

Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool:

Documentation and User Manual

Version 1.32

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1. Abstract

Semmens, D.J., S.N. Miller, M. Hernandez, W.P. Miller, D.C. Goodrich, W.G. Kepner, 2002, Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual; U.S. Department of Agriculture, Agricultural Research Service, ARS-1446.

Planning and assessment in land and water resource management are evolving from simple, local-scale problems toward complex, spatially explicit regional ones. Such problems have to be addressed with distributed models that can compute runoff and erosion at different spatial and temporal scales. The extensive data requirements and the difficult task of building input parameter files, however, have long represented an obstacle to the timely and cost-effective use of such complex models by resource managers.

The USDA-ARS Southwest Watershed Research Center, in cooperation with the U.S. EPA Office of Research and Development, has developed a GIS tool to facilitate this process. A geographic information system (GIS) provides the framework within which spatially-distributed data are collected and used to prepare model input files and evaluate model results for two watershed runoff and erosion models: KINEROS2 and SWAT.

AGWA is designed as a tool for performing relative assessment (change analysis) resulting from land cover/use change. Areas identified through large-scale assessment with SWAT as being most susceptible to change can be evaluated in more detail at smaller scales with KINEROS2. Results can be visualized as percent or absolute change for a variety of output and derived parameters. These features are intended to assist resource managers in identifying the most important areas for watershed restoration efforts and preventative measures.

2. Disclaimer

The development of this document and the AGWA tool has been funded by the U.S. Environmental Protection Agency and carried out by the U.S. Department of Agriculture's Agricultural Research Service. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency or the Department of Agriculture. The Automated Geospatial Watershed Assessment (AGWA) tool described in this manual is applied at the user's own risk. Neither the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, nor the system authors can assume responsibility for system operation, output, interpretation, or use.

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3. Acknowledgements

The Automated Geospatial Watershed Assessment (AGWA) tool was developed by the USDA-ARS Southwest Watershed Research Center in close collaboration with the US-EPA National Research Exposure Lab, Las Vegas, NV. The authors would like to thank several EPA colleagues who assisted in the development of this tool, especially Bruce Jones, Daniel Heggem, Megan Mehaffey, Kim Devonald, and Curt Edmonds. The authors benefited greatly from the thoughtful comments and reviews of ARS staff scientists, most notably Carl Unkrich, Ginger Paige, Jeff Stone, and Susan Moran.

The software extension and manual were reviewed by Craig Wissler, and Dr. D. Phillip Guertin from the University of Arizona, Tucson, AZ, and Alissa Coes from the USGS Water Resources Division, Tucson, AZ. AGWA benefited greatly from their reviews and we thank them for their time and attention.

AGWA is based on two existing watershed runoff and erosion models, KINEROS and SWAT, and we would like to acknowledge the authors of those models for providing assistance with integrating the models. Carl Unkrich of the Southwest Watershed Research Center was kind enough to create an AGWA-specific KINEROS program. Thanks also to Jeff Arnold of the USDA-ARS Blackland Research Center, Temple, TX, for his assistance in developing the SWAT interface.

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4. Introduction

The Automated Geospatial Watershed Assessment (AGWA) tool is a multipurpose hydrologic analysis system for use by watershed, water resource, land use, and biological resource managers and scientists in performing watershed- and basin-scale studies. It was developed by the U.S. Agricultural Research Service's Southwest Watershed Resource Center to address four objectives:

- To provide a simple, direct, and repeatable method for hydrologic model parameterization
- To use only basic, attainable GIS data
- To be compatible with other geospatial watershed-based environmental analysis software
- To be useful for scenario development and alternative futures simulation work at multiple scales.

AGWA provides the functionality to conduct all phases of a watershed assessment for two widely used watershed hydrologic models: the [Soil Water Assessment Tool \(SWAT\)](#); and the [KINematic Runoff and EROSION model, KINEROS2](#). SWAT, developed by the U.S. Agricultural Research Service, is a long-term simulation model for use in large (river-basin scale) watersheds. KINEROS, also developed by the U.S. Agricultural Research Service, is an event driven model designed for small (< ~100 km²) semi-arid watersheds. The AGWA tool has intuitive interfaces for both models that provide the user with consistent, reproducible results in a fraction of the time formerly required with the traditional approach to model parameterization.

Data used in AGWA include Digital Elevation Models (DEMs), land cover grids, soils data, and precipitation data. All are available at no cost over the internet for North America, and other areas around the world. A more detailed description of these data types can be found in the [Data Requirements](#) section below.

AGWA is an extension for the Environmental Systems Research Institute's (ESRI's) ArcView versions 3.x, a widely used and relatively inexpensive geographic information system (GIS) software package. The GIS framework is ideally suited for watershed-based analysis, which relies heavily on landscape information for both deriving model input and presenting model results. In addition, AGWA shares the same ArcView GIS framework as the U.S. Environmental Protection Agency's Analytical Tool Interface for Landscape Assessment (ATILA), and Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). This facilitates comparative analyses of the results from multiple environmental assessments. In addition, output from one model may be used as input in others, which can be particularly valuable for scenario development and alternative futures simulation work.

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5. AGWA Tool Overview

The AGWA tool is an extension for the ESRI ArcView GIS software that uses geospatial data to parameterize two watershed runoff and erosion models: [KINEROS](#), and [SWAT](#). A schematic of the procedure for utilizing these models with AGWA is presented below in figure 1. AGWA is a modular program that is designed to be run in a step-wise manner.

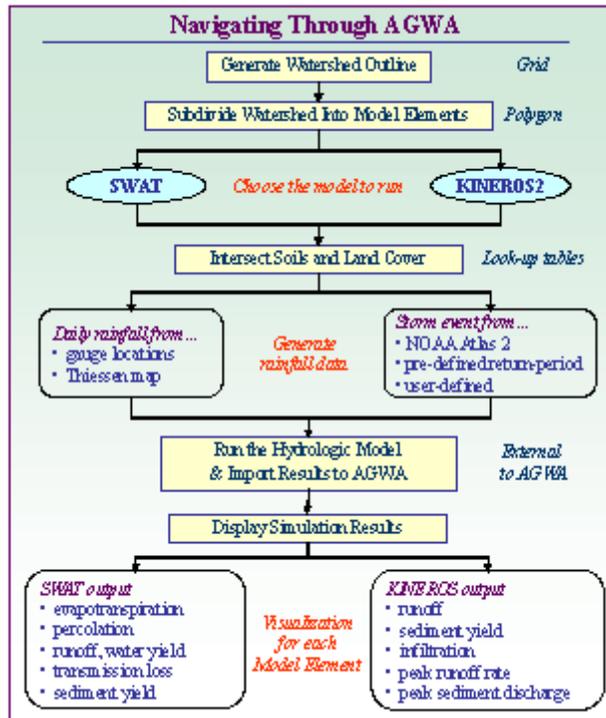
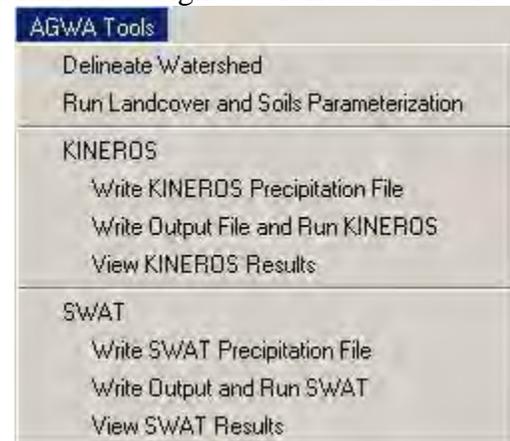


Figure 1. Flow chart showing the general framework for using KINEROS and SWAT in AGWA.

The AGWA extension for ArcView adds the 'AGWA Tools' menu to the View window, and must be run from an active view. The AGWA Tools menu is designed to reflect the order of tasks necessary to conduct a watershed assessment, which is broken out into five major steps:

1. Watershed delineation
2. Land cover and soils parameterization
3. Writing a precipitation file for model input
4. Writing parameter files and running the chosen model
5. Viewing results



In more detail...

Step 1: The user first creates a watershed outline, which is a grid based on the accumulated flow to the designated outlet (pour point) of the study area.

Step 2: A polygon shapefile is built from the watershed outline grid created in step (1). The user specifies the threshold of contributing area for the establishment of stream channels, and the watershed is divided into model elements required by the model of choice. From this point, the tasks are specific to the model that will be used, but both follow the same general process. If internal runoff gages are present for model validation, they can be used to further subdivide the watershed.

Step 3: AGWA is predicated on the presence of both land cover and soil GIS coverages. In step 3, the watershed is intersected with these data and parameters necessary for the hydrologic model runs are determined through a series of look-up tables. The hydrologic parameters are added to the polygon and stream channel tables.

Step 4: Rainfall input files are built. For SWAT, the user must provide daily rainfall values for rainfall gages within and near the watershed. If multiple gages are present, AGWA will build a Thiessen polygon map and create an area-weighted rainfall file. For KINEROS, the user can select from a series of pre-defined rainfall events or choose to build his/her own rainfall file through an AGWA module. Precipitation files for model input are written from uniform (single gauge) rainfall or distributed (multiple gauge) rainfall data.

Step 5: At this point, all necessary input data have been prepared: the watershed has been subdivided into model elements; hydrologic parameters have been determined for each element; rainfall files have been prepared. The user can proceed to run the hydrologic model of choice. AGWA will automatically import the model results and add them to the polygon and stream maps' tables for display. A separate module controls the visualization of model results. The user can toggle between viewing the total depth or accumulated volume of runoff, erosion, and infiltration output for both upland and channel elements. This enables problem areas to be identified visually so that limited resources can be focused for maximum effectiveness. Model results can also be overlaid with other digital data layers to further prioritize management activities.

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6. Hardware and Software Requirements

The AGWA tool is not a stand alone program. It requires the [Environmental Systems Research Institute's](#) (ESRI) [ArcView 3.x](#) software and the [Spatial Analyst Extension](#) for working with grid-based data. The AGWA tool is designed to run on Microsoft Windows versions 95, 98, NT 4.0, 2000, ME, and XP. Processor speed does have a significant impact on the time required to perform the watershed delineation and other tasks in AGWA. For reference, the following table lists the time required to delineate and discretize watersheds of different sizes at different levels of geometric complexity (contributing source area), using a Pentium III, 866 MHz with 256 Mb RAM.

Watershed Boundary		Discretization Level (CSA)		
		20%	10%	2.5%
Area (km ²)	Delineation Time			
150*	0:03	0:22	0:25	0:27
150	0:56	0:28	0:35	0:43
750	1:18	0:48	1:13	1:30
1940	2:03	2:50	2:45	3:20
3370	3:03	5:37	5:43	6:13
7550	6:50	9:05	9:30	10:36

* Data was clipped to small buffer around the watershed.

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7. Installation

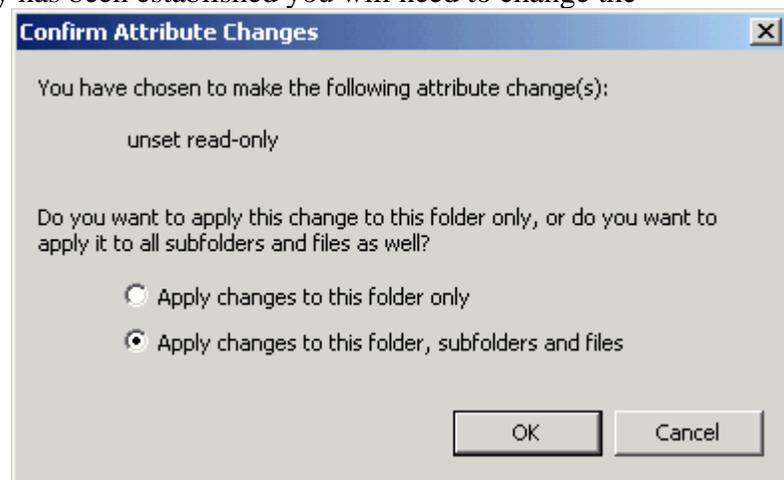
The AWGA tool comes as a collection of files that are necessary for its operation. These files are organized as follows in both `agwa1_3.zip`, and the AGWA CD:

- ArcView extension `agwa1_3.avx`
- Datafiles directory - database files and supplementary extensions (`grid01.avx`, and `xtools.avx`).
- Models directory - model executables and associated files
- GISdata directory - example data
- Documents directory - presentations and example documents
- Manual directory - user manual and associated files

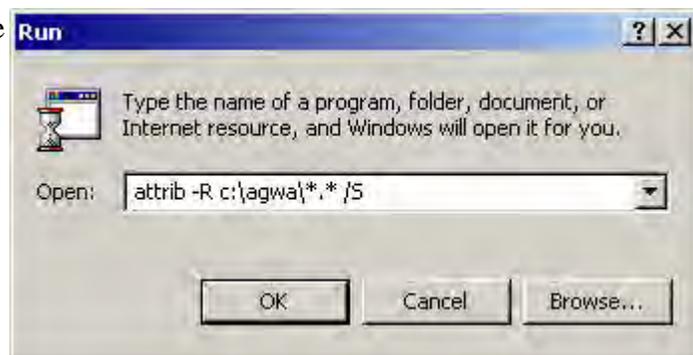
For users *downloading* the file `agwa1_3.zip` please unzip to a directory called AGWA, e.g. `C:\AGWA`.

For users with an *AGWA CD*, please copy the entire AGWA directory to your computer, creating e.g. `C:\AGWA`. Once this directory has been established you will need to change the *permissions* for it (everything is converted to 'read only' when written to the CD).

- For Windows 2000 and XP - Right click on the AGWA directory and uncheck the 'read only' box. When you click 'OK' or 'Apply', the Confirm Attribute Changes window (left) will pop up and prompt you to choose whether you would like to apply the change to just the specified AGWA directory, or to also include subfolders and files. Please select the latter as shown here to ensure that 'read-only' is unset for all files in the directory.



- For Windows 95, 98 and NT - File permissions cannot be set recursively for subfolders and files through a folder properties window. Instead select 'Run' from the Start Menu to bring up the window shown on the right. Type "`attrib -R C:\AGWA*.* /S`" in the text box to open a DOS window



and hit return or click 'OK'. Substitute the location of your AGWA directory if you have used something other than C:\AGWA.

When the AGWA directory and its associated subdirectories has been created on your hard drive:

1. Drag or paste the extension file (agwa1_3.avx) into the \ESRI\AV_GIS30\ARCVIEW\EXT32\ directory. Two supplementary extensions (grid01.avx, and xtools.avx) can optionally be copied from the 'datafiles' subdirectory to \ESRI\AV_GIS30\ARCVIEW\EXT32\. These two extensions provide the user with additional capabilities when preparing data for AGWA, and potentially for analyzing results within ArcView.
2. Open ArcView and select 'Extensions...' from the 'File' menu. To activate the AGWA extension click the box next to its name in the Extensions window and then click 'Okay'. You are now ready to begin using AGWA, but be sure to read the [File Management](#) section below first. If the two supplementary extensions will be used then they can be turned on at this time as well, but these can be turned on/off and used at any time.
3. Optional but highly recommended - set an AGWA environmental variable on your computer:

3.1 For Windows 2000 and XP

- A. From the Start Menu select Settings --> Control Panel
- B. Double click on the 'System' icon
- C. From the System Properties window select the 'Advanced' tab, and then click the 'Environment Variables...' button.
- D. For the user variables, click on the 'New' button and set its name to 'AGWA' (without the quotes), and its value to 'C:\AGWA' or wherever you have established your AGWA directory. This will give AGWA a head start in locating files and save you time in the long run. ** Do not use spaces anywhere in the path to this directory (e.g. "C:\My Documents\AGWA") because ArcView has problems dealing with file and folder names that contain spaces.

3.2 For Windows NT

- E. From the Start Menu select Settings --> Control Panel
- F. Double click on the 'System' icon
- G. From the System Properties window select the 'Environment' tab, and then click the 'Environment Variables...' button.
- H. For the user variables, click on the 'New' button and set its name to 'AGWA' (without the quotes), and its value to 'C:\AGWA' or wherever you have established your AGWA directory. This will give AGWA a head start in locating files and save you time in the long run. ** Do not use spaces anywhere in the path to this directory (e.g. "C:\My Documents\AGWA") because ArcView has problems dealing with file and folder names that contain spaces.

3.3 For Windows 95 & 98

- I. Open the file `c:\autoexec.bat` in a text editor - this can be accomplished by right clicking on the file in the Explorer window and selecting 'Edit'.
- J. Add the following line to the `autoexec.bat` file:

```
set AGWA=agwadir
```

where 'agwadir' is the folder that will contain all your AGWA-related files and directories, for example: `C:\AGWA`. Do not use spaces anywhere in the path to this directory (e.g. "`C:\My Documents\AGWA`") because ArcView has problems dealing with file and folder names that contain spaces.

- K. Restart your computer to activate the changes to `autoexec.bat`.

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8. Data Requirements

The AGWA tool is designed to be used with geospatially referenced data, which includes most data types supported by ArcView. These include: coverages, shapefiles, and grids. Images can be used for reference within a view, but are not used directly by the AGWA tool. Specific data requirements for each of the model components are outlined below, and are described in more detail in the sections describing each component.

Watershed Delineation

- USGS Digital Elevation Model (DEM) - available at multiple sites
 - <http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html>
 - <http://edc.usgs.gov/webglis>
 - <http://edcsns17.cr.usgs.gov/EarthExplorer/>
 - <http://seamless.usgs.gov/> (easiest download site)
 - <http://lighthouse.nrcs.usda.gov/gateway/>
- Point coverage or shapefile of gauging station location(s) (optional)

Land Cover and Soils Parameterization

Land Cover grid

- [North American Land Cover Characterization \(NALC\)](#)
 - http://eosims.cr.usgs.gov:5725/CAMPAIGN_DOCS/nalc_proj_camp.html
- [Multi-Resolution Land Characteristics \(MRLC\) Consortium](#) - National Land Cover Data (NLCD)
 - <http://www.epa.gov/mrlc/nlcd.html>
 - [NLCD dataset info](#) (local, does not require internet connection to follow this link)
 - <http://seamless.usgs.gov/> (easiest download site)
 - <http://lighthouse.nrcs.usda.gov/gateway/>
- [New York](#) - state-specific classification scheme
 - <http://www.epa.gov/owow/watershed/landcover/lulcny.html>
- [User-Defined](#) – this can cover any other classification scheme

Soil Polygon Map

- [State Soil Geographic Database \(STATSGO\)](#) soils coverage/shapefile
 - http://www.ftw.nrcs.usda.gov/statsgo_ftp.html (by state)
 - <http://water.usgs.gov/lookup/getspatial?ussoils> (by basin)
- [Soil Survey Geographic \(SSURGO\) Data Base](#) – higher resolution soils coverage/shapefile. Can be used with KINEROS ONLY.
 - http://www.ftw.nrcs.usda.gov/ssur_data.html
 - <http://lighthouse.nrcs.usda.gov/gateway/>

KINEROS Precipitation Data (one of the following)

- Uniform, single gage (AGWA can format model input (*.pre) files)
 - [National Weather Service](#)
 - [NOAA Atlas 2](http://www.nws.noaa.gov/oh/hdsc/noaaatlas2.htm) <http://www.nws.noaa.gov/oh/hdsc/noaaatlas2.htm>
 - AGWA design storm database, dsgnstrm.dbf - this is provided with AGWA, and should be located in your datafiles directory
 - User defined storms can be entered
- Distributed, multiple gauges (Input files require formatting by user - we have provided a Perl script in the 'datafiles' directory that can help with this if very specific input data format requirements are met. The script is called convert.pl, and formatting requirements are contained within it.)
 - [National Weather Service](#)
 - [National Climatic Data Center](http://www.ncdc.noaa.gov/) <http://www.ncdc.noaa.gov/>
 - [Western Regional Center](http://www.wrcc.sage.dri.edu) <http://www.wrcc.sage.dri.edu>

SWAT Precipitation Data (one of the following)

- Uniform, single gage (AGWA can format model input (*.pcp) files)
- Distributed, multiple gauges (AGWA can format weighted model input (*.pcp) files)
 - [National Weather Service](#)
 - [National Climatic Data Center](http://www.ncdc.noaa.gov/) <http://www.ncdc.noaa.gov/>
 - [Western Regional Center](http://www.wrcc.sage.dri.edu) <http://www.wrcc.sage.dri.edu>

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9. File Management

File management in any ArcView-based application is extremely important. ArcView projects maintain references to many files that are generated or used, and moving or deleting these files incorrectly will cause problems. Since this happens frequently when working and data directories are not fixed (i.e. user-selected or default directories), the AGWA extension manages them for you. When the AGWA extension is loaded into a project it prompts the user to select a name for a new project directory. This directory is then created and the project is automatically saved to it. In addition, several additional subdirectories are created for writing various input and output files used by AGWA. This, in combination with the option to set a system environmental variable 'AGWA', allows AGWA to locate many files without prompting the user, and in other instances when the user must select a file it opens the appropriate directory when asking the user to select a file.

