Introduction to AGWA
The Automated Geospatial Watershed Assessment Tool

Land Cover Change and Hydrologic Response

Introduction:	In this exercise you will investigate the manner in which land cover changes over a 25 year period have affected runoff processes in SE Arizona.
Goal:	To familiarize yourself with AGWA and the various uses and limitations of hydrologic modeling for landscape assessment.
Assignment:	Run the SWAT model on a large watershed in the San Pedro River Basin and the KINEROS model on a small sub-basin using 1973 and 1997 NALC land cover.
Keywords:	Watershed assessment, Hydrologic model, Rainfall interpolation, Continuous vs. event-based modeling

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A Short Introduction to Hydrologic Modeling for Watershed Assessment

The basic tenet of watershed management is that direct and powerful linkages exist among spatially distributed watershed properties and watershed processes. Stream water quality changes, especially due to erosion and sediment discharge, have been directly linked to land uses within a watershed. For example, erosion susceptibility increases when agriculture is practiced on relatively steep slopes, while severe alterations in vegetation cover can produce up to 90% more runoff than in watersheds unaltered by human practices.

The three primary watershed properties governing hydrologic variability in the form of rainfall-runoff response and erosion are soils, land cover, and topography. While topographic characteristics can be modified on a small scale (such as with the implementation of contour tillage or terracing in agricultural fields), variation in watershed-scale hydrologic response through time is primarily due to changes in the type and distribution of land cover.

Watershed modeling techniques are useful tools for investigating interactions among the various watershed components and hydrologic response (defined here as rainfall-runoff and erosion relationships). Physically-based models, such as the KINEmatic Runoff and EROSion model (KINEROS) are designed to simulate the physical processes governing runoff and erosion (and subsequent sediment yield) on a watershed. Lumped parameter models such as the Soil & Water Assessment Tool (SWAT) are useful strategic models for investigating long-term watershed response. These models can be useful for understanding and interpreting the various interactions among spatial characteristics insofar as the models are adequately representing those processes.

The percentage and location of natural land cover influences the amount of energy that is available to move water and materials. Forested watersheds dissipate energy associated with rainfall, whereas watersheds with bare ground and anthropogenic cover are less able to do so. The percentage of the watershed surface that is impermeable, due to urban and road surfaces, influences the volume of water that runs off and increases the amount of sediment that can be moved. 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.

The Study Area

These exercises will use the Upper San Pedro River Basin from the Charleston USGS stream gage in Southern Arizona as the study area. The San Pedro River flows north from Sonora, Mexico into southeastern Arizona (Figure 1). With a wide variety of topographic, hydrologic, cultural, and political characteristics, the basin represents a unique study area for addressing a range of scientific and management issues. The area is a transition zone between the Chihuahuan and Sonoran deserts and has a highly variable climate with significant biodiversity. The study watershed is approximately 2886 km^2 and is dominated by desert shrub-steppe, riparian, grasslands, agriculture, oak and mesquite woodlands, and pine forests. The basin supports one of the highest numbers of mammal species in the world and the riparian corridor provides nesting and migration habitat for over 400 bird species. Large changes in the socio-economic framework of the basin have occurred over the past 25 years, with a shift from a rural ranching economy to considerably greater urbanization. As the human population has grown, so too has groundwater withdrawal, which threatens the riparian corridor and the long-term economic, hydrologic, and ecological stability of the basin.

Significant land cover change occurred within the San Pedro Basin between 1973 and 1997. Satellite data were acquired for the San Pedro basin for a series of dates covering the past 25 years: 1973, 1986, 1992, and 1997. Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) satellite images have been reclassified into 10 land cover types ranging from high altitude forested areas to lowland grasslands and agricultural communities with 60 meter resolution. The most significant changes were large increases in urbanized area, mesquite woodlands, and agricultural communities, and commensurate decreases in grasslands and desert scrub. This overall shift indicates an increasing reliance on groundwater (due to increased municipal water consumption and agriculture) and potential for localized large-scale runoff and erosion events (due to the decreased infiltration capacities and roughness associated with the land cover transition).

