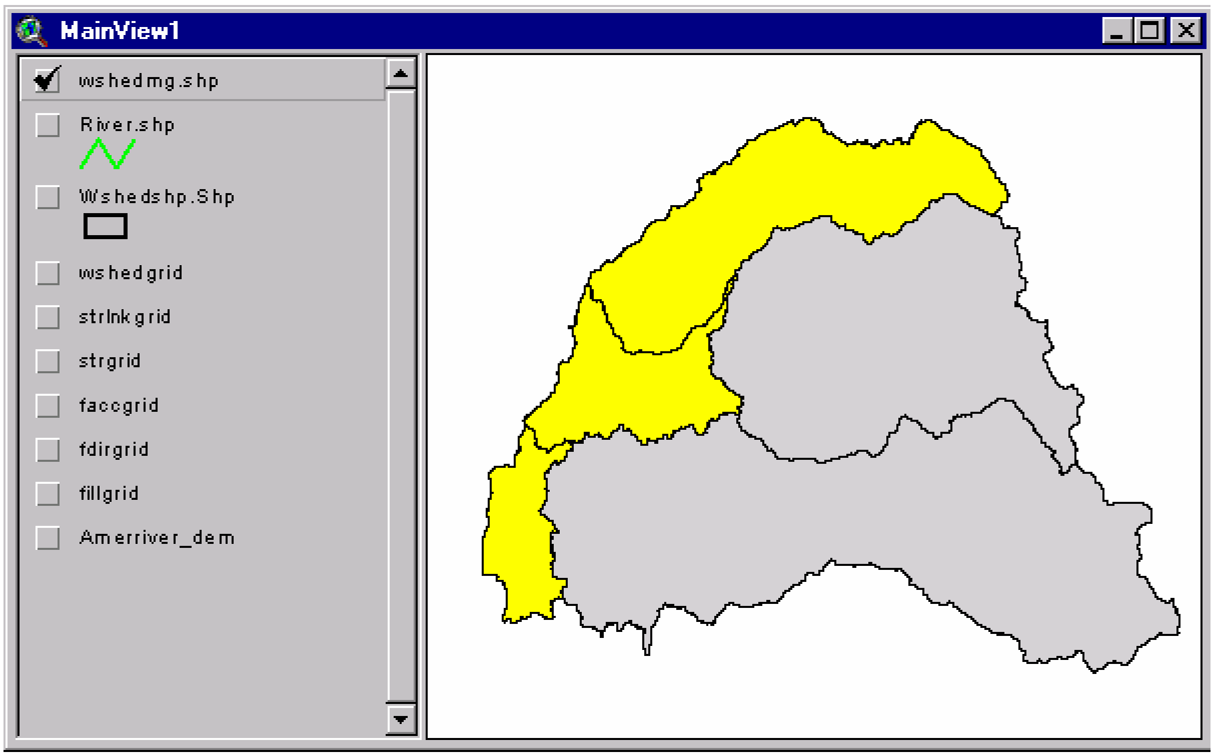
H. Stream Segment Processing

- Select **Terrain Preprocessing ⇒ Stream Segment Processing**.
- Confirm that the input of the **LinkGrid** is "StrLnkGrid" and **FlowDirGrid** is "FDirGrid". The output of the **River** is "River". "River" is a default name that can be edited by the user.
- Press **OK**. (This step takes about 10 seconds.)



I. Watershed Aggregation

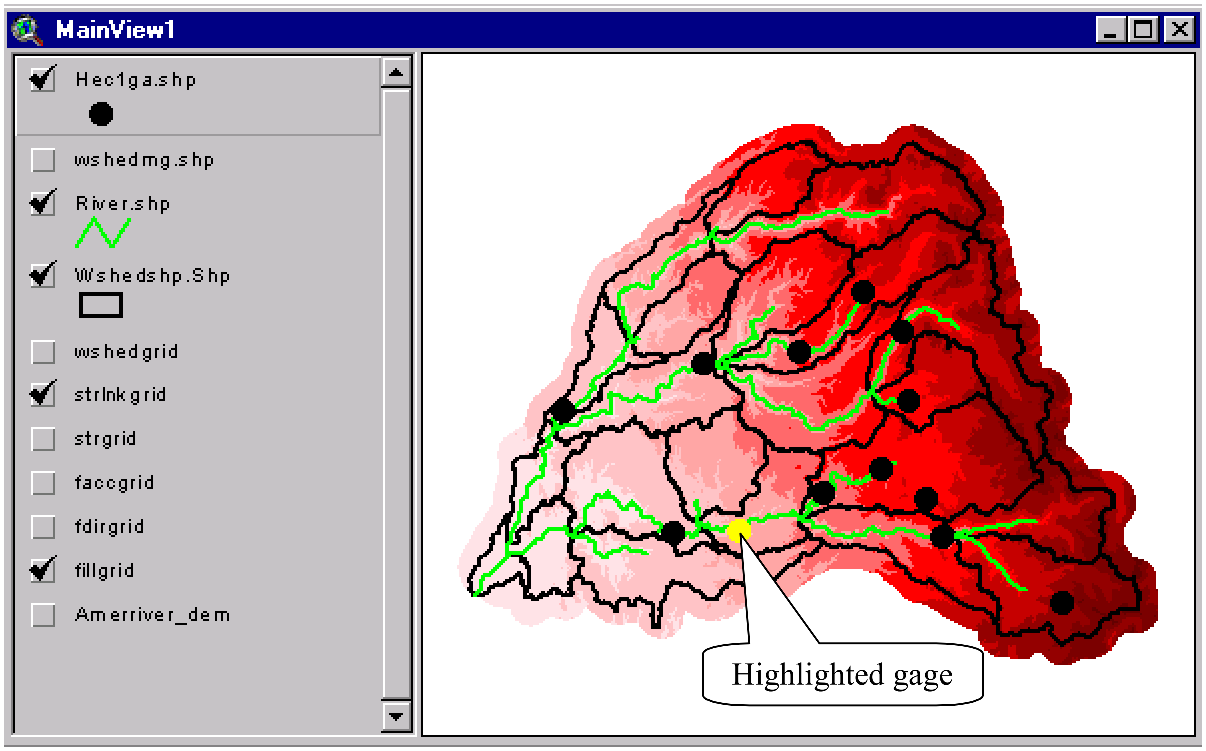
- Select **Terrain Preprocessing** ⇒ **Watershed Aggregation**.
- Confirm that the input of the **River** is "River.shp" and **Watershed** is "Wshedshp.shp". The output of the **AggregatedWatershed** is "WshedMg.shp". "WshedMg.shp" is a default name that can be edited by the user.
- Press **OK**. (This step takes about 30 seconds.)



4. Extract pertinent spatial data and setup a hydrologic model

In this step, a watershed is defined by its outlet. A watershed can also be defined by an outlet and one or more source points which represent inflows from other drainage basins. The watershed outline is delineated by GeoHMS, and a project view is created which contains the newly delineated subbasins, or project model.

- Add the streamflow gage theme called "HEC1ga.shp" to the **MainView** to help determine the outlet location.
- Make the "HEC1ga.shp" active and identify the gages shown below.

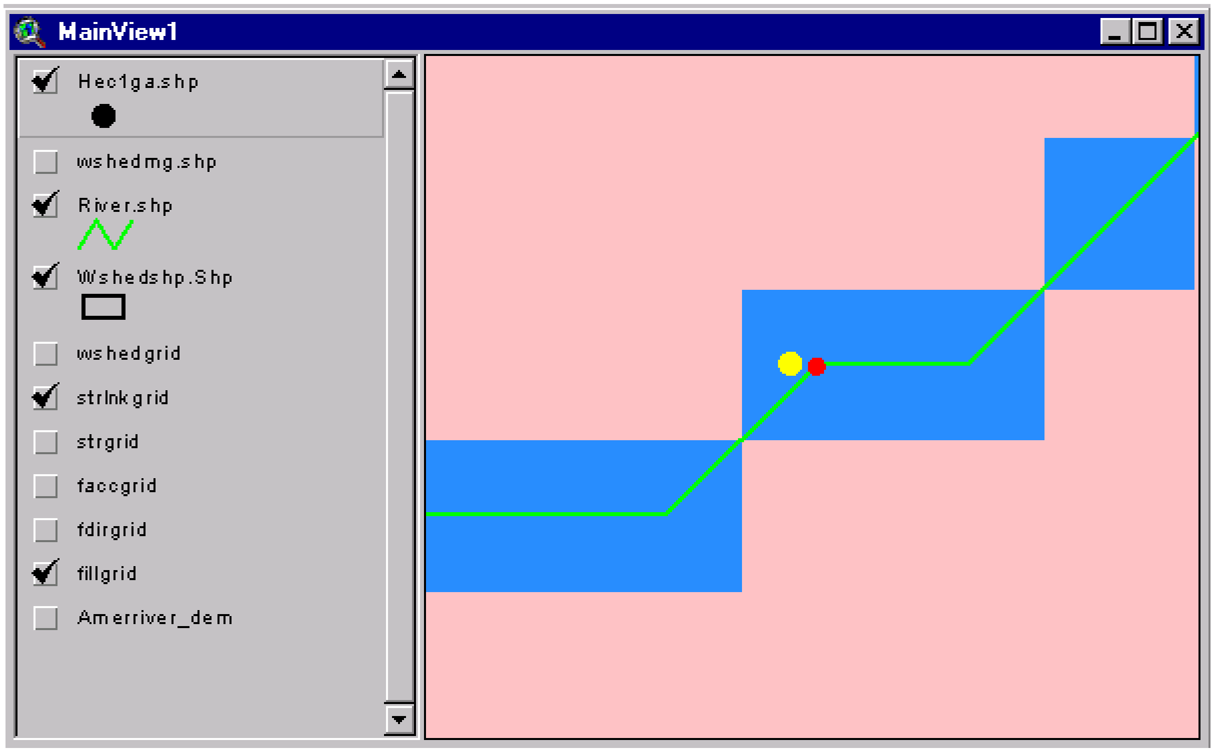


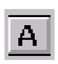
- The identified gage has a drain area of about 493 sq. miles under the "Drain_area" heading.

Attributes of Hec1ga.shp

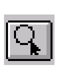
Agency	County	Record_yrs	Latitude	Longitude	Drain_area	Huc	Am_hec1
USGS	EL DORAD	74	38.7731	-120.7006	493	18020129	K
USGS	PLACER	30	39.0567	-120.4069	114	18020128	K
USGS	AMADOR	74	38.6714	-120.1217	15	18020129	K
USGS	EL DORAD	36	38.8239	-120.5383	171	18020129	K
USGS	EL DORAD	74	38.7636	-120.3275	193	18020129	K
USGS	EL DORAD	72	38.8189	-120.3642	28	18020129	K
USGS	PLACER	54	38.9361	-121.0228	342	18020128	K

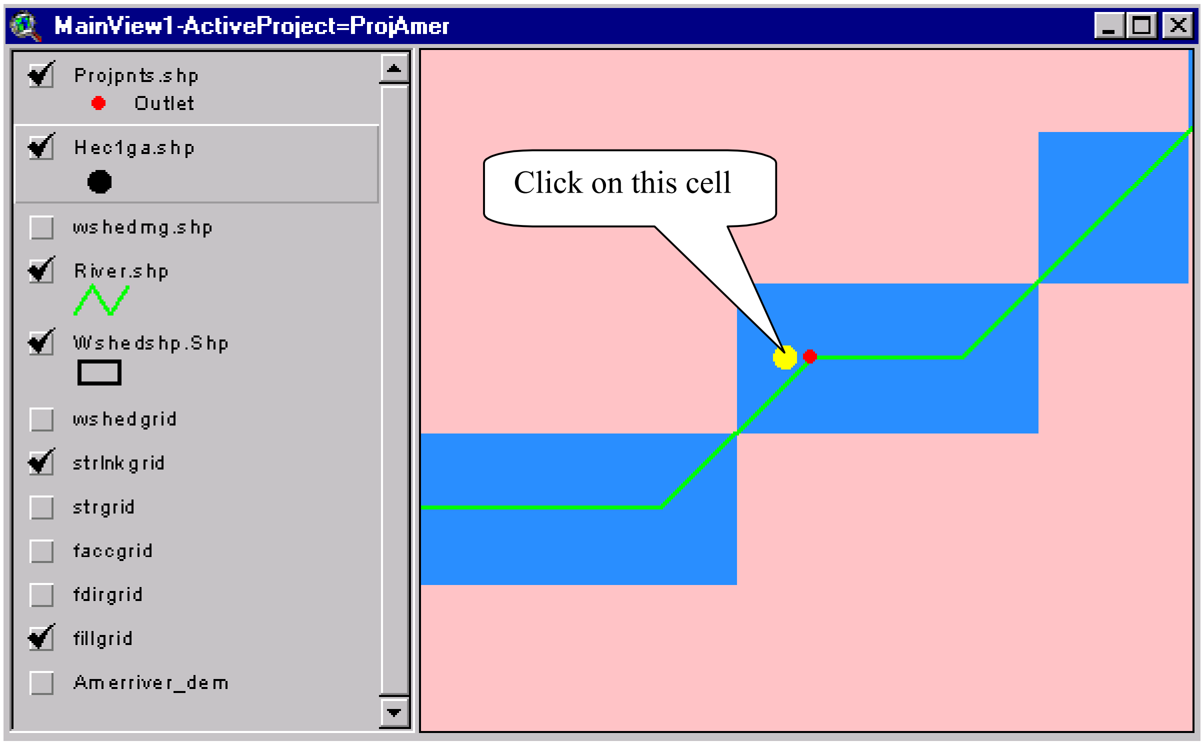
- Zoom in on the gage and make the "StrlnkGrid" theme visible.



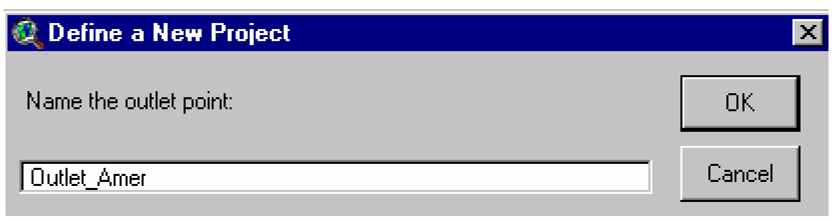
- Use the  tool and click on the grid cell with the identified gage. The grid cell has 492.009 sq mi of drainage area. The result The area is : 492.009 miles squared. is shown in the lower left corner. This cell has a drainage area that is adequately close to that of the gage.
- Now analyze the watershed that is tributary to this grid cell.

- Select **HMS Project Setup ⇒ Start New Project**.
- Enter "ProjAmer" as the project name.
- Press **OK**.

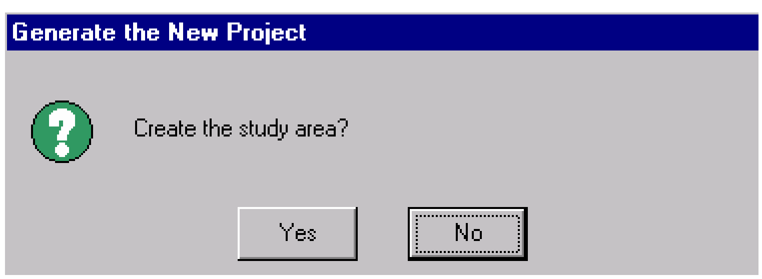
- Select  and click on the cell to specify the outlet location.



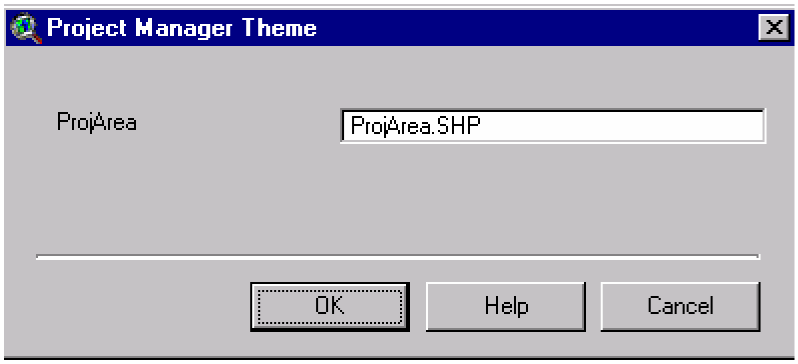
- Name the outlet point as "Outlet_Amer".



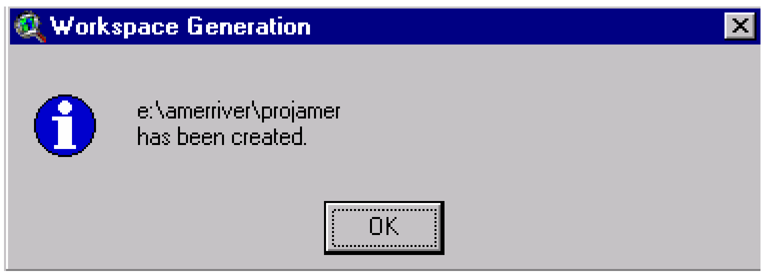
- Press **OK**.



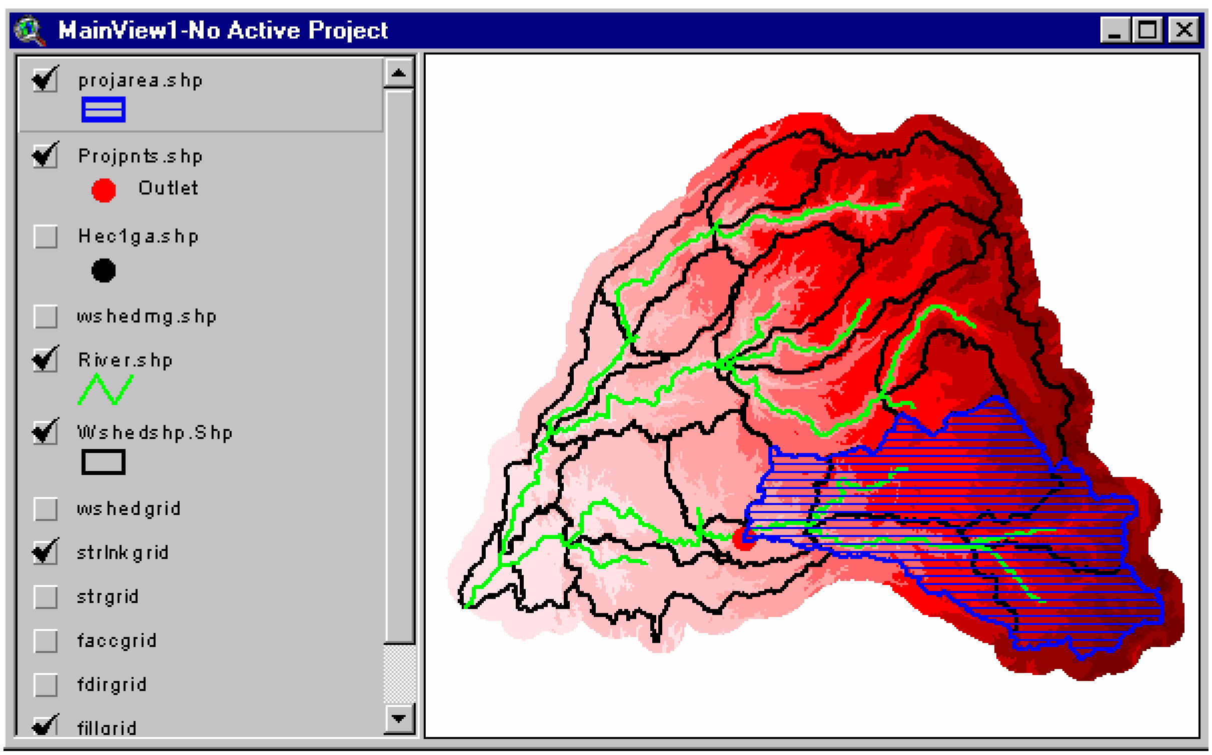
- Select **HMS Project Setup** ⇒ **Generate Project**.
- Select the "Original stream definition" from the dropdown menu.
- Press **OK**.
- Verify the watershed outline boundary and press **Yes**.



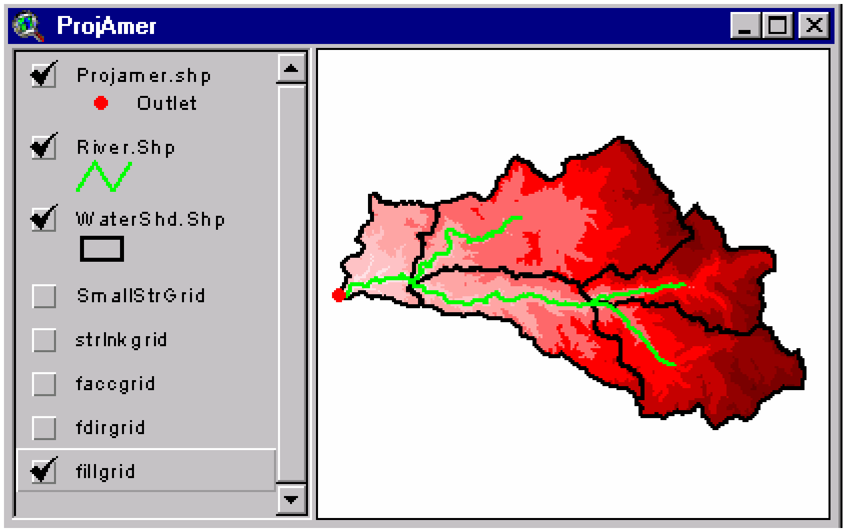
- Verify the project area shapefile and then press **OK**.