Prior to describing the AGWA data structure in more detail it is important to describe the various types of files used and created in an AGWA project. These files can be split into six categories: primary coverages/grids, secondary or temporary coverages/grids, primary tables, secondary or temporary tables, model executables, and model input/output files.

Primary Coverages/Grids - These include the major spatial data sets used in the watershed delineation, land cover and soils parameterization, and in writing the precipitation files: DEM, , land cover, soils, and rain gages. These are all data sets that you will be likely to use more than once, and should be easily accessible. They can be located anywhere (locally is recommended to minimize processing time), but if they are moved after a project is created then ArcView will lose its reference to them and prompt you to relocate them (a tedious process). For your convenience, we suggest you store them in the 'gisdata' directory under your AGWA home directory. This is where AGWA will prompt you to look first if the data has not been previously added to the view.

Secondary or Temporary Coverages/Grids - These include any coverages/grids (themes) generated during an AGWA project. Secondary themes are here taken to be those which may need to be accessed again, whereas temporary themes are generated as a byproduct AGWA tasks. Both types are written automatically to the 'av_cwd' directory in your project directory, but the temporary themes are deleted when the task during which they were created is complete. Secondary themes continue to reside in the 'av_cwd' directory with names that are set to be the same as in the project so they can be easily identified. As with all themes in a project, the secondary themes should not be deleted until either the project is deleted, or after they are deleted from the project.

Secondary themes generated during the course of a watershed assessment may include (in the order in which they are generated):

- Flow direction grid
- Flow accumulation grid
- Stream channel grid (specific to a DEM)
- Watershed boundary grid

- Watershed shapefiles (upland elements and streams)
- Thiessen polygon shapefiles (SWAT only, when more than 2 gages are used to generate the precipitation file)
- Intersection shapefiles (SWAT only, when more than 2 gages are used to generate the precipitation file)

** Note that any themes generated by the user in a project with the AGWA extension loaded, but not using AGWA tools, will be written to the 'av_cwd' directory associated with the project.

Primary Tables - Running AGWA requires a suite of database files used at various stages in the watershed assessment. These files are provided with AGWA in the 'datafiles' directory, and should remain there to minimize inconvenience to the user. If the system environmental variable 'AGWA' is set, then every time one of these files is accessed AGWA automatically points to the 'datafiles' directory first. If the files are located elsewhere then the user will have to browse to that new location every time. If the environmental variable is not set then AGWA will open to the project directory. The primary tables include:

- *final_kin_soil_lut.dbf* - the soil lookup table for KINEROS, which is used to derive the model hydrologic parameters from the soil coverage codes
- *final_swat_soil_lut.dbf* - the soil lookup table for SWAT, which is used to derive the model hydrologic parameters from the soil coverage codes
- *soil_lut.dbf* - a secondary soil lookup table for SWAT
- *dsgnstrm.dbf* - a file containing design storm information for different durations and return periods. At this writing it only contains data for SE Arizona.
- *wgnfiles.dbf* - a file containing the weather generator stations in the western U.S. that are available in AGWA - for SWAT. This file contains pointers to the weather generator files, which are described in the model input/output files.

Secondary or Temporary Tables - At various stages in a watershed assessment database files are generated by AGWA and/or the user and added to the project. These files are by default written to the various project subdirectories, and should remain there to minimize inconvenience to the user. By default, every time one of these files is accessed AGWA automatically points to the directory where it should reside. If the files are located elsewhere then the user will have to browse to that new location every time. These files include:

- *Rainfall tables* - a rainfall database file for SWAT must be generated by the user and added to the project (it would be best if this is saved into the rainfall directory). In addition, uniform rainfall files for KINEROS that are entered by the user through the 'Design Storm Data Entry' dialog.
- *weights.dbf* - this file is created as part of the Thiessen weighting during the generation of precipitation input files for SWAT, and is written to the 'av_cwd' directory. It is added to the project as a table, and may be helpful to view, but does not ever need to be modified by the user. It is overwritten every time a distributed precipitation file is generated for SWAT.
- *swatpptfiles.dbf* - this file maintains a record of all the various combinations of watershed configuration, precipitation files, the location of the precipitation files, and the start/end

dates for precipitation files. This file is written to the project subdirectory 'rainfall', and added to the project as a table. It is crucial to the process of running SWAT and must *not* be deleted from the rainfall directory.

- *Output tables* - results from model simulations are written into channel and upland (plane) database files that are added to the project as tables. The names for these output files are simple modifications of the simulation name; the channel output tables have a 'c' before the simulation name, and upland tables have a 'p' before the simulation name. For KINEROS, the output table names end in '.out', and for SWAT the output table names end in '.res'.

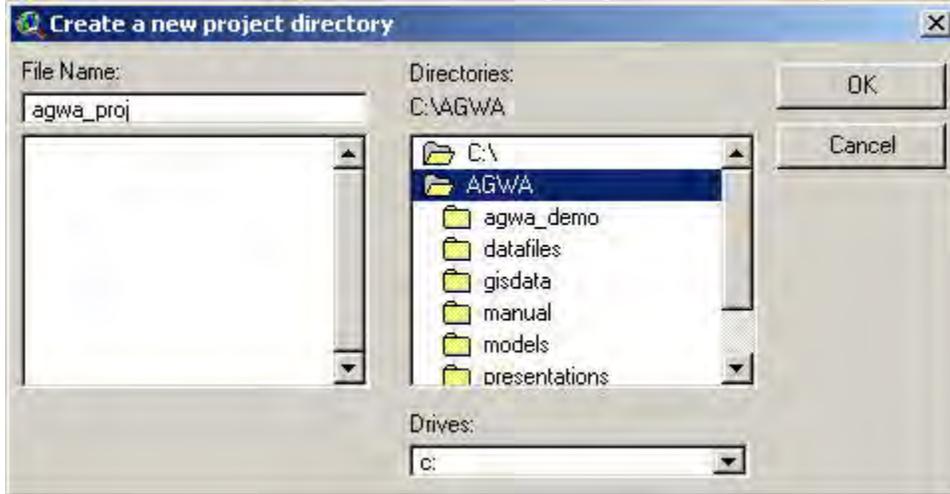
Model Executables - The KINEROS and SWAT executables are provided with AGWA, and should be stored in one central location for easy access. If the system environmental variable 'AGWA' is set then both KINEROS and SWAT will run automatically, otherwise the first time the executables are called by AGWA during each session the user must point to the location where they are stored. For SWAT, AGWA places a copy of the executable into the simulation directory where the input parameter files are being written. This is a requirement of the SWAT model and the executable can be deleted once the model has been run if it will not be used again outside of AGWA.

Model Input/Output Files - Model input and output files are generated each time either KINEROS or SWAT is run. AGWA controls where these files go in all instances, but there are some differences depending on the model.

- KINEROS
 - Input precipitation files (*.pre) are written to the 'rainfall' directory located in the project directory.
 - Each time KINEROS is run, a file called 'kin.fil' located in the same directory as the executable is modified to tell KINEROS which files to use in the simulation. This file is overwritten every time the model is run, and will be created if it somehow doesn't exist.
 - All KINEROS input parameter files (*.par) are written to a single subdirectory called 'kin_sims', which is located in the 'simulations' directory in the project directory.
 - All KINEROS output files (*.out) are also written to the 'kin_sims' directory, which is located in the 'simulations' directory in the project directory.
- SWAT
 - For each SWAT simulation a large number of input files are generated. Each of 11 file types are generated for each subwatershed in the watershed discretization, in addition to 14 other supporting file types of which there can be multiple files. Including the executable and output file that is a total of 27 file types and frequently hundreds of files.
 - It is a requirement of SWAT that all files used in a simulation are located in a single directory. As a result, the SWAT executable, input and output files are all copied or written to a SWAT simulation subdirectory. To keep these myriad files from getting mixed up each simulation is stored in its own directory under the 'simulations' directory, and is named by the user.

- Input precipitation files generated for SWAT (*.pcp) are written to the project subdirectory 'rainfall', and then *copied* to the simulation subdirectory.
- Temperature files (*.tmp). These can be generated on the fly, but are more reliable if created by the user. If generated on the fly they are written to the appropriate simulation subdirectory.

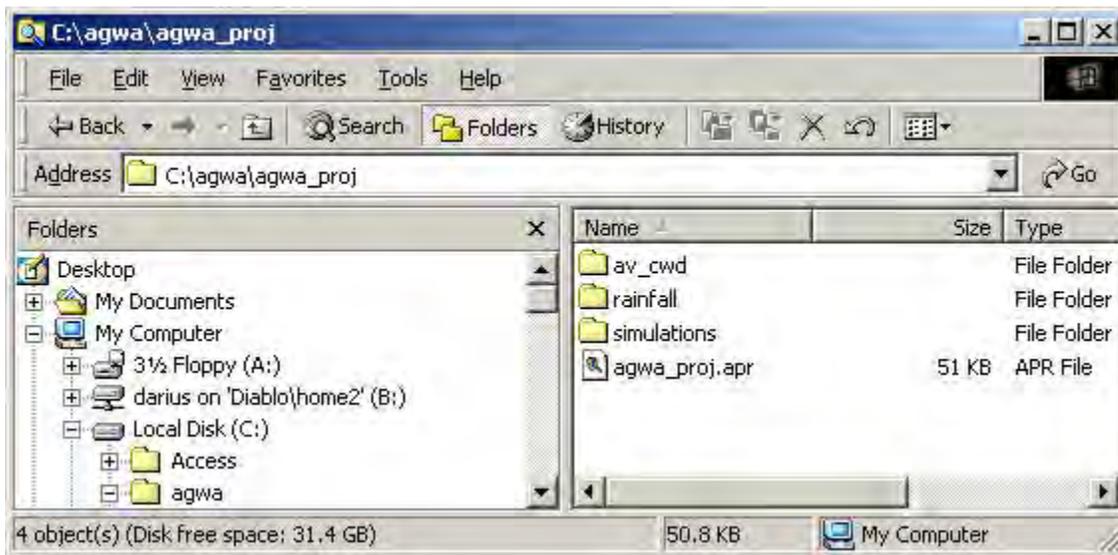
Setting Up the Project and the Working Directory - The working directory is the default location where ArcView will write coverages, grids, and tables generated during the watershed



assessment process. When the AGWA extension is first turned on, the user is prompted to save/create a new project as shown below. AGWA will use the name provided by the user and create a standard project file structure. Given the project name "agwa_proj"

under "c:\agwa" as shown here, a directory will be created called "c:\agwa\agwa_proj", and the project will be named "c:\agwa\agwa_proj\agwa_proj.apr". The current working directory for the project will be pointed to a folder called "c:\agwa\agwa_proj\av_cwd".

The resultant file structure is shown here:



All files created by AGWA in the course of the project will be placed in the current working directory. ***Please note:*** even if a project has been previously saved as another name, AGWA will force the user to save the project with a new name with the above-described file structure.

A Note About Moving Spatial Data - It is important to remember that when using ArcView spatial data (coverages, themes, shapefiles, and grids) should not be moved from one directory into another using Microsoft Windows Explorer. This can create errors within the spatial data files, and should not be attempted unless the entire directory (up one level from the data sets themselves) in which the files reside is moved. Alternatively, if individual spatial data layers must be moved, then this should be done using ArcView. When a view is active, select 'Manage Data Sources' from the 'File' menu at the top of the screen. This will bring up a window that will enable you to transfer data layers from one directory to another without breaking the internal structure of spatial data files.

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10. Watershed Modeling

Since the development of the Stanford Watershed Model (Crawford and Linsley, 1966) numerous hydrologic models have been developed that use watersheds as the fundamental spatial unit to describe the various components of the hydrologic cycle. Watershed models have five basic components: watershed (hydrologic) processes and characteristics; input data; governing equations; initial and boundary conditions; and output (Singh, 1995). Despite their uniform general structure, however, various treatments of the five model components has resulted in a significant range of available model types. Distinguishing between these different model types is an important first step in selecting the appropriate model for a project.

Watershed models are generally classified according to the method they use to describe the hydrologic processes, the spatial and temporal scales for which they are designed, and any specific conditions or intended use for which they are designed. Some knowledge of these components is highly recommended when selecting the combination that is best suited to a specific watershed and task.

Process Description

Watershed models can be divided into two main types according to how they treat the spatial component of watershed hydrology (figure 2). Lumped, or lumped-parameter models treat an entire watershed as one unit and take no account of the spatial variability in processes, input, boundary conditions, or the hydrologic properties of the watershed. In contrast, distributed models ideally account for all spatial variability in the watershed explicitly by solving the governing equations for each pixel in a grid. In reality, neither of these extremes are suitable for watershed modeling because a lumped framework is a gross oversimplification and a distributed framework requires enormous amounts of data that is not readily obtainable. As a result most models have combined aspects of both approaches and subdivide the watershed into smaller elements with similar hydrologic properties that can be described by lumped parameters. This model type is commonly referred to as partially distributed, or quasi-distributed.

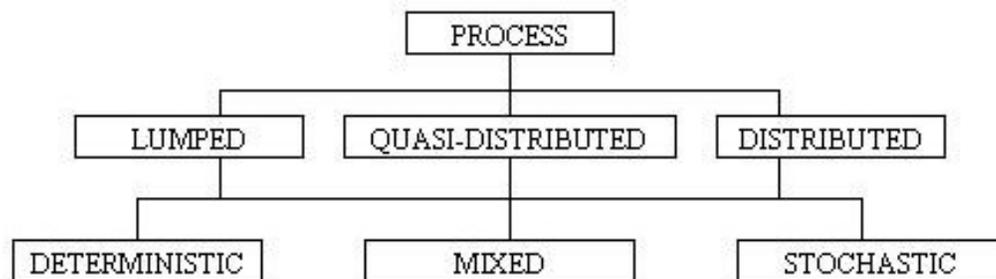


Figure 1. Process-based classification of watershed models, after Singh (1995)

The description of the hydrologic processes within a watershed model can be deterministic, stochastic, or some combination of the two. Deterministic models are models in which no random variables are used, i.e. for each unique set of input data the model will compute fixed,

repeatable results (e.g. Law and Kelton, 1982). The governing equations describing the hydrologic and soil erosion processes in a deterministic model should be a major factor in selecting a model. Models with equations based on fundamental principles of physics or robust empirical methods the most widely used in computing surface runoff and sediment yield. Stochastic models, in contrast, use distributions for each variable to generate random values for model input (e.g. Clarke, 1998). As a result, the output from a stochastic model is itself random, with its own distribution, and can thus be presented as a range of values with confidence limits.

The vast majority of watershed models are deterministic, including both KINEROS and SWAT. Fully stochastic models, in which all components of the model are stochastic, are virtually non-existent (Singh, 1995). Stochastic generation of input variables, however, is commonly used to optimize models, or determine model sensitivity to various input variables. If only parts of a model are described by the laws of probability then it is commonly referred to as quasi-deterministic, quasi-stochastic, or mixed.

Spatial Scale

A watershed can range from as little as one hectare to hundreds of thousands of square kilometers. The spatial scale for which a model is designed can play a significant role in how specific processes are treated. Runoff in large watersheds ($> 1000 \text{ km}^2$), for instance, is dominated by channel storage. In contrast, runoff from small watersheds ($< 100 \text{ km}^2$) is dominated by overland flow. For intermediate watersheds it is important to account for the essential concept of homogeneity and averaging of hydrologic process in the models.

Spatial scale is an important criterion in the selection of a model because the storage characteristics may vary at different watershed scales, that is, large watersheds have well developed channel networks and channel phase, and thus, channel storage is dominant. Such watersheds are less sensitive to short duration, high intensity rainfalls. On the other hand, small watersheds are dominated by the land phase and overland flow, have relatively less conspicuous channel phase, and are highly sensitive to high intensity, short duration rainfalls.

Temporal Scale

Hydrologic processes may occur at different time scales, therefore it is important to consider models that operate from event to daily to yearly time scales. At the event time scale, models typically do not compute inter-storm soil moisture conditions and therefore this information must be provided as an initial condition to initiate the model run. Event based models may be employed for storm events of relatively short duration or to finalize the design of technically complex structural and nonstructural management practices. On the other hand, continuous-time hydrologic models can simulate precipitation, available surface storage, snowmelt, evapotranspiration, soil moisture, and infiltration in a seasonal framework. These models typically operate on a time interval ranging from a fraction of an hour to a day. The principal advantage of continuous modeling is that it can provide long-term series of water and pollutants loadings.

Land Use

Many studies have shown that the land uses within a watershed can account for much of the variability in stream water quality (Omernick, 1987; Hunsaker et al., 1992; Charbonneau and Kondolf, 1993; Roth et al., 1996). Agriculture on slopes greater than three percent, for example, increases the risk of erosion (Wischmeier and Smith 1978). A drastic change in vegetation cover, such as clear cutting in the Pacific northwest, can produce 90% more runoff than in watersheds unaltered by human practices (Franklin, 1992). The linkage between intact riparian areas and water quality is well established (Karr and Schlosser, 1978; Lowrance et al., 1984). For example, riparian habitats function as “sponges”, greatly reducing nutrient and sediment runoff into streams (Peterjohn and Correll, 1984).

The percentage and location of natural land cover influences the amount of energy that is available to move water and materials (Hunsaker and Levine, 1995). Forested watersheds dissipate energy associated with rainfall, whereas watersheds with bare ground and anthropogenic cover are less able to do so (Franklin, 1992). The percentage of the watershed surface that is impermeable, due to urban and road surfaces, influences the volume of water that runs and increases the amount of sediment that can be moved (Arnold and Gibbons, 1996). Watersheds with highly erodible soils tend to have greater potential for soil loss and sediment delivery to streams than watersheds with non-erodible soils.

Moreover, intense precipitation events may exceed the energy threshold and move large amounts of sediments across a degraded watershed (Junk et al., 1989; Sparks, 1995). It is during these events that human-induced landscape changes may manifest their greatest negative impact.

A direct and powerful link exists between vegetation and hydrological processes in semi-arid environments. Vegetation plays a pivotal role in determining the amount and timing of the runoff which ultimately supplies mass and energy for the operation of hydrologic and erosive processes (Graf, 1988). Most analyses that assess the variability of sediment yield demonstrate that at the lower end of the precipitation scale (representing semi-arid conditions), small changes in annual precipitation bring about major changes in vegetation communities and associated sediment yields (Graf, 1988). For example, for a mean annual temperature of 10° C, the Langbein and Schumm (1958) curve reaches a peak at an effective precipitation of about 300 mm (figure 3), trailing off at lower values because of lower runoff totals and at higher ones because an increasingly abundant vegetation cover affords better protection against erosion.

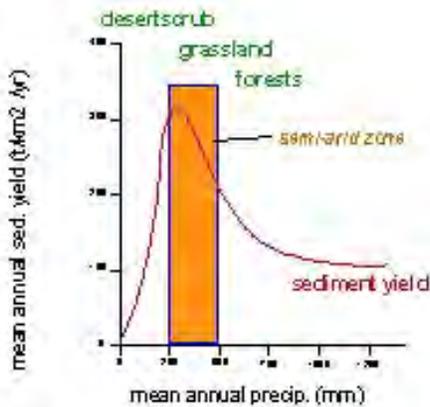


Figure 2. Erosion as a function of precipitation. After Langbein & Schumm (1958)

It should be clearly noted that methods for transforming various land cover and land use characteristics into distributed hydrologic model parameters are not well developed for a wide range of conditions. For management purposes many approaches rely largely on empirical studies from large numbers of small plots and catchments to relate land cover and land use to effective hydrologic model parameters. The curve number method (Chow et al., 1988) and the USLE or RUSLE method for predicting soil erosion (Renard et al., 1997) are examples of this type of approach to related land cover/land use to hydrologic model parameters. The transformation of land cover/land use conditions into meaningful hydrologic and erosion parameters, and quantifying the associated uncertainty is a major challenge in watershed modeling.

Effects of aggregation of landscape attributes on watershed response

Recent papers (e.g. Roth et al., 1996; Weller et al., 1996) suggest that the importance of landscape features may change in different environmental settings, or when moving from one spatial scale to another. Therefore, methods to analyze and interpret broad spatial scales are becoming increasingly important for hydrological and ecological studies. Parameters and processes important at one scale are frequently not important or predictive at another scale, and information is often lost as spatial data are considered at coarser scales of resolution (Meentemeyer and Box, 1987). Furthermore, hydrological problems may also require the extrapolation of fine-scale measurement for the analysis of broad-scale phenomena. Therefore, the development of methods that will preserve information across scales or quantify the loss of information with changing scales has become a critical task.

Wood et al. (1988) carried out an empirical averaging experiment to assess the impact of scale. They averaged runoff over small subwatersheds, aggregating the subwatersheds into larger watersheds, and repeating the averaging process. By plotting the mean runoff against mean subwatershed area, they noted that the variance decreased until it was rather negligible at a watershed scale of about 1 km². That analysis has been repeated for the runoff ratio (Wood, 1994) and evaporation (Famiglietti and Wood, 1995) using data from Kings Creek, which was

part of the FIFE '87 experiment. Results from the experiment show that at small scales there is extensive variability in both runoff and evaporation. This variability appears to be controlled by variability in soils and topography whose correlation length scales are on the order of $10^2 - 10^3$ m, typical of hillslopes. At an increased spatial scale, the increased sampling of hillslopes leads to a decrease in the difference between subwatershed responses. At some scale, the variance between hydrologic response for watersheds of the same scale should reach a minimum.