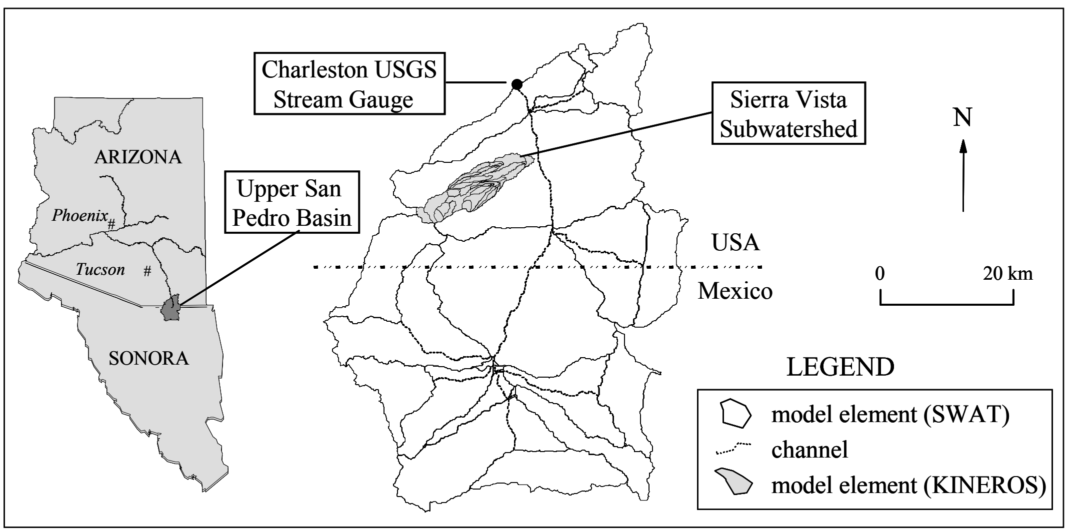
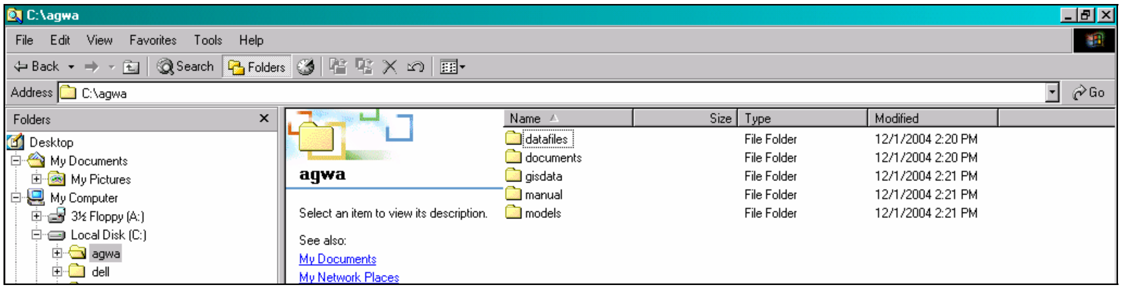


Figure 1. Locations of the two study areas within the Upper San Pedro River Basin you will be modeling today. The larger basin (2886 km^2) will be modeled using SWAT and drains to the Charleston USGS runoff gaging station. This basin encompasses the smaller watershed (92 km^2), labeled here as "Sierra Vista Subwatershed", to be modeled using KINEROS. Upland and channel elements are shown as they may be used in the SWAT simulations, and the upland and lateral elements (channels are withheld for clarity) used to parameterize KINEROS are outlined in the smaller watershed.

Installation

All of the data necessary to model runoff within the study area is provided on the AGWA website or on the accompanying CD. To install AGWA perform the following steps:

1. To install AGWA from a CD, copy the necessary data onto your hard drive.
   a. *Easy installation*: drag the entire contents of the CD onto your hard drive. This will require approximately 700 Mb of disk space. **Important:** do NOT use spaces in the path or ArcView will not be able to access the files. It is best to install AGWA at the **c:** prompt. You should end up with a directory structure like this:



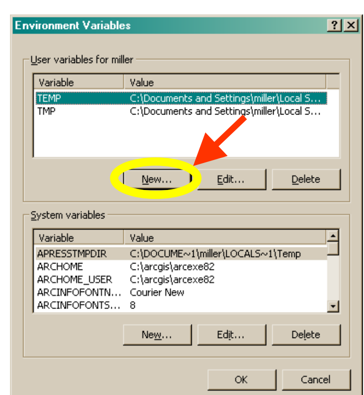
   b. *Alternative installation*. If you prefer not to add all the data from the CD onto your hard drive, you may opt to re-create only part of the installation. At a minimum, AGWA will need access to files found under the *datafiles* and *models* directories.