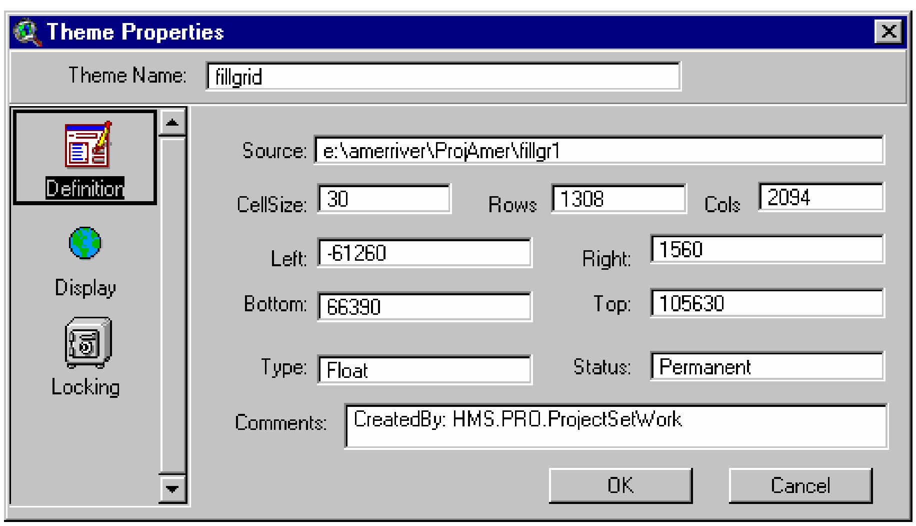
- Note the workspace location and press **OK**.
- Turn on the "ProjArea.shp" theme to show the area extracted for an HMS model.



The pertinent data sets are extracted from the specified outlet location. A **ProjView** named “ProjAmer” is used for basin processing, basin characteristics, and HMS inputs.



The extracted data sets are smaller. For example, the extracted data for the “fillgrid” has 1308 rows and 2094 columns as compared to the original 2834 rows and 3662 columns. The following window can be accessed by activating the “FillGrid” theme and selecting **Theme ⇒ Properties**.



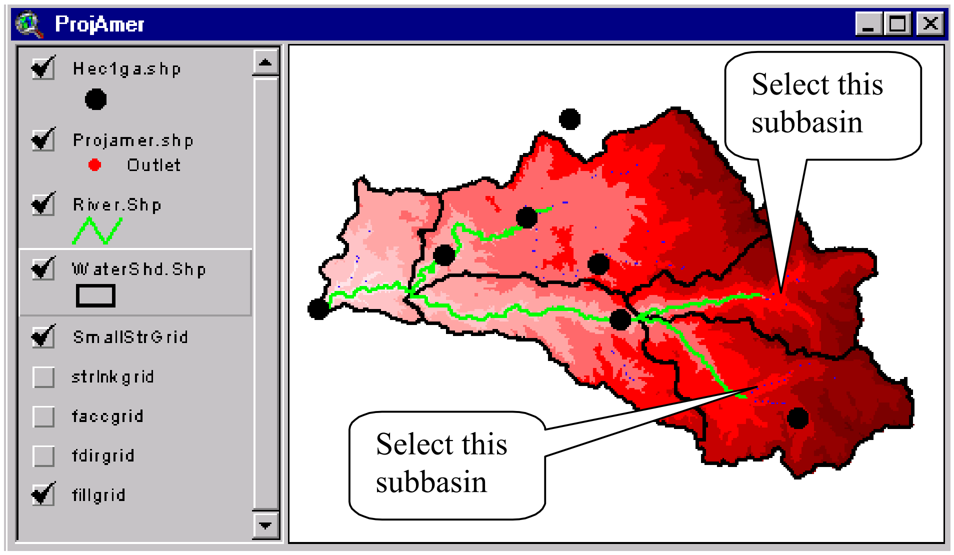
Task II. Basin Processing

5. Revise subbasin delineation

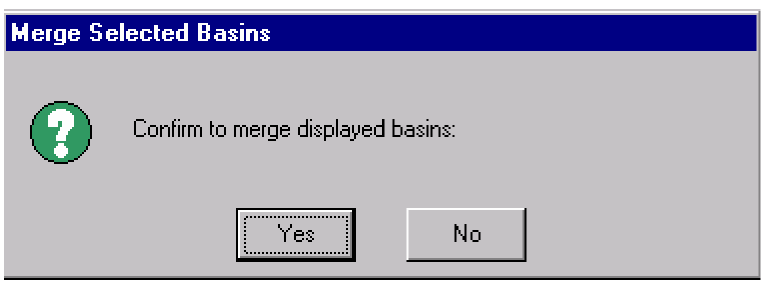
A. Merge Basins

This process merges selected subbasins into one.

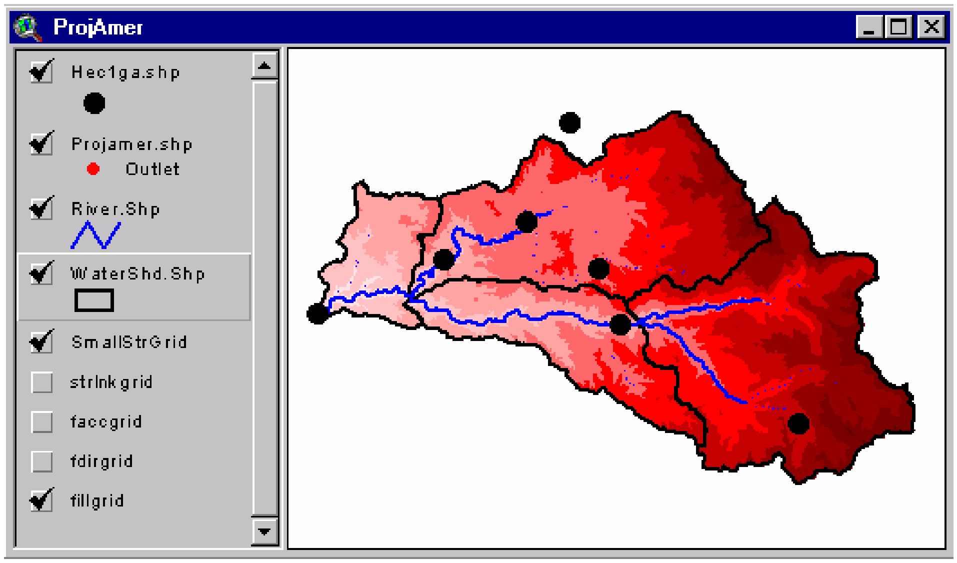
- Make the "WaterShd.Shp" active by clicking on the theme with the (**pointer**) tool. The active theme appears raised.
- Use the (**select**) tool and select the two subbasins shown below.



- Select **Basin Processing ⇒ Basin Merge**.
- The result of the merged subbasin is shown with a red outline.
- Press **Yes** to accept the resulting merged subbasin.

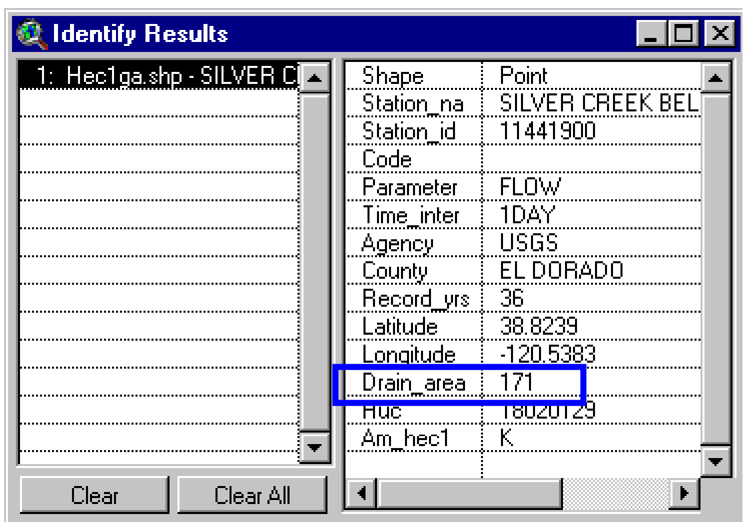


The result of the merged basin is committed as shown below.

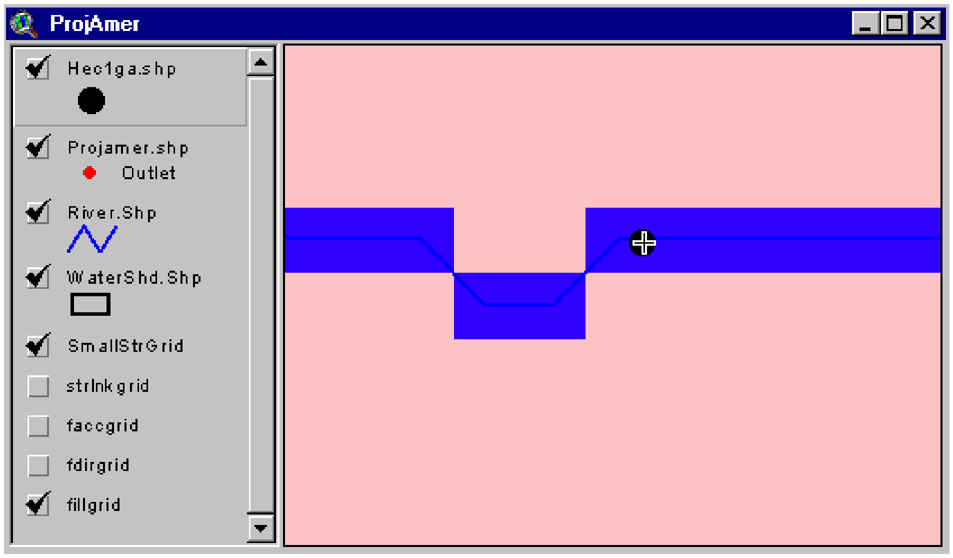


B. Subdivide a Basin

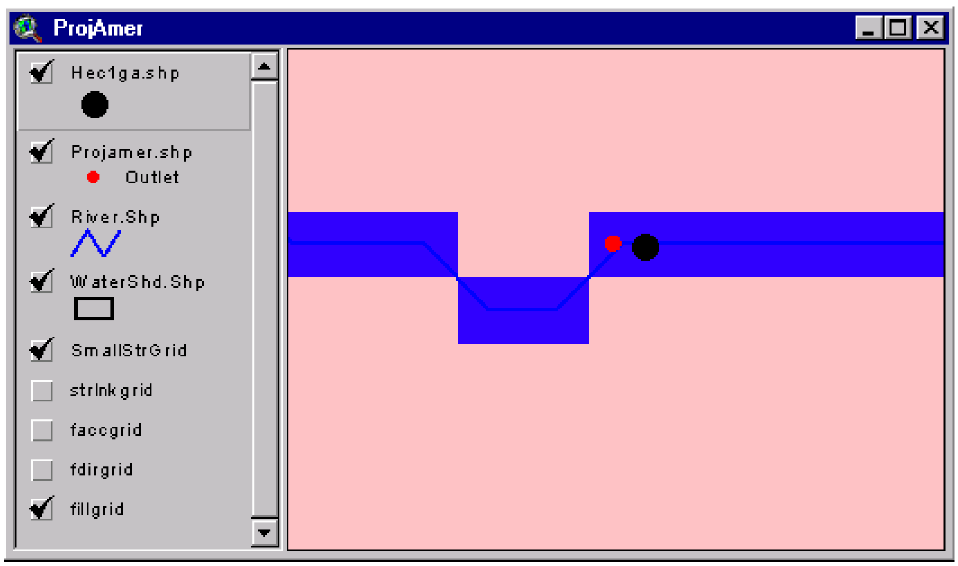
- Make the “Hec1ga.shp” theme active on the “ProjAmer” window.
- Using the **Identify** tool on the streamflow gage with Station_ID 1144190.
- Notice that the reported drainage area is 171 sq.miles.

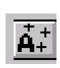


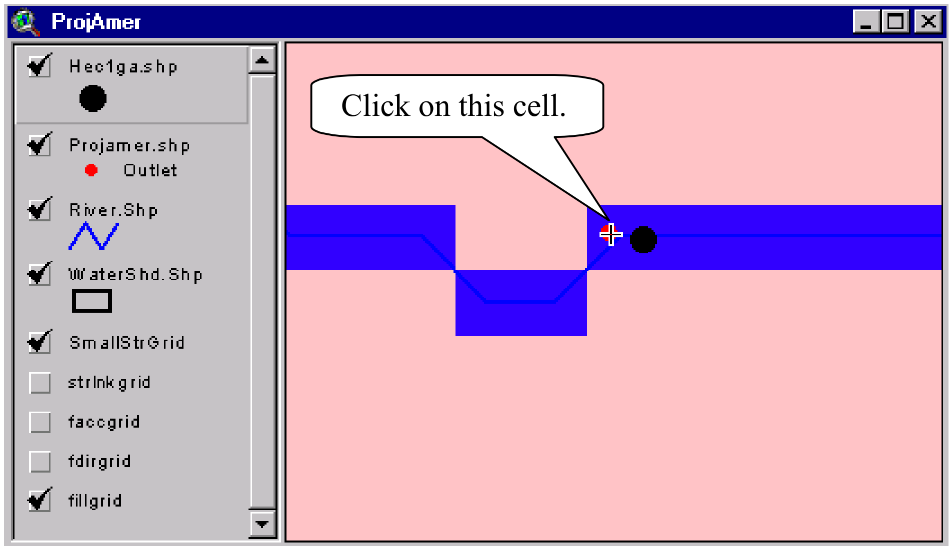
- Zoom in on the gage location.
- Use the [A] (**Identify Area**) tool to find the computed drainage area.
- Select the [A] tool.
- With the “SmallStrGrid” visible, click on the cells near the gage to compute drainage areas.



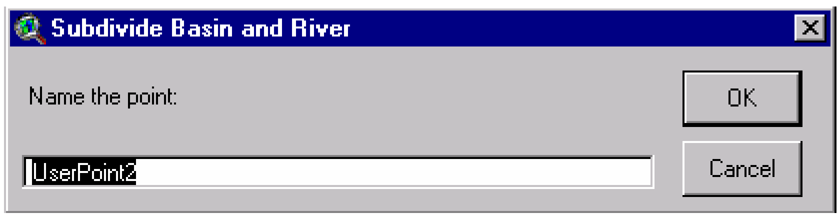
- After searching nearby cells, the cell shown below is an adequate location for an outlet. The computed drainage area is The area is : 171.065 miles squared.



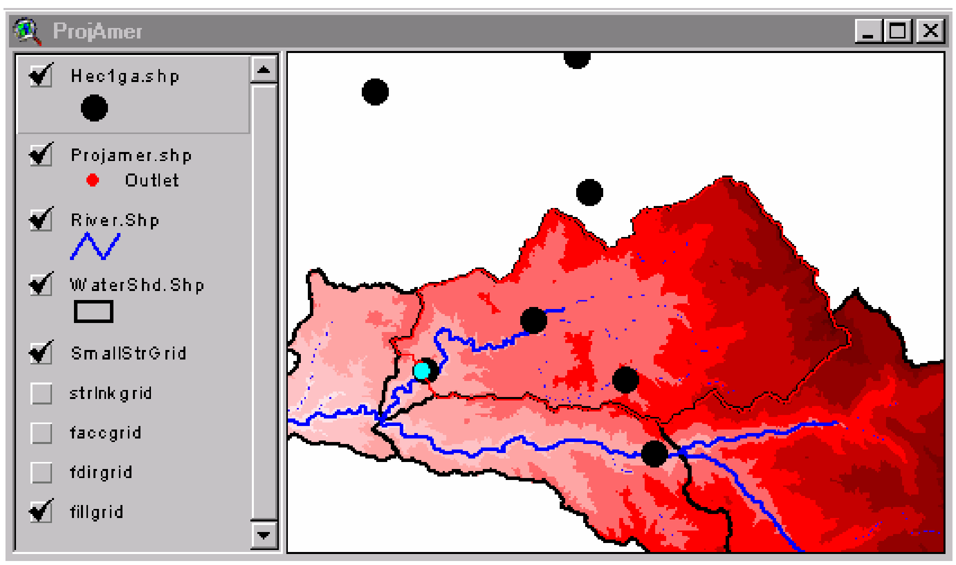
- Select the  tool.
- Click on the cell shown below to subdivide the subbasin.



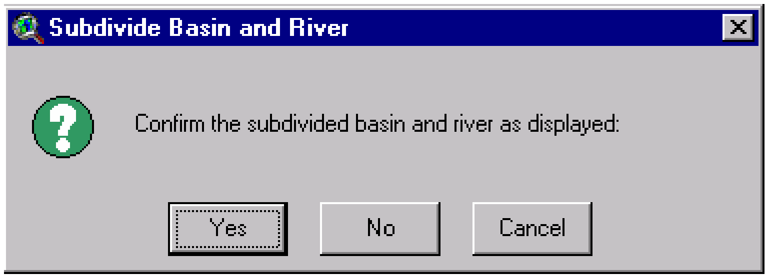
- Press **OK**.



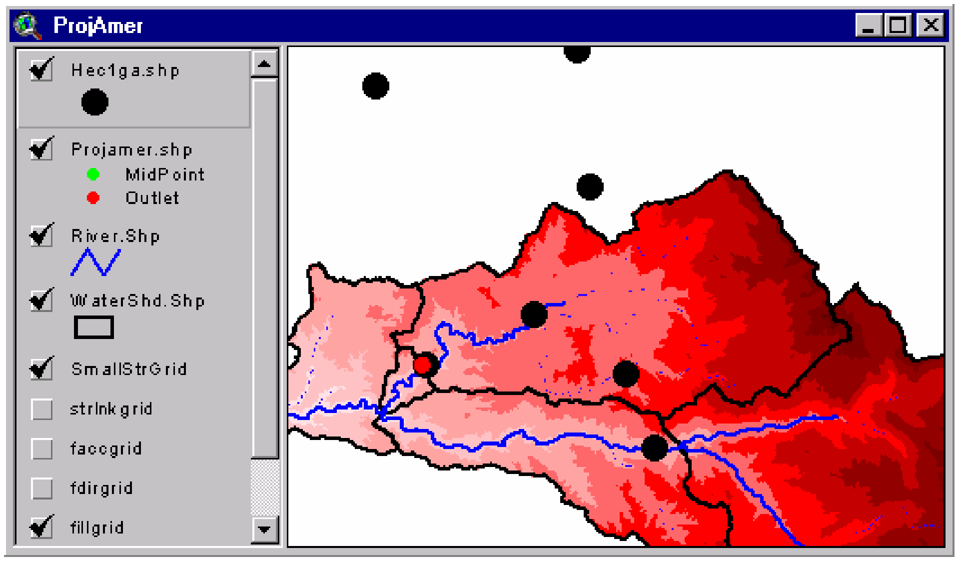
- Verify the result shown below.



- Press **Yes**.

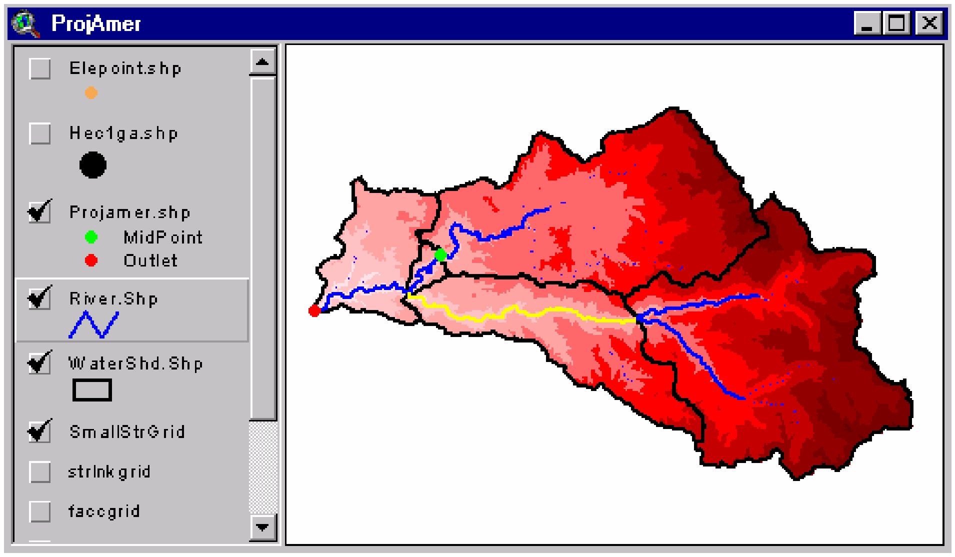


The result of basin subdivision is shown below.