Integration of geographic information systems and remote sensing in hydrologic modeling

Spatially distributed models of watershed hydrological processes have been developed to incorporate the spatial patterns of terrain, soils, and vegetation as estimated with the use of remote sensing and geographic information systems (GIS) (Band et al., 1991; 1993; Famiglietti and Wood, 1991; 1994; Moore and Grayson, 1991; Moore et al., 1993; Wigmosta et al., 1994; Star et al., 1997). This approach makes use of various algorithms to extract and represent watershed structure from digital elevation data. Land surface attributes are mapped into the watershed structure as estimated directly from remote sensing imagery (e.g. canopy leaf area index), digital terrain data (slope, aspect, contributing drainage area) or from digitized soil maps, such as soil texture or hydraulic conductivity assigned by soil series.

Over the past decade numerous approaches have been developed for automated extraction of watershed structure from grid digital elevation models (e.g. Mark et al., 1984; O' Callaghan and Mark, 1984; Band, 1986; Jenson and Dominique, 1988; Moore et al., 1988; Martz and Garbrecht, 1993; Garbrecht and Martz, 1993; 1995; 1996). O' Callaghan and Mark (1984) define a digital elevation model (DEM) as any numerical representation of the elevation of all or part of a planetary surface, given as a function of geographic location. The most widely used method for the extraction of stream networks that has emerged is to accumulate the contributing area upslope of each pixel through a tree or network of cell to cell drainage paths and then prune the tree to a finite extent based on a threshold drainage area required to define a channel or to seek local morphological evidence in the terrain model that a channel or valley exists (Band and Moore, 1995).

The techniques used for delineation of the drainage path network by surface routing of drainage area and local identification of valley forms are ultimately dependent on a topographic signal generated in a local neighborhood on the DEM. As the approach is used to extract watershed structure with increasingly lower resolution terrain data, higher frequency topographic information is lost as the larger sampling dimensions of the grids act as a filter. Therefore, if watershed structural information is used to drive the hydrological model, the scaling behavior and consistency of the derived stream network with grid dimension needs to be addressed. One of the primary questions dealing with automated extracted channel network is that of the appropriate drainage density. Some authors suggest criteria to find this appropriate scale. For example, Goodrich (1991) found a drainage density of approximately 0.65 to 1.52×10^{-3} m for watersheds greater than 1 hectare was adequate for kinematic runoff modeling in semi-arid regions. Similarly, La Barbera and Roth (1994) proposed a filtering procedure based on the identification of threshold value for the quantity AS_k , where A is the contributing area, S the

stream slope and $k = 2$. This procedure consists in the progressive removal from the drainage network of the first order stream which presents the minimum ASk value; the procedure is iterated up to a given target value for the area drained by first order streams. Calore et al. (1997) found that above a certain threshold, an increase in resolution in the spatial description of drainage networks obtained from a DEM cannot be directly linked to an increase of information. The criterion they used for assessing the amount of information contained in the drainage was based on the information entropy concept of Shannon (1948).

Land use is an important watershed surface characteristic that affects infiltration, erosion, and evapotranspiration. Thus, almost any physically based hydrologic model uses some form of land use data or parameters based on these data (Spanner et al., 1990; 1994; Nemani et al., 1993). Distributed models, in particular, need specific data on land use and their location within the basin. Some of the first research for adapting satellite-derived land use data was done by Jackson et al. (1976) with the US Army Corps of Engineers STORM Model (US Army Corps of Engineers, 1976). However, most of the work on adapting remote sensing to hydrologic modeling has been with the Soil Conservation Service (SCS) runoff curve number model (US Department of Agriculture, 1972). The SCS model has been widely used in hydrology and water resources planning of agricultural areas. The model was originally developed for predicting runoff volumes from agricultural fields and small watersheds. However, it has been expanded for subsequent use in a wide variety of conditions at many basin sizes including urban and suburban areas. In early work with remotely sensed data, Jackson et al. (1977) demonstrated that land cover (particularly the percentage of impervious surface) could be used effectively in the STORM Model (US Army Corps of Engineers, 1976). In a study of the upper Anacostia River basin in Maryland, Ragan and Jackson (1980) demonstrated that Landsat-derived land use data could be used for calculating synthetic flood frequency relationships. Results can be erroneous if land use is mislabeled. A study by the US Army Corps of Engineers (Rango et al., 1983) estimated that any individual pixel may be incorrectly classified about one-third of the time. However, by aggregating land use over a significant area, the misclassification of land use can be reduced to about 2% (Engman and Gurney, 1991).

More recently, vegetation classification studies implementing digital satellite data have utilized higher spatial, spectral, and radiometric resolution Landsat Thematic Mapper (TM) data with much more powerful computer hardware and software. These studies have shown that the higher information content of TM data combined with the improvements in image processing power result in significant improvements in image processing power resulting in significant enhancement in classification accuracy for more distinctive classes (Congalton et al., 1998).

A detailed analysis of the effects of the thematic accuracy of land cover is necessary before any attempt on using the hydrologic modeling tool to determine the vulnerability of semi-arid landscapes to land cover changes. The accuracy of maps made from remotely sensed data is measured by two types of criteria (Congalton and Green, 1999): location accuracy and, classification or thematic accuracy. Location accuracy refers to how precisely map items are located relative to their true location on the ground. Thematic accuracy refers to the accuracy of the map label in describing a class or condition on the earth. For example, if the earth's surface was classified as forest, thematic map accuracy procedures will determine whether or not forest has been accurately labeled forest or inaccurately labeled as another class, such as water.

The widespread acceptance and use of remotely sensed data has been and will continue to be dependent on the quality of the map information derived from it. However, map inaccuracies or error can occur at many steps throughout any remote sensing project. According to Congalton and Green (1999), the purpose of quantitative accuracy assessment is the identification and measurement of map errors. Quantitative accuracy assessment involves the comparison of a site on a map against reference information for the same site. The reference data is assumed to be correct.

The history of accuracy assessment of remotely sensed data is relatively short, beginning around 1975. Researchers, notably Hord and Brooner (1976), van Genderen and Lock (1977), proposed criteria and techniques for testing map accuracy. In the early 1980s more in-depth studies were conducted and new techniques proposed (Rosenfield et al., 1982; Congalton et al., 1983; and Aronoff, 1985). Finally, from the late 1980s up to present time, a great deal of work has been conducted on accuracy assessment. An important contribution is the error matrix, which compares information from reference sites to information on the map for a number of sample areas. The matrix is a square array of numbers set out in rows and columns that express the labels of samples assigned to a particular category in one classification relative to the labels of samples assigned to a particular category in another classification. One of the classifications, usually the columns, is assumed to be correct and is termed the reference data. The rows usually are used to display the map labels or classified data generated from remotely sensed data. Error matrices are very effective representation of map accuracy, because the individual accuracy of each map category are plainly described along with both errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the map (Congalton and Green, 1999). A commission error occurs when an area is included in an incorrect category. An omission error occurs when an area is excluded from the category to which it belongs. In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy.

Soils information derived from a GIS are generally gathered in a similar manner to vegetation, with the exception that remote sensing often cannot provide critical information about soil properties, especially if the soil is obscured by a vegetation canopy (Band and Moore, 1995). Substantial progress has been made in estimating near-surface and profile soil water content with active and passive microwave sensors and in the estimation of hydraulic properties by model inversion (e.g. Entekhabi et al., 1994). However, in general, soil spatial information is the least known of the land surface attributes relative to its well-known spatial variability that has been observed in many studies (Nielsen and Bouma, 1985).

10.1 Kinematic Runoff and Erosion Model - KINEROS

KINEROS utilizes a network of channels and planes to represent a watershed and the kinematic wave method to route water off the watershed (figure 2). It is a physically-based model designed to simulate runoff and erosion for single storm events in small watersheds less than about 100 km². More detailed technical information about KINEROS can be found at <http://www.tucson.ars.ag.gov/kineros/>.

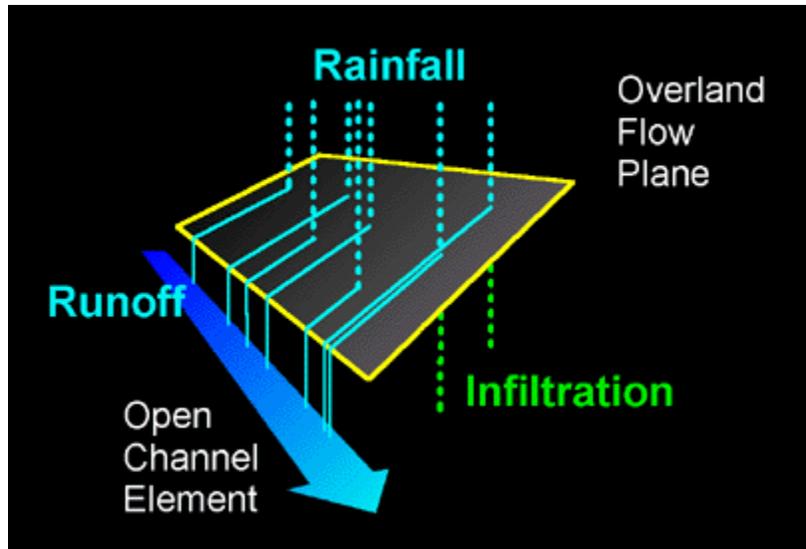


Figure 3. A schematic representation of the KINEROS program.

10.2 Soil Water Assessment Tool - SWAT

The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1994) was developed to predict the effect of alternative management decisions on water, sediment, and chemical yields with reasonable accuracy for ungauged rural basins. It is a distributed lumped-parameter model developed at the USDA Agricultural Research Service (ARS) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large (basin scale) complex watersheds with varying soils, land use and management conditions over long periods of time (> 1 year). SWAT is a continuous-time model, i.e. a long-term yield model, using daily average input values, and is not designed to simulate detailed, single-event flood routing. Major components of the model include: hydrology, weather generator, sedimentation, soil temperature, crop growth, nutrients, pesticides, groundwater and lateral flow, and agricultural management. The Curve Number method is used to compute rainfall excess, and flow is routed through the channels using a variable storage coefficient method developed by Williams (1969). Additional information and the latest model updates can be found at <http://www.brc.tamus.edu/swat/>.

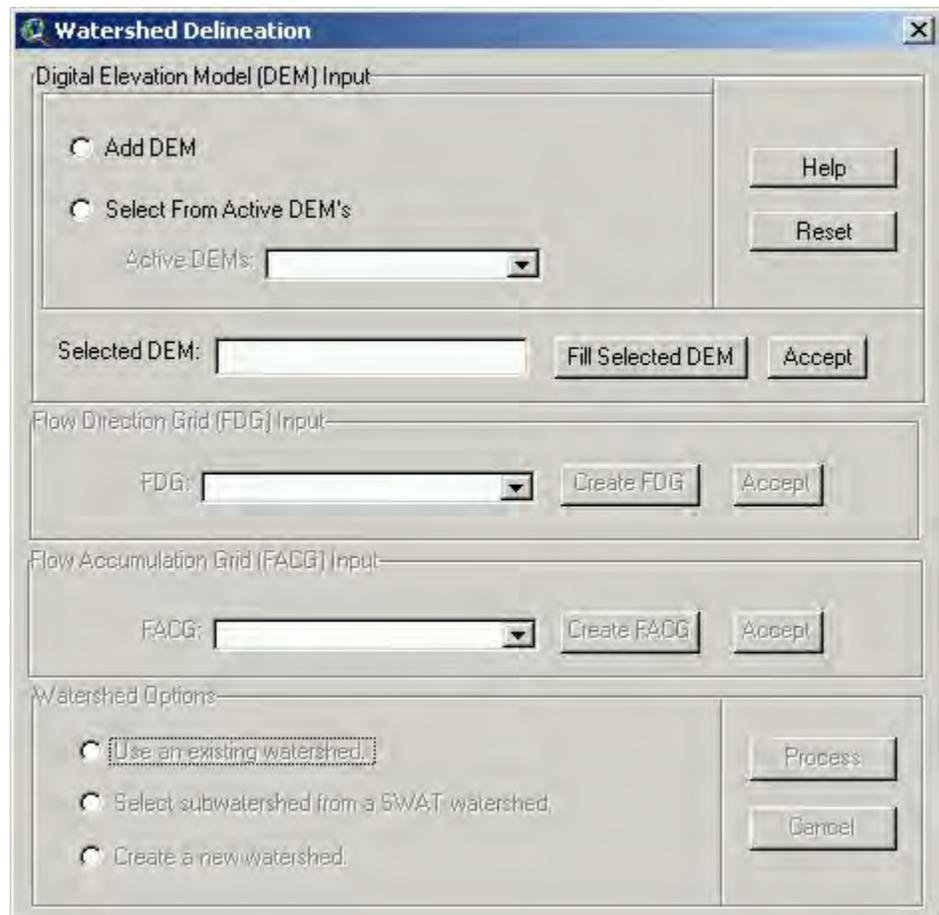
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11. Watershed Delineation

Watershed delineation is the first step in the process of using the AGWA tool. The Watershed Delineation dialog is called from the 'AGWA Tools' menu, and is used for both KINEROS or SWAT. This dialog requires that you enter the basic data types (described above) that are required to compute the watershed boundary and then divide the watershed into a series of planes or subwatersheds. Clicking on the 'Help' button in the upper right hand corner of the dialog should bring you directly to this section of the User's Manual. The Watershed Delineation dialog is organized into 7 components:

1. Digital Elevation Model (DEM) Input

Input - if you have not already added a DEM to the view you are given the option to do so here, otherwise select the DEM for the watershed you would like to delineate. Once a DEM is selected (it must be actively selected from the drop-down menu) then you are given the option of filling sinks. Sinks are isolated depressions in the elevation surface that can cause flow routing



problems, and are common in USGS DEMs that have not been corrected. The 'Accept' button must be clicked before proceeding to the next step.

- Flow Direction Grid (FDG) Input** - If an FDG for the DEM selected in (1) has not already been added to the view you must click the 'Create FDG' button to create one and add it to the view, otherwise the FDG must be selected from the drop-down menu to the left. Click 'Accept' to proceed to the next step.
- Flow Accumulation Grid (FACG) Input** - If an FACG for the DEM selected in (1) has not already been added to the view you must click the 'Create FACG' button to create one and add it to the view, otherwise the FACG must be selected from the drop-down menu to the left. Click 'Accept' to proceed to the next step. At this point AGWA will create the

[stream2500](#) grid and you must select a watershed boundary option. You may select 'Use an existing watershed' if a boundary already exists; a select dialog will pop up after clicking 'Process' so that you may choose the correct existing boundary. You may also select 'Select subwatershed from a SWAT watershed' if you want to further delineate a subbasin of a SWAT watershed for a KINEROS simulation. If selecting a subwatershed from a SWAT watershed, a dialog will open asking the name of the existing SWAT watershed and asking you to supply a name for the subwatershed. When selecting the subwatershed within the SWAT watershed, you must select a subwatershed that has no stream channels in it. Your final option is to create a new watershed boundary. The first option will take you directly to the next step. The second or third option will open a new window that must be completed - see [Watershed Outline](#) below, before you may proceed to the next step.

4. **Watershed**

Options – This step allows you to incorporate internal gages, ponds/retention structures, or nothing into the watershed delineation process. If internal gages or ponds are selected, a dialog will open with a drop-down menu containing available point coverages. This dialog allows the

user to select point locations from a point theme in the view. To select the points, first select the point theme and then click the selection tool button in the lower left hand corner of the dialog. This allows you to select gages/ponds by clicking directly on them while holding the SHIFT key, or by dragging a box around multiple points. The number of gages/ponds that has been selected is shown in the dialog box just to the left of the 'OK' button.

5. **Watershed Name** - Type the name of the watershed shapefile that you are creating, and then click 'Accept'. **Note that this name will be used for two shapefiles: watershed configuration, and streams. To distinguish these from other shapefiles in the view the letter 'w' will be added to the beginning of the watershed configuration, and the letter 's' will be added to the streams.
6. **Contributing Area Threshold Values** - This step tells AGWA the contributing source area (CSA) that is required before flow becomes channelized. Smaller numbers result in a larger number of smaller planes and visa versa, so the CSA is a measure of the geometric complexity at which the watershed is discretized. The default value is 2.5% of the watershed area, and has produced the best results in a preliminary analysis. A more detailed

investigation of and recommendations for appropriate CSA values is not yet complete. The CSA can be changed by entering a specific area (units of acres or hectares can be selected) or by entering a percentage of the watershed. Changing either one of these values causes the other to be updated, so it should be impossible to enter inconsistent values. Once the CSA value and units have been chosen click 'Accept' to proceed.

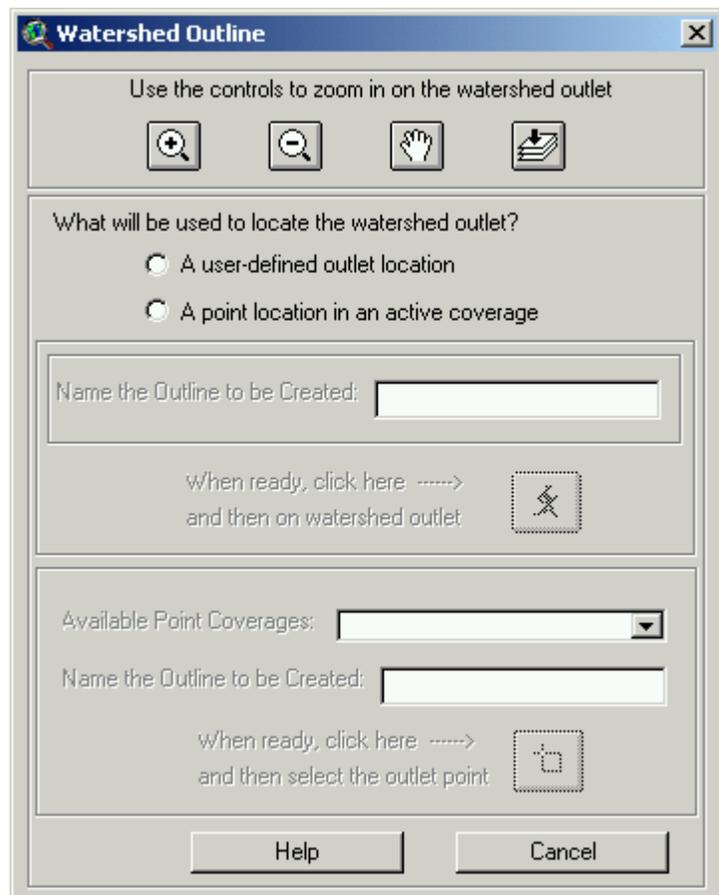
7. **Model Selection** - At this point you must choose which model you intend to develop the parameter file for: KINEROS, or SWAT. It is important to note that the watershed shapefile you create is specific to the model you choose; a separate watershed shapefile will have to be created to run the other model. Once the model is selected click 'Process' to generate the watershed shapefile.

Stream2500 Grid

The stream2500 grid is a theme containing all of the streams for a specific DEM. It is created by selecting all cells from the flow accumulation grid with values greater than 2500. In other words, it represents all cells in the DEM to which greater than 2500 upstream cells contribute runoff. The stream2500 grid is used to guide the user in selecting a watershed outlet during the delineation process. Since there may be more than one DEM used for watershed delineations within a view, the name of the DEM used to derive a particular stream2500 grid is written into its comments, which can be viewed by clicking the 'Theme' menu and then selecting 'Properties'. The stream2500 grid does not require any attention from the user, and may be deleted with no consequence if desired.

11.1 Watershed Outline

The Watershed Outline window is designed to allow the user to designate the location of the watershed outlet. The first step is to select either a user-defined watershed outlet location, or a location in an active point coverage. The point location can come from any active point coverage or shapefile, allowing the user to place the watershed outlet at known locations. If no such coverage exists, then choose the 'user-defined outlet location' option. Depending on the option selected, enter the name of the outline to be created or select the point coverage that contains the desired point location and enter the name of the outline to be created. Proceed to selecting the outlet location by clicking

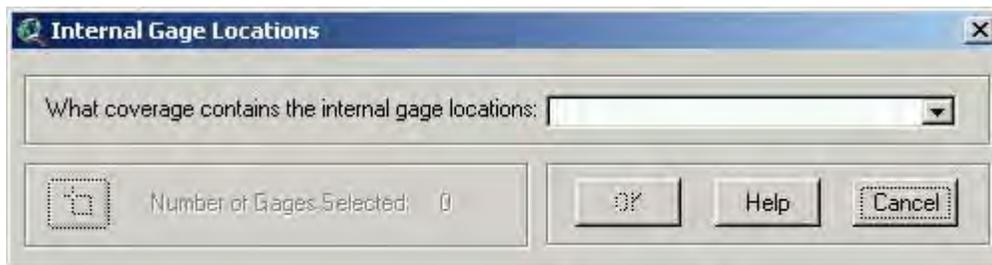


on the appropriate button after choosing an outline name.