   Important: Change the permissions of these files so AGWA can read and write to them. When copying from a CD, all files are automatically changed to "read only". Right click on the *AGWA* directory. Uncheck the "read only" box and click **Apply**. Then click **Apply changes to all subfolders and files**. If your operating system is Windows 98 or older, you will have to select all files and directories manually, right click to change the properties, and uncheck the "read only" box. Click **Apply**.

2. To install AGWA by downloading the data from the AGWA website, http://www.tucson.ars.ag.gov/agwa/, create a new directory at the **c:** prompt named *AGWA*, and unzip the *agwa_package.zip* file there. Your directory structure should look like the illustration above.

3. Copy the AGWA extension named *agwa1_5.avx* (or a newer version if one is available) into the extensions folder on your hard drive. This folder is named *EXT32* and is usually located in the following path: c:*\ESRI\AV_GIS30\ARCVIEW\EXT32*, where *c:* is the drive onto which ArcView was installed.

4. Add an environmental variable to your system folder. AGWA requires the environmental variable to locate files:



   a. *Windows* 2000 and XP:
      1. Go to **Start>Settings>Control Panel>System**
      2. Click on the **Advanced** tab, then **Environmental Variables**
      3. Click the **New** button
      4. Variable Name: **AGWA**
      5. Variable Value: **c:\agwa** (or the path of the AGWA directory created in step 1 or 2)
      6. Reboot before using AGWA.

   b. *Windows NT:*

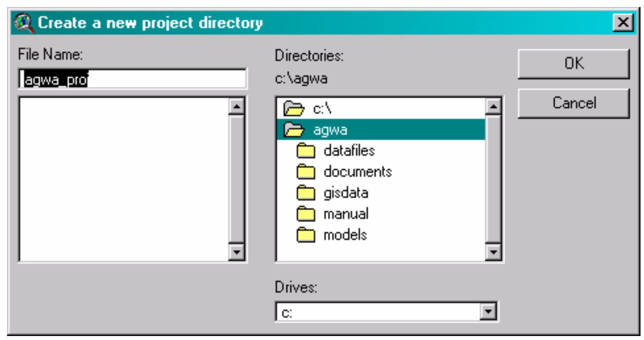
1. Go to **Start>Settings>Control Panel>System**
2. Select the **Environment** tab
3. Fill in the Variable field: **AGWA**
4. Fill in the Value field: **c:\agwa** (or the path of the AGWA directory created in step 1 or 2)
5. Click the **Set** button.
6. Reboot before using AGWA.

c. *Windows 95/98*:
1. Use any text editor to open the autoexec.bat file, located at the **c:** prompt on most Windows machines.
2. Add the following line to the autoexec.bat file: **set AGWA=c:\agwa** (or set the variable equal to the path of the AGWA directory created in step 1 or 2)
3. Save the file and exit the text editor.
4. Reboot before using AGWA.

Getting Started

Open a new ArcView session, and turn on the AGWA extension. To do this, select **File> Extensions**. Check the box next to "AGWA v1.5" (or the name corresponding to a newer version if one is available).