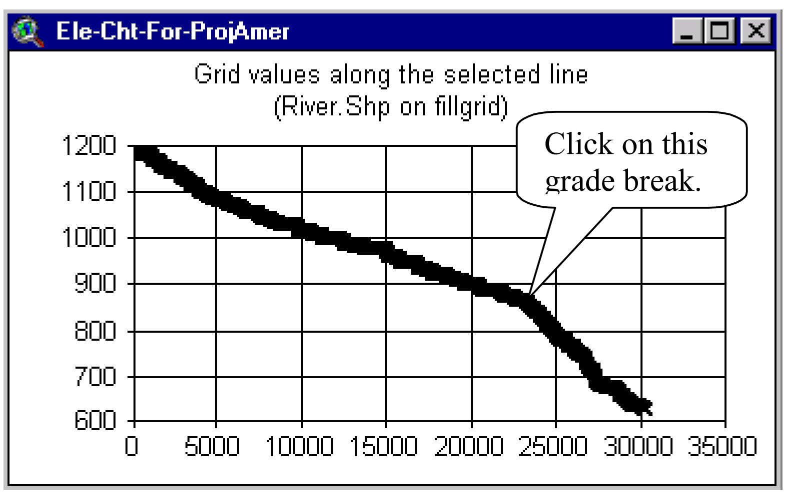


C. Obtain River Profile and subdivide from the grade break

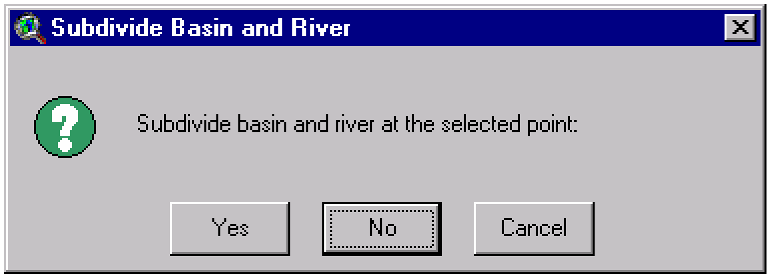
- Activate the "River.Shp" theme.
- Select the stream segment shown in the figure below with the (**select**) tool.



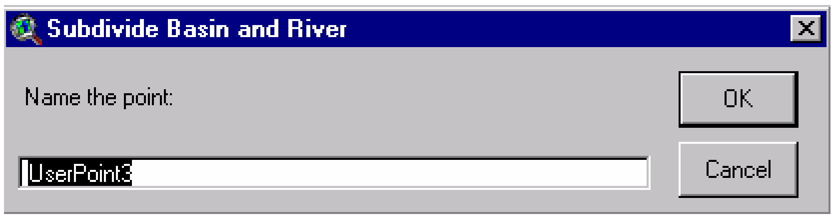
- Select **Basin Processing ⇒ River Profile**.



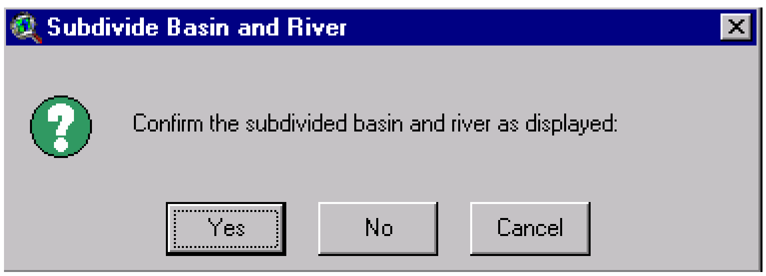
- Review the stream profile.
- The user can subdivide the basin based on the grade break shown in the above figure.
- Select the (**point delineate**) tool.
- Click on the profile approximately where the grade breaks as shown in the profile.



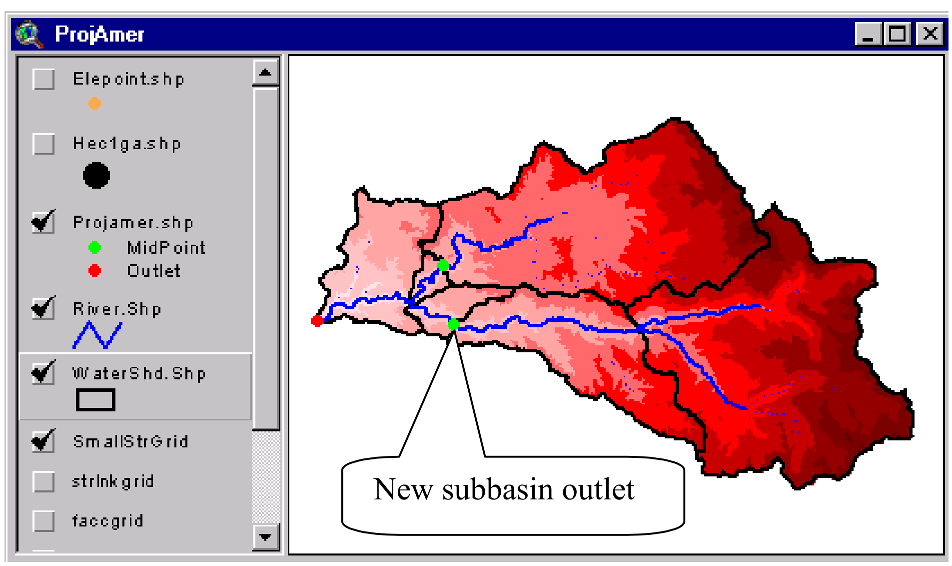
- Click **Yes**.



- Press **OK**.
- Review the result and press **Yes**.



The result of the basin subdivision is shown below.



6. Extract Physical Characteristics of Streams and Subbasins

The physical characteristics of the streams and subbasins are extracted and saved in attribute tables.

A. River Length

- Select **Basin Characteristics ⇒ River Length**.
- Press **OK** at the message box.
- A "Riv_Length" column is added to the "River.Shp" attribute table.

Attributes of River.Shp

Shape	Arcid	Grid_code	From_node	To_node	Wshld	RivId	Length	Riv_Length
PolyLine	1	14	1	2	14	14	8074	8074.5
PolyLine	2	17	2	4	17	17	13826	13826.1
PolyLine	3	18	3	5	18	18	14767	14766.5
PolyLine	4	20	5	2	20	20	6691	6690.7
PolyLine	5	21	6	5	18	21	16439	16439.1
PolyLine	0	14	0	0	21	22	21041	21040.8
PolyLine	0	20	0	0	22	23	23624	23624.5

B. River Slope

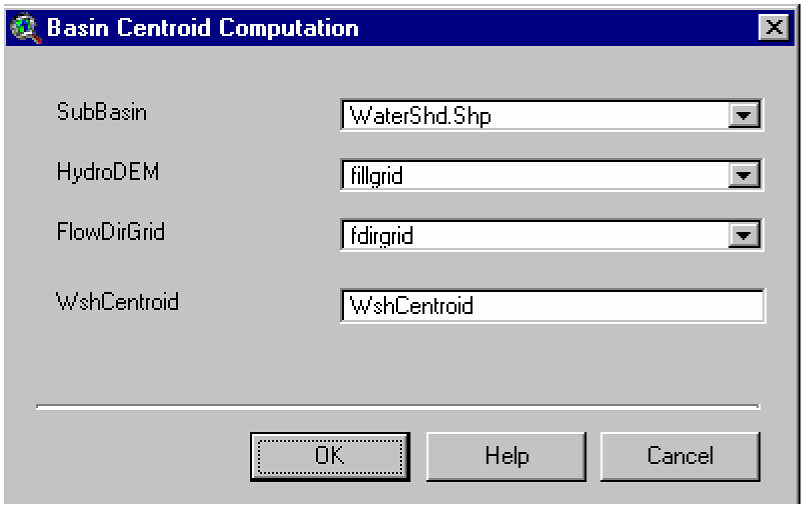
- Select **Basin Characteristics ⇒ River Slope**.
- Select the **DEM Vertical Units** as "meters" because the terrain data has vertical units in meters.
- Press **OK**.
- "Slp_Endpt", "US_Elv", and "DS_Elv" columns are added to the "River.Shp" attribute table.

Attributes of River.Shp

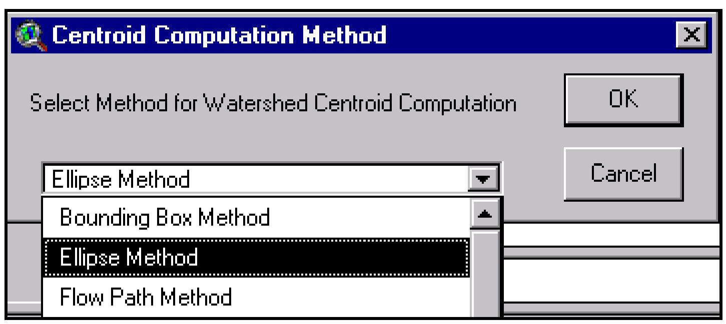
Wshld	RivId	Length	Riv_Length	Slp_Endpt	us_Elv	ds_Elv
14	14	8074	8074.5	0.0225	811.7000	629.8000
17	17	13826	13826.1	0.0096	629.8000	497.7000
18	18	14767	14766.5	0.0312	1657.3000	1196.7000
20	20	6691	6690.7	0.0328	849.3000	629.8000
18	21	16439	16439.1	0.0355	1780.9000	1196.7000
21	22	21041	21040.8	0.0316	1476.0000	811.7000
22	23	23624	23624.5	0.0147	1196.7000	849.3000

C. Basin Centroid

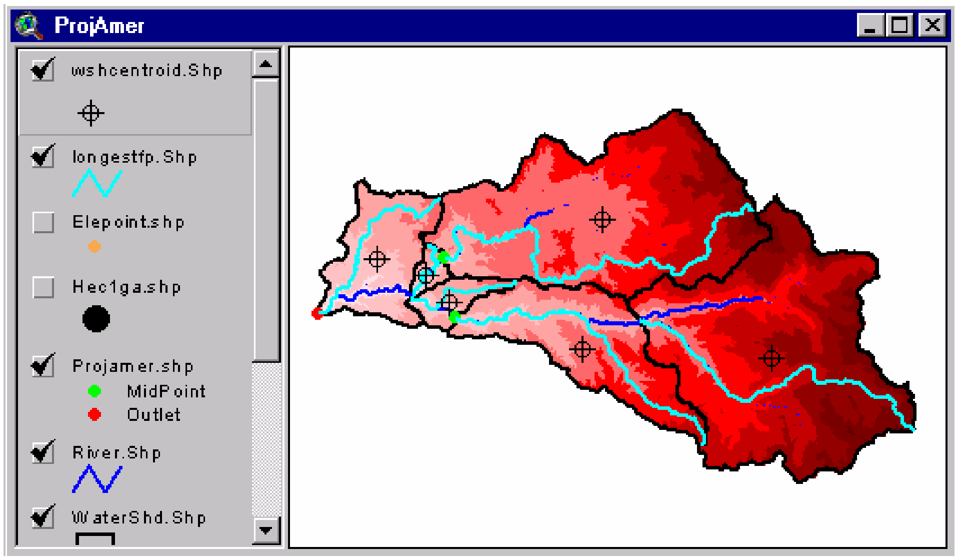
- Select **Basin Characteristics ⇒ Basin Centroid**.
- Confirm the three inputs and one output in the operation as shown below.



- Press **OK**.
- Select the Ellipse Method from the dropdown menu.



- Press **OK**.
- A new theme, "WshCentroid.Shp", is created to represent the centroid locations.



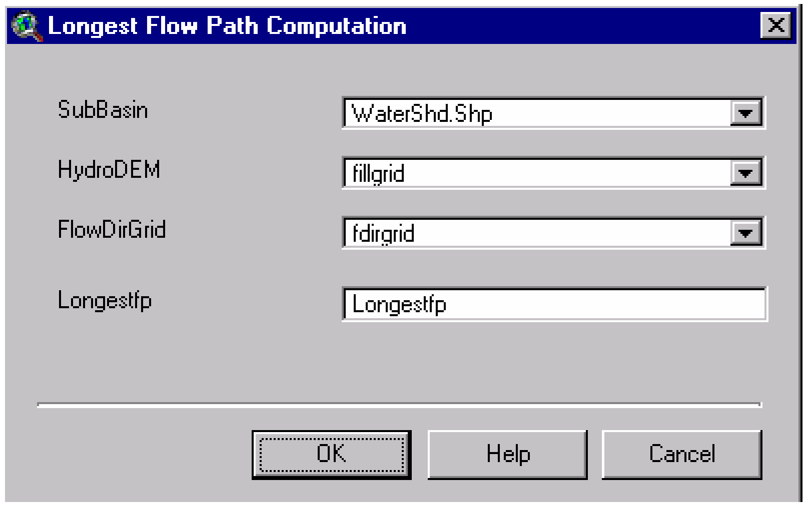
The centroidal elevation is saved under the “Elevation” column in the “WaterShd.Shp” attribute table.

Attributes of WaterShd.Shp

Gridcode	Area	Wshid	TopoDone	Perimeter	Elevation
14	13374900.00	14	0	21120.00000	821.3000
17	117179100.0	17	0	75960.00000	1133.0000
18	489244500.0	18	0	156600.0000	2235.5000
20	30275100.00	20	0	38100.00000	1145.0000
14	443059200.0	21	0	141960.0000	1550.0000
20	181171800.0	22	0	102540.0000	1573.1000

D. Longest Flow Path

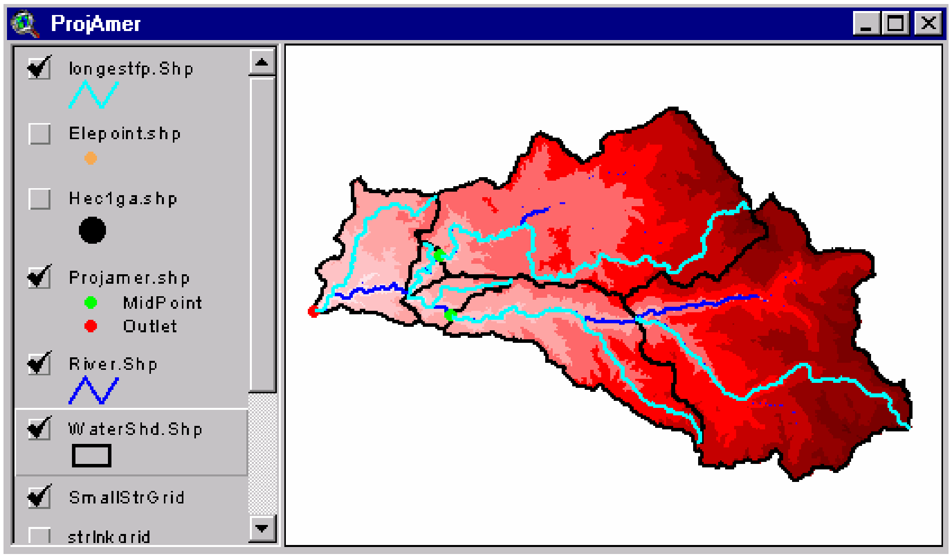
- Select **Basin Characteristics** ⇒ **Longest Flow Path**.



- Review the input and output themes. Press **OK**. (This step takes about 5 minutes.)

- Press **OK** on the confirmation screen.

The results of the longest flow path operation are shown below.



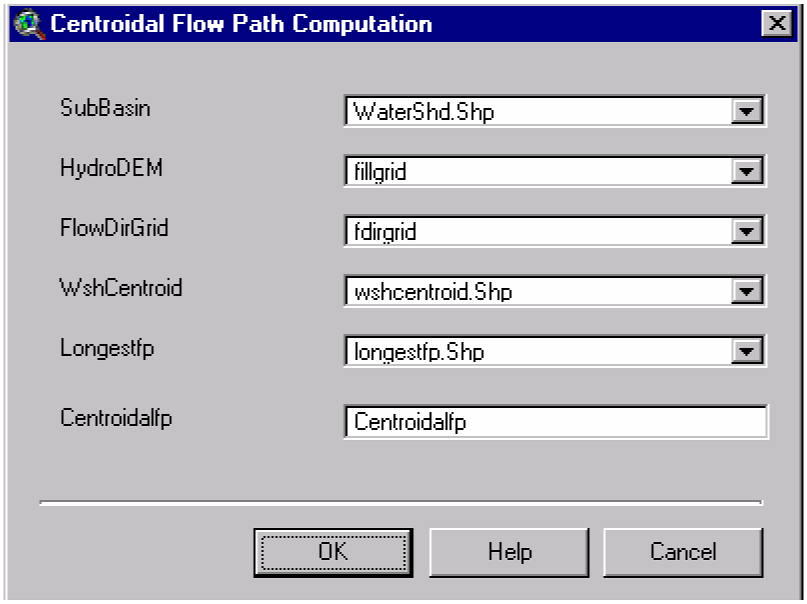
The longest flow path computation also stores the physical parameters in the watershed's attribute table as shown below.

Attributes of WaterShd.Shp

Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
821.3000	630.1000	0.084	0.089	9909.991	1465.0000
1133.0000	497.7000	0.044	0.043	24127.922	1556.0000
2235.5000	1198.2000	0.043	0.034	41774.747	2983.0000
1145.0000	629.1000	0.060	0.066	14610.580	1508.0000
1550.0000	811.7000	0.033	0.021	61271.277	2854.0000
1573.1000	849.3000	0.036	0.034	38839.162	2235.0000

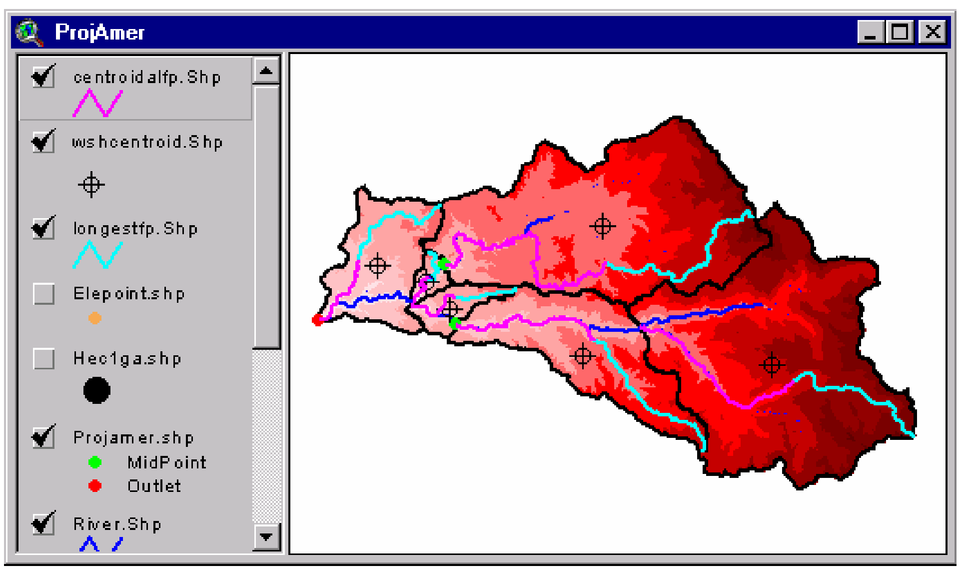
E. Centroidal Flow Path

- Select **Basin Characteristics ⇒ Centroidal Flow Path**.
- The program prompts the user to verify the five data inputs and one output.



- Press **OK**.

The result of the centroidal flow path operation is the line shapefile named "Centroidalfp.Shp" and its attribute table as shown in the figures below. The centroidal flow length in the "CentroidalFL" column is also stored in the "WaterShd.shp" theme attribute table.



Attributes of WaterShd.Shp

DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv	CentroidalFL
630.1000	0.084	0.089	9909.991	1465.0000	4760.437
497.7000	0.044	0.043	24127.922	1556.0000	9742.052
1198.2000	0.043	0.034	41774.747	2983.0000	22982.775
629.1000	0.060	0.066	14610.580	1508.0000	7155.290
811.7000	0.033	0.021	61271.277	2854.0000	37148.868
849.3000	0.036	0.034	38839.162	2235.0000	18743.149

7. Develop HMS Inputs

A. Reach AutoName

- Select **HMS ⇒ River AutoName**.
- Press **OK** on the confirmation message box.

The Reach Autoname creates a “Name” column in the stream’s attribute table as shown in the table below.

Attributes of River.Shp

Slp_Endpt	us_Elv	ds_Elv	Name
0.0225	811.7000	629.8000	R140
0.0096	629.8000	497.7000	R170
0.0312	1657.3000	1196.7000	R180
0.0328	849.3000	629.8000	R200
0.0355	1780.9000	1196.7000	R210
0.0316	1476.0000	811.7000	R220
0.0147	1196.7000	849.3000	R230

B. Basin AutoName

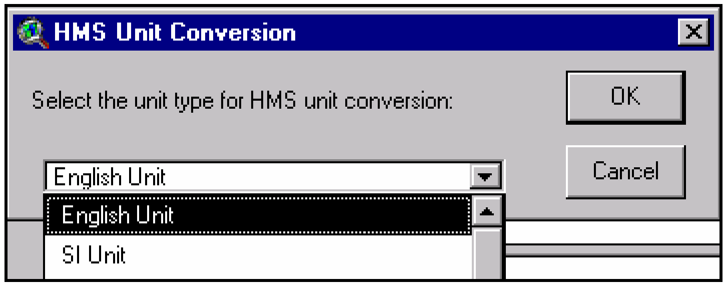
- Select **HMS ⇒ Basin AutoName**.
- The Basin Autoname creates a “Name” column in the subbasin’s attribute table as shown in the table below.