** Remember that the buttons at the top of the window provide the functionality to pan and zoom within the view.

11.2 Internal Gauges

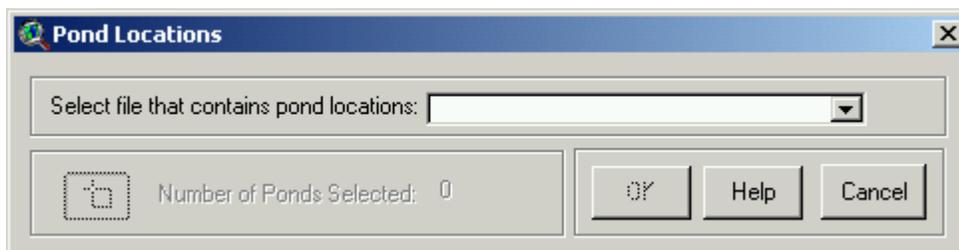
When internal gauges are used in the watershed discretization process the watershed map will be split at those locations where gauges are present. This makes it possible to compare measured and computed discharge at a point or series of points. It can also be useful in designing check dams or other retention structures. Although the capacity to introduce these structures within AGWA is not presently available, KINEROS2 can accommodate them if provided with an outflow rating curve. Input requirements for retention structures (pond elements) in KINEROS2 are straightforward - more information can be found at: <http://www.tucson.ars.ag.gov/kineros/>



** Please note that if a gauge point location is more than 100 map units (usually meters) from a channel created based on the contributing area threshold (CSA) value you entered for the discretization then AGWA will ask if you would like to proceed without that point or if you would like to stop and edit the point theme. Gauges located within this 100 meter radius of a channel will be snapped onto the channel if not exactly on it already. Additionally, having gauges in close proximity to one another is a known cause of problems with the watershed discretization. Please see the [Troubleshooting](#) section for more information.

11.3 Ponds

When ponds are used in the watershed discretization process...



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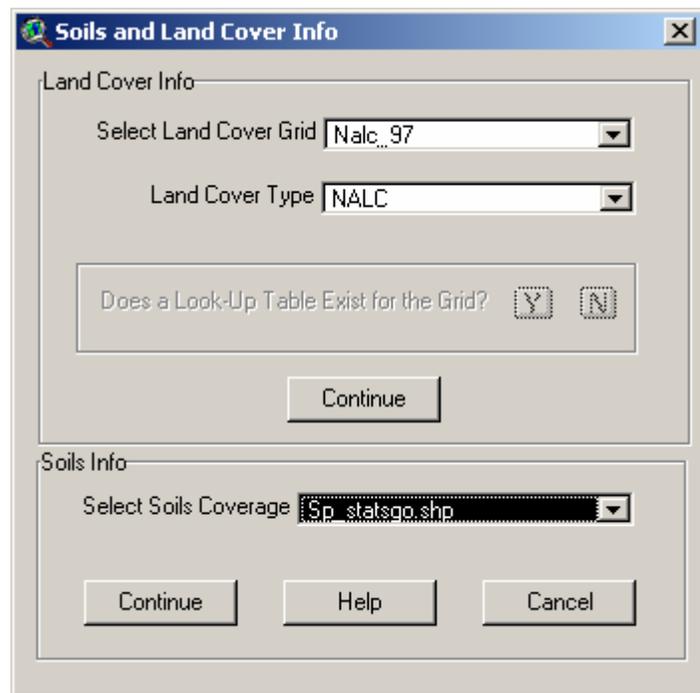
Landcover and Soils Parameterization

Before running the KINEROS or SWAT models on your AGWA watershed, hydrologic parameters must be derived from the landcover and soil data and added to the attribute data of the watershed. To do this, select "Run Landcover and Soils Parameterization"

from the AGWA tools menu. This will bring up a window asking which watershed theme you wish to use. The land cover and soils parameterization routine is not specific to either KINEROS or SWAT, but will add different parameters to the watershed theme attribute table depending on which model was selected during the watershed discretization.



Once a watershed theme is selected, the 'Soils and Land Cover Info' window will open. Select the landcover grid to be used in the simulation from the pull-down menu. Then select the land cover type, whether it is NALC, MRLC, New York, or User-Defined. At this writing these are the only three land cover data types for which look-up tables have been created, but the option to create user-defined look-up tables is available in AGWA versions 1.32 and later. The available data types for which lookup tables have been created (NALC, MRLC/NLCD, and NY) are described in more detail in the [Data Requirements](#) section of the manual. Using the 'User-Defined' option is described in more detail below.



Once a data type has been selected, click 'Continue' to enable the 'Select Soils Coverage' drop-down menu. This menu is populated with all coverages and shapefiles for which attribute data contain the fields 'MUIR' (SSURGO Soils, KINEROS only) or 'MUID' (STATSGO Soils). AGWA knows which of the two soil data types (STATSGO or SSURGO) has been selected based on the presence of one of these fields, and will prompt the user for additional information if necessary. Click 'Continue' once a soil theme has been selected.

** If no coverages show up in this drop-down menu then it is most likely because a soils theme (with one of these field names in the feature attribute table) has not yet been added to the view. Should this happen simply click 'Cancel', add the data to the view, and then rerun 'Landcover and Soils Parameterization' from the AGWA Tools menu.

** SSURGO soil weighting is NOT available for SWAT

12.1 STATSGO Soil Weighting for KINEROS

The following section outlines the logic used in deriving hydrologic parameters for input into KINEROS based on the STATSGO soils data. The process is designed such that the relationship between soil texture and associated hydrologic parameter values can be manipulated by the user if it is deemed necessary. To make this relationship as transparent as possible the parameter values associated with each soil texture are provided in the form of an editable look-up table (Table 12.1, kin_lut.dbf) that is referenced when soil properties are weighted for each model element.

To get an average value for each of the KINEROS input parameters on each model element AGWA performs both depth and area weighting of texture properties. To explain this process it is prudent to first convey how STATSGO stores soil texture information. STATSGO soil types are uniquely distinguished by an MUID (map unit ID) field or identifier. When downloading STATSGO data from the web you obtain a simple shapefile with polygons, each characterized by a single MUID. For each MUID, however, there are predefined *components* that describe the spatial variation within a particular soil type. For instance, there may be 3 components associated with MUID = AZ061 (see figure below). Each component makes up a certain percentage of the larger soil type (MUID), and the component percentages necessarily sum to 1. Component information for each MUID is stored in a file called 'comp.dbf'. Since MUIDs vary from state to state AGWA stores a separate comp.dbf file in each of the state subdirectories of the 'datafiles' directory. These are provided with AGWA for all 50 U.S. states.

To account for soil variability with depth each MUID component can have multiple layers. For KINEROS, AGWA is primarily concerned with the uppermost 9 inches of soil because of its dominant influence on event runoff. As a result, parameter values associated with soil textures within the uppermost 9 inches of a component soil must be weighted by depth/thickness to get an average value. Layer information for each component is stored in a file called 'layer.dbf', and again these are organized by state and provided in the AGWA 'datafiles' directory.

Following the example pictured below, a single set of parameter values for MUID AZ061 is found by:

1. Depth weighting values for each layer to get a single set of values for each component
2. Area weighting values from each component to get the average parameter set for each MUID

Average parameter sets for each MUID are written to a table that is added to the project and named temp_kin_soil_lut.dbf. The final step in the soil weighting process involves using the intersection (soil and watershed) theme to determine the MUID makeup of each watershed element. If more than one MUID type intersects a watershed element (plane), then the percent presence of each MUID in the element is used to derive an area-weighted average of the MUID average values in temp_kin_soil_lut.dbf for each model element (not shown in Figure 12.1). These values are then written to the attribute table for the watershed theme.

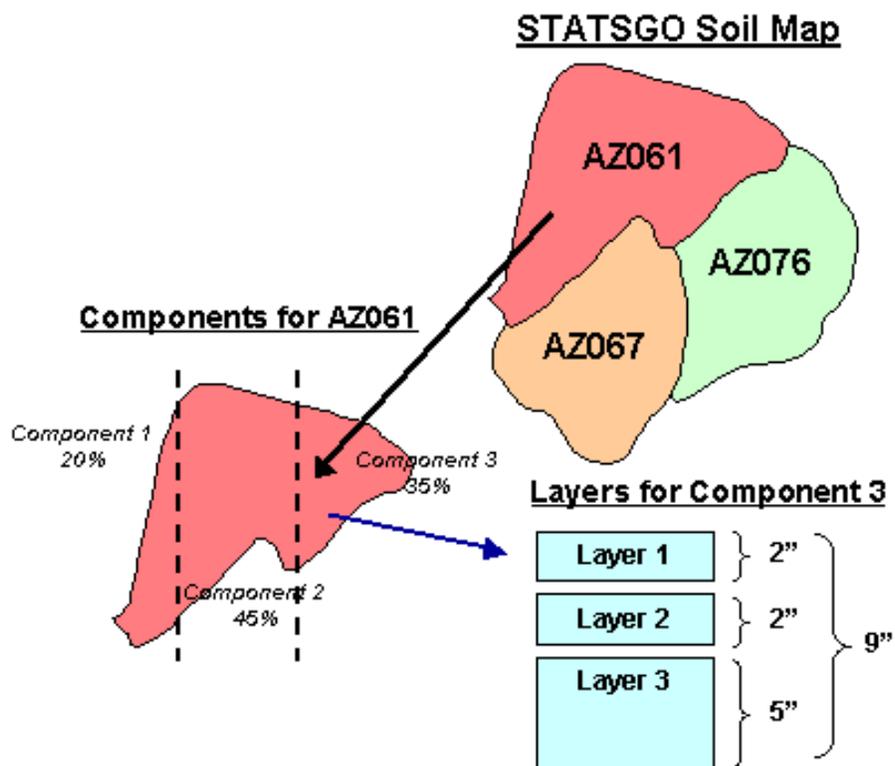


Figure 12.1 AGWA soil weighting procedure for KINEROS.

Table 12.1 The STATSGO/SSURGO soil look up table that relates soil texture to model input parameter values. This table is provided with AGWA in the 'datafiles' directory, and is called kin_lut.dbf.

Texture	Ks	G	Por	Smax	Cv	Sand	Silt	Clay	Dist	Kff
C	0.60	407.0	0.48	0.81	0.50	27.00	23.000	50.00	0.160	0.34
CBV	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.050
CEM	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.280
CIND	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.020
CL	2.30	259.0	0.46	0.84	0.94	32.00	34.00	34.00	0.240	0.390
COS	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.150
COSL	26.0	127.0	0.45	0.91	1.90	65.00	23.00	12.00	0.380	0.240
FB	0.60	407.0	0.48	0.81	0.50	27.00	23.00	50.00	0.160	0.050
FRAG	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.050
FS	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.200
FSL	26.00	127.0	0.45	0.91	1.90	65.00	23.00	12.00	0.380	0.350
G	210.0	46.0	0.44	0.95	0.69	27.00	23.00	50.00	0.160	0.150
GYP	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.050
HM	0.60	407.0	0.48	0.81	0.50	27.00	23.00	50.00	0.160	0.020
ICE	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
IND	0.30	100.0	0.20	0.30	0.20	0.000	0.000	0.000	0.000	0.250
L	13.0	108.0	0.46	0.94	0.40	42.00	39.00	19.00	0.250	0.420
LCOS	61.0	63.0	0.44	0.92	0.85	83.00	7.000	10.00	0.550	0.180
LFS	61.0	63.0	0.44	0.92	0.85	83.00	7.000	10.00	0.550	0.250
LS	61.0	63.0	0.44	0.92	0.85	83.00	7.000	10.00	0.550	0.230

LVFS	61.0	63.0	0.44	0.92	0.85	83.00	7.000	10.00	0.550	0.440
MUCK	0.60	407.0	0.48	0.81	0.50	27.00	23.00	50.00	0.160	0.020
PEAT	0.60	407.0	0.48	0.81	0.50	27.00	23.00	50.00	0.160	0.020
S	210.0	46.0	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.180
SC	1.20	302.0	0.43	0.75	1.00	50.00	4.000	46.00	0.340	0.360
SCL	4.30	263.0	0.40	0.83	0.60	59.00	11.00	30.00	0.400	0.360
SI	3.00	260.0	0.45	0.92	0.55	8.000	81.00	11.00	0.130	0.430
SIC	0.90	375.0	0.48	0.88	0.92	9.000	45.00	46.00	0.150	0.310
SICL	1.50	345.0	0.47	0.92	0.48	12.00	54.00	34.00	0.180	0.400
SIL	6.80	203.0	0.50	0.97	0.50	23.00	61.00	16.00	0.230	0.490
SL	26.0	127.0	0.45	0.91	1.90	65.00	23.00	12.00	0.380	0.320
SR	26.0	127.0	0.45	0.91	1.90	65.00	23.00	12.00	0.380	0.330
UWB	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.020
VAR	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.550
VFS	210.0	46.00	0.44	0.95	0.69	91.00	1.000	8.000	0.690	0.460
VFSL	26.00	127.0	0.45	0.91	1.90	65.00	23.00	12.00	0.380	0.500
WB	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.020
MPT	0.60	407.0	0.48	0.81	0.50	27.00	23.00	50.00	0.160	0.020

Origins of and Modifications to Look-Up Parameters

The parameters in the kin_lut.dbf file are derived from the KINEROS Documentation and User's Manual (Woolhiser et al., 1990) and Rawls et al. (1982). USLE soil erodibility factor, Kff, values in kin_lut.dbf were derived by averaging STATSGO values for the soil textures in Arizona and Nevada. The values in kin_lut.dbf, however, are used only when the STATSGO tables have no data or report a zero value for particular soil. Our assumption here is that all non-indurated soils are erodible.

The USLE soil erodibility factor is not a KINEROS input parameter, but it is used in AGWA to compute the rainsplash and hydraulic erosion coefficients following the methodologies laid out in Woolhiser (1990):

- Reduction factor for splash = 80% (20% reduction)
- Reduction factor for cohesion = 50%

$$c_f = 422 * Kff * 0.80$$

if ($f_{cl} \leq 0.22$) then

$$c_g = 5.6 * Kff / (188 - 468 * f_{cl} + 907 * f_{cl}^2) * 0.5$$

else

$$c_g = 5.6 * Kff / 130 * 0.5$$

end

where f_{cl} is the fractional clay content, c_f is the rainsplash coefficient, and c_g is the hydraulic erosion coefficient.

Saturated hydraulic conductivity, Ks, is modified to account for rock in the soil. Rock is calculated using the Goodrich dissertation approach and based on Bouwer and Rice (1984).

$$(1 - Porosity) * (1 - Void Ratio)$$

$$1 - Porosity * (1 - Void Ratio)$$

where porosity = $(2.65 - \text{bulk density}) / 2.65$; and void ratio = inverse of STATSGO rock estimate. The STATSGO rock estimate is equal to the percent retained by the number 10 sieve. K_s is modified to get effective K_s by:

$$K_{se} = K_s * \text{rock}$$

12.2 STATSGO Soil Weighting for SWAT

The SWAT model requires that each subwatershed be characterized according to its hydrologic soil group and saturated hydraulic conductivity (K_s). The hydrologic soil group value (A, B, C, or D) is extracted for each component within a given soil map unit (MUID) and converted to a numeric value (i.e. A = 1, B = 2, C = 3, D = 4). Values are then area-weighted to derive a single estimated value for each MUID as the area-weighted average of the values from each component soil type in the map unit.

Estimated values for K_s are derived from the AGWA soils look-up table (kin_lut.dbf, Table 12.1) based on soil texture in layer 1 of each component soil type. This differs from the KINEROS procedure, in which soil parameters are depth weighted through the top 9 inches of each component soil profile. The K_s and hydrologic soil group weighting happens in the ws.statsgo.weighting.swat script.

Average values of K_s and hydrologic soil group are stored in a temporary database file called 'watershed name + _temp_swat_soil_lut.dbf' for each MUID that is present in the watershed. This table is then accessed to do the second area weighting that averages parameters from each MUID in a subwatershed. Calculated average values are written to the attribute table of the watershed theme. Also at this time, AGWA identifies the dominant soil type (MUID) in each subwatershed and writes it to the attribute table. This happens in the ws.soil.process.swat script.

In addition to the soil-derived parameters added to the watershed attribute table, there are several additional parameters derived from the STATSGO data that ultimately go directly into the SWAT input soil (.sol) file for each subwatershed. These include:

- USLE K Factor (K_{ff} in STATSGO)
- Saturated hydraulic conductivity
- Bulk density
- Available water capacity
- Organic carbon content
- Percent clay
- Percent silt
- Percent sand
- Percent rock (>3mm) by weight
- Layer thickness

These parameters are derived entirely from the STATSGO tables (as opposed to the AGWA look-up table, kin_lut.dbf), and weighted according to a different scheme than the other

parameters because our objective with these is to describe an average soil profile for each MUID. To do this we select the first layer for all components in an MUID, and weight the above parameters according to the component percent to get average values for that layer. This process is repeated for up to 6 layers, if present, and the values are written into a file named 'watershed name + _soil_lut.dbf' in the ws.statsgo.weighting.swat script. This file name starts with the watershed name to ensure that AGWA will be able to find the file for a specific watershed when the user selects 'Write output and run SWAT'. This file added to the project tables, and stored in the project av_cwd directory. When writing the SWAT input files (ws.write.swat script), AGWA queries the *watershed_name_soil_lut.dbf* file based on dominant MUID from the watershed attribute table, and writes layer information to a soil (.sol) file for each subwatershed.

Modifications to Parameters

Since the STATSGO tables are sometimes missing data, three procedures are in place to ensure that appropriate values are obtained for the soil layer parameters.

- The sand, silt, and clay fractions are manipulated and normalized to ensure that they sum to 1.
 - If the record is just missing clay, then set clay to 0 and balance sand/silt
 - If the record is just missing silt, then set silt to 0 and balance sand/clay
 - If the record is missing both silt and clay, then set all three to 0
 - If the silt and clay fractions sum to greater than 1, then normalize them and set sand to 0
- If the USLE K factor (Kff in STATSGO) is 0 (i.e. non-erodible soil), then we obtain the Kff value from the AGWA look-up table *kin_lut.dbf* for that particular soil texture.
- All other missing values from the STATSGO tables are set to 0.

12.3 SSURGO Soil Weighting for KINEROS

SSURGO soil weighting for KINEROS follows basically the same procedure as the STATSGO soil weighting, with a few minor exceptions. SSURGO data is generally downloaded by county in zip files containing three directories: cov, shp, and tables. It does not matter where you store these directories on your computer, and you may add either the coverage or shapefile to your view for the soils parameterization. It is left up to the user, however, to make sure all of their data is in the same projection. In both the shp and cov directories there will be multiple data layers, most of which are not needed. Generally you want the data layer with the two-character state abbreviation, three-digit number, and '_a', e.g. AZ671_a. This should be visibly the obvious choice if you preview all of the layers.

To use SSURGO data in AGWA does not require any special steps or set up. Simply add the SSURGO data to your view just as you would for STATSGO data. AGWA recognizes these two types of soils data by the presence of a map unit ID field: MUID for STATSGO, and MUIR for SSURGO. All shapefiles/coverages that contain one of these fields will be added to your list of choices for soils data in the Soil and Land Cover Info dialog. AGWA will also know exactly which type of data has been selected based on this field name.

Once a SSURGO dataset has been selected you will be prompted to locate a file called comp.txt. This file is located in the 'tables' directory that came with your SSURGO data, so you will need to point to this directory to find it. Once you have pointed out the location of comp.txt, AGWA takes two additional files from that directory: chtexgrp.txt, and chorizon.txt. These three files are in a special format that cannot be easily read by standard database/spreadsheet software, so AGWA parses through each file, modifies illegal characters, and reads the text into ArcView database files. The files are written to the av_cwd directory, and added as tables to the project with the following names:

- SoilThemeName_comp.dbf
- SoilThemeName_hor.dbf
- SoilThemeName_tex.dbf

The horizon and texture database files are joined to create the equivalent of the STATSGO layer database file, and weighting proceeds according to the exact same methodology as described for STATSGO.

12.4 Landcover Parameterization

Hydrologic parameters are derived for each land-cover class using look-up tables with values derived from a combination of sources: Maidment (1993), Wollhiser et al. (1990), USDA-SCS (1986), and Rawls et al. (1982). Look-up tables for three pre-defined vegetation classification schemes are stored in the datafiles directory:

- nalc_lut.dbf
- mrlc_lut.dbf
- ny_lut.dbf

Values stored in the look-up tables include: CN, cover percent, interception depths, and Manning's roughness. SWAT requires CN and cover, whereas KINEROS requires cover, interception, and roughness (figure 12.1). Versions prior to 1.32 used the same values, but they were embedded in the AGWA scripts, and could not be easily viewed or manipulated.

Only one value for any give parameter can be assigned to a model element, regardless of model, so the weighting procedure is the same for both KINEROS and SWAT. The landcover grid is intersected with the watershed polygons using the Spatial Analysis command TabulateAreas. This results in the creation of a temporary database file called tarea.dbf (which you never see in AGWA unless you get an error). Within this file we can get the percentage makeup of each land-cover class in each watershed element. This percentage is used to weight values for the relevant hydrologic parameters taken from the landcover look-up table.