Setting Up the Project and the Working Directory



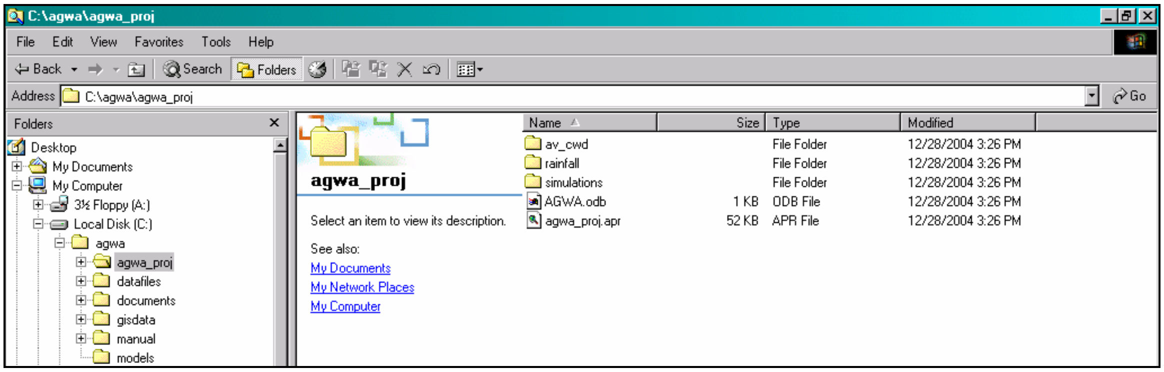
When the AGWA extension is first turned on, AGWA will automatically ask you to name the new project. After you do this, AGWA will create a customized directory structure for each project file to simplify file management. The default project name is *agwa_proj* as shown in the image to the right, although we recommend using a more meaningful name to help identify the project.

You may want to consider making a projects directory in your *AGWA* directory to help organization. If you do, navigate to that directory before clicking **OK** when naming your project.

If you do not change the project name or make a projects directory, a directory will be created with the new name named *c:\agwa\agwa_proj,* and the project will be named *agwa_proj.ap*r and located in the *AGWA* directory.

AGWA accesses 5 SWAT data files (crop2000.dat, urban2000.dat, fert2000.dat, pest2000.dat, and till2000.dat) during various parameterization and simulation steps. The files are provided as part of the AGWA *datafiles* download and can be modified to suit the modeling needs of different users. Because of this, AGWA asks that you identify the set of DAT files to use as a default for the various steps. This can be changed at any time through **AGWA Tools>Preferences**. At this point, if AGWA cannot locate the files in the *datafiles* directory, it will prompt you to locate the crop2000.dat file.

The working directory is the default location where ArcView will write coverages, grids, and tables generated during the watershed assessment process. If you did not change the project name or make a *projects* directory, the working directory for the project will be a folder named *c:\agwa\agwa_proj\av_cwd*. The resulting file structure is shown below:



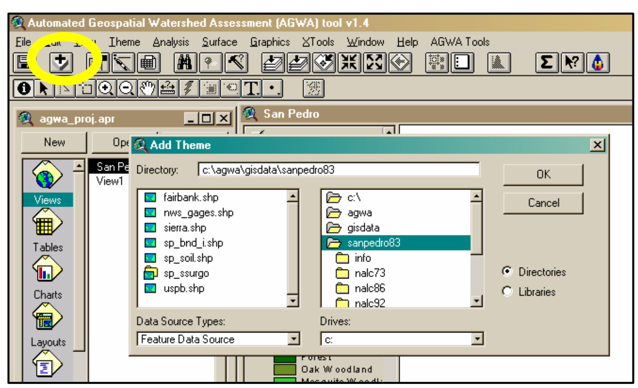
All files created by AGWA in the course of the project will be placed in the current working directory. **Please note:** even if a project has been previously saved as another name, when you open the AGWA extension, you will be forced to save the project with a new name in the above-described file structure.

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. If individual spatial data layers must be moved, use ArcView's **File>Manage Data Sets** option. 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. AGWA watersheds should be moved using **AGWA Tools>Manage AGWA datasets**.

Part I: Modeling Runoff at the Basin Scale Using SWAT

In this exercise you will create a large watershed in the San Pedro Basin, and use the SWAT model to determine change in runoff due to land cover changes over a 25 year period. Start this exercise by creating a new view, and loading data into it. Change the name of the view to "San Pedro" by going to **View>Properties**. Change the Map Units to METERS.