Attributes of WaterShd.Shp

Slp_1085	LongestFL	USElv	CentroidalFL	Name
0.089	9909.991	1465.0000	4760.437	R140W140
0.043	24127.922	1556.0000	9742.052	R170W170
0.034	41774.747	2983.0000	22982.775	R180W180
0.066	14610.580	1508.0000	7155.290	R200W200
0.021	61271.277	2854.0000	37148.868	R220W210
0.034	38839.162	2235.0000	18743.149	R230W220

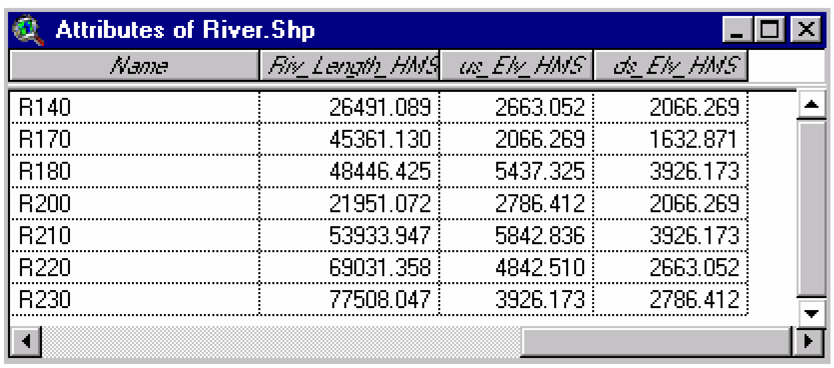
C. Map to HMS Units

- Select **HMS ⇒ Map to HMS Units**.
- Select English from dropdown menu.



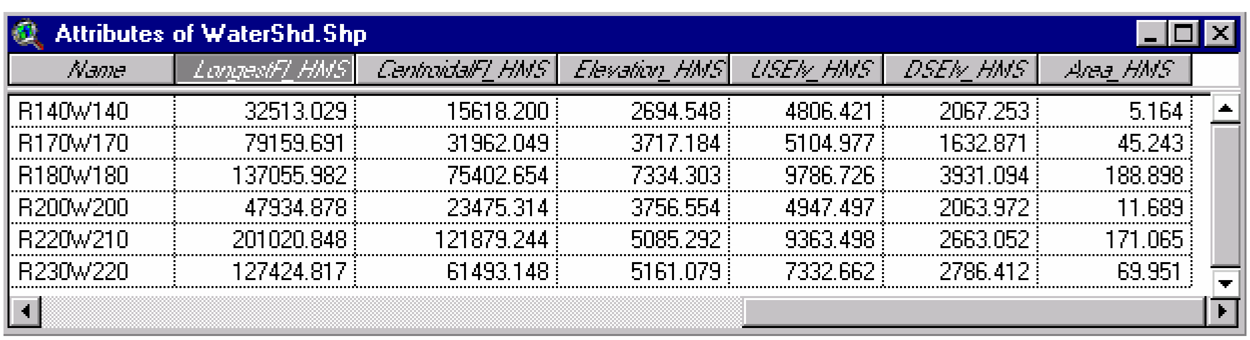
- Press **OK** and press **OK** again to confirmation message box.

The results of the unit conversion are three added columns to the stream's attribute table and six added columns to the subbasin's attribute table. The added columns contain the ending "_HMS".



Attributes of River.Shp

Name	Riv_Length_HMS	us_Elv_HMS	ds_Elv_HMS
R140	26491.089	2663.052	2066.269
R170	45361.130	2066.269	1632.871
R180	48446.425	5437.325	3926.173
R200	21951.072	2786.412	2066.269
R210	53933.947	5842.836	3926.173
R220	69031.358	4842.510	2663.052
R230	77508.047	3926.173	2786.412

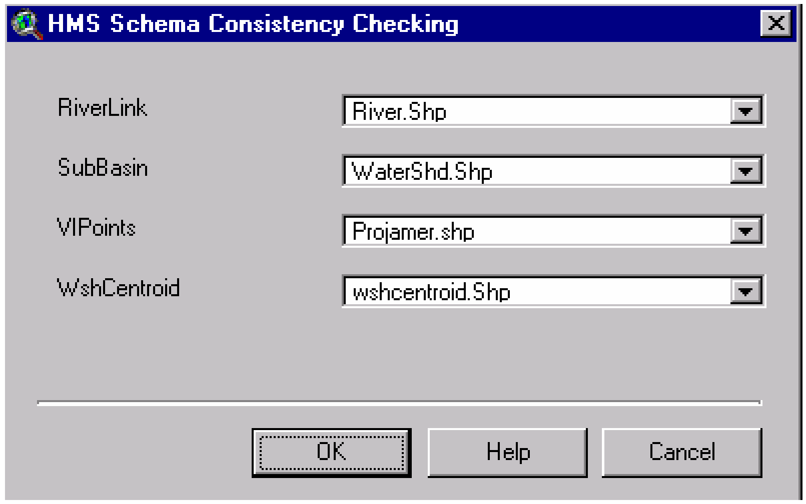


Attributes of WaterShd.Shp

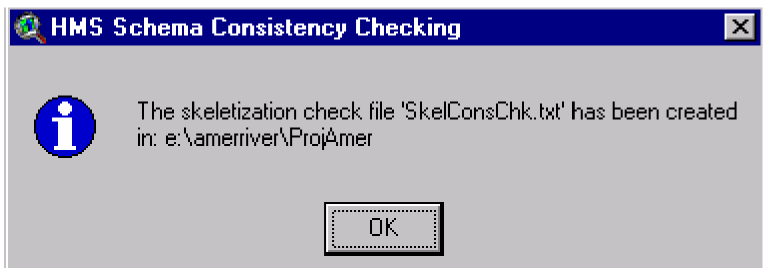
Name	LongestFl_HMS	CentroidalFl_HMS	Elevation_HMS	USElv_HMS	DSElv_HMS	Area_HMS
R140W140	32513.029	15618.200	2694.548	4806.421	2067.253	5.164
R170W170	79159.691	31962.049	3717.184	5104.977	1632.871	45.243
R180W180	137055.982	75402.654	7334.303	9786.726	3931.094	188.898
R200W200	47934.878	23475.314	3756.554	4947.497	2063.972	11.689
R220W210	201020.848	121879.244	5085.292	9363.498	2663.052	171.065
R230W220	127424.817	61493.148	5161.079	7332.662	2786.412	69.951

D. HMS Check Data

- Select **HMS ⇒ HMS Check Data**.
- Verify the input data sets below.

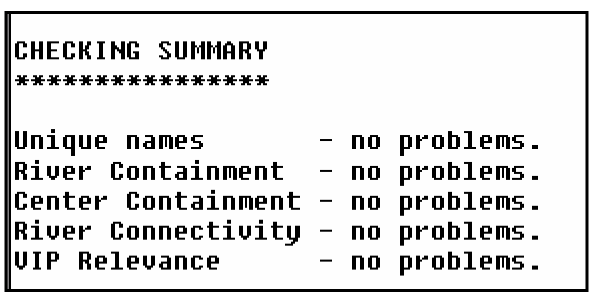


- Press **OK**.



- Make a note of the filename and its location. Press **OK**.

The output file, "SkelConsChk.txt", contains the results of the check results. The end portion of the file is shown below.

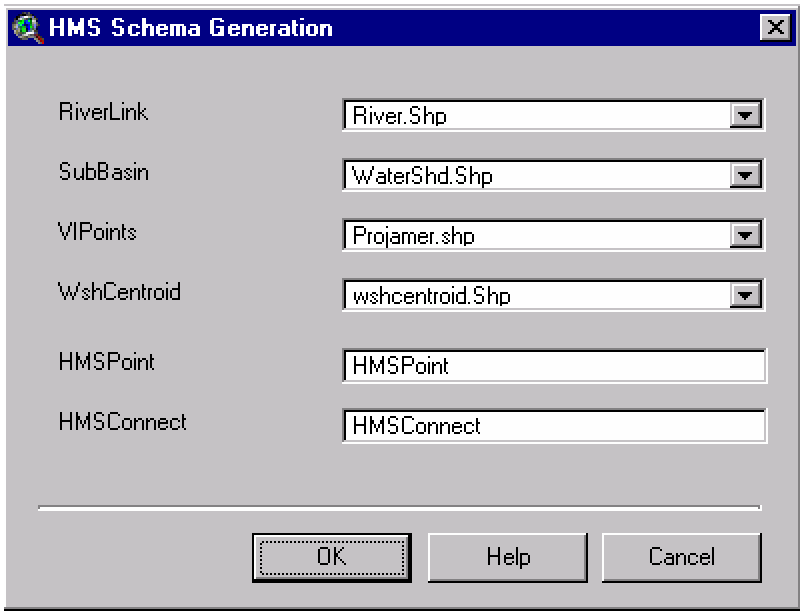


```
CHECKING SUMMARY
****************

Unique names         - no problems.
River Containment    - no problems.
Center Containment   - no problems.
River Connectivity   - no problems.
VIP Relevance        - no problems.
```

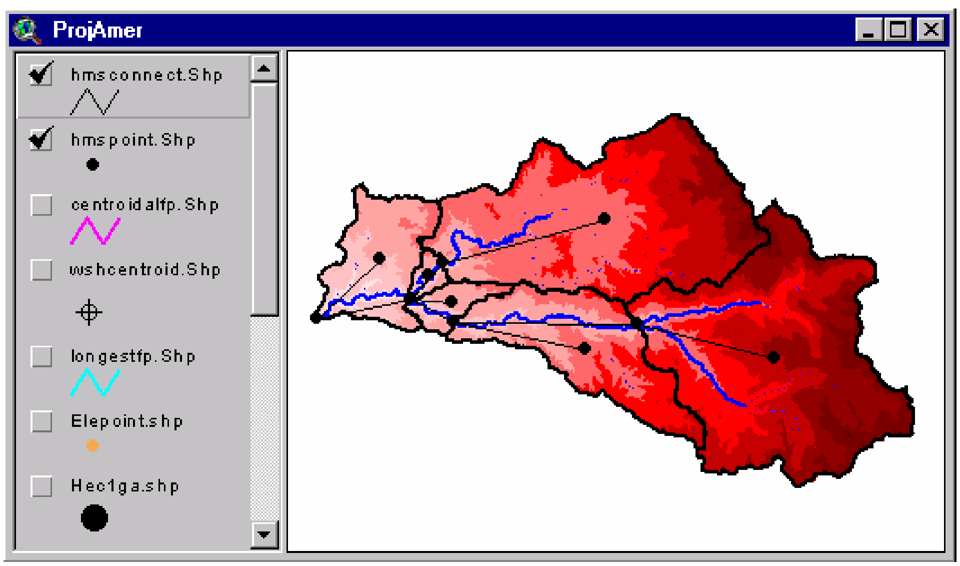
E. HMS Schematic

- Select **HMS ⇒ HMS Schematic**.
- Review the input and output data sets as shown the window below.



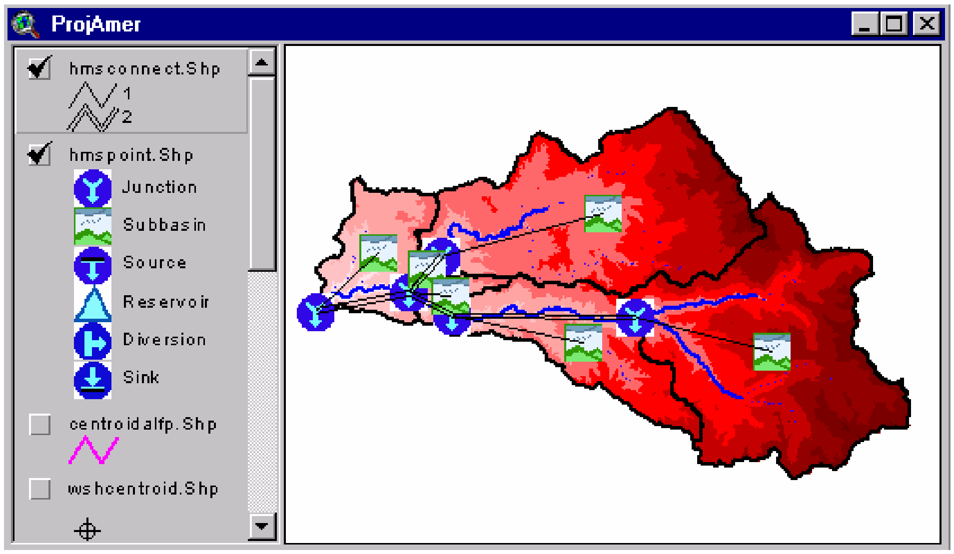
- Press **OK** and press **OK** again at the confirmation message box.

The HMS schematic with ArcView symbols is shown in the figure below.



F. HMS Legend

- Select **HMS ⇒ HMS Legend**.
- The user can toggle between HMS Legend and Regular Legend by selecting **HMS ⇒ HMS or Regular Legend**.



G. Add Coordinates

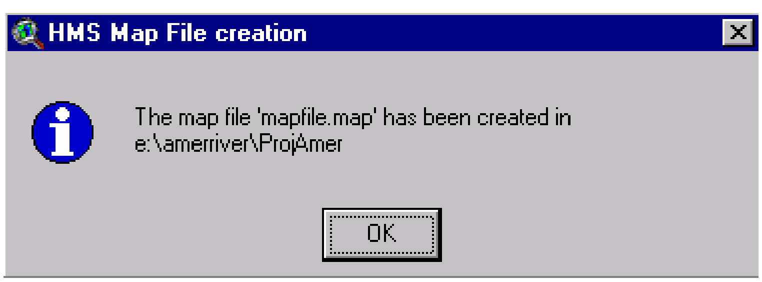
This step attaches geographic coordinates to hydrologic elements in the attribute tables of "HMSPoint.shp" and "HMSConnect.shp". The attachment of coordinates allows GIS data to be exported to a non-proprietary ASCII format and still preserve the geographic information.

- Select **HMS ⇒ Add Coordinates**. Press **OK**.

H. Background-Map File

The background-map file captures the geographic information of the subbasin boundaries and stream alignments in an ASCII text file that can be read by HMS.

- Select **HMS ⇒ Background-Map File**.



- Make a note of the filename and its location. Press **OK**.

I. Lumped-Basin Model

The lumped-basin model captures the hydrologic elements, their connectivity, and related geographic information in an ASCII text file that can be read by HMS. This basin model should be used for a hydrologic model with lumped, not distributed, basin parameters.

- Select **HMS** ⇒ **Lumped-Basin Model**.

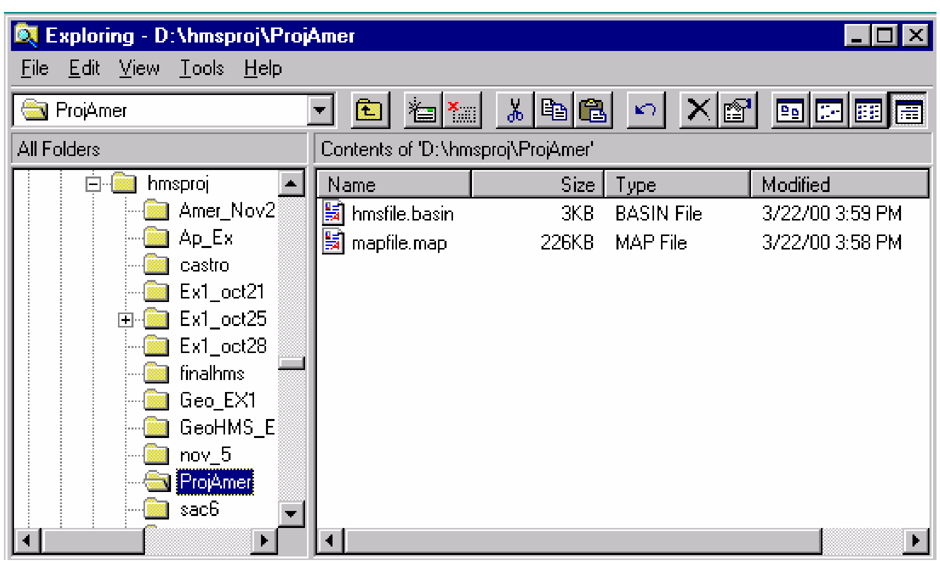
- Make a note of the file name and its location. Press **OK**.

<u>Task III. Hydrologic Modeling System</u>

8. Setup an HEC-HMS model with inputs from HEC-GeoHMS

A. Directory Setup

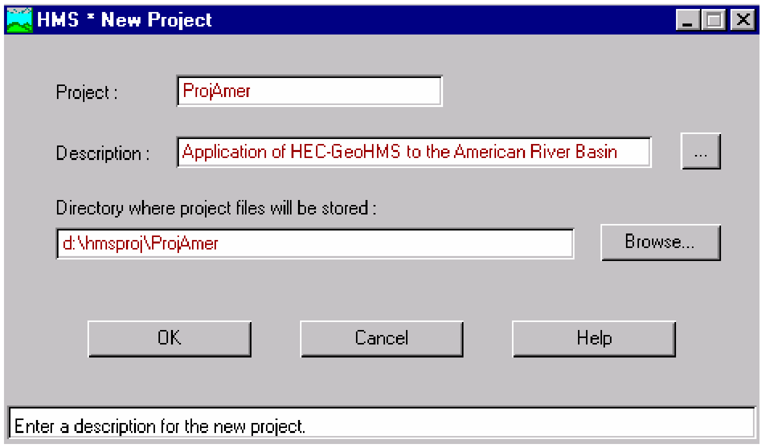
- Create the HMS project first, and then copy the background-map file, basin-model file, and grid-cell parameter file, if appropriate, into D:\hmsproj\ ProjAmer.



B. HMS Setup

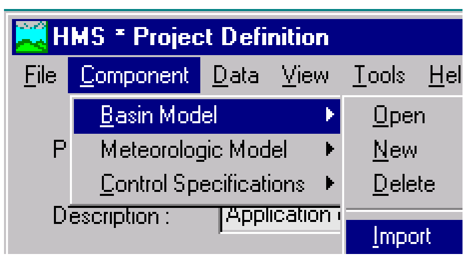
- Start the HMS program.

- Select **File ⇒ New Project**.
- Enter the **Project** as “ProjAmer” and **Description** as “GIS Application of HEC-GeoHMS to the American River Basin”.

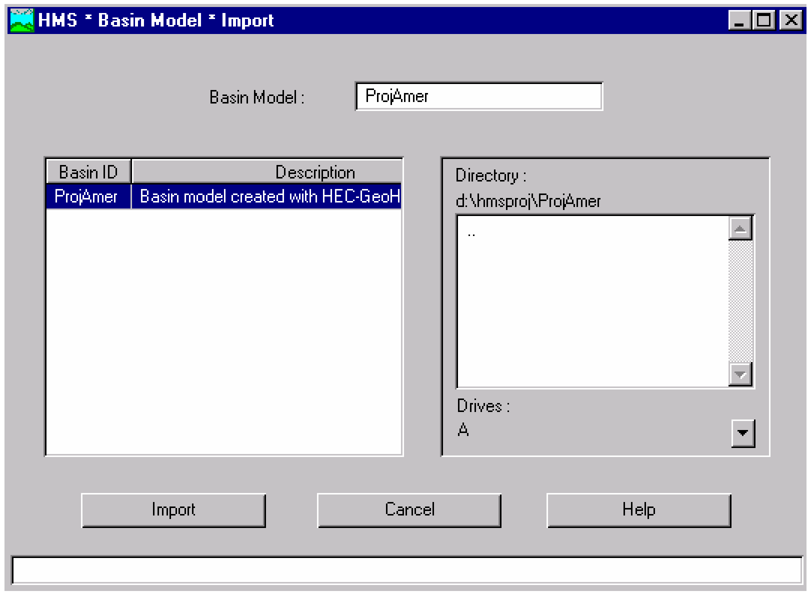


- Press **OK**.

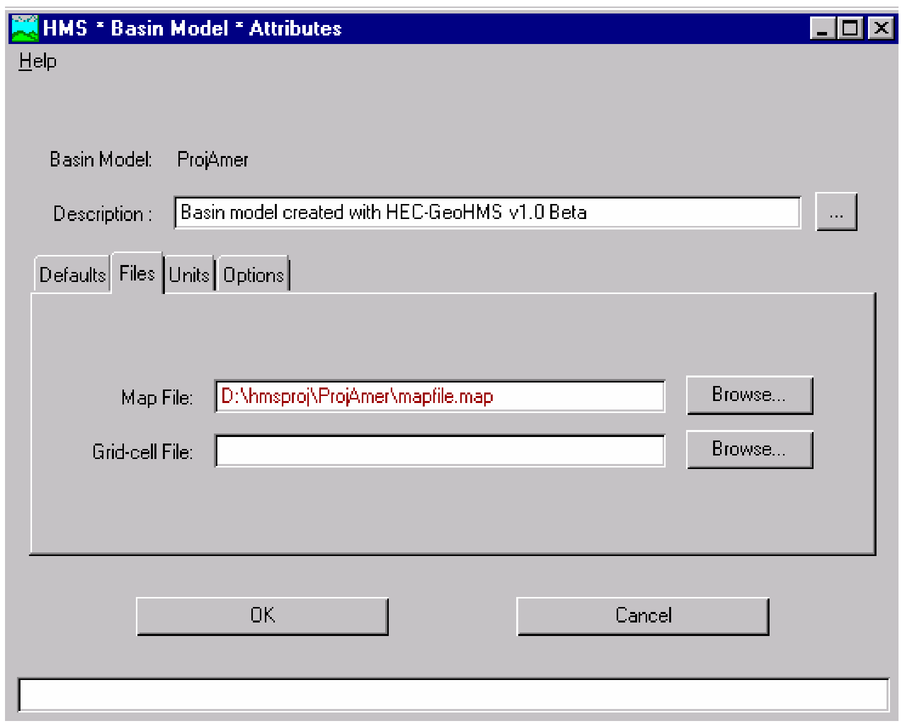
- Import the Basin Model on the **HMS * Project Definition** window, select **Component ⇒ Basin Model ⇒ Import.**



- Navigate to “D:\hmsproj\ ProjAmer”.
- Select “ProjAmer” under the **Basin ID**.