<i>Class</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>Cover</i>	<i>Int</i>	<i>N</i>
1	Forest	36	60	73	79	30	1.15	0.150
2	Oak Woodland	48	48	57	63	20	1.15	0.050
3	Mesquite Woodland	71	71	81	89	20	1.15	0.050
4	Grassland	49	69	79	84	25	2.00	0.150
5	Desert Scrub	63	77	85	88	25	3.00	0.055
6	Riparian	30	55	70	77	70	1.15	0.060
7	Agriculture	66	77	85	89	50	2.80	0.040
8	Urban	77	85	90	92	15	0.10	0.015
9	Water	100	100	100	100	0	0.00	0.000
10	Barren	90	92	94	96	0	0.00	0.035
11	Clouds	0	0	0	0	0	0.00	0.000

Figure 12.1. The look-up table for the NALC landcover classification scheme.

12.4 User-Defined Landcover Classification

Any land-cover classification scheme can be used with AGWA if the user supplies a properly formatted look-up table, such as the one shown in figure 12.1 (above). To develop a user-defined landcover look-up table we recommend that you start with the LC_lut.xls Excel workbook provided in the datafiles directory (or with the extension download). There are instructions in the 'Notes' worksheet in this file.

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13. KINEROS

The remaining steps required to run KINEROS through the AGWA interface include:

1. Generating the precipitation input file for the model run
2. Writing the input parameter file and running KINEROS
3. Viewing results, or the difference between results (optional)

Each of these is described in greater detail below.

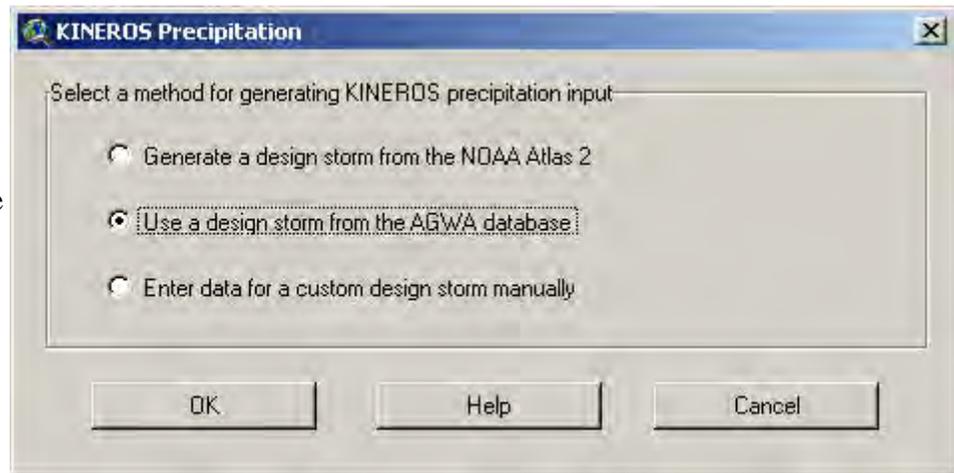
13.1 Writing precipitation files

AGWA can create uniform, single-gauge precipitation input files for KINEROS, but not multiple gauge input files. If data from multiple gages are available, KINEROS does have the ability to interpolate rainfall depths/intensities across the watershed,

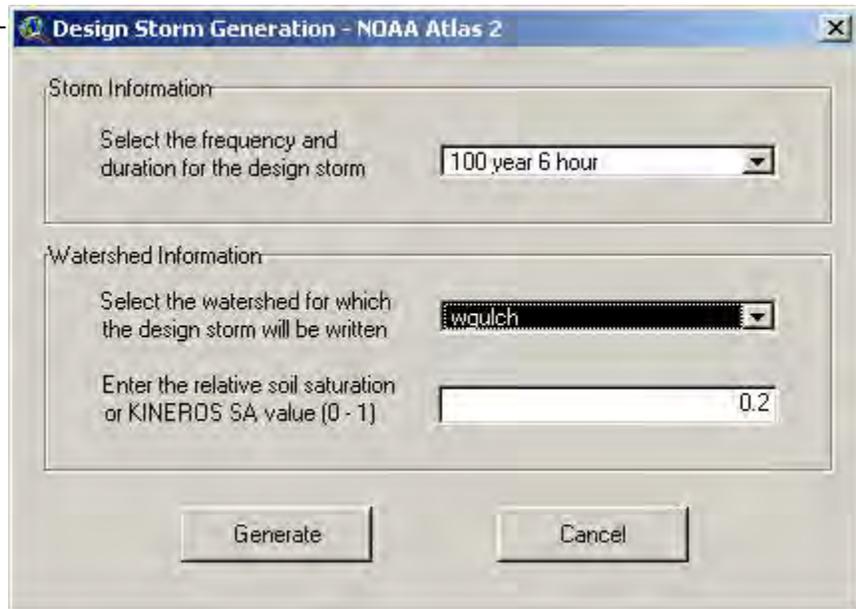
but the coding and user preparation necessary to synchronize gage time with event time for writing multiple-gage input files make this option impractical for implementation in AGWA. We have, however, provided a Perl script in the 'datafiles' directory that can help with this if very specific input data format requirements are met. The script is called `convert.pl`, and formatting requirements are contained within it. Methodologies for implementing radar data as an option for building KINEROS rainfall files in AGWA are currently being investigated.

After selecting 'Write KINEROS Precipitation File' from the AGWA tools menu, the 'KINEROS Precipitation' window pops up and offers three methods that can be used to generate uniform precipitation (design storm) input files. As shown in the figure to the right, these include: NOAA Atlas 2, the AGWA design storm database, and manually-entered design storms.

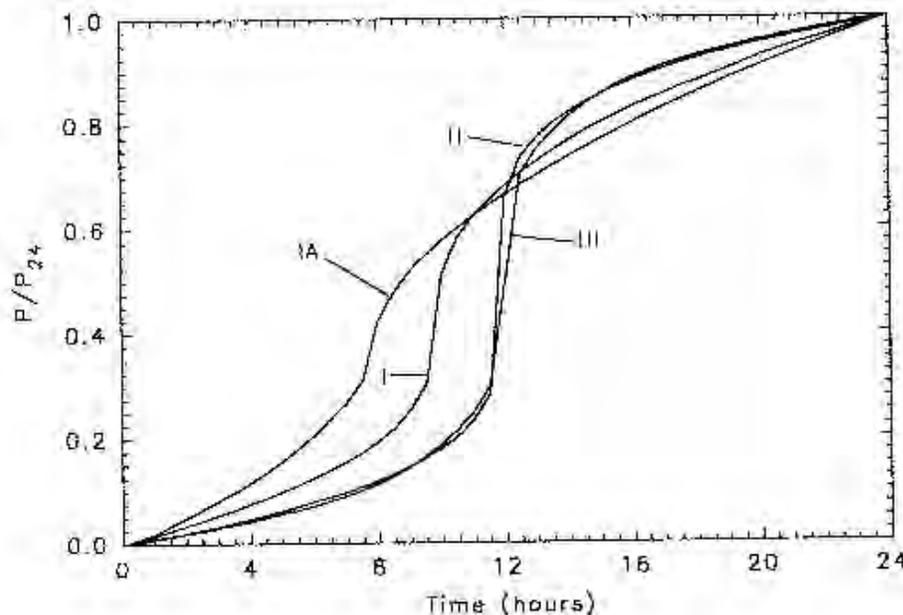
All three methodologies require the specification of a relative soil saturation value for the onset of the storm. This is equivalent to the KINEROS SA parameter and can vary between 0 and 1. See <http://www.tucson.ars.ag.gov/kineros/> for more information.



NOAA Atlas 2 - Precipitation-frequency maps for 6-hour and 24-hour events with return periods from 2 to 100 years for the 11 Western states. Currently only the 6-hour storms with return periods of 2 and 100 years have been converted into GIS rasters by NOAA, and these are provided with AGWA. Once completed, AGWA users will be able to download and use the remaining maps from this series.



AGWA takes the watershed centroid and punches it through the NOAA grid to get the storm total depth value. The depth value is converted to a hyetograph using the SCS methodology (SCS, 1973) and a type II distribution. The type II distribution and several others are shown in the figure below. The type II distribution is appropriate for deriving the time distribution of rainfall for most of the country, as shown in the map below (SCS, 1986). For the 11 Western states where rainfall data are available, the entire interior West is characterized by the type II curve.





AGWA Database - A growing database of return period storms called dsgnstrm.dbf (shown below) is available in the 'datafiles' directory provided with AGWA. Return period depths are available only for select locations for which we have been able to find data, and the range of available return periods and durations varies as a result. The location and frequency/duration are selected in the window shown to the right. Again, the SCS methodology and a type II distribution are used to convert the return period depths to hyetographs.

The AGWA Database can be edited by the user to add data for additional locations, return periods, and/or durations. Simply open the table and select 'Start Editing' from the 'Table' menu. To add a new record (row), select 'Add Record' from the 'Edit' menu. To modify an existing value, click on the 'Edit' button on the lower half of the toolbar and then click on the cell that you want to change. If you have return period depths for your area and think that other AGWA users might benefit from them, please e-mail them to us at agwa@tucson.ars.ag.gov.

Locid	Frequency	Duration	Depth
ClarkCountyLV	100	3.00	2.48
ClarkCountyLV	100	6.00	2.77
ClarkCountyLV	100	24.00	2.96
San Pedro	5	0.50	0.68
San Pedro	5	1.00	1.07
San Pedro	10	0.50	1.16
San Pedro	10	1.00	1.35
San Pedro	100	0.50	1.71
San Pedro	100	1.00	2.04

At this writing only the San Pedro data can be reduced as a function of watershed size. For these data the reduction factor is computed using the Osborn et al. (1980) method for thunderstorms in the southwestern United States. This functionality is presently embedded directly in the script `ws.dsgnstrm2.generate`, and can be easily modified to allow for

other methods if we are made aware of them (write to agwa@tucson.ars.ag.gov).

User-Defined Storms - If a design storm database file does not exist but there are only one or two design storm data sets that must be run, then that data can be entered manually through the 'User-Defined (Design) Storm' dialog (shown on the right). This dialog is generally divided into two parts: file information, and data. File information includes an (optional) text header with information about the precipitation event you are writing to the file, the watershed (soil) saturation index (see [KINEROS2](#) documentation for more information), the units for your data, and the number of time-depth/intensity pairs that you would like to enter. Don't forget that the first "Time" must be 0, and the last "Time" must be equal to the duration of the design storm.

Storm Description - comments to be included in *.pre file header (optional):

** AGWA does not apply an area reduction factor to these data.

Watershed Saturation Index (0 - 1):

Select whether you have rainfall intensity or depth data:

Intensity (mm/hr) Depth (mm)

Enter the number of time - depth/intensity pairs, including time 0:

Proceed Quit if a baby

Double click on cells to edit...

Number	Time	Depth
1	0.0	0.00
2	5.0	2.00
3	15.0	8.00

Write to .pre file Cancel

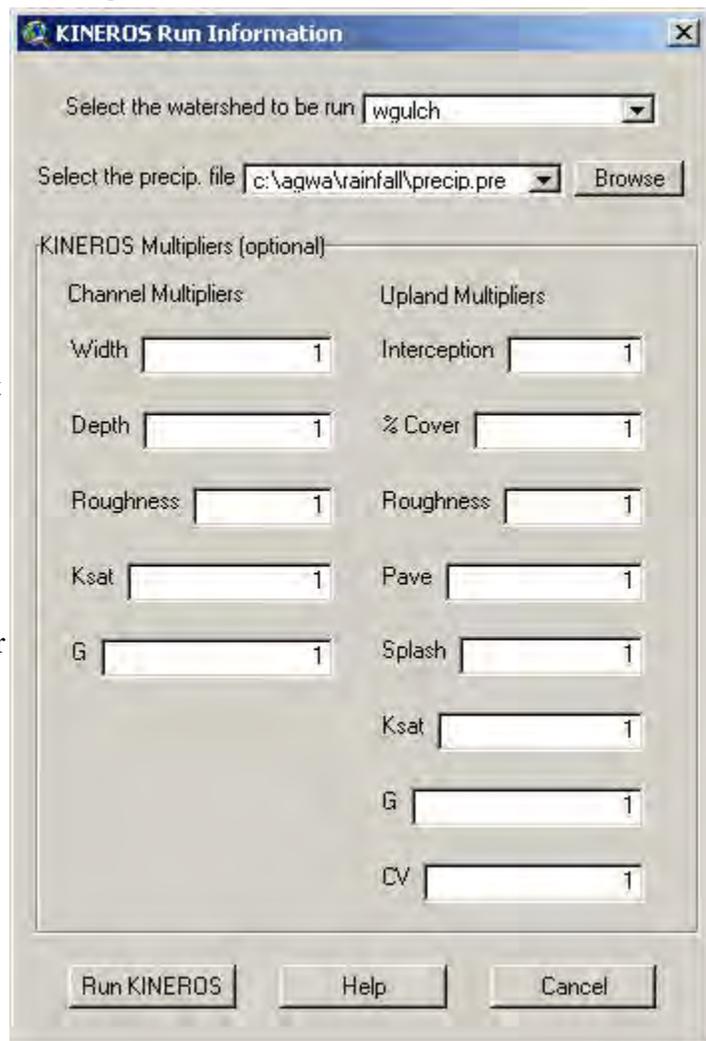
Once the file information is complete and the 'Proceed' button is clicked the list box for data entry in the lower portion of the dialog becomes active with the appropriate number of rows. There will only be three columns, the first is the record number (do not change these values), the second is the time (minutes), and the third is the depth/intensity (mm or mm/hr). To enter values either double click the appropriate cell or highlight it and then hit 'Enter' on the keyboard. This will pop up a window into which the value may be typed. Hit 'Enter' or click okay when the value is entered. When the data entry is complete click the 'Write to .pre file' button at the bottom to generate the input precipitation file for KINEROS.

13.2 Writing the output file and running KINEROS

Once the watershed has been delineated, intersected with soil and land cover data, and a precipitation file has been prepared, you are ready to run KINEROS. Select "Write Output File and Run KINEROS" from the AGWA Tools menu. This opens the 'KINEROS Run Information' window shown to the right. Begin by selecting the watershed you would like to work with. Then select the precipitation (*.pre) file from those within the project 'rainfall' directory (automatic) or browse to a file in another location.

KINEROS multipliers are an optional means of adjusting parameter values prior to running the model. Parameter values for each of the listed parameters are multiplied by the value in the corresponding text box when writing the KINEROS input file. This does NOT modify the original values that are listed in the watershed and stream channel shapefiles (themes).

If you have designated the system environmental variable 'AGWA', then you will not be prompted to locate the KINEROS executable. Otherwise, if KINEROS has not been run since ArcView was opened you will be prompted to point out its location to AGWA - this step will not be required again until the next time you exit and restart ArcView. You will then be prompted to select the watershed theme and select name and location for the KINEROS input parameter (*.par) file. The KINEROS output (*.out) file will automatically be given the

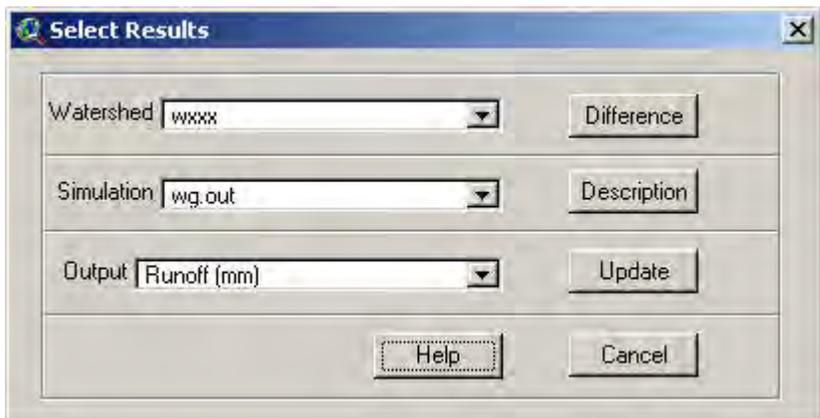


same name and written to the same location as the parameter file. AGWA will then ask for a specific precipitation (*.pre) file to be used in the model run. Once this is selected AGWA will open an MS-DOS window and run KINEROS. When the run is complete AGWA will retrieve the results from the KINEROS output file and import them into ArcView in the form of 2 database files: pxxxx.out and cxxxx.out. The 'xxxx' in these file names represents the 4-character basin identifier entered previously. The 'p' indicates to AGWA that the results are for planar watershed elements, and the 'c' indicates that the results are for stream channels. Both of these files will be visible in the 'Tables' module of ArcView.



13.3 Viewing results

To view the KINEROS results, select 'View KINEROS Results' from the AGWA Tools menu. This brings up the 'Select Results' window, which provides the functionality to view results in two different ways: individually, or as the difference between two simulations.

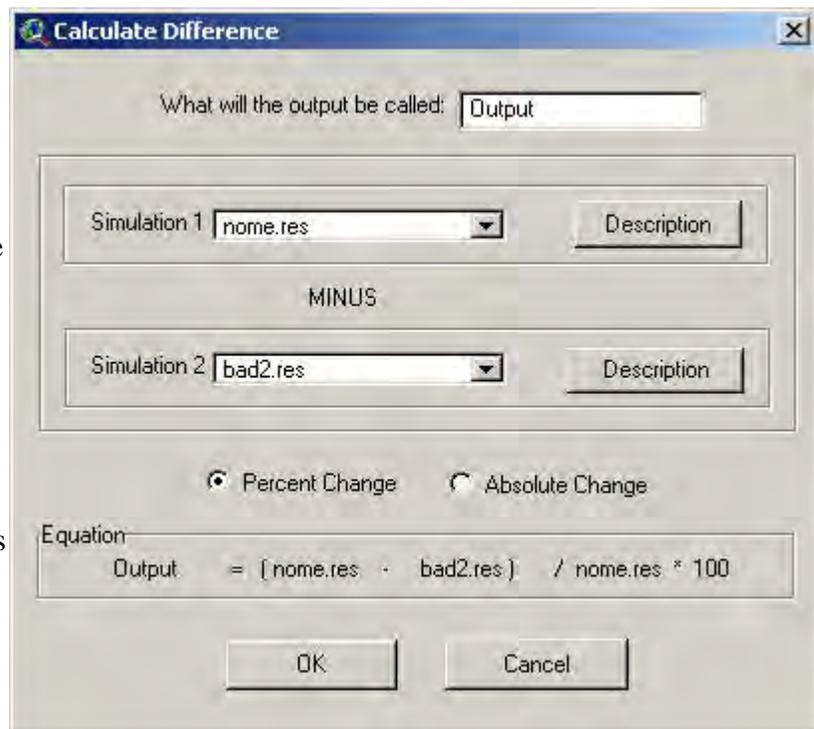


To view results from a single model run select the watershed in the 'Select Results' window. Once a watershed is selected the simulation drop-down menu will become active and you can select from the simulation(s) that have been run for that watershed. When a simulation has been selected the 'Description' button becomes active and can provide a reminder of the specific data used in that simulation - this can be particularly valuable if multiple simulations have been run.



The final step in viewing the results of a simulation involves selecting the output parameter that you wish to be displayed in the View. There are seven choices: infiltration (mm), runoff (mm), runoff (m³), sediment yield (kg/ha), peakflow (m³/s), peakflow (mm/hr), and peak sediment discharge (kg/s). When one of the output parameters is selected click the 'Update' button; the watershed and stream coverages will be updated in the View and Legend with the new parameter and a pre-defined color scheme. Viewing results from an individual plane or channel can be accomplished by selecting the appropriate theme in the Legend, selecting the 'Identity' button on the toolbar, and then clicking on the desired feature.