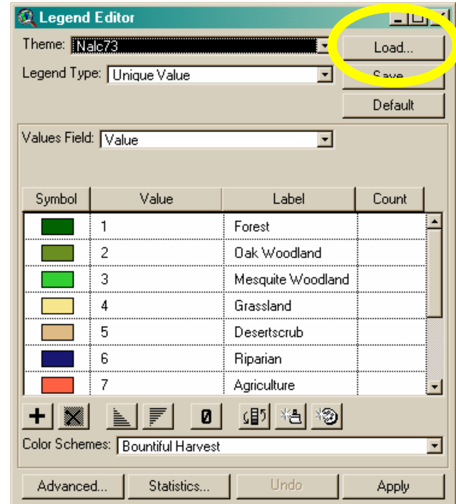
Add data to the view by clicking on the "+" button at the top of the screen. Make sure the **Data Source Type** is set to "Feature data source" and navigate to *agwa\gisdata\sanpedro* and add the following shapefiles:



- *Fairbank.shp* – National Weather Service Fairbank raingage
- *NWS_gages.shp* – Multiple raingages throughout the basin
- *Uspb.shp* – Outlet of the Upper San Pedro watershed for SWAT
- *Sierra.shp* – Outlet of the Sierra Vista watershed for KINEROS
- *Sp_statsgo.shp* – STATSGO soils

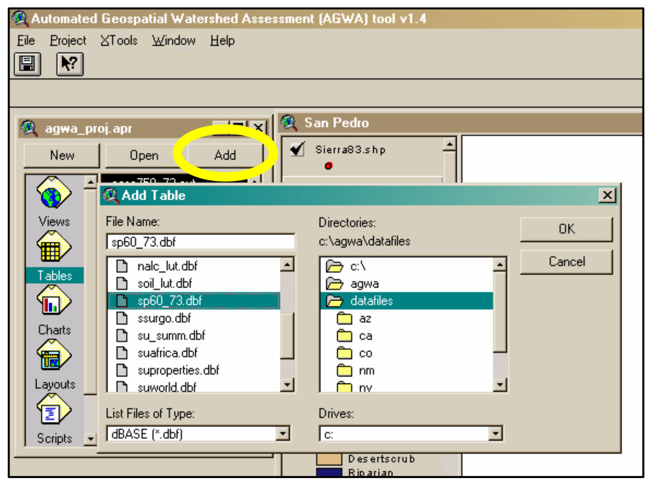
Click on the “+” button again. Make sure you change the **Data Source Type** to “Grid data source” and add the following grids:

- *Nalc73* – NALC 1973 land cover classification (60m)
- *Nalc97* – Landsat TM data classified into NALC land cover categories (60m)
- *Sp_dem* – Digital elevation model (30m)
- *Sp_accum* – Flow accumulation grid
- *Sp_dir* – Flow direction grid



To add an existing legend to the NALC data, double-click on its legend. You will get a pop-up window like the one to the right. Click on the **Load** button and navigate to the *agwa\datafiles* subdirectory, and select the *nalc.avl* file. This will load in a legend with pre-defined colors and names and should end up looking like the image shown here. Keep the default "Value" field in the pop-up and be sure to click the **Apply** button to set the changes.

You will also need to add some other data to the project. To do this, click on the **Tables** icon in the project. Click on the **Add** button and navigate through the *agwa\datafiles* subdirectory to add in the following database files:



- *dsgnstrm.dbf* – return period rainfall for KINEROS
- *kin_lut.dbf* – master look-up table for soil parameters
- *Sp60_73.dbf* – San Pedro rainfall from 1960-1973 for all the NWS gages in the basin
- *Wgnfiles.dbf* – database table of weather generator stations for SWAT

After loading these files into the project, you can close the tables to clean up the display. Loading these files into the project is NOT a necessary step when using AGWA, but was done here to make you familiar with the files that AGWA uses during a watershed assessment.

At this point we have all the data necessary to start modeling: **topography, soils, land cover, and rainfall.** Save your project, and continue to the next step.

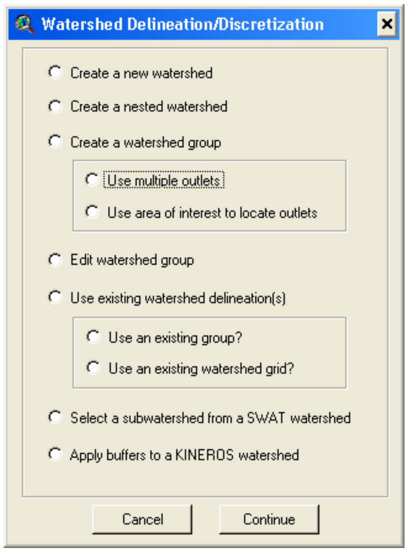
Step 1: Subdividing the watershed