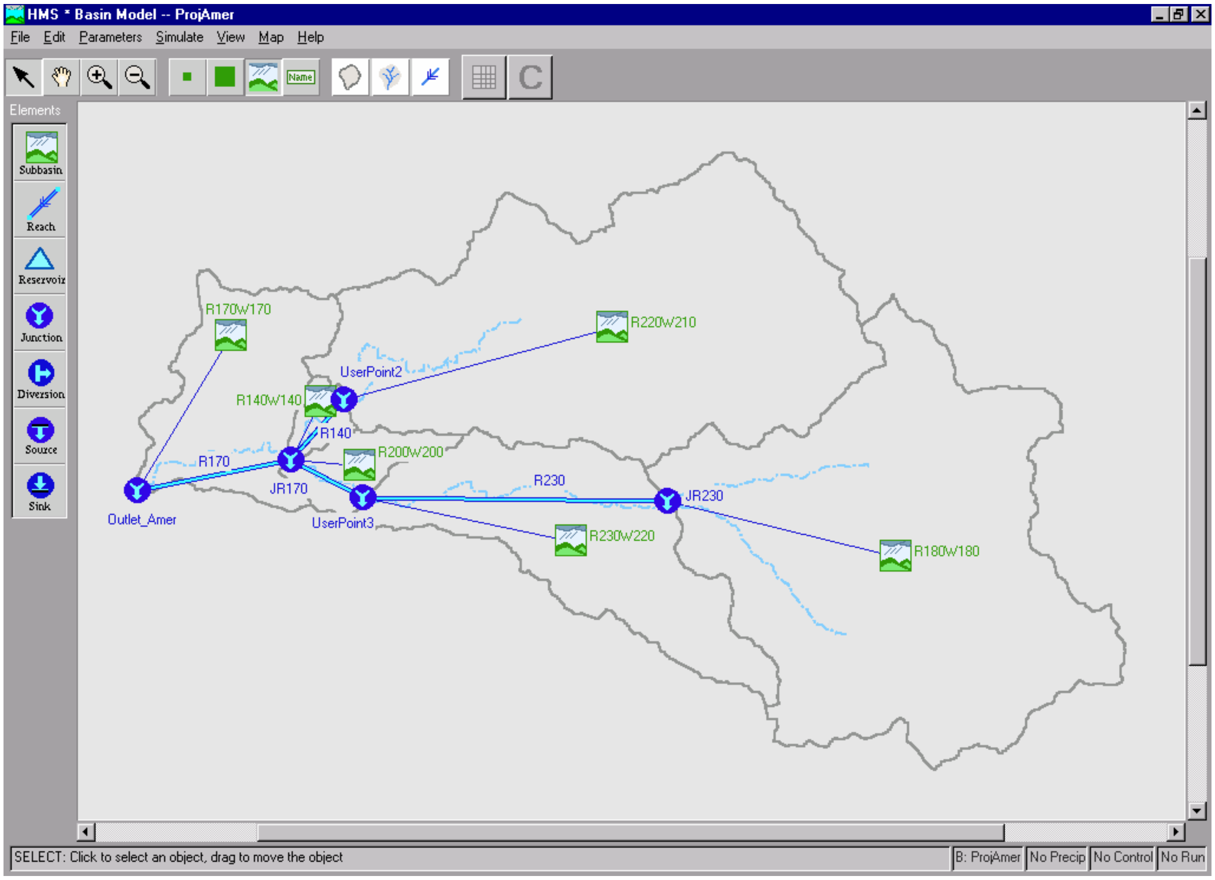


- Press **Import**.
- Specify the background-map file by selecting **File** ⇒ **Basin Model Attributes**.
- To specify the **Map File**, press on "Browse…" button.
- Navigate to the "D:\hmsproj\ ProjAmer" and select the file "Mapfile.map".



- Press **OK**.

The basin model and the background-map files are brought into HMS resulting in the following HMS Basin Schematic.



The subbasin and routing elements parameters are then input via HMS editors. That information may be available from previous studies and/or a new regional analysis by calibrating the model to gaged storms and then relating model parameters to physical characteristics of the subbasins.

APPENDIX A

References

Hydrologic Engineering Center (2000). *HEC-DSS User's Guide and Utility Manuals: User's Manual*. U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (1998). *HEC-1 Flood Hydrograph Package: User's Manual*. U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (1999). *GageInterp: User's Manual*. DRAFT. U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2000). *Hydrologic Modeling System (HEC-HMS): Technical Reference Manual*. U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2001). *Hydrologic Modeling System (HEC-HMS): User's Manual*. U.S. Army Corps of Engineers, Davis, CA.

Kull, D.W. and A.D. Feldman (1998). "Evolution of Clark's unit graph method to spatially distributed runoff". *J. Hydrologic Engineering*, 3(1), 9-19.

Peters, J.C. and D.J.Easton (1996). "Runoff simulation using radar rainfall data". *J.AWRA*, 32(4), 753-760.

APPENDIX B

Background-Map File Format

Watershed boundaries and stream lines can be displayed as a background for hydrologic elements on the *Basin Model* screen. The use of a background map is optional and not required for any calculations. This appendix describes the background-map file format. The file can be produced using available geographic information system (GIS) tools.

File Definition

Watershed boundary and stream line features are both defined in the same file, which is in plain ASCII format. Each feature type is contained in a separate section of the file; it is not important which section is first in the file. Each section begins with the keyword "MapGeo" followed by a colon and either "BoundaryMap" or "RiverMap" (Figure B-1).

A map segment defines a list of map coordinates that are connected by a line. A closed segment defines a polygon and an open segment defines a line. Closed segments are used for watershed boundaries and open segments are used for stream lines. Each segment begins with the keyword "MapSegment" followed by a colon and either "Closed" or "Open." The last coordinate in a closed segment is automatically connected to the first coordinate.

Segment coordinates are defined with x-y pairs. Map features are automatically scaled in the *Basin Model* screen. Coordinates are therefore independent of projection, units, and offset. All segments must be in the same coordinate system.

```
MapGeo:  BoundaryMap
MapSegment:  closed
   582242.875000, 4174922.500000
   582220.875000, 4174961.500000
   582205.625000, 4175013.750000
   581981.000000, 4174672.750000
   582025.812500, 4174696.250000
   582068.812500, 4174711.000000
MapSegment:  closed
   582810.125000, 4174024.500000
   582874.687500, 4173973.750000
   582950.687500, 4173902.750000
   582554.000000, 4174000.250000
   582667.687500, 4174003.750000
   582810.125000, 4174024.500000
MapGeo:  RiverMap
MapSegment:  open
   582750.187500, 4176706.000000
   582687.000000, 4176594.000000
   582657.375000, 4176468.500000
   582613.125000, 4176359.500000
```

Figure B-1.   Sample background map file.

APPENDIX C

Grid-Cell Parameter File Format

The ModClark transform method requires a grid-cell file. The file defines cells for each subbasin. Parameters for each cell are also included in the grid-cell file. This appendix describes the grid-cell file format. The file can be produced using available geographic information system (GIS) tools.

File Definition

The grid-cell file begins with the keyword "Parameter Order" followed by a colon and parameter keywords indicating the order for reading parameters from the file (Figure C-1). The keyword "End" must be on a line by itself after the "Parameter Order" line. Valid parameter keywords are shown in Table C-1. Parameter keywords are not case sensitive and are separated by spaces. If the parameter order is not defined, it is assumed to be: Xcoord Ycoord TravelLength Area. The coordinate system of Xcoord and Ycoord used in the file must match the coordinate system used in the gridded DSS precipitation records. Typically the coordinate system will be either Hydrologic Rainfall Analysis Project (HRAP) or Standard Hydrologic Grid (SHG).

The data for a subbasin begins with the keyword "Subbasin" followed by a colon and the subbasin identifier. One line beginning with the keyword "Grid Cell" follows for each cell in the subbasin. Data for the subbasin ends with the keyword "End". Keywords are not case sensitive and may contain spaces. Blank lines can be included and lines beginning with "#" are ignored as comments. The same grid-cell file can be referenced by more than one subbasin, allowing data for many subbasins to be stored in the same file. The identifier for a subbasin must be exactly the same in the grid-cell file as it is in the basin model.

Table C-1. Parameter keyword definitions.

Keyword	Definition	Units
XCoord	x-coordinate of the southwest corner of the cell	integer value
YCoord	y-coordinate of the southwest corner of the cell	integer value
TravelLength	travel time index from the cell to the subbasin outlet	kilometers
Area	area of cell within the subbasin	square kilometers
ScsCn	SCS curve number of the cell	real value (0.0-100.0)
SmaUnit	Soil moisture accounting unit name	character string

```
Parameter Order: Xcoord YCoord TravelLength Area SCSCN
End:
Subbasin: 85
Grid Cell:   633  359   88.38    3.76
Grid Cell:   634  359   84.51    0.18
Grid Cell:   633  358   85.55   16.13
Grid Cell:   632  358   82.55   12.76
Grid Cell:   625  348   13.75   12.07
Grid Cell:   626  348   17.12    0.09
Grid Cell:   622  347   21.19    3.26
Grid Cell:   623  347   15.56    9.96
End:
Subbasin: 86
Grid Cell:   637  361   59.13    6.79
Grid Cell:   638  361   59.04    6.95
Grid Cell:   636  361   56.68    1.17
```

Figure C-1. Sample grid-cell parameter file.

APPENDIX D

Grids in HEC-DSS and HRAP and SHG Grid Systems

Grids in HEC-DSS

Contents of a Grid Record in HEC-DSS

HEC-DSS records, including grid records, consist of a block of sequential data with an associated header array describing the data in the block. In a time-series record, the sequence represents the variation of a parameter's value through time at a fixed location. In a grid record, the sequence represents the variation of a parameter's value over a region of the earth's surface for a single interval of time. The header array of a grid record contains information about the parameter values (their units and some summary statistics) and the two-dimensional array in which they are stored (the number of rows and columns in the array, and the location of the grid in geo-referenced coordinates).

The contents of the header are described below for three types of grids. All grid headers contain basic parameter and grid extent information. In addition, the headers for HRAP grids and Albers equal-area grids (including SHG grids) contain additional descriptive information.

Storage of Grid Values

In the DSS file, grid parameter values are stored in a single array, starting with the value in the minimum-x, minimum-y (or lower left) cell in the two-dimensional array. The values proceed by row in increasing column numbers and increasing row numbers, as illustrated in the figure below.

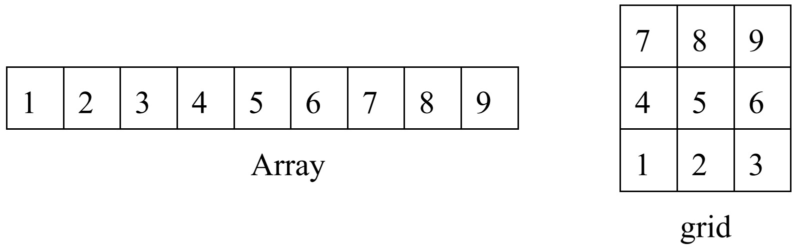


Figure. One-Dimensional Array Storing Two-Dimensional Grid of Parameter Values

The array of parameter values is always compressed before it is written to a DSS file. Two compression methods are used. One is a run-length encoding method, which replaces repeated zero values with the number of times zero was repeated. The second method is the deflate method, which is included in the zlib library described in RFC 1950. The deflate format itself is described in RFC 1951. The deflate format and zlib are included in Javasoft's Java Development Kit version 1.1 and higher.

Grid Header Contents

The contents of the grid header array are as follows

Field	**Type**	**Size** (integers)
Info Flat Size	Integer	1
Grid Type	Integer	1
Grid Info Size	Integer	1
Start Time	Integer	1
End Time	Integer	1
Data Units	Text	3
Data Type	Integer	1
Lower Left Cell X	Integer	1
Lower Left Cell Y	Integer	1
Number of Cells X	Integer	1
Number of Cells Y	Integer	1

Cell Size	Float	1
Compression Method	Integer	1
Compressed Array Size	Integer	1
Compression Scale Factor	Float	1
Compression Base	Float	1
Max Data Value	Float	1
Min Data Value	Float	1
Mean Data Value	Float	1
Number of Ranges	Integer	1
Range Limit Table	Float	20
Range Counts	Integer	20
HRAP Headers append the following		
Data Source	Text	3
Albers Headers (including SHG) append the following		
Projection Datum	Integer	1
Projection Units	Text	3
First Standard Parallel	Float	1
Second Standard Parallel	Float	1
Central Meridian	Float	1
Latitude of Origin	Float	1
False Easting	Float	1
False Northing	Float	1
X Coordinate of Cell (0,0)	Float	1
Y Coordinate of Cell (0,0)	Float	1

HRAP Grid System

The Hydrologic Rainfall Analysis Project (HRAP) grid is a square-celled mapgrid based on a Polar Stereographic map projection with the following parameters.

Units: Meters

Datum: Sphere (radius = 6371.2 km)

Standard Parallel: 60º 0’ 0” North

Central Meridian: 105º 0’ 0” West

The mesh (cell) size of the grid is 4.7625 km, and the grid Y axis is aligned parallel with the central meridian (105E W). The grid is registered so that the north pole lies exactly 400 cells in the positive X direction and 1600 cells in the positive Y direction from the grid origin. Equivalently, the lower left corner of cell number (401, 1601) is located at the north pole.

Examples

As examples of cell identification in the HRAP system, indices of cells containing points in the western US and the eastern US are given.

Western US:

The location 121º 45′ west, 38º 35′ north (near Davis, California) projects to 260,174 m easting, 2,143,782 m northing, in the specified polar stereographic projection. In the HRAP system the indices of the cell containing this point are

i = 54

j = 450

Eastern US:

The location 76º 30′ west, 42º 25′ north (near Ithaca, New York) projects to 4,410,804 m easting, 3,018,420 m northing, in the specified polar stereographic projection. In the HRAP system the indices of the cell containing this point are

i = 926

j = 633

SHG Grid System

The standard hydrologic grid (SHG) is a variable-resolution square-celled map grid defined for the conterminous United States. The coordinate system of the grid is based on the Albers equal-area conic map projection with the following parameters.

Units: Meters

Datum: North American Datum, 1983 (NAD83)

1st Standard Parallel: 29º 30’ 0” North

2nd Standard Parallel: 45º 30’ 0” North

Central Meridian: 96º 0’ 0” West

Latitude of Origin: 23º 0’ 0” North

False Easting: 0.0

False Northing: 0.0

Users of the grid can select a resolution suitable for the scale and scope of the study for which it is being used. For general-purpose hydrologic modeling with NEXRAD radar precipitation data, HEC recommends 2000m cells, and HEC computer programs that use the SHG for calculation will select this cell size as a default. HEC will also support the following grid resolutions: 10,000 m, 5,000 m, 1,000 m, 500 m, 200 m, 100 m, 50 m, 20 m, 10 m. The grids resulting from the different resolutions will be referred to as SHG-2km, SHG-1km, SHG-500m and so on. A grid identified as SHG with no cell-size indication will be assumed to have 2km cells

For identification, each cell in the grid has a pair of integer indices (i, j) indicating the position, by cell count, of its southwest (or minimum-x, minimum-y) corner, relative to the grid’s origin at 96E W, 23E N. For example the southwest corner of cell (121, 346) in the SHG-2km grid is located at an easting of 242000 m and a northing of 692000 m. To find the indices of the cell in which a point is located, find the point’s easting and northing in the projected coordinate system defined above, and calculate the indices with the following formulas.

$i = floor(easting / cellsize)$

$j = floor(northing / cellsize)$

Where floor(x) is the largest integer less than or equal to x.

Examples

As examples of cell identification in the SHG system, indices of cells containing points in the western US and the eastern US will be given in the 1km, 2km, and 500 m SHG grids.

Western US:

The location 121° 45′ west, 38° 35′ north (near Davis, California) projects to -2185019 m easting, 2063359 m northing, in the specified Albers projection. In the SHG-2km system the indices of the cell containing this point are

$i = floor(-2185019 / 2000) = floor(-1092.5) = -1093$

$j = floor(2063359 / 2000) = floor(1031.7) = 1031$

In the SHG-1km grid the indices are (-2186, 2063), and in SHG-500m they are (-4371, 4126)

Eastern US:

The location 76° 30′ west, 42° 25′ north (near Ithaca, New York) projects to 1583506 m easting, 2320477 m northing, in the specified Albers projection. In the SHG-2km system the indices of the cell containing this point are

$i = floor(1583509 / 2000) = floor(791.8) = 791$

$j = floor(2320477 / 2000) = floor(1160.2) = 1160$

In the SHG-1km grid the indices are (1583, 2320), and in SHG-500m they are (3167, 4640).

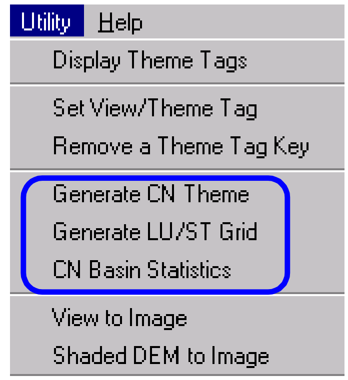
References

Hydrologic Engineering Center. March 1995. HEC-DSS User’s Guide and Utility Manuals (CPD-45). US Army Corps of Engineers, Davis, CA.

APPENDIX E

Curve Number Grid Development

The purpose of this appendix is to familiarize the users with the process of developing the curve number grid that is used as an input to GeoHMS for lumped and grid-based curve number computation for the subbasin. The following new features under the **Utility** menu under the **ProjView** GUI will be described. Other ArcView standard tools, such as conversion from polygon theme to a grid and the Geoprocessing Wizard will be discussed to help the user go through the five steps of curve number development.

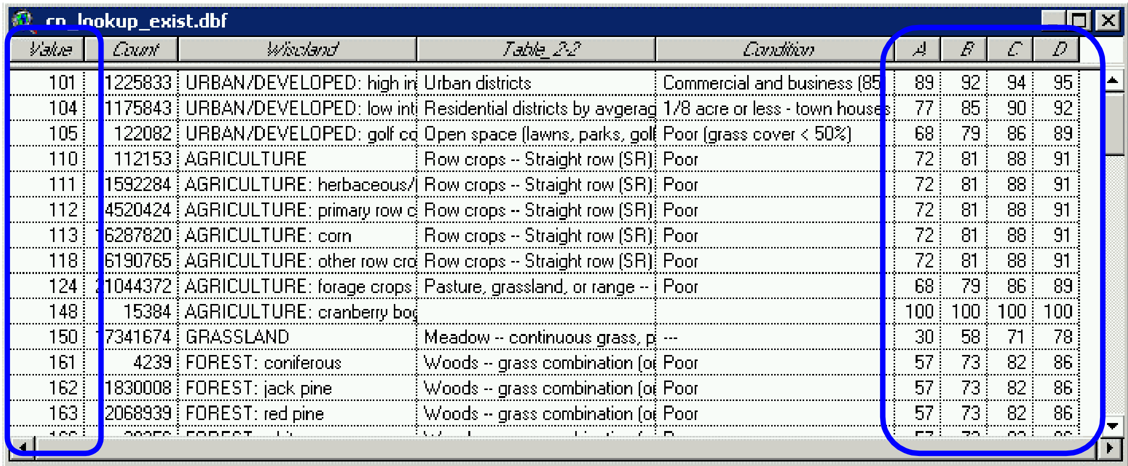


The new features in GeoHMS are circled in the above figure and are discussed below.

Generate CN Theme

This function computes a composite curve number for polygons in the CNPoly theme. The CNPoly theme is a polygon theme in which each polygon has a unique combination of land use and soil type.

The CNPoly theme needs to have a field (Landuse) identifying the land use type and fields (Pcta, Pctb, Pctc, and Pctd) identifying percentage of hydrologic soil group. The curve number values (CN) for each land use and hydrologic soil group are retrieved from a CN lookup table (in dbf format). The user needs to develop their own CN lookup table. In this table as shown below, the field "Value" contains the reference to the land use while fields A, B, C, and D contain the CN value for the different hydrologic soil groups (A, B, C, and D respectively).



cn_lookup_exist.dbf

Value	Count	Wisland	Table_2-2	Condition	A	B	C	D
101	1225833	URBAN/DEVELOPED: high in	Urban districts	Commercial and business (85	89	92	94	95
104	1175843	URBAN/DEVELOPED: low int	Residential districts by avgerag	1/8 acre or less - town houses	77	85	90	92
105	122082	URBAN/DEVELOPED: golf co	Open space (lawns, parks, golf	Poor (grass cover < 50%)	68	79	86	89
110	112153	AGRICULTURE	Row crops -- Straight row (SR)	Poor	72	81	88	91
111	1592284	AGRICULTURE: herbaceous/	Row crops -- Straight row (SR)	Poor	72	81	88	91
112	4520424	AGRICULTURE: primary row c	Row crops -- Straight row (SR)	Poor	72	81	88	91
113	6287820	AGRICULTURE: corn	Row crops -- Straight row (SR)	Poor	72	81	88	91
118	6190765	AGRICULTURE: other row cro	Row crops -- Straight row (SR)	Poor	72	81	88	91
124	1044372	AGRICULTURE: forage crops	Pasture, grassland, or range --	Poor	68	79	86	89
148	15384	AGRICULTURE: cranberry bog			100	100	100	100
150	7341674	GRASSLAND	Meadow -- continuous grass, p	---	30	58	71	78
161	4239	FOREST: coniferous	Woods -- grass combination (o	Poor	57	73	82	86
162	1830008	FOREST: jack pine	Woods -- grass combination (o	Poor	57	73	82	86
163	2068939	FOREST: red pine	Woods -- grass combination (o	Poor	57	73	82	86

The user will be asked to identify the CN lookup table each time the function is run. This provides the flexibility to compute a composite CN value for different conditions, by pointing to a different CN lookup table.