To view results as a difference between two simulations, for instance when two different land cover or precipitation files have been used, click the 'Difference' button once the watershed has been selected. This brings up the 'Calculate Difference' window, which enables the user to select the two simulations, compute the difference between them, and save this output as a new simulation result that can be viewed in the same manner described previously. The user is given the opportunity to report the difference between the two simulations in terms of the percent change or the absolute

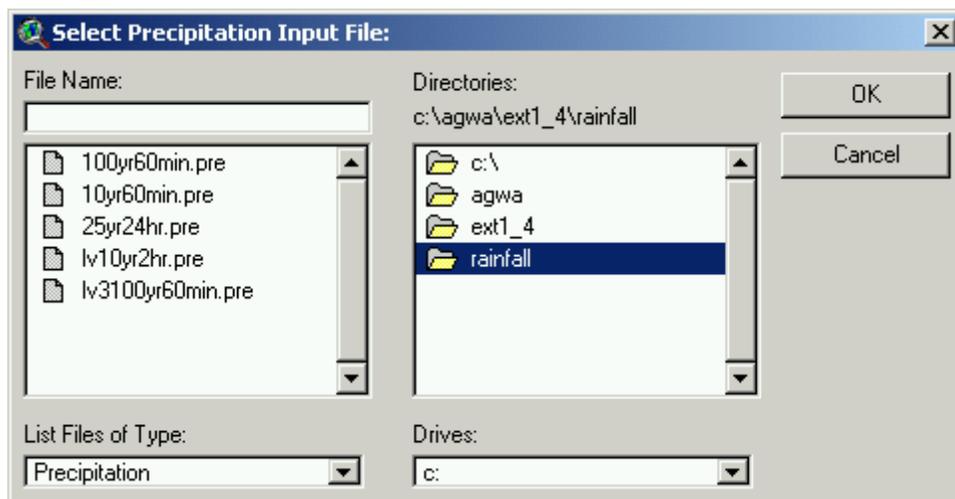
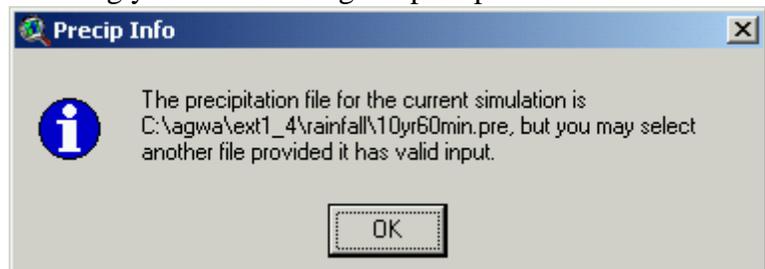


change, and the formula used in the calculation is shown at the bottom of the window. The calculated difference is written to two new database files (one for the planes and one for the channels, as described above) with the name entered at the top of the 'Calculate Difference' window. For example, if the calculated difference is to be called 'Output', then pOutput.res and cOutput.res will be created and added to the project tables.

After clicking OK at the bottom of the Calculate Difference window, the name you selected for your output will show up as a simulation result in the Select Results window that can be selected and viewed just as any other.

13.4 Rerunning existing simulations

To rerun an existing KINEROS simulation, select 'Rerun Existing Simulation' from the KINEROS section of the AGWA Tools menu. This brings up the 'Rerun Simulations' window where you select the watershed that contains the simulation to rerun. With the watershed selected, the watershed 'Description' button and 'Simulations' drop-down menu become enabled, allowing you to view a description of the selected watershed and to select a simulation to rerun. Once a simulation to rerun is selected, the simulation 'Description' button and 'Rerun' button become enabled, allowing you to view the simulation description and initiate the rerun. After clicking 'Rerun' you are presented with message box informing you what the original precipitation file was. At this point, you may choose to use the original precipitation file or select another through the 'Select Precipitation Input File:' dialog. Once a file is selected and 'OK' is clicked, the KINEROS simulation is rerun.



The rerunning of simulations is provided to enhance the functionality of KINEROS in AGWA. It gives users the ability to modify the input files for KINEROS to alter the results of the simulation. The original simulation results are maintained so that results between the original and rerun can be compared. AGWA relies on the user's ability to edit the input files correctly and assumes that if the files necessary to run the simulation are in place, then they have the correct formatting required by KINEROS.

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14. SWAT

Once the SWAT-specific watershed configuration has been created and intersected with soil and land cover data, as described above, two additional tasks must be performed before results can be viewed through the AGWA interface:

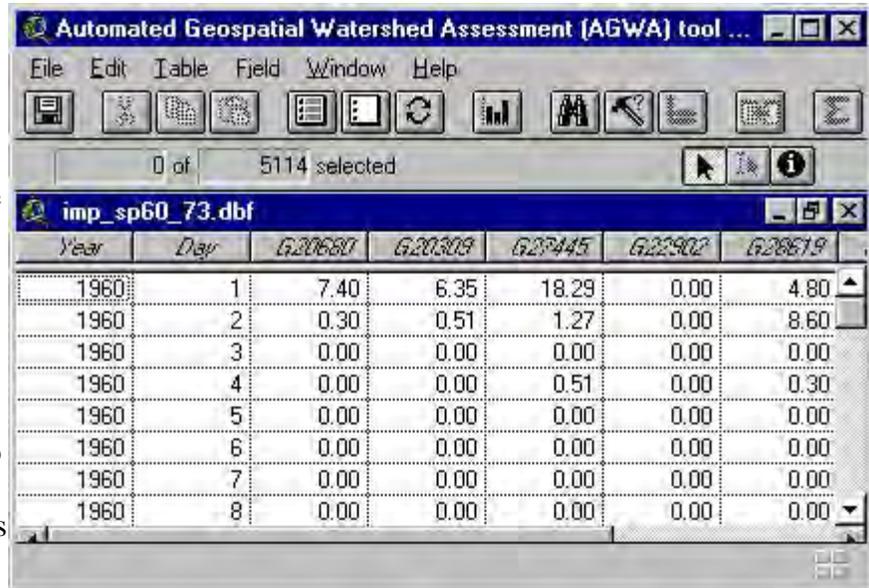
1. Generating the precipitation input file for the model run
2. Writing the input parameter file and running SWAT

There are two options for creating precipitation files for SWAT: uniform rainfall, or distributed rainfall.

Uniform rainfall is taken from one gage (closest to the center of the watershed), whereas distributed rainfall is derived from multiple gages and relies on a Thiessen weighting technique to assign appropriate rainfall depths to the various subwatersheds.

At this writing, both methods *require that the user create an unweighted precipitation*

database file (example shown on the right) consisting of a minimum of three fields: year, day, and gage precipitation. The year field must contain a 4-digit year in every record. The day field represents day of year (1-366), and should repeat for each year in the file. The gage field(s) contain average daily precipitation in *millimeters* for the gage listed in the field header row. Missing data can be accommodated through a weighting scheme described below. Any negative precipitation depths are interpreted to represent missing data (no data).



The screenshot shows the AGWA tool interface with a data table titled 'imp_sp60_73.dbf'. The table has columns for Year, Day, and five gage IDs: G20680, G20309, G20445, G22902, and G26619. The data rows show precipitation values in millimeters for the year 1960, days 1 through 8.

Year	Day	G20680	G20309	G20445	G22902	G26619
1960	1	7.40	6.35	18.29	0.00	4.80
1960	2	0.30	0.51	1.27	0.00	8.60
1960	3	0.00	0.00	0.00	0.00	0.00
1960	4	0.00	0.00	0.51	0.00	0.30
1960	5	0.00	0.00	0.00	0.00	0.00
1960	6	0.00	0.00	0.00	0.00	0.00
1960	7	0.00	0.00	0.00	0.00	0.00
1960	8	0.00	0.00	0.00	0.00	0.00

**** Note that the gage field names MUST have two important attributes:**

- Gage field names must always begin with 'G' so that AGWA can recognize them as gages.
- The gage ID must follow the letter 'G', and this ID must correspond with the gage ID in the rain gage point theme in your project. If this is not the case AGWA will be unable to find the appropriate gages.

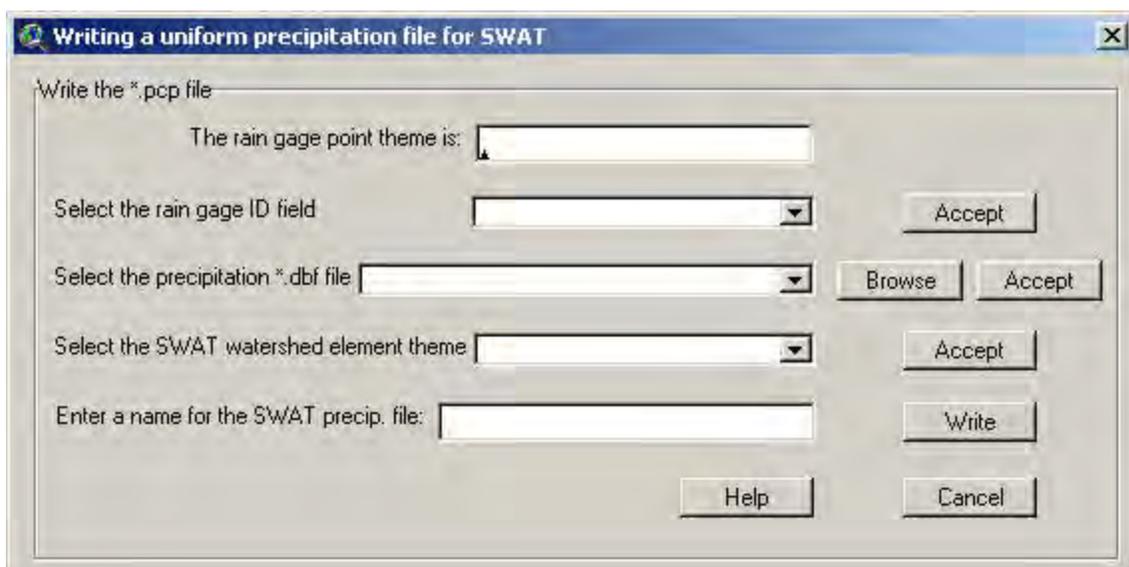
No limit has been placed on the number of gages that may be included in the unweighted precipitation file, but beware that the more gages it contains the longer it will take to generate the distributed precipitation input files for SWAT.

Also prior to writing the SWAT precipitation file, a rain gage point theme must be added to the view. The decision to generate uniform versus distributed precipitation files is governed by the number of gages in this theme. If there are three or more gages in the theme you will be routed to the Thiessen weighting window for distributed rainfall, and if there are less than three gages then you will be routed to the uniform precipitation window.

Regardless of whether a uniform or distributed rainfall file is generated, AGWA creates and maintains a record of each unique combination of watershed configuration and precipitation file. These are stored in a secondary table called swatpptfiles.dbf, which is added to the list of tables in the project and stored in the rainfall directory. For each unique combination the location of the precipitation file, and its start and end dates are written to the swatpptfiles.dbf file. This enables AGWA to ensure that the user does not accidentally use the wrong precipitation file for a given watershed configuration, or enter incorrect dates for a simulation. It also, however, requires that the locations where precipitation files are stored do not change once they have been created, so take care to ensure they are written to the correct directory.

14.1 Uniform Rainfall

If the rain gage point theme has less than three gages (points, or records) then you will automatically be routed to the uniform rainfall window, 'Writing the SWAT precipitation file'. The first information required in this window is the rain gage ID field from the point theme. Next, the location of the unweighted precipitation file must be entered. When 'Accept' is clicked after these first two tasks AGWA checks to make sure that at least one gage from the point theme corresponds to a gage in the unweighted precipitation file. Next, the SWAT watershed element theme must be selected so that AGWA can compute which gage is closest to the centroid of the watershed if there are two gages available. Finally, the user must enter a name for the SWAT precipitation file that will be generated. When the 'Write' button is clicked the *.pcp file will be written to the 'rainfall' subdirectory of the project directory.



The screenshot shows a dialog box titled "Writing a uniform precipitation file for SWAT". The dialog box contains the following fields and buttons:

- A text field labeled "The rain gage point theme is:" with a dropdown arrow.
- A dropdown menu labeled "Select the rain gage ID field" with a dropdown arrow.
- A text field labeled "Select the precipitation *.dbf file" with a dropdown arrow.
- A dropdown menu labeled "Select the SWAT watershed element theme" with a dropdown arrow.
- A text field labeled "Enter a name for the SWAT precip. file:".

Buttons are located on the right side of the dialog box:

- An "Accept" button next to the "Select the rain gage ID field" dropdown.
- "Browse" and "Accept" buttons next to the "Select the precipitation *.dbf file" dropdown.
- An "Accept" button next to the "Select the SWAT watershed element theme" dropdown.
- A "Write" button next to the "Enter a name for the SWAT precip. file:" text field.
- "Help" and "Cancel" buttons at the bottom center of the dialog box.

Missing data values in the unweighted precipitation file provided by the user (again interpreted to be any negative precipitation depths) are automatically converted to zero depth when the SWAT *.pcp file is written.

14.2 Distributed Rainfall

If three or more gages exist in the rain gage point theme then you are automatically routed to the distributed rainfall window 'Thiessen Precipitation Weighting'. Three tasks are required to generate a distributed rainfall file:

1. Creating a Thiessen polygon theme from the rain gage point theme
2. Intersecting the Thiessen polygon theme with the watershed configuration
3. Computing the weighted precipitation depth for each subwatershed and writing it to the SWAT precipitation file.

The 'Thiessen Precipitation Weighting' window (next page) is organized according to these same three tasks. In the event that one of the first two tasks has already been completed during an earlier model run, one or both of the first two may be skipped by selecting the appropriate radio button at the beginning of their sections.

During the creation of the Thiessen polygon theme AGWA checks to make sure that polygons are not created for gages in the rain gage point theme for which no data exist in the unweighted precipitation file supplied by the user. If a discrepancy is found and there are more gages in the point theme than the database file, then AGWA will pop up a 'Gage Name Error' window (next page) to inform the user which gages will and will not be used.

Thiessen Precipitation Weighting

Generate Thiessen Polygons

Does the Thiessen polygon coverage already exist? Yes No

The rain gage point theme is:

Define the rain gage ID field

Enter a name for the Thiessen polygon theme:

Buttons: Help, Reset, Accept, Generate, Cancel

Intersect Polygons

Have the Thiessen and watershed element polygons already been intersected? Yes No

Select the watershed element polygon theme Add Accept

Select the Thiessen polygon theme Add Accept

Enter a name for the Intersection theme: Generate Cancel

Generate Weighted Precipitation File for SWAT

The input, unweighted precipitation file is:

Select the intersection theme

Enter a name for the SWAT precip. file:

Buttons: Generate, Cancel

Gage Name Error

The gages in the 'Station_id' field are not exactly the same as those in the unweighted precipitation file. Thiessen polygons will be built with only those gages common to both.

The following gages will not be used:
 20300, 20683, 20690, 20768, 20773, 20775, 20958, 21330, 21664,
 21870, 22648, 22659, 22659, 22664, 24864, 25418, 26186, 26353,
 26716, 27334, 27342, 27567, 27880, 28206, 29334,

The following gages WILL be used:
 20309, 20680, 22140, 22902, 23120, 27445, 28619, 29562.

OK

Generating distributed input precipitation files for SWAT is the most time consuming process in the course of using AGWA to conduct a watershed assessment. The length of time this will take increases with the number of gages, the length of the precipitation record, and the complexity of the watershed configuration. Be patient and avoid killing a run because you think it is taking too long. For comparison, with eight gages, 14 years of record, and 30-40 subwatersheds it took us 1-2 hours to generate the weighted precipitation file. We found that a defragmented hard drive significantly reduces the time required to complete this process.

Weighting Scheme:

The weighting scheme used to assign weighted precipitation depths to each subwatershed in a SWAT input file is rather elaborate to account for the frequent occurrence of missing (no data) data values. The weighting scheme outline below is applied on a daily basis and relies on the following notation: WD = weighted depth for a subwatershed; GD = gage depth; GW = gage weight, or weighted influence of a gage on the computed WD for a subwatershed; BW = bad weight, the sum of all the GWs for a subwatershed where GD < 0 (missing data).

- If all the gages have data then $WD = GD * GW$
- If all the gages for a day have either zero values or no data then $WD = 0$ for all watershed elements. In the situation where all the gages are missing data for a day an error log file entitled 'ppt_error.txt' is written to the same directory as the *.pcp file, and updated for each day that this occurs.
- If one or more gages in the watershed have no data (and at least one non-zero value) then:
 - If all gages for a subwatershed have no data then find the closest gage with data:
 - If only one gage in the watershed with data that day, then $WD = \text{depth from the gage with data for all subwatersheds}$
 - If the number of gages with data is ≥ 1 and $<$ the number of gages in the watershed, then $WD = \text{depth from the gage with data that is closest to the centroid of the subwatershed}$
 - If some but not all of the gages intersecting a subwatershed have data:
 - If $GD \leq 0$ then $WD = GD * GW$ (i.e. the weighted depth for a subwatershed is not affected by no data values)
 - If $GD > 0$ then $WD = GD * GW / (1 - BW)$ (i.e. missing data is excluded from the weighting scheme)

14.3 Writing the output file and running SWAT

Once the input precipitation file has been generated select 'Write output and run SWAT' from the AGWA Tools menu. This brings up the 'SWAT Dialog' window shown to the right.

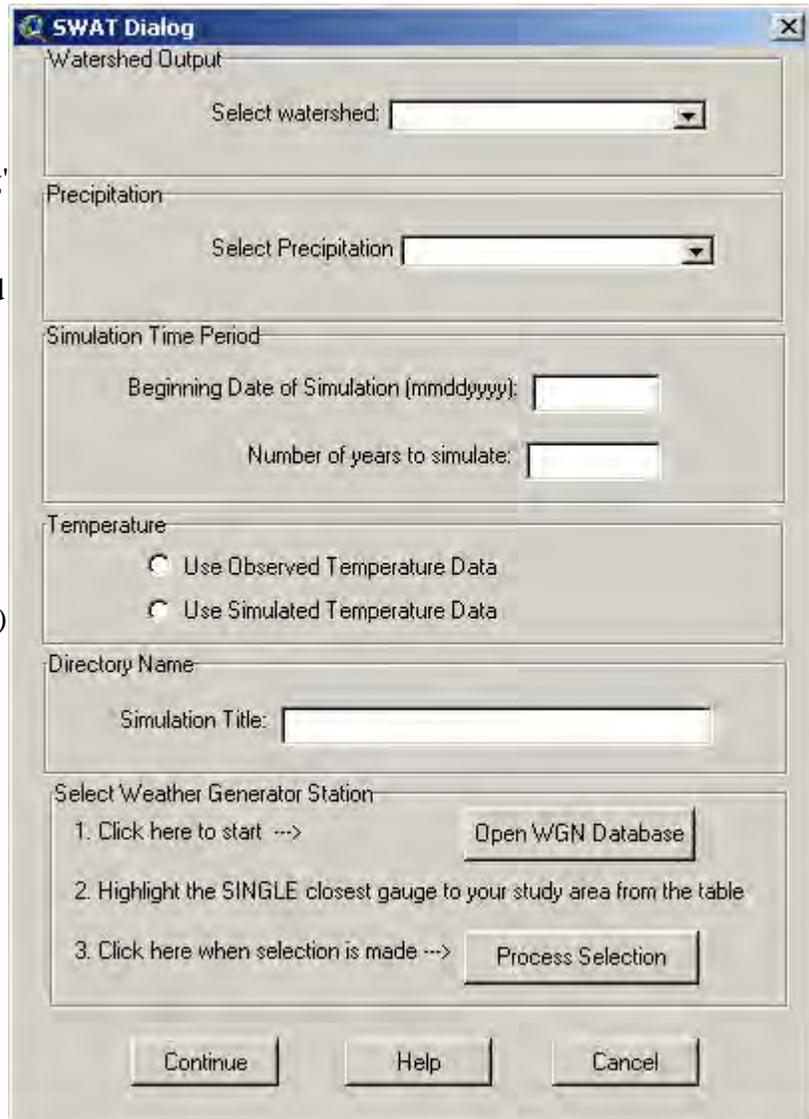
(1) To begin, select the watershed you wish to run the simulation on. This will bring up a list of precipitation files for that watershed in the next drop-down menu.

(2) Select a precipitation file. When a precipitation file is selected the date (MMDDYYYY) for the first day in the precipitation file is automatically entered as the beginning date for the simulation. This can be changed if it is not the desired start date for the simulation.

(3) Enter the duration of the simulation in years. If the duration entered is longer than the period of record in the precipitation file then you will be scolded and allowed to try again.

(4) Choose either to use observed or simulated temperature data for the simulation. Observed temperature data is the best option, but may not be available.

(5) Enter a directory name or simulation title for the SWAT input files that will be written (remember that SWAT will most likely generate upwards of 100 input files in this directory). This name is limited to five characters, and is used as both the simulation directory name and the simulation name for the SWAT input files. The five character limit is designed to prevent SWAT input file names from exceeding a maximum of eight characters after a subwatershed number is attached. A new directory will be created with this name under the 'simulations' subdirectory in the project directory, and all input/output files for this model run will be written to it. If a simulation directory with the name you entered already exists you will be asked to select a new name. The only way to overwrite an existing simulation is to delete it manually using Windows Explorer beforehand.



The image shows a screenshot of the 'SWAT Dialog' window. The window has a title bar with 'SWAT Dialog' and a close button. The main area is divided into several sections:

- Watershed Output:** A dropdown menu labeled 'Select watershed:'.
- Precipitation:** A dropdown menu labeled 'Select Precipitation:'.
- Simulation Time Period:** Two text input fields: 'Beginning Date of Simulation (mmddyyyy):' and 'Number of years to simulate:'.
- Temperature:** Two radio button options: 'Use Observed Temperature Data' and 'Use Simulated Temperature Data'.
- Directory Name:** A text input field labeled 'Simulation Title:'.
- Select Weather Generator Station:** A list of instructions: '1. Click here to start -->', '2. Highlight the SINGLE closest gauge to your study area from the table', and '3. Click here when selection is made -->'. There are two buttons: 'Open WGN Database' and 'Process Selection'.

At the bottom of the window are three buttons: 'Continue', 'Help', and 'Cancel'.