The operation will add or update a user-specified field in the CNPoly theme. The user will be prompted to specify whether to generate a new CN field, or to update an existing one. If the user wants to create a new field, the user will have to provide a name for the field. For updating the field, the user will have to select from the list of fields in the CNPoly theme. This approach allows multiple CN fields to be associated with a single CNPoly theme. For example, a set of CN fields might be created to identify normal, dry, and wet soil conditions.

- UserDefinedField (SCSCN by default): Average CN value for each polygon in the CNPoly theme. This average is computed based on the percent of hydrologic soil groups in the polygon (that has a unique land use type) and CN values from the lookup table. The total percent of hydrologic soil groups in the polygon is always used for averaging, thus avoiding potential problems when the total percentages in a polygon do not add to 100. It is best to account for all the hydrologic soil groups in a polygon to avoid potential problems in interpretation.

It is the user responsibility to keep track on which CN field represents what conditions, and use it appropriately. The CNPoly theme will be used to generate the CNGrid theme, using the standard Polygon to Grid conversion through the ArcView user interface. When doing this conversion, the user will be prompted to define the field whose values will be assigned to the newly created grid. In case of CNGrid construction, this should be one of the CN fields. When naming the new grid, it is recommended to use a descriptive name that will help identify what CN field conditions were used.

Generate LU/ST Grid

The purpose of this function is to create a landuse/soil type grid that will be used to compute curve number grid statistics. The resulting landuse/soil type grid is used in later step under the CN Basin Statistics. This utility function generates a land use/soil type grid that is used as an intermediate step in the computation of CN basin statistics. This grid needs to exist before the CN basin statistics can be computed.

This function requires three inputs:

- HydroDEM grid
- Curve number shapefile
- Composite curve number field in the curve number shapefile ("Scscn" field – this field is picked by the user from the list of fields in the CNPoly theme at the time the function is executed). There must be a field in the CNPoly theme called "SoilCode". The "SoilCode" field represents the soil type. For example, when working with STATSGO data, the user should set the "SoilCode" field equal the "Muid" field.

The function will perform the following operations:

It will add or update the following field in the CNPoly theme:

- Soil_lu: String obtained by concatenating the land use type ("Landuse" field), the soil type ("Unit_Id" field) if not blank, or hydrologic soil group letter if that field is blank, and the composite curve number ("Scscn" field).

It will generate a land use/soil type grid, which has the same raster structure as the DEM grid. The values in the grid correspond to "SOIL_LU" entry in the CNPoly theme.

CN Basin Statistics

This function generates a table containing curve number statistics for watersheds. The function operates on a selected set of watersheds in the subbasin theme. If no watershed has been selected, the function will process all the watersheds. A results table is created in which for each watershed a set of unique land use/soil type combination is presented. For each of these combinations, a percent area in the watershed and CN are presented. This table can be used to identify which land use/soil type combination has the largest impact on the overall watershed curve number.

This function requires the following inputs:

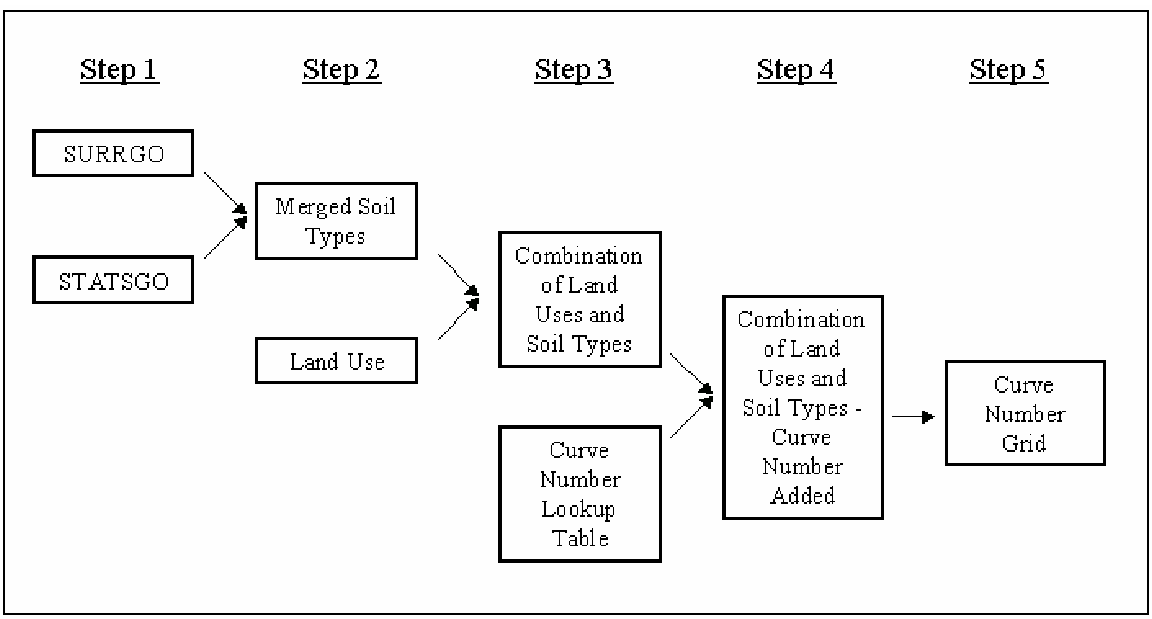
- Subbasin shapefile
- Curve Number polygon shapefile
- Soil landuse grid
- CN field to use for classification ("Scscn").

This function generates a CN statistic table, which contains the following information:

- WshID: Sub basin identifier.
- Landuse: Land use type.
- Soil: Soil type (hydrologic soil group or Unit_Id).
- Scscn: Average CN value for the subbasin, for a given land use and soil type.
- Cum_Area: Area of the subbasin having the given land use and soil type.
- Area_Pct: Percentage of the area of the sub basin having the given land use and soil type.

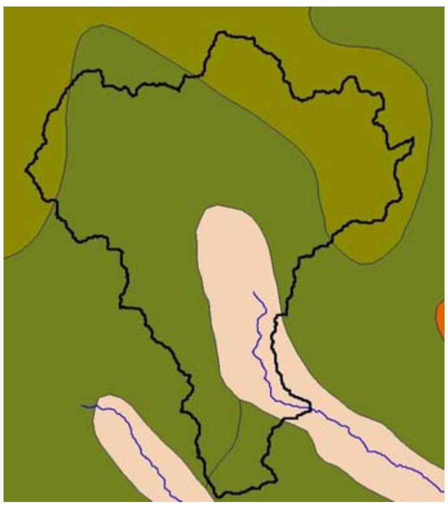
<u>Five steps of Data Processing for Curve Number Grid Developement</u>

The data processing part of the curve number grid development are separated in five steps shown in the figure below.



Step 1: Processing soil types

The two commonly used soil data sources are State Soil Geographic (STATSGO) and Soil Survey Geographic (SSURGO) soil database. These soil data sources are provided by the Natural Resources Conservation Service (NRCS). The STATSGO data types are coarser than the SSURGO data. Comparing the STATSGO and SSURGO data as shown in the figures below shows that the STATSGO data has broader boundaries than the SSURGO data. Often times, user will need to combine STATSGO and SSURGO together to have the best available data coverage of the study area.



STATSGO Database

SSURGO Database

The user will find a variety of methods and software available for processing these soil database. An example of soil processing performed with ArcInfo is discussed in Appendix F.

Step 2: Merge soil data sources and create land use data

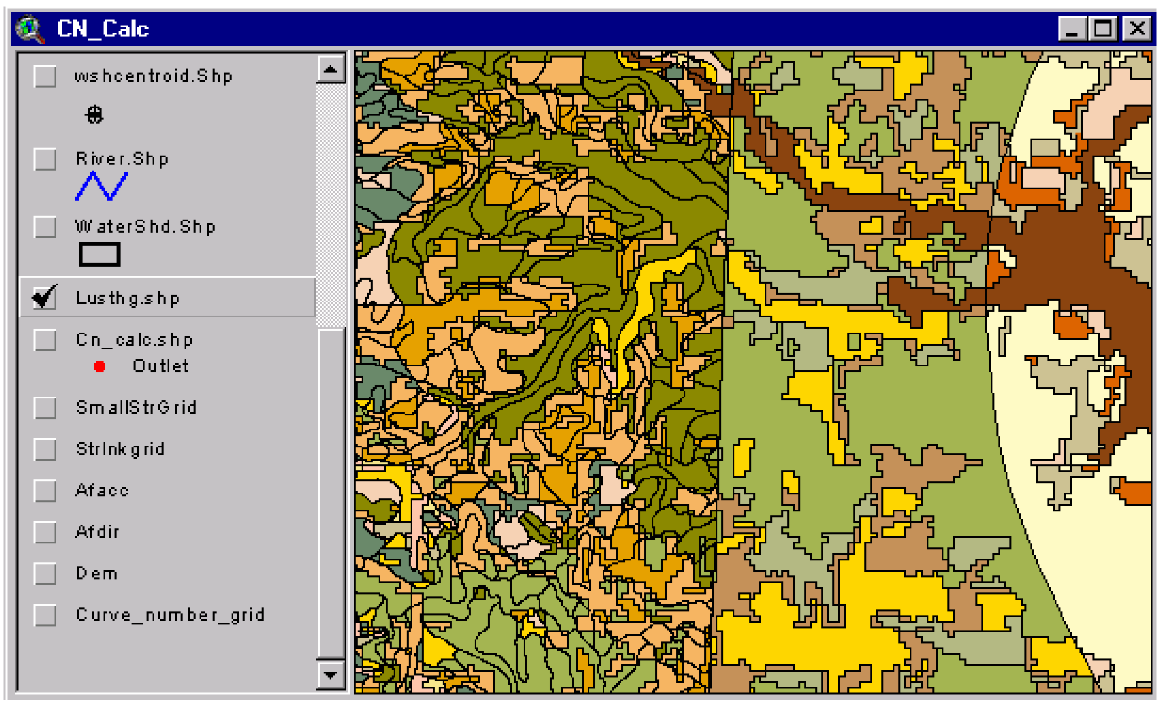
The user will need to merge various soil databases by structuring tables with common fields. Then the user will need to create or process land use data by digitizing land use data from areal photos and other sources.

Then the user will need to union the merged soil data with the landuse data to create unigue combination of soil types and land use polygon theme. The user may be able to use the Geoprocessing Wizard Extension from the ArcView 3.2 or later software package. The Geoprocessing Wizard DOES NOT update the area field. The user can use the following procedure to update the area of new polygons:

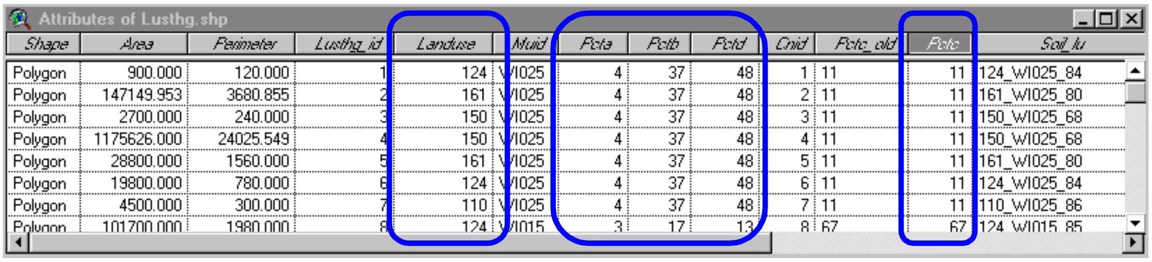
1) Run the geoprocessing wizard and do the union function.
2) Open the table of the resulting theme and start editing it.
3) Make the area field active.
4) Open the field calculator (it will be computing the values for the Area field).
5) Build the following expression: [Shape].ReturnArea
6) Click on OK.

There are other tools (public domain that can be downloaded from ESRI's site) that do similar job that might update the area of the resulting polygons automatically.

After performing step 2, the user should have a polygon theme containing unigue combination of land uses and soil types as shown the figures below. In the middle of the figure below, the vertical line shows land use and the SSURGO soil data on the left and the STATSGO soil data on the right.



The attribute table for the land use/ soil type polygon theme is shown below. It shows the land use code in the "landuse" field with the percentage of hydrologic soil groups under fields "PctA", "PctB", "PctC", and "PctD".

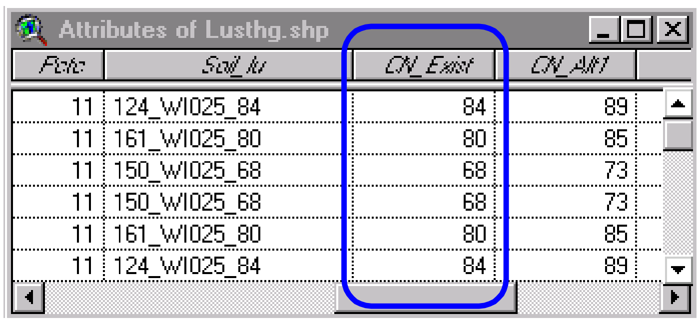


Attributes of Lusthg.shp

Shape	Area	Perimeter	Lusthg_id	Landuse	Muid	Pcta	Pctb	Pctd	Cnid	Pctc_old	Pctc	Soil_lu
Polygon	900.000	120.000	1	124	WI025	4	37	48	1	11	11	124_WI025_84
Polygon	147149.953	3680.855	2	161	WI025	4	37	48	2	11	11	161_WI025_80
Polygon	2700.000	240.000	3	150	WI025	4	37	48	3	11	11	150_WI025_68
Polygon	1175626.000	24025.549	4	150	WI025	4	37	48	4	11	11	150_WI025_68
Polygon	28800.000	1560.000	5	161	WI025	4	37	48	5	11	11	161_WI025_80
Polygon	19800.000	780.000	6	124	WI025	4	37	48	6	11	11	124_WI025_84
Polygon	4500.000	300.000	7	110	WI025	4	37	48	7	11	11	110_WI025_86
Polygon	101700.000	1980.000	8	124	WI015	3	17	13	8	67	67	124_WI015_85

Step 3: Curve Number Lookup

The user can use GeoHMS to accomplish this step. With the land use/ soil type combination polygon theme and a curve number lookup table, the user can apply the **Generate CN Theme** menu item under the **Utility** menu. This step creates or updates a user-specified field with a curve number to each polygon as shown in the figure below based on the curve number lookup table. The land use/ soil type combination polygon theme with the curve number field is now refered to as the curve number polygon theme.



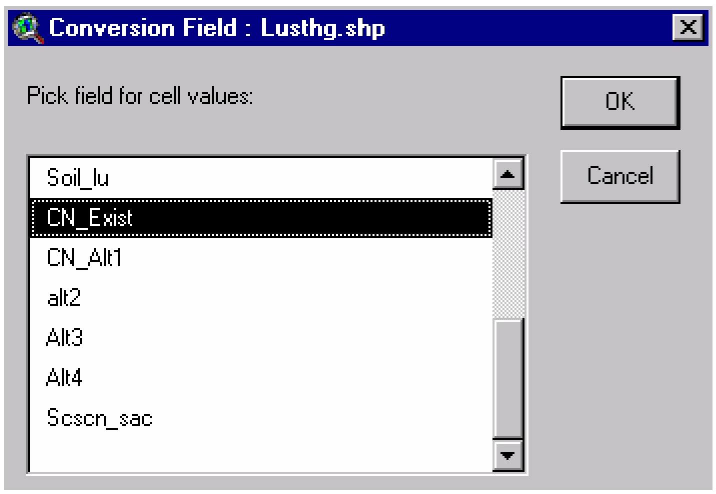
Attributes of Lusthg.shp

Pctc	Soil_lu	CN_Exist	CN_Alt1
11	124_WI025_84	84	89
11	161_WI025_80	80	85
11	150_WI025_68	68	73
11	150_WI025_68	68	73
11	161_WI025_80	80	85
11	124_WI025_84	84	89

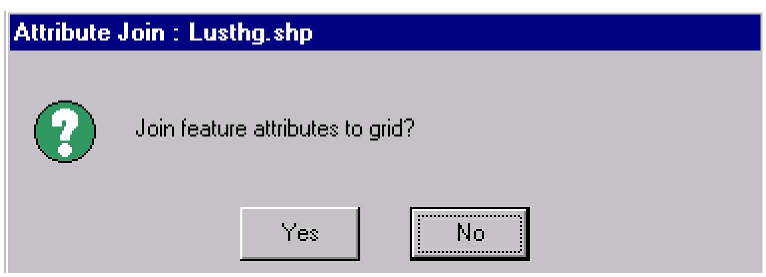
Step 4: Conversion of Curve Number Polygon Theme into Curve Number Grid

To convert the curve number polygon theme into a curve number grid, the user can use standard tool from the **Spatial Analyst** Extension. The user can toggle off the GeoHMS extension to expose the **Spatial Analyst** Extension functionality. The user can set the analysis extent and cell size to be the same as the DEM under the **Properties** menu item under the **Analysis** menu. With the curve number polygon theme active, the user can apply the **Convert to Grid** menu item under the **Theme** menu.

The user also needs to select a field to be used for the curve number value. In the figure below, the "CN_Exist" field represents the curve number for existing condition was used for the curve number grid development.



The user should choose "**No**" to not join the feature attributes to the grid as shown in the figure below. The user should remember to toggle back to the GeoHMS extension.



Step 5: Curve Number Grid

The user should save the curve number grid.   To use the curve number grid for lumped and grid-based curve number computation for the subbasin, the user should add the curve number grid as a theme in the **ProjView** document.

APPENDIX F

Example - SCS Curve Number Computation Process

This example, written by ESRI for the Wisconsin Department of Natural Resources, describes the procedures used to compute the SCS Curve Number data for Wisconsin in ArcInfo. Attempts were made to perform these procedures in ArcView; however, the sizes of the datasets were prohibitive. ArcInfo is much more efficient at such processes. The basic steps are:

I. STATSGO Preprocessing

II. SSURGO Preprocessing

III. Soil Merging

IV. Land Use Processing

V. Curve Number Generation

All coverages and tables used are in RED type and `Courier New` font. All ArcInfo commands will be referenced with the **Arc:** prompt and in BLUE type. *Cnty* or *xxx* in Italics refer to an individual county name or code.

I. STATSGO Preprocessing

Before merging the STATSGO and SSURGO data, they must have the same database structure. The 'WDNR-Flood Hydrology Tool' will take a shapefile with the numeric fields 'pctA', 'pctB', 'pctC', and 'pctD' and compute a weighted average Curve Number based on the landuse and the CN lookup table. First, the required fields must be created in STATSGO. The STATSGO user manual should be read to understand the complex database design. Basically, we can only determine the percent of each hydrologic soil group within each STATSGO polygon. The lookup table with this information and final Statsgo coverage can be found at (J: = \\central\libraries):

J:\gencov\cn\statsgo

The original STATSGO data and related tables are located at:

✓ STATSGO soil coverage = `sgdpw92d` (statewide)

Location: /geo/wtm_data/geodb/wislib91/tile_1/sgdpw924

✓ STATSGO tables:

Location: /geo/wtm_data/geodb/arcstorm/info_tables/1/info/sgdpw22d.mpu

Location: /geo/wtm_data/geodb/arcstorm/info_tables/1/info/sgdpw22d.cmp

The basic steps to compute the hydrologic soil group attributes are as follows:

1. Add the field 'Mu_hyd' to the `sgdpw22d.cmp` table where 'Mu_hyd' = 'Muid' ++ 'Hydgp'.
2. Summarize on the field 'Mu_hyd'. Include in the table 'First_muid', 'First_hydgp', and 'Sum_comppc'. This gives the sum percentage of each unique 'Mu_hyd' > `summary.dbf`.
3. In the `sgdpw22d.mpu` table, add the fields 'pctA', 'pctB', 'pctC', 'pctD', 'pctA/D', 'pctB/D', 'pctC/D' and calculate everything = 0.
4. For each hydgp possibility, create a unique table by selecting one hydgp in `summary.dbf` and creating a new table so that there are seven unique tables (i.e. sum_a.dbf, sum_ad.dbf, sum_b.dbf, etc.).
5. Join the first unique hydgp table (sum_a.dbf) to `sgdpw22d.mpu`. Calculate 'pctA' = 'Sum_comppc'. Remove the join.
6. Repeat step six for each unique hydgp table. This will give the percentage of each hydrologic soil group within each 'Muid'.
7. The final 'pctD' column should contain the sum of 'pctA/D', 'pctB/D', 'pctC/D', and 'pctD'. Also, if the total percentages (A-D) do not add up to 100, then the remaining amount is added to pctD.
8. The final table is called `statsgohg.dbf`. For use in ArcInfo, permanent items 'pctA-D' were added to `sgdpw92d.pat`. Then the `statsgohg.dbf` table was related to the .pat to populate the items.

II. SSURGO Preprocessing

To simplify the SSURGO data, we will dissolve the polygons on the hydrologic soil group attribute. The required coverages and tables include:

✓ SSURGO soil coverage = *`cnty`*`pw9` (countywide)

Location: /geo/dnrdop/cty_soil/*cnty*_sl/cov/*cnty*pw9

✓ SSURGO hydrologic soil group lookup table = `wi`*`xxx`*`pro.txt`

Location: /geo/dnrdop/cty_soil/*cnty*_sl/tables/wi*xxx*pro.txt

1. In ArcInfo, create a new workspace and copy all required coverages and tables to that location.
2. Use ArcView 3.2 to convert the `wi`*`xxx`*`pro.txt` table into an INFO table.
   - Start ArcView and add the .txt table to the project
   - Under **Table** > **Properties**, check off all fields except ***Musym*** and ***Hydgp***
   - With the table active, select **File > Export**
   - Choose **INFO** as the export format
   - Navigate to the INFO directory in your workspace and name the table *`cnty`*`pw9.pro`
3. In ArcInfo, add a field to the SSURGO polygon attribute table for hydrologic soil group.

   Arc: additem *cnty*pw9.pat *cnty*pw9.pat hydgp 11 11 c

4. When relating tables, the relate fields must have the same name and field properties. Therefore, the Musym field in the *`cnty`*`pw9.pro` table will have to be redefined to match that of the *`cnty`*`pw9.pat` table (Note: All caps must be used in INFO, and the user name is 'ARC').

   Arc: additem *cnty*pw9.pro *cnty*pw9.pro tmp 8 8 c # musym

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > SEL *CNTY*PW9.PRO

   ENTER COMMAND > IT (Optional: displays items in the selected table)

   ENTER COMMAND > MOVE MUSYM TO TMP

   ENTER COMMAND > LI MUSYM, TMP (Optional: displays values in the 'musym' and 'tmp' fields)

   ENTER COMMAND > Q STOP

   Arc: dropitem *cnty*pw9.pro *cnty*pw9.pro musym

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > **SEL *CNTY*PW9.PRO**

   ENTER COMMAND > ALTER

   ITEM NAME > TMP

   ITEM NAME > MUSYM

   * Hit enter for the rest of the field properties

5. Next the *cnty*pw9.pro table will be related to the *cnty*pw9.pat table and the new ***hydgp*** field will be populated. Then, for all records that do not contain a hydrologic group, ***hydgp*** will be populated with the ***musym*** code for record keeping (Note: still in INFO).

   ENTER COMMAND > SEL *CNTY*PW9.PAT

   ENTER COMMAND > RELATE *CNTY*PW9.PRO MUSYM ORDERED RO

   ENTER COMMAND > MOVE $1HYDGP TO HYDGP

   ENTER COMMAND > RESEL HYDGP = ‘’

   ENTER COMMAND > MOVE MUSYM TO HYDGP

   ENTER COMMAND > Q STOP

6. Dissolve each county based on ***hydgp***.

   Arc: dissolve *cnty*pw9 *cnty*dw9 hydgp poly

   *(**Note**: all dissolve coverages are stored in **J:\gencov\cn\ssurgo**)*

7. Delete the original coverage from the workspace.

   Arc: kill *cnty*pw9 all

Update procedure for new SSURGO data is described in Appendix G.

III. Soil Merging

The SSURGO and STATSGO data must be merged into a seamless layer containing attributes of % A, B, C, and D hydrologic soil groups. Ideally, this would be done statewide, but disk space was prohibitive. Instead, the soil was processed in four major tiles and then clipped by basin for unioning with Wiscland. The overall procedure is to union the SSURGO layers into one coverage, calculate the %A-D fields for SSURGO, remove the extent of the SSURGO coverage from the STATSGO layer, and union the STATSGO and SSURGO layers. The required coverages include:

✓ STATSGO soil coverage = sgdpw92d (statewide)

  Location: J:\gencov\cn\statsgo\sgdpw92d

✓ SSURGO soil coverage = *cnty*dw9 (countywide)

  Location: J:\gencov\cn\ssurgo*cnty*dw9

✓ Basin clip coverages = *bsn-id*_clip

  Location: J:\gencov\cn\basin_clip\cov*bsn-id*_clip

1. The dissolved SSURGO coverages will be unioned into one coverage. First, change the name of the 'hydgp' item in the second coverage so that it can be joined to the union.pat (union will not join items of the second coverage if that item name already exists in the first coverage).

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > SEL *CNTY2*DW9.PAT

   ENTER COMMAND > ALTER

   ITEM NAME > HYDGP

   ITEM NAME > HYDGP1

   * Hit enter for the rest of the field properties

   ENTER COMMAND > Q STOP

2. Union the first two SSURGO coverages into one layer.

   Arc: union *cnty1*dw9 *cnty2*dw9 ssurgo1 # join

3. Now populate the 'hydgp' field in the resulting coverage for those polygons added.

   Arc: ae   (starts Arcedit module)

   Arcedit: ec ssurgo1   (selects edit coverage)

   Arcedit: ef poly   (specifies edit feature)

   Arcedit: de poly   (specifies draw environment)

   Arcedit: display 9999

   Arcedit: draw   (Optional: may take some time for a large coverage)

   Arcedit: sel hydgp = ' '   (selects all records without hydgp attributes)

   Arcedit: moveitem hydgp1 to hydgp

4. The unioned coverage will most likely contain a number of sliver polygons at county boundaries that will not contain attributes. Theoretically, one would identify the neighboring polygons of the sliver and attribute it with the appropriate soil group. However, this is not feasible due to the number of slivers encountered. These slivers are attributed with some value (i.e. 'NA') for record keeping. (Note: still in ArcEdit with the coverage selected.)

   Arcedit: sel hydgp = ' '

Arcedit: ds (draw selected: make sure there are only slivers without attributes)

Arcedit: moveitem 'NA' to hydgp

Arcedit: q

Keep all edit changes?: y

Do you really want to do this?: y

5. Remove the unnecessary items from the .pat (do not remove the 'ssurgo1#' and 'ssurgo1–ID' fields for the coverage!).

   Arc: items ssurgo1.pat (displays all items in the ssurgo1 polygon attribute table)

   Arc: dropitem ssurgo1.pat ssurgo1.pat *cnty1*dw9#, *cnty1*dw9-ID, *cnty2*dw9#, *cnty2*dw9-ID, hydgp1

6. Repeat steps 8-13 for all SSURGO counties, this time using the previous union coverage as the input union coverage, i.e.:

   Arc: union ssurgo1 *cnty3*dw9 ssurgo2 # join

   *(**Note:** Dane county contained significant overlap between Rock and Sauk counties and was clipped before union).*

   (As mentioned, this process was carried out in four major tiles due to disk space.) The final coverage with all SSURGO data unioned into one will be referred to as `unssurgo`.

7. Next determine the extent of `unssurgo`.

   Arc: additem unssurgo.pat unssurgo.pat dslv 1 1 c

   Arc: ae

   Arcedit: ec unssorgo

   Arcedit: ef poly

   Arcedit: sel all

   Arcedit: moveitem 'y' to dslv

   Arcedit: q

   Keep all edit changes?: y

   Do you really want to do this?: y

   Arc: dissolve unssurgo ssrgoext dslv poly

*(**Note**: the statewide dissolved ssurgo extent (4-10-01) is stored in **J:\gencov\cn\ssurgo**)*

8. Next we will remove the SSURGO extent from the STATSGO layer (this will create a statewide STATSGO layer with 'holes' where SSURGO data exists). Union the `ssrgoext` and `sgdpw92d` coverages.

   Arc: union sgdpw92d ssrgoext statonly # join

9. Now select all STATSGO polygons within the SSURGO extent and remove them.

   Arc: ae

   Arcedit: ec statonly

   Arcedit: ef poly

   Arcedit: de poly

   Arcedit: display 9999

   Arcedit: draw

   Arcedit: sel dslv = 'y'   (selects all polygons within the SSURGO boundary)

   Arcedit: delete   (deletes all selected polygons and labels)

   Arcedit: q

   Keep all edit changes?: y

   Do you really want to do this?: y

*(**Note**: the STATSGO layer with SSURGO extent removed is stored in **J:\gencov\cn\statsgo**)*

10. Add % A, B, C, and D hydrologic soil group fields to the `unssurgo.pat`.

    Arc: additem unssurgo.pat unssurgo.pat pctA 3 3 i

    Arc: additem unssurgo.pat unssurgo.pat pctB 3 3 i

    Arc: additem unssurgo.pat unssurgo.pat pctC 3 3 i

    Arc: additem unssurgo.pat unssurgo.pat pctD 3 3 i

11. There are a number of possibilities for hydrologic soil group in the SSURGO data. Each polygon can have up to three different groups. For example, 'A-B-A/D' would indicate that group A, group B, and group A/D soils were all found in that polygon. Since we do not know the percentages within a polygon, they will be split up evenly (giving the highest percentage to D, C, or B, as it is most conservative). A/D indicates a soil behaves as A when drained, and D when undrained. 100 percent in

soil D is the most conservative in this case (assuming undrained). For each unique ***hydr_gp***, add the appropriate percentages to the four new fields. Examples follow:

HYD_GP	PctA	PctB	PctC	PctD
A	100	0	0	0
B	0	100	0	0
C	0	0	100	0
D	0	0	0	100
A/D	0	0	0	100
B/D	0	0	0	100
C/D	0	0	0	100
A-B	50	50	0	0
A-C	50	0	50	0
A-C/D	50	0	0	50
A/D-C/D	0	0	0	100
A-B-C	33	33	34	0
A-B/D-A/D	33	0	0	67
A-C-A/D	33	0	33	34
None	0	0	0	100

In ArcInfo, use the following commands:

Arc: additem unssurgo.pat unssorgo.pat done 1 1 c

Arc: info

ENTER USER NAME > ARC

ENTER COMMAND > SEL UNSSURGO.PAT

ENTER COMMAND > MOVE ‘N’ TO DONE

ENTER COMMAND > RESEL HYDGP = ‘A’

ENTER COMMAND > CALC PCTA = 100

ENTER COMMAND > MOVE ‘Y’ TO DONE

ENTER COMMAND > ASEL   (selects all records)

ENTER COMMAND > RESEL HYDGP = ‘A-B’

ENTER COMMAND > CALC PCTA = 50

ENTER COMMAND > CALC PCTB = 50

ENTER COMMAND > MOVE 'Y' TO DONE

ENTER COMMAND > ASEL

Etc.

Do this for each major category (i.e. A, B, C, D, A/D, B/D, and C/D). You do not have to do it for every possibility. We can use the 'Done' field to keep track of which ones still need attributing.

ENTER COMMAND > ASEL

ENTER COMMAND > RESEL DONE = 'N'

ENTER COMMAND > LIST HYDGP (lists HYDGP values for selected records)

By selecting the records not yet attributed (DONE = N) and using the LIST command, you can see which records are left. Attribute all remaining records using the commands above. All unknown values (NA, W, soil names carried over, etc.) should get '100' in 'pctD'.

12. Next, Mapjoin the unioned SSURGO coverage with the `statonly` coverage. In order to do this, the item definitions must be the same in both coverages.

    Arc: items unssurgo.pat

    Arc: items statonly.pat

    Compare the item definitions of both coverages. Use the ADDITEM command to add the missing items from each coverage (and make sure they are in the same order – see additem usage). I.e.,

    Arc: additem unssurgo.pat unssurgo.pat unit_id 7 7 c

    Arc: additem statsonly.pat statsonly.pat hydgp 11 11 c

    Arc: additem statsonly.pat statsonly.pat done 1 1 c

    Arc: mapjoin mjsoil poly features

    Enter the 1st coverage: unssurgo

    Enter the 2nd coverage: statonly

    Enter the 3rd coverage: end

13. This results in a final soil coverage with SSURGO data where available and STATSGO data elsewhere, and contains attributes of %A-D hydrologic soil group. Due to file size and processing limitations, the coverage should be clipped by basin.

    Arc: clip mjsoil *bsn-id*_clip soil_*bsn-id* poly

    *(**Note**: the merged soil coverages clipped by basin are stored in **J:\gencov\cn\soilmerge\bsn-idcov\soil_bsn-id**)*

IV. Land Use Processing

The Wiscland land cover grid data must be reclassified to reduce redundant classes, converted into a polygon coverage, and clipped by basin before unioning with the soil data. The required layers are:

✓ Wiscland land cover grid = `wlcgw930` (statewide)

   Location: K:\wlclib\wlcgw930\wlcgw930

✓ Basin clip coverages = *`bsn-id`*`_clip`

   Location: J:\gencov\cn\basin_clip\cov*bsn-id*_clip

1. Identify the WWI classification of WLC (value). For example, all of the forested classes will receive the same Curve Number, so classes 161-190 will be lumped into one category (see the **cn_lookup.dbf** table at *J:\wtgislib\hydrology_tool\input_data*).

   101 = High Urban

   104 = Low Urban

   105 = Golf Course

   110-118 = Agriculture

   124 = Forage Crops

   148 = Cranberry Bog

   150 = Grassland

   161-190 = Upland Forest

   200 = Open Water

   211-220 = Non Forested Lowland

   223-234 = Forested Lowland

   240 = Barren

   250= Shrubland

   255 = Cloud Cover

2. Add an item 'WWI' to wlcgw930.vat (full classification of WLC).

   Arc: additem wlcgw930.vat wlcgw930.vat wwi 3 3 I

3. Calculate the new 'WWI' item to equal the following values:

   value 101 = 101 (High Urban)

   value 104 = 104 (Low Urban)

   value 105 = 105 (Golf Course)

   value 110-118 = 110 (Agriculture)

   value 124 = 124 (Forage Crops)

   value 148 = 148 (Cranberry Bog)

   value 150 = 150 (Grassland)

   value 161-190 = 161 (Upland Forest)

   value 200 = 200 (Open Water)

   value 211-220 = 211 (Non Forested Lowland)

   value 223-234 = 223 (Forested Lowland)

   value 240 = 240 (Barren)

   value 250 = 250 (Shrubland)

   value 255 = 255 (Cloud Cover)

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > SEL WLCGW930.VAT

   ENTER COMMAND > RESEL VALUE = 1O1

   ENTER COMMAND > CALC WWI = 101

   ENTER COMMAND > ASEL

   Etc.

4. Create an info table to do a reclass.

   Arc: frequency wlcgw930.vat wlc.frq

   Enter the 1st item: value

   Enter the 2nd item: wwi

Enter the 3rd item: end

Enter the 1st item: end

5. Reclassify the grid with the info table option.

   Arc: grid

   Grid: wwi_grid = reclass (wlcwg930, wlc.frq, nodata, value, wwi)

   Grid: q

6. Convert the reclassified grid into a polygon coverage.

   Arc: gridpoly wwi_grid wwi_poly

7. Clip the polygon coverage by basin for intersecting with soil data.
   Arc: clip wwi_poly *bsn-id*_clip wlc_*bsn-id* poly 0.001

   *(**Note**: the reclassified Wiscland coverages clipped by basin are stored in* ***J:\gencov\cn\wiscland*****bsn-id*****cov\wlc*****_bsn-id***)*

V. Curve Number Generation

The land cover and soil data must be unioned to provide unique polygons containing both land cover and soil information. Then, the curve number is generated for each polygon, and the coverage converted into a grid for efficient processing with the HEC-GeoHMS Version 1.1. The required datasets are:

✓ Wiscland land cover coverage = `wlc_`*`bsn-id`* (basinwide)

   Location: J:\gencov\cn\wiscland*bsn-id*cov\wlc_*bsn-id*

✓ Merged soil coverage = `soil_`*`bsn-id`* (basinwide)

   Location: J:\gencov\cn\soilmerge*bsn-id*cov\soil_*bsn-id*

✓ Basin clip grids = *`bsn-id`*`_clipg`

   Location: J:\gencov\cn\basin_clip\grid*bsn-id*_clipg

1. Union the soil and land cover coverages for each basin.

   Arc: union soil_*bsn-id* wlc_*bsn-id* cnply_*bsn-id* # join

2. Check for sliver polygons resulting from the union and populate the soil properties.

   Arc: ae

   Arcedit: ec cnply_*bsn-id*

   Arcedit: ef poly

   Arcedit: sel pcta = 0 and pctb = 0 and pctc = 0 and pctd = 0

   Arcedit: de poly

   Arcedit: display 9999

   Arcedit: ds (draws selected polygons – should only be slivers)

   Arcedit: moveitem ‘na’ to hydgp

   Arcedit: calc pctd = 100

   Arcedit: q

   Keep all edit changes?: y

   Do you really want to do this?: y

3. Generate the curve number theme using the ‘HEC-GeoHMS Version 1.1’ in ArcView.

   - Open ArcView and load the HEC-GeoHMS Version 1.1 extension
   - Open a new **ProjView** and add the `cnply_`*`bsn-id`* polygon theme
   - Open the theme table for `cnply_`*`bsn-id`* (with the theme active, choose **Theme** > **Table**)
   - From the **Table** menu, choose **Properties**
   - Scroll down and type ***Landuse*** as an alias to ***Grid-code*** and click **OK**
   - From the **Edit…** menu, choose **Select All**
   - Close the theme table and make the **ProjView** active
   - From the **Utility** menu, choose **Generate CN Theme**
   - When prompted for the CNPoly tag, choose `cnply_`*`bsn-id`* and click **OK**
   - Navigate to the ***Cn_lookup.dbf*** table and click **OK** (i.e. *J:\wtgislib\hydrology_tool\input_data\cn_lookup.dbf*)
   - If the error “*Attempt to access record out of range 0*” occurs, try again and it should work.

*(**Note**: the CN polygon coverages clipped by basin are stored in **J:\gencov\cn\CN_poly\bsn-idcov\cnply_bsn-id**)*

4. Convert the CN polygon coverage into a grid using the grid module in ArcInfo. Make sure to set the extent and cell size to be equal to the clip grids.

   Arc: grid

   Grid: arctools

   - Click on **Grid Tools** from the ***ArcTools*** box and click **OK**
   - From the ***GridTools*** box, choose **Analysis > Properties…**
   - In the ***Grid Analysis Environment*** box, choose **Grid…** for the ***Cell size***
   - Navigate to and choose the ***bsn-id*_clipg** grid and click **OK**
   - Again, choose Grid… for the ***Analysis window***
   - Navigate to and choose the ***bsn-id*_clipg** grid and click **OK**
   - Click **OK** to close the **Grid Analysis Environment** box
   - From the ***GridTools*** box, choose **ArcTools > Commands…**
   - Type in the following command and hit enter:

     Cngrd_*bsn-id* = Int(polygrid(cnply_*bsn-id*, scscn, #, #, #))
   - When it finishes processing, quite from the ***GridTools*** and ***ArcTools*** boxes

*(**Note**: the CN grids clipped by basin are stored in **J:\gencov\cn\CN_grid\cngrd_**__bsn-id__)*

A P P E N D I X   G

UPDATE PROCEDURE FOR NEW SSURGO DATA

Use the following procedure, written by ESRI for the Wisconsin Department of Natural Resources, to update the curve number data when new SSURGO data becomes available. The data is tiled by basin, so the following procedure must be carried out for all basins intersecting the new county. See the document "CN Computation in AI.doc" for more information on these datasets. The Wisconsin datasets are used as an example in the following procedure.

All coverages and tables used are in RED type and `Courier New` font. All ArcInfo commands will be referenced with the **Arc:** prompt and in BLUE type. *Cnty* or *xxx* in Italics refer to an individual county name or code.

First, map to the K: and J: drives:

J:\\centralwwi\libraries

K:\\centraletgo\libraries

The required coverages and tables are:

- ✓ New SSURGO soil coverage = *`cnty`*`pw9`

  Location: K:\cty_soil*cnty*_sl\cov*cnty*pw9

- ✓ New SSURGO boundary coverage = *`cnty`*`bw9`

  Location: K:\cty_soil*cnty*_sl\cov*cnty*bw9

- ✓ New SSURGO hydrologic soil group lookup table = `wi`*`xxx`*`pro.txt`

  Location: K:\cty_soil*cnty*_sl\tables\wi*xxx*pro.txt

- ✓ Merged soil coverage = `soil_`*`bsn-id`*

  Location: J:\gencov\cn\soilmerge*bsn-id*cov\soil_*bsn-id*

- ✓ Basin clip coverages = *`bsn-id`*`_clip`

  Location: J:\gencov\cn\basin_clip\cov*bsn-id*_clip

- ✓ Wiscland land cover polygon coverages = `wlc_`*`bsn-id`* (basinwide)

  Location: J:\genvcov\cn\wiscland*bsn-id*cov\wlc_*bsn-id*

✓ Basin clip grids = `bsn-id_clipg`

Location: J:\gencov\cn\basin_clip\grid*bsn-id*_clipg

1. In ArcInfo, create a new workspace and copy all required coverages and tables to that location.

2. Use ArcView 3.2 to convert the `wixxxpro.txt` table into an INFO table.
   - Start ArcView and add the .txt table to the project
   - Under **Table** > **Properties**, check off all fields except ***Musym*** and ***Hydgp***
   - With the table active, select **File** > **Export**
   - Choose **INFO** as the export format
   - Navigate to the INFO directory in your workspace and name the table `cntypw9.pro`

3. In ArcInfo, add a field to the SSURGO polygon attribute table for hydrologic soil group.

   Arc: additem *cnty*pw9.pat *cnty*pw9.pat hydgp 11 11 c

4. When relating tables, the relate fields must have the same name and field properties. Therefore, the Musym field in the `cntypw9.pro` table will have to be redefined to match that of the `cntypw9.pat` table (Note: All caps must be used in INFO, and the user name is 'ARC').