(6) Click the 'Open WGN Database' button to select the closest weather generator station to the watershed in question. When this button is clicked the table wgnfiles.dbf is opened behind the SWAT Dialog. Select the appropriate weather generator station (that has to be determined by the user), and then click 'Process Selection'.

(7) Click 'Continue' to open the 'ws_SWAT' dialog which allows extra parameters to be configured for SWAT. These parameters do not need to be changed and will run with the default values. If you are not familiar with SWAT and the displayed parameters, it is recommended these values be left alone. Click 'Continue' to initiate the model run.

SWAT Input Parameters

Subbasin General Input File (.sub)

Monthly Rainfall adjustment factors (% change, integer values)

Jan.: Feb.: Mar.: Apr.: May: Jun.:

Jul.: Aug.: Sep.: Oct.: Nov.: Dec.:

Groundwater Input File (.gw)

SHALLST: DEEPST: GW_DELAY:

ALPHA_BF: GWQMN: GW_REVAP:

REVAPMN: RCHRG_DP: GW_SPYLD:

Output Frequency

Daily Monthly Yearly

Continue

If the system environmental variable 'AGWA'

has been set then you will not be prompted to point to the SWAT executable. Otherwise, the first time that SWAT is run after opening a project AGWA will prompt you to point (browse) to the SWAT2000 executable. AGWA will write a copy of the executable into each directory where SWAT input files are written (a requirement of SWAT), and AGWA will remember where the executable is for subsequent model runs.

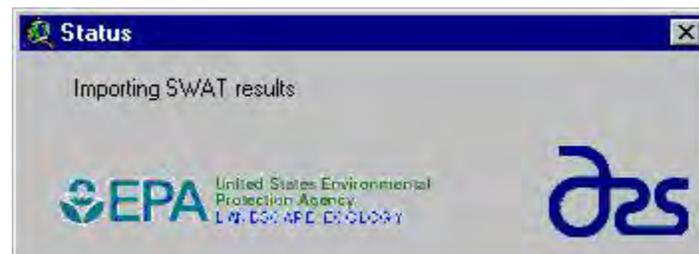
When the 'Process' button is clicked at the end of the 'SWAT Input Parameters' window, a status window will open that informs the user which tasks are being performed and a message box will pop up asking if the DEM elevations are in meters.. The status window will remain open in the background while all of the various tasks are being performed, and until the model run is complete. While SWAT is actually running, the MS-DOS window will open and display the year of the simulation as it is computed. When SWAT is finished this window will close and AGWA will automatically initiate the transfer of model results into ArcView in the form of 2 database files: pxxxx.res and cxxxx.res. The 'xxxx' in these file names represents the 5-

character simulation name entered previously. The 'p' indicates to AGWA that the results are for planar watershed elements, and the 'c' indicates that the results are for stream channels.



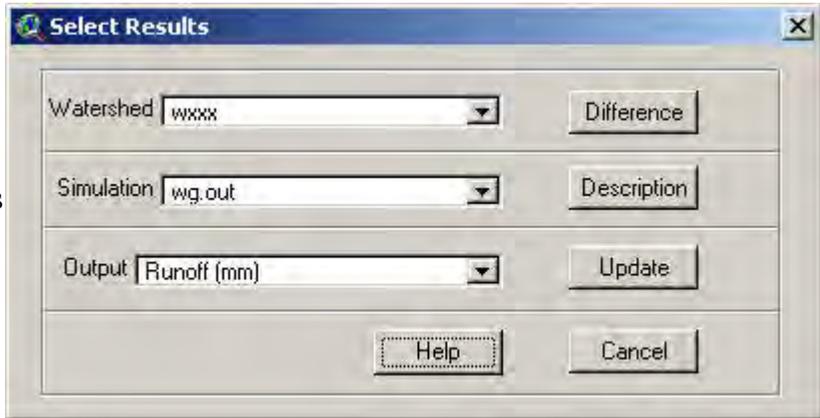
```
C:\WINNT\System32\cmd.exe
c:\projects\agwa_demo>c:
c:\projects\agwa_demo>cd \Projects\agwa_demo\Simulations\swat1\
C:\Projects\agwa_demo\Simulations\swat1>cmd /C swat2000
      SWAT2000
      Soil & Water Assessment Tool
      PC Version
      Program reading from file.cio . . . executing

      Executing year      1
      Executing year      2
      Executing year      3
      Executing year      4
      Executing year      5
      Executing year      6
      Executing year      7
      Executing year      8
      Executing year      9
      Executing year     10
      Executing year     11
      Executing year     12
```



14.4 Viewing Results

To view the SWAT results, select 'View SWAT Results' from the AGWA Tools menu. This brings up the 'Select Results' window, which provides the functionality to view results in two different ways: individually, or as the difference between two simulations.



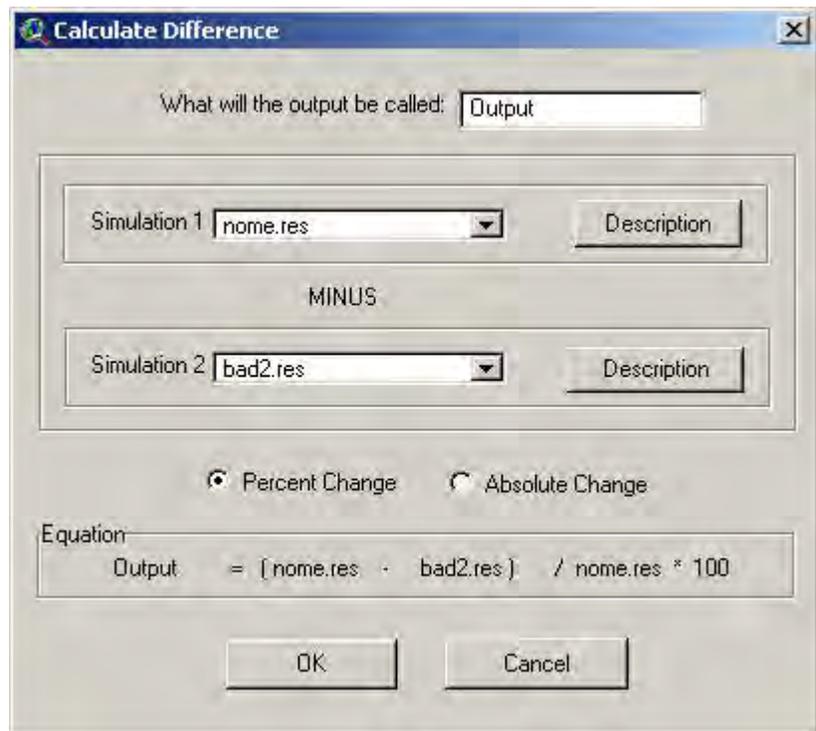
To view results from a single model run select the watershed in the 'Select Results' window. Once a watershed is selected the simulation drop-down menu will become active and you can select from the simulation(s) that have been run for that watershed. When a simulation has been selected the 'Description' button becomes active and can provide a reminder of the specific data used in that simulation - this can be particularly valuable if multiple simulations have been run.



The final step in viewing the results of a simulation involves selecting the output parameter that you wish to be displayed in the View. There are seven choices: Precipitation (mm), ET (mm), Percolation (mm), Surface Runoff (mm), Transmission Loss (mm), Water Yield (mm), and Sediment Yield (t/ha). Some of these choices are not available for the stream channels. When one of the output parameters is selected click the 'Update' button; the watershed and stream coverages will be updated in the View and Legend with the new parameter and a pre-defined color scheme. Viewing results from an individual plane or channel can be accomplished by selecting the appropriate theme in the Legend, selecting the 'Identity' button on the toolbar, and then clicking on the desired feature.

To view results as a difference between two simulations, for instance when two different land cover or precipitation files have been used, click the 'Difference' button once the watershed has been selected.

This brings up the 'Calculate Difference' window, which enables the user to select the two simulations, compute the difference between them, and save this output as a new simulation result that can be viewed in the same manner described previously. The user is given the opportunity to report the difference between



the two simulations in terms of the percent change or the absolute change, and the formula used in the calculation is shown at the bottom of the window. The calculated difference is written to two new database files (one for the planes and one for the channels, as described above) with the name entered at the top of the 'Calculate Difference' window. For example, if the calculated difference is to be called 'Output', then pOutput.res and cOutput.res will be created and added to the project tables.

After clicking OK at the bottom of the Calculate Difference window, the name you selected for your output will show up as a simulation result in the Select Results window that can be selected and viewed just as any other.

14.5 Rerunning existing simulations

To rerun an existing SWAT simulation, select 'Rerun Existing Simulation' from the SWAT section of the AGWA Tools menu. This brings up the 'Rerun Simulations' window where you

select the watershed that contains the simulation to rerun. With the watershed selected, the watershed 'Description' button and 'Simulations' drop-down menu become enabled, allowing you to view a description of the selected watershed and to select a simulation to rerun. Once a simulation to rerun is selected, the simulation 'Description' button and 'Rerun' button become enabled, allowing you to view the simulation description and initiate the rerun.



The rerunning of simulations is provided to enhance the functionality of SWAT in AGWA. It gives users the ability to modify the input files for SWAT to alter the results of the simulation. The original simulation results are maintained so that results between the original and rerun can be compared. AGWA relies on the user's ability to edit the input files correctly and assumes that if the files necessary to run the simulation are in place, then they have the correct formatting required by SWAT.

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15. Temporary Files - Cleanup

Temporary files are generated during the watershed discretization and landcover and soils parameterization. These files accumulate rapidly if AGWA is used frequently, and use an unacceptable amount of disk space, in addition to cluttering your workspace. Unfortunately, due to limitations associated with ArcView it is not possible to remove these files as they are created (the project maintains pointers to these files and produces an unlink error if they are deleted from within ArcView), and it has instead been necessary to come up with a creative alternative. Our solution has been to modify the ArcView system script 'project.save' to clean up the working directory (\project\av_cwd) each time the user saves the project. Unfortunately, this alone is insufficient to avoid the unlink error problem in all situations, and it was further necessary to pop up a DOS command window to remove the files outside of ArcView. This results in several black windows flashing up on your screen every time you save your work, but represents the only foolproof method we could come up with. If you have a more elegant solution please let us know! agwa@tucson.ars.ag.gov

The temporary files include:

- intsec#.shp, .shx, and .dbf - the ArcView files for a temporary intersection theme generated during the landcover and soils parameterization.
- delta#.shp, .shx, and .dbf - the ArcView files for a temporary theme generated during the watershed discretization.
- tarea#.dbf - a temporary database file generated as a byproduct of the Spatial Analyst 'Tabulate Areas' command issued during the landcover and soils parameterization.

where the # represents a number appended sequentially by ArcView as the files are created. It does not matter how many of these files are in your working directory; all of the temporary files will be removed regardless of the number.

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16. Troubleshooting

A help menu specifically for AGWA is not currently available. We have, however, compiled a list of helpful tips and tricks that can be used to correct some common errors. In addition, help specific to ArcView should be available to you through the help menu.

16.1 Tips and Tricks

- **DEM Handling**
 - In many situations a watershed will lie on two or more DEMs, which must be mosaiced together before the watershed can be delineated. An ArcView extension called Grid Utilities, written by Min-Lang Huang huang@dprc.ncku.edu.tw, provides the functionality to *mosaic DEMs* in this situation. The extension, grid01.avx, and a Grid Utilities v1.1 User Guide.pdf are provided with AGWA in the 'datafiles' directory. There is an example problem provided with AGWA that provides step-by-step instructions on how to do this.
 - Clipping your DEM to a small buffer around the watershed will reduce processing time for the watershed delineation. The XTools extension, written by Mike DeLaune, Oregon Department of Forestry, provides the capability to *buffer and clip grids*. It is provided in the 'datafiles' directory (xtools.avx) with AGWA. More information about XTools can be found at: <http://www.odf.state.or.us/stateforests/sfgis/Documents/Xtools.htm>
 - Flow direction and flow accumulation grids generated from a DEM can be used more than once. Avoid generating these multiple times for the same area to minimize the space that will be used on your hard drive.
- **Naming Files**
 - *No spaces* - ArcView has problems reading directory and file names with spaces in them. We have attempted to prevent you from using spaces in file and directory names entered through AGWA, but user-generated files that are added to the project can still cause problems.
 - *Minimize name length* - In general, longer file names are less efficient than shorter ones. In certain situations throughout AGWA there are specific maximum file name lengths, and you will be notified if you enter a name that is too long. Beware, however, that we may not have caught all of these, and consider that there can be name length restrictions if you are having difficulty with a particular file.
 - *Reserved names* - several file names have been designated for temporary files created by AGWA as well as those used and users should NOT use them. They include: tarea (any file type), delta (any file type), intsec (any file type), dsgnstrm.dbf, kin_lut.dbf, swatpptfiles.dbf, and wgnfiles.dbf
- **Managing Themes (grids, coverages and shapefiles)**
 - *Grids and coverages* - Do NOT move grids or coverages using Windows Explorer unless you copy the entire directory in which they reside. If an individual grid or coverage must be moved from one directory to another, use the 'Manage Data Sources...' option under the 'File' menu when a view is active. Also use this option if you must delete a grid from your hard drive.

- *Shapefiles* - A shapefile actually consists of five files: .shx, .shp, .sbn, .sbx, and .dbf. If necessary these can be copied or deleted using Windows Explorer, but be sure to *copy/delete/move all of them together*.
- **SWAT Input Files** - The input precipitation file for SWAT (*.pcp) contains the average latitude, longitude, and elevation of the watershed. The average elevation value is derived from the DEM, and precipitation values are adjusted for elevation in subbasins where elevation bands are defined (AGWA does not do this, but the user may opt to). The latitude and longitude values, however, are simply for your records, and are not used by the model. Due to the difficulty of converting UTM data into Lat/Long coordinates we have used fixed values in the precipitation file that do NOT reflect the watershed you have selected.
- **Data Projections** - One of the problems with downloading data from various sources is that the data are not always in common projections. The NLCD data, for example, come in either "Interrupted Goode Homolosine" or "Lambert Azimuthal Equal Area" projections, while the STATSGO data are projected in "Albers Equal Area" and USGS data are mostly in "UTM". AGWA presumes that the user has working knowledge with projecting data, but it is *crucial that the GIS data share common projections* before geospatial assessments are made. Please consult the ArcView Help menu if you are not sure how to declare/transform the projection of a data theme.
- **Very Small Watersheds** - Very small watersheds are difficult to delineate in AGWA because of the minimum value that is set for the CSA (20 acres or 8.1 hectares), and a relatively large threshold used in creating the stream2500 grid. To get around these problems you will need to do the following:
 - 1a. From the project window select 'Scripts' and click 'New'. Next, from the 'Script' menu select 'Load system script', and then select the script 'ws.dialog.wd2.contPanel.contArea.accept' and click 'OK'.
 - 1b. Scroll down to find the minimum CSA value, which is called 'myMinValueAC'. Change this value to the desired minimum level**, and then click the button at the top of the page to compile the script.
 - 1c. From the 'Script' menu select 'Properties' and change the name to 'ws.dialog.wd2.contPanel.contArea.accept'
 - 2a. From the project window select 'Scripts' and click 'New'. Next, from the 'Script' menu select 'Load system script', and then select the script 'ws.dialog.wd.contPanel.flowAccum.accept' and click 'OK'.
 - 2b. Scroll down to find the first occurrence of the variable 'myStreamGrid', and then lower the value of 2500 to the desired value. Click the button at the top of the page to compile the script.
 - 2c. From the 'Script' menu select 'Properties' and change the name to 'ws.dialog.wd.contPanel.flowAccum.accept'

** Note that we have set a minimum CSA value because using areas smaller than 20 acres creates the potential for errors to arise during the land cover and soils parameterization - see error message I., below. Also, bear in mind that using a small CSA value on a large watershed will result in a very large number of planes and channels, and other problems may arise.

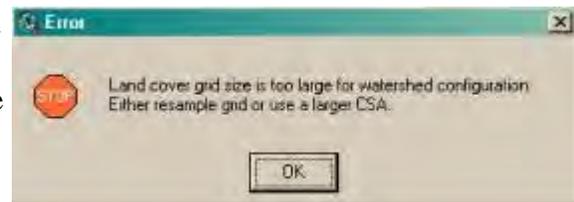
- **No Data In Results** - In certain rare situations for specific CSA values there can be a problem with the watershed discretization that results in KINEROS not running to completion. This happens because of an error in the watershed discretization process that occurs when a stream channel forks just below two adjacent upland elements. It can be avoided by changing your CSA value up or down slightly until the problem goes away. Efforts are currently under way to trap and rectify this problem during the discretization process and before KINEROS is run, so watch for updates soon.

16.2 Error Messages

Despite our best effort to trap likely errors, the determined/frequent user will still undoubtedly get error messages on occasion. Three of the most common of these are described below along with suggested solutions.

I. Land cover grid cell size is too large for the subdivided watershed.

In the case where the CSA is quite small and the landcover grid has a relatively large resolution, AGWA cannot accurately determine the average land cover properties of the watershed elements. In this case, the user has two options to get around the error:

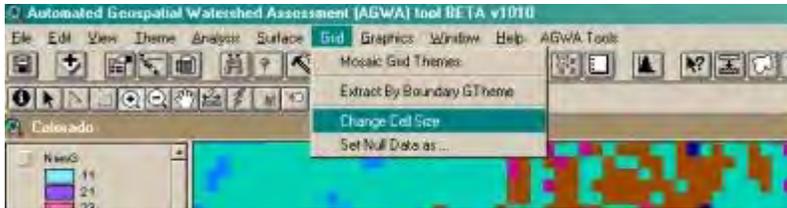


Option 1: Re-run the watershed delineation routine, this time with a larger CSA so that none of the individual planes is smaller than the cell resolution.

Option 2: Resample the land cover grid so that the resolution is less than the original data set. *Note: resampling the grid to reduce the cell size does not affect the AGWA algorithms that are used to define watershed characteristics; nor does it “improve” the land cover data, and users are advised to use the original data in all subsequent GIS operations.*

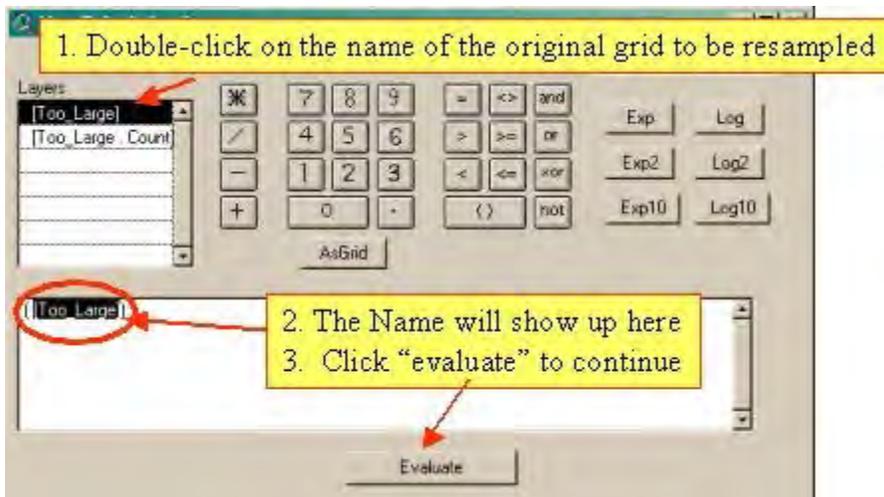
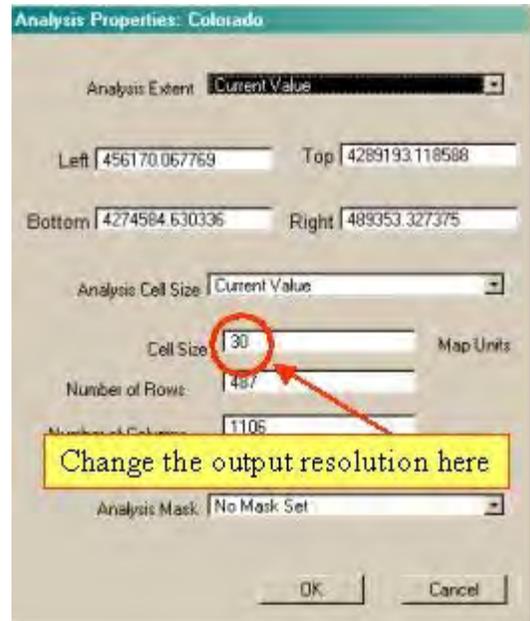
To proceed with option 2, the user has several methods at his/her disposal. If the “Grid Utilities v1.1” extension has been loaded (this extension can be found in the “agwa\datafiles” directory), the grid can be resampled by:

1. clicking on the table of contents of the grid you wish to resample
2. clicking on “grid... change cell size”, as shown here:



3. set the new cell size to a lower resolution than the original grid

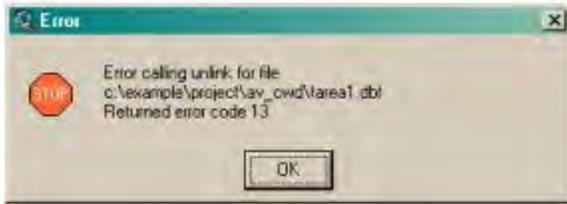
An alternative approach is to use the native ArcView / Spatial Analyst functions. To do so, **first set the Analysis Properties** of the View such that the resolution is lower than the original grid. For example, if the original grid had a resolution of 60m, the user could select a resolution of 30m, as shown here. Next, use the Map Calculator to create a new grid based on the old one:



At this point, a new grid with a smaller resolution will have been created. Use this grid in subsequent land cover parameterizations.