   Arc: additem *cnty*pw9.pro *cnty*pw9.pro tmp 8 8 c # musym

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > SEL *CNTY*PW9.PRO

   ENTER COMMAND > IT (Optional: displays items in the selected table)

   ENTER COMMAND > MOVE MUSYM TO TMP

   ENTER COMMAND > LI MUSYM, TMP (Optional: displays values in the 'musym' and 'tmp' fields)

   ENTER COMMAND > Q STOP

   Arc: dropitem *cnty*pw9.pro *cnty*pw9.pro musym

   Arc: info

   ENTER USER NAME > ARC

   ENTER COMMAND > **SEL *CNTY*PW9.PRO**

   ENTER COMMAND > ALTER

ITEM NAME > TMP

ITEM NAME > MUSYM

* Hit enter for the rest of the field properties

5. Next the `cnty`pw9.pro table will be related to the `cnty`pw9.pat table and the new ***hydgp*** field will be populated. Then, for all records that do not contain a hydrologic group, ***hydgp*** will be populated with the ***musym*** code for record keeping (Note: still in INFO).

    ENTER COMMAND > SEL *CNTY*PW9.PAT

    ENTER COMMAND > RELATE *CNTY*PW9.PRO MUSYM ORDERED RO

    ENTER COMMAND > MOVE $1HYDGP TO HYDGP

    ENTER COMMAND > RESEL HYDGP = ‘’

    ENTER COMMAND > MOVE MUSYM TO HYDGP

    ENTER COMMAND > Q STOP

6. Dissolve the coverage based on ***hydgp***.

    Arc: dissolve *cnty*pw9 *cnty*dw9 hydgp poly

    *(**Note**: all dissolve coverages are stored in **J:\gencov\cn\ssurgo**)*

7. Delete the original coverage from the workspace.

    Arc: kill *cnty*pw9 all

8. Next we will remove the extent of the new SSURGO coverage from each of the merged soil layers that intersect the county. First, add an identifier (ssrgo) to select the new coverage area. Then, union the `cnty`bw9 and soil_`bsn-id` coverages.

    Arc: additem *cnty*bw9 *cnty*bw9 ssrgo 1 1 c

    Arc: ae

    Arcedit: ec *cnty*bw9

    Arcedit: ef poly

    Arcedit: moveitem ‘s’ to ssrgo

    Arcedit: q

    Keep all edit changes?: y

    Do you really want to do this?: y

    Arc: union soil_*bsn-id* *cnty*bw9 rmsoil*bsn-id* # join

9. Now select all STATSGO polygons within the new SSURGO coverage boundary and remove them.

   Arc: ae

   Arcedit: ec rmsoil*bsn-id*

   Arcedit: ef poly

   Arcedit: de poly

   Arcedit: display 9999

   Arcedit: draw

   Arcedit: sel ssrgo = 's'   (selects all polygons within the SSURGO boundary)

   Arcedit: delete   (deletes all selected polygons and labels)

   Arcedit: q

   Keep all edit changes?: y

   Do you really want to do this?: y

10. Add % A, B, C, and D hydrologic soil group fields to the *cnty*dw9.pat.

    Arc: additem *cnty*dw9.pat *cnty*dw9.pat pctA 3 3 i

    Arc: additem *cnty*dw9.pat *cnty*dw9.pat pctB 3 3 i

    Arc: additem *cnty*dw9.pat *cnty*dw9.pat pctC 3 3 i

    Arc: additem *cnty*dw9.pat *cnty*dw9.pat pctD 3 3 i

11. There are a number of possibilities for hydrologic soil group in the SSURGO data. Each polygon can have up to three different groups. For example, 'A-B-A/D' would indicate that group A, group B, and group A/D soils were all found in that polygon. Since we do not know the percentages within a polygon, they will be split up evenly (giving the highest percentage to D, C, or B, as it is most conservative). A/D indicates a soil behaves as A when drained, and D when undrained. 100 percent in soil D is the most conservative in this case (assuming undrained). For each unique ***hydr_gp***, add the appropriate percentages to the four new fields. Examples follow:

HYD_GP	PctA	PctB	PctC	PctD
A	100	0	0	0
B	0	100	0	0
C	0	0	100	0

D	0	0	0	100
A/D	0	0	0	100
B/D	0	0	0	100
C/D	0	0	0	100
A-B	50	50	0	0
A-C	50	0	50	0
A-C/D	50	0	0	50
A/D-C/D	0	0	0	100
A-B-C	33	33	34	0
A-B/D-A/D	33	0	0	67
A-C-A/D	33	0	33	34
None	0	0	0	100

In ArcInfo, use the following commands:

Arc: additem *cnty*dw9.pat *cnty*dw9.pat done 1 1 c

Arc: info

ENTER USER NAME > ARC

ENTER COMMAND > SEL *CNTY*DW9.PAT

ENTER COMMAND > MOVE ‘N’ TO DONE

ENTER COMMAND > RESEL HYDGP = ‘A’

ENTER COMMAND > CALC PCTA = 100

ENTER COMMAND > MOVE ‘Y’ TO DONE

ENTER COMMAND > ASEL (selects all records)

ENTER COMMAND > RESEL HYDGP = ‘A-B’

ENTER COMMAND > CALC PCTA = 50

ENTER COMMAND > CALC PCTB = 50

ENTER COMMAND > MOVE ‘Y’ TO DONE

ENTER COMMAND > ASEL

Etc.

Do this for each major category (i.e. A, B, C, D, A/D, B/D, and C/D). You do not have to do it for every possibility. We can use the ‘Done’ field to keep track of which ones still need attributing.

ENTER COMMAND > ASEL

ENTER COMMAND > RESEL DONE = 'N'

ENTER COMMAND > LIST HYDGP (lists HYDGP values for selected records)

By selecting the records not yet attributed (DONE = N) and using the LIST command, you can see which records are left. Attribute all remaining records using the commands above. All unknown values (NA, W, soil names carried over, etc.) should get '100' in 'pctD'.

12. Next, Mapjoin the SSURGO coverage with the `rmsoil`*`bsn-id`* coverage. In order to do this, the item definitions must be the same in both coverages.

    Arc: items *cnty*dw9.pat

    Arc: items rmsoil*bsn-id*

    Compare the item definitions of both coverages. Use the ADDITEM command to add the missing items from each coverage (and make sure they are in the same order – see additem usage). I.e.,

    Arc: additem *cnty*dw9.pat *cnty*dw9.pat unit_id 7 7 c

    Arc: mapjoin mjsoil poly features

    Enter the 1st coverage: *cnty*dw9.pat

    Enter the 2nd coverage: rmsoil*bsn-id*

    Enter the 3rd coverage: end

13. This results in a final soil coverage with SSURGO data where available and STATSGO data elsewhere, and contains attributes of %A-D hydrologic soil group. The coverage should then be clipped to the basin extent.

    Arc: clip mjsoil *bsn-id*_clip soil_*bsn-id* poly

    *(**Note**: the new merged soil coverage clipped by basin should be stored in **J:\gencov\cn\soilmerge**___**bsn-id**___**cov\soil_**___**bsn-id**___)*

14. Next, union the soil and land cover coverages for the basin.

    Arc: union soil_*bsn-id* wlc_*bsn-id* cnply_*bsn-id* # join

15. Check for sliver polygons resulting from the union and populate the soil properties.

    Arc: ae

    Arcedit: ec cnply_*bsn-id*

    Arcedit: ef poly

    Arcedit: sel pcta = 0 and pctb = 0 and pctc = 0 and pctd = 0

    Arcedit: de poly

    Arcedit: display 9999

    Arcedit: ds (draws selected polygons – should only be slivers)

    Arcedit: moveitem 'na' to hydgp

    Arcedit: calc pctd = 100

    Arcedit: q

    Keep all edit changes?: y

    Do you really want to do this?: y

16. Generate the curve number theme using the HEC-GeoHMS Version 1.1 in ArcView.

    - Open ArcView and load the **HEC-GeoHMS Version 1.1** extension
    - Open a new **ProjView** and add the `cnply_`*`bsn-id`* polygon theme
    - Open the theme table for `cnply_`*`bsn-id`* (with the theme active, choose **Theme** > **Table**)
    - From the **Table** menu, choose **Properties**
    - Scroll down and type ***Landuse*** as an alias to ***Grid-code*** and click **OK**
    - Close the theme table and make the **ProjView** active
    - From the **Edit…** menu, choose **Select All**
    - From the **Utility** menu, choose **Generate CN Theme**
    - When prompted for the CNPoly tag, choose `cnply_`*`bsn-id`* and click **OK**
    - Navigate to the ***`Cn_lookup.dbf`*** table and click **OK** (i.e. *J:\wtgislib\hydrology_tool\input_data\cn_lookup.dbf*)
    - If the error *"Attempt to access record out of range 0"* occurs, try again and it should work.

    *(**Note**: the CN polygon coverages clipped by basin are stored in*
    J:\gencov\cn\CN*_poly\bsn-id*cov\cnply*_bsn-id*)

17. Convert the CN polygon coverage into a grid using the grid module in ArcInfo. Make sure to set the extent and cell size to be equal to the clip grids.

    Arc: grid

    Grid: arctools

    - Click on **Grid Tools** from the ***ArcTools*** box and click **OK**
    - From the ***GridTools*** box, choose **Analysis > Properties…**
    - In the ***Grid Analysis Environment*** box, choose **Grid…** for the ***Cell size***
    - Navigate to and choose the ***bsn-id*_clipg** grid and click **OK**
    - Again, choose Grid… for the ***Analysis window***
    - Navigate to and choose the ***bsn-id*_clipg** grid and click **OK**
    - Click **OK** to close the **Grid Analysis Environment** box
    - From the ***GridTools*** box, choose **ArcTools > Commands…**
    - Type in the following command and hit enter:

        Cngrd_*bsn-id* = Int(polygrid(cnply_*bsn-id*, scscn, #, #, #))

    - When it finishes processing, quite from the ***GridTools*** and ***ArcTools*** boxes

    *(**Note**: the CN grids clipped by basin are stored in **J:\gencov\cn\CN_grid\cngrd_**)***bsn-id***

18. Make sure to update all revised data layers in ***J:\gencov*** and the CN grid in ***J:\wtgislib\hydrology_tool*****bsn-id_*****base***. Notify all 'WDNR-Flood Hydrology Tool' users of the new datasets.

A P P E N D I X   H

Frequently Asked Questions and Corrections

Frequently Asked Questions

1. What projections and spheroids are supported in GeoHMS?

   Answer   Projection support in GeoHMS is important when the users intend to perform distributed modeling with ModClark transformation method. When the user wants to create a grid cell parameter file for ModClark, GeoHMS will project the subbasin boundary shapefiles to the precipitation grid projection, which can be SHG or HRAP. GeoHMS will then overlay the subbasin boundary shapefiles with the selected precipitation projection. Finally, GeoHMS will reproject the intersected subbasin boundaries back to the original projection.

   In GeoHMS Version 1.0, only the Albers Equal-Area projection with spheroid of GRS1980 was available.

   In GeoHMS Version 1.1, projection support has been expanded to include Universal Tranverse Mercator (UTM), Tranverse Mercator, Lambert, and the State Plane and the following spheroids - GRS1980, WGS84, WGS72, SPHERE, CLARKE1880, CLARKE1866, KRASOVSKY, INT1909, EVEREST, BESSEL, AUSTRALIAN, and AIRY.

2. Why does my ModClark grid cell parameter file not work when I update to a new version of HMS?

   Answer   The ModClark grid cell parameter file produced using GeoHMS Version 1.0 will NOT work with the current HMS Version 2.2. TheHMS grid cell parameter file format has changed in Version 2.2. The only change is the heading for the curve number data; it is now “SCSCN” instead of “CurveNumber”, see following figures. To correct this, change the keyword “CurveNumber” to “SCSCN”.

   GeoHMS Version 1.1 produces the ModClark grid cell parameter file in the new format that is compatible with the current HMS Version 2.2.

```
ModClark.mod - Notepad
File  Edit  Search  Help
PARAMETER ORDER: Xcoord Ycoord TravelLength Area SCSCN
END:
SUBBASIN:  R20W20
GRIDCELL:  -1042  1029  0.000000  0.000900
GRIDCELL:  -1042  1029  1.007049  0.709561
```

New Format of the ModClark grid cell parameter file

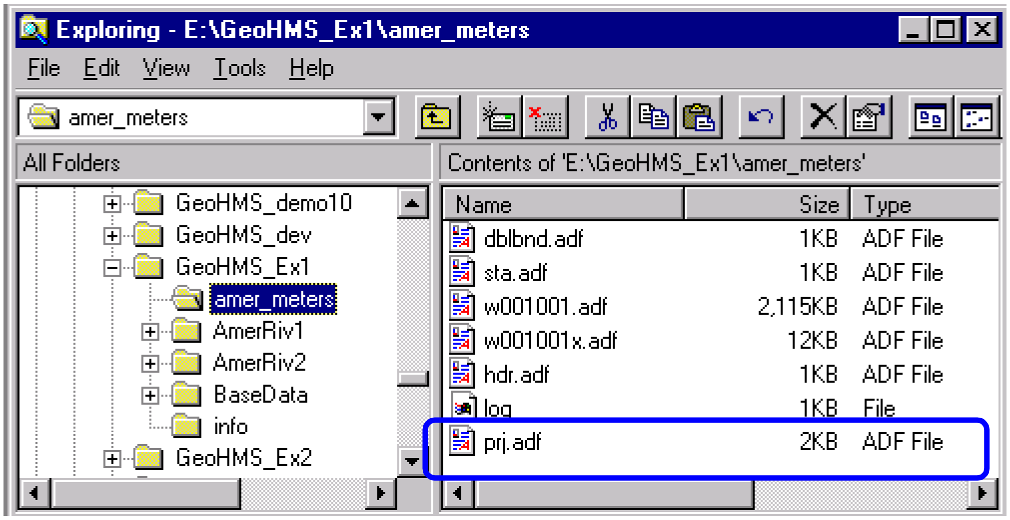
```
ModClark.mod - Notepad
File  Edit  Search  Help
PARAMETER ORDER: Xcoord Ycoord TravelLength Area CurveNumber
END:
SUBBASIN:  R20W20
GRIDCELL:  -1042  1029  0.000000  0.000900
GRIDCELL:  -1042  1029  1.007049  0.709561
```

Old Format of the ModClark grid cell parameter file

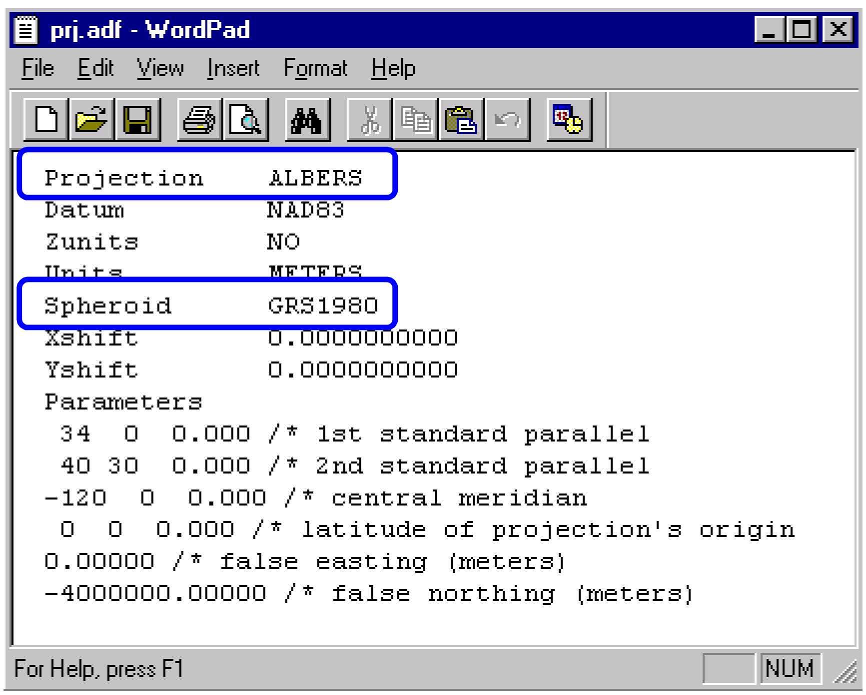
3. When trying to create the ModClark cell parameter file, I sometimes encounter the following error messages. What do they mean?

   - No Intersecting records found
   - Need VAT in zone grid …
   - Zonal statistics program failed

Answer The projection file (prj.adf) is necessary when performing the ModClark grid cell parameter file step. If the user does not have the projection file or uses an unsupported projection in GeoHMS, they will get an error message. To solve this problem, the user should verify the existence of a projection file (prj.adf) as part of the metadata for the terrain prior to analysis in GeoHMS to avoid the program prompting for it during execution. The user should check that the projection and spheroid in the prj.adf file is supported by GeoHMS as shown in the figures below.



Location of the Projection file (prj.adf) in the grid folder



Content of the projection file – Check for support for the projection and spheroid

4. Can I adapt the profile tool to plot other grid values along a line?

Answer   Yes, the profile tool by default plots the DEM values along a stream but it can be used to plot values of any grid along a line theme. To use this feature, the user will need to select a grid and a line theme and then click on the plot profile tool.

5. Is the Fill Sinks operation the same in ArcView and ArcInfo?

   Answer: Conceptually the Fill Sinks operation works the same way in ArcView and ArcInfo. However, the Fill Sinks operation in ArcView appears not to be as reliable as the Fill command in ArcInfo. If the Fill Sinks operation fails in ArcView, then the user should try running it in ArcInfo. The Fill command in ArcInfo is capable of processing larger grids and greater numbers of sinks than in ArcView.

6. Once in a while, I encounter a dialogue box prompting me to decide if a stream segment is an outlet? For example: Stream Processing - Is this an outlet option 1,2,3,4 ? When and why does this dialogue come up?

   Answer: This can happen when doing the "Stream Segment Processing" in the "Terrain Processing" menu. As one of several stream segment processing steps, it is necessary to identify if a segment is an outlet or not. An outlet is a segment that "drains" to the outside of the area of interest. In most cases, we can identify this automatically based on the flow accumulation grid and from-to node orientation of the segment. Where this approach fails is in areas with very short stream segments (basically one cell) where from and to nodes fall in the same grid cell and thus there is no distinction in flow accumulation between from and to nodes.

   Getting the one-cell stream segments does not happen often, and usually in the following cases.

   1) when dealing with small grids and small thresholds
   2) with DEMs that drain to flat areas
   3) with DEMs that include the buffer zone around the main area of interest that actually do not contribute to the main flow

7. What should I do when I encounter a problem with processing the terrain in the Full Delineation Setup?

   Answer: When the user encounters a problem with processing the terrain with the Full Delineation Setup, then the user should consider a step-by-step approach, which allows the user to check for problems and respond to program inquiries for additional information. As an example, sometimes the program asks the user if a point is an outlet? The user will need to answer some of these program inquiries before a preliminary watershed is generated.

8. What are the future plans for updating GeoHMS from ArcView 3.x to ArcGIS 8.x?

Answer HEC-GeoHMS Version 2.0 will be based on the ArcGIS 8.x platform or higher. Currently, the internal "framework" library and terrain preprocessing capability are being programmed in ArcGIS 8.x or higher. Future work are as follows:

- Migration to ArcGIS 8 – The rest of the GeoHMS 1.1 code will be ported in the ArcGIS 8.x platform or higher with the ArcHydro Data Model.

- Comprehensive stream and watershed characteristics - GeoHMS will extract a more comprehensive list of stream and watershed characteristics to facilitate hydrologic parameter estimation and regional regression analysis for gaged and ungaged basins.

- Hydrologic Parameter estimation – GeoHMS will facilitate users with tools and procedures to estimate unit hydrograph, loss rates, routing parameters, and snow melt parameters to support both lumped and distributed basin modeling.

- Meteorologic Model – GeoHMS will develop meteorologic models based on gage weighting methods supported in HMS, such as Thiessen polygon and inverse distance. In addition, GeoHMS will implement precipitation weighting techniques that account for orographic affects.

- Data Storage System (HEC-DSS) connection – Users will be able to connect to DSS and access DSS and grid-based DSS files from GeoHMS to visualize hydrographs at gages and grid-based precipitation. Users will be able to track both the spatial and temporal variation of precipitation.

- Digital Dozer Terrain Data Assembly – The Digital Dozer software package is an ArcGIS extension for editing grid data. This extension allows the user the edit the terrain data to better reflect the field conditions. Digital terrain data in grid format is compiled using many different sources and technologies. Recognizing the need to combine these data into one coherent and representative terrain model for the watershed, GeoHMS will provide support for an interface with a newly created DEM editing software for DEM assembly and editing.

Corrections

1. There is a correction on page 72 in the GeoHMS Version 1.0 User's Manual, July 2000. The third sentence in section entitled "Method 3: Basin Subdivision on Tributary" contains an error.

   Original: Clicking on the delineation point with the **Point Delineation** tool delineates a subbasin at a specified point not on the existing stream, traces a new stream, and splits the existing stream at the confluence."

   Corrected: Clicking on the delineation point with the **Basin Subdivision** tool delineates a subbasin at a specified point not on the existing stream, traces a new stream, and splits the existing stream at the confluence."

2. There is a correction on page 33 in the GeoHMS Version 1.0 User's Manual, July 2000. The second entry in Table 5-2 contains an error.

   Original: Spheroid: **Clarke 1866**

   Corrected: Spheroid: **GRS1980**

APPENDIX I

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INDEX

A

B

C

D

E

F

G

H

I

L

M

N

P

R

S

T

U

W