Note: if the new name of the grid is overly long or contains spaces, re-name it.

II. Error calling unlink for file: Returned Error Code 13.



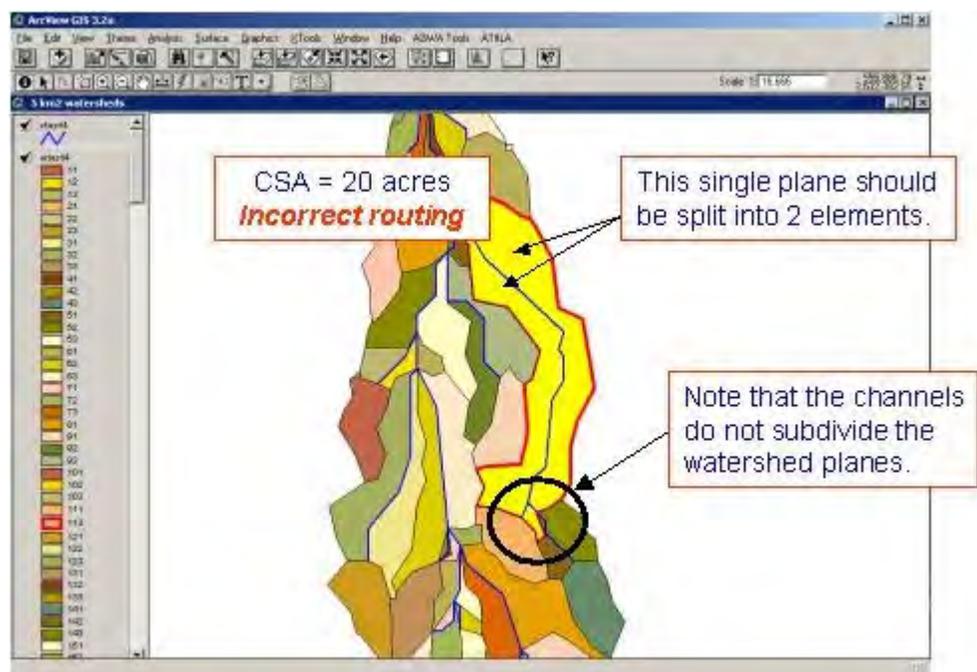
This error should have been fixed by our modifications to the ArcView system script 'project.save', but may still cause problems. The error occurs when AGWA does not complete the land cover and soils parameterization. In this case, files are orphaned on the hard drive but still

connected to the ArcView project. If the error appears you should save the project and try again. If this is unsuccessful these files must be cleaned up by the user before AGWA will proceed.

- Step 1. Identify the working directory in the Project. To do so, open a View and click on “File... Set Working Directory”. You need to remember this location for the next step. A good technique is to highlight the path and copy it into the Windows buffer.
- Step 2. Close the project & quit ArcView
- Step 3. In Windows, navigate to the Working Directory you found above.
- Step 4. Select all the files starting with “delta”, e.g. delta1.dbf, delta1.shp, etc. Delete these files. Doing so will not harm your AGWA project but will allow you to keep working.
- Step 5. Re-start your AGWA project & continue to work.

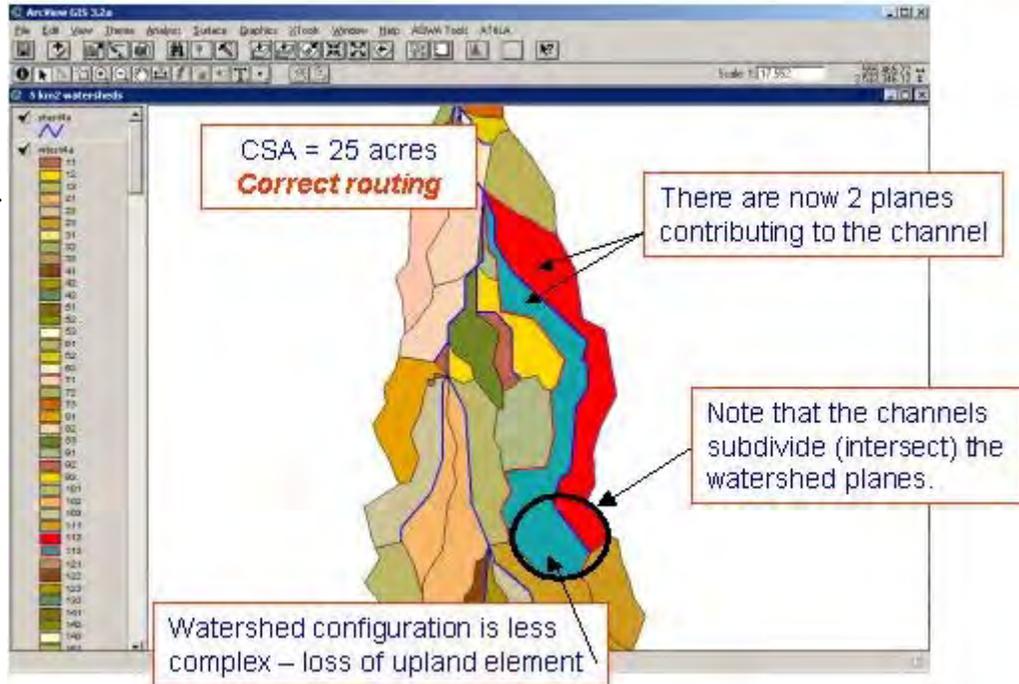
III. “There was an error running KINEROS. Please try again”. Topography & Channel Routing is Ill-Defined

This is the hardest of the AGWA errors to spot immediately. The user is usually unaware that something has gone wrong until either the SWAT or KINEROS model has been run (and failed). This normally happens when the channel network is quite linear or the



topography is relatively flat. In this case, AGWA fails to determine the correct routing structure and does not subdivide the watershed into the appropriate watershed elements, as shown here. Note that in this picture the watershed has been re-drawn with the legend type of “Unique Value” and the “Value Field” set to “WS #” so that it shows the watershed planes as unique colors. In this case the planes are not subdivided properly.

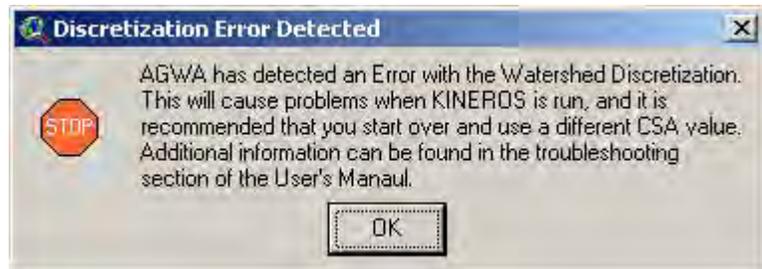
To fix this problem, the user must go back and re-select a new, slightly larger or smaller CSA. The problem arises based on the intersection of channels, and changing the CSA will alter the routing structure, hopefully resulting in a proper subdivision of the watershed.



In the picture shown above, the CSA was enlarged to 25 acres and the watershed subdivision was successful.

IV. Watershed Discretization Error (KINEROS)

Under certain circumstances the planes will be numbered incorrectly, and this will result in the sand, silt, and clay fractions not summing to 1 (+- 0.03). This will cause problems when attempting to run KINEROS, even though it does not complain. Although we believe we have isolated and corrected this problem, we have left the error trapping in place to warn users that a problem exists before any time is spent manipulating and running a particular watershed.



V. Problems with Internal Gauges (KINEROS2)

When using internal gauges in the watershed discretization, having gauges in close proximity to one another is a known cause of problems with the watershed discretization. In addition, having gauges in close proximity to channel junctions causes problems with the discretization. Both of these situations cause very small lateral elements to be created, but because these elements are so small they are snapped out of existence during the discretization (an unfortunately necessary step in the process). Problems associated with either of these situations will generally result in the error messages described in sections III and IV. To avoid them, try to keep gauge locations as far apart as possible, and as far from channel junctions as possible. The insertion of gauges at channel junctions is unnecessary because the planes/channels are already split there, and output will therefore be reported by KINEROS2.

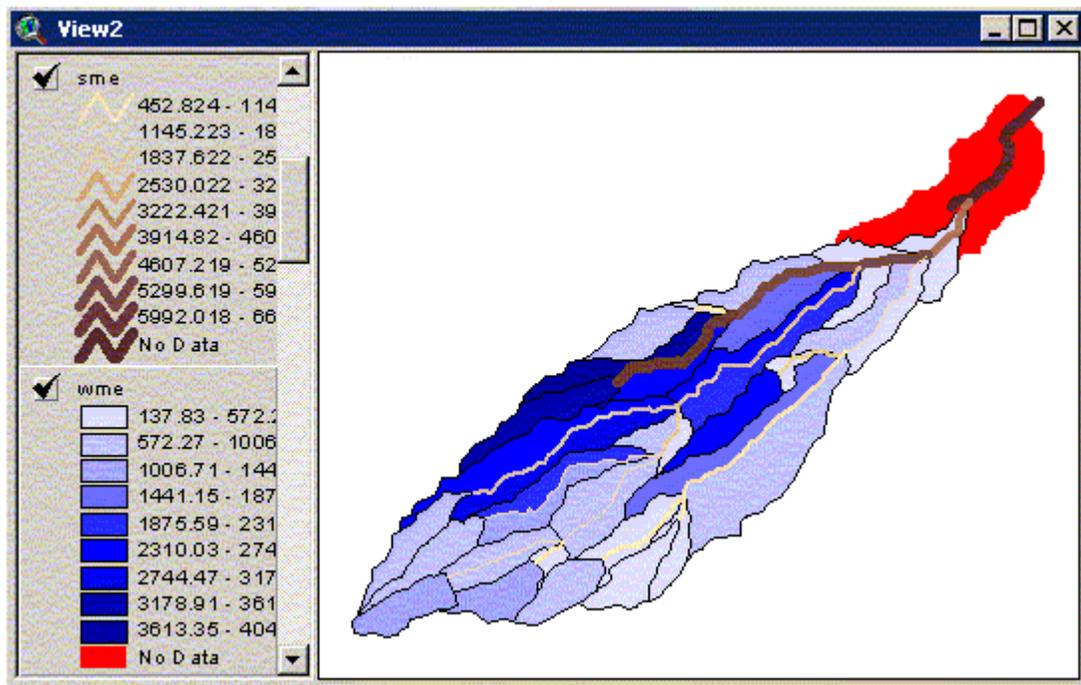
Questions and/or comments regarding additional program errors may be directed to:

Team AGWA:

agwa@tucson.ars.ag.gov

16.3 Other Known Problems

Problems with the watershed discretization (subdivision) - Despite attempts to catch this problem early, on certain occasions KINEROS or SWAT will not run completely and no error will be produced. This generally happens when there is a problem with the watershed discretization, and results in no output data being written to certain model elements. To help users catch this problem we have changed the color for 'no data' values in the results visualization to RED (shown to the right). If you see red watershed elements when you view results that means that KINEROS or SWAT must have not run correctly. Unfortunately there is no easy fix for this problem because it results from awkward channel/plane configurations that occur at specific combinations of channel network shape and the user-selected CSA value. We recommend increasing or decreasing the CSA value slightly and trying again.



16.4 Getting Help in AGWA

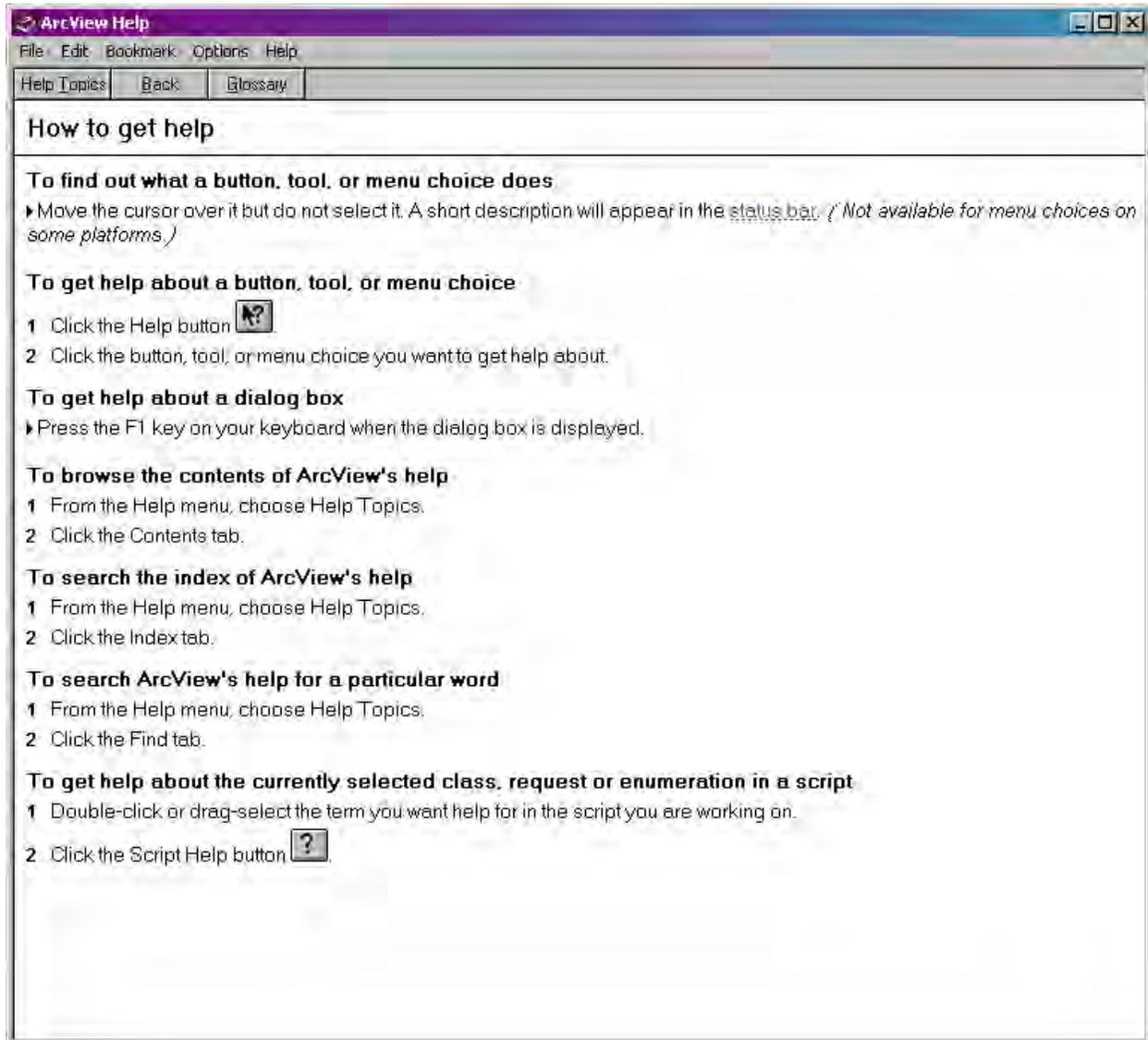


While using AGWA it is possible to open the user's manual and get help simply by clicking on the AGWA help button shown in the picture above. If your AGWA environmental variable is set and the user's manual is saved on your hard drive in the expected location then AGWA will open it in your default web browser. If the manual is not found locally then the AGWA web page will be opened: <http://www.tucson.ars.ag.gov/agwa/>. If you are using Netscape as your default web browser and any of its modules are already open the AGWA help button may not function properly. The easiest solution is to simply exit Netscape before clicking the help button.

** Note the AGWA help button shown above is only available when a view is active.

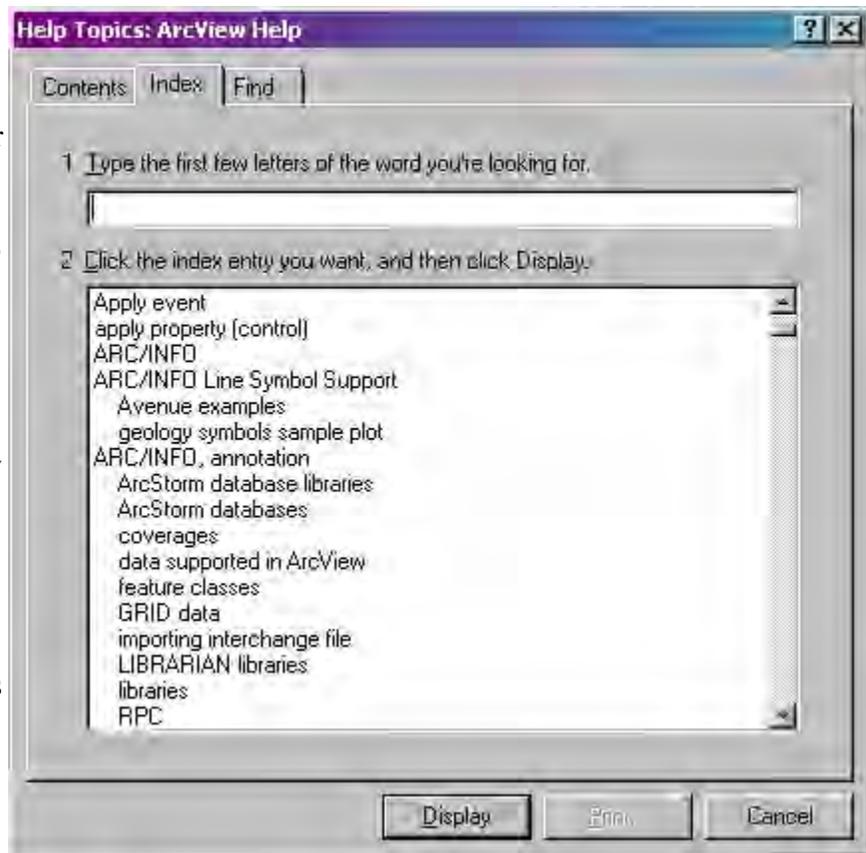
Help may also be obtained by clicking the 'Help' buttons that are present on most of the AGWA dialogs (windows). These buttons will open the User's Manual directly to the section that describes the part of AGWA you are working on when you click the button.

16.5 How to Get (ArcView) Help



AGWA is so helpful and easy to use that it will actually help you to get help! Just select "How to Get Help" from the "Help" menu and this window will help you to find help for whatever you may need help with. This window is very similar to that of one that appears after the Index of the Help menu is used.

Perhaps the most useful tool in ArcView help is the index feature located under the "Help" menu in the menu bar in the submenu "Help Topics." Here, the user can type in a word that he wishes to learn more about and find a matching topic that will bring up a definition and perhaps an example or how to use the feature in question. This is particularly useful if you are in the middle of an application and would like a brief but informative amount of material to help you further your interests. Other choices in the window are the "Contents" and "Find" tabs which are more detailed and usually unnecessary variations on the "Index" tab.

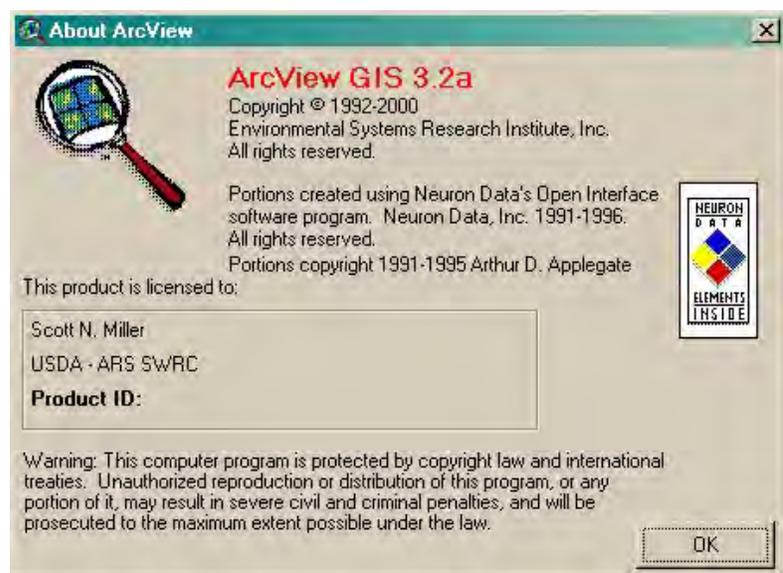


Once a topic is selected, a "ArcView Help" window will appear and become a plethora of information to the user and providing a detailed account of actions and features the user may be interested in. Many of the help windows also include an example so that the user can see the steps applied to a practical situation, perhaps similar to their own predicament. The window also includes the option to search the glossary or return to the Help Topics window. Also present in most help windows are links to related topics, that the user may wish to browse at their leisure to obtain a more in-depth answer to their question.

16.6 About ArcView

Here you can find out various legal information about ArcView and reference information you may need.

[Contents](#)



17. References

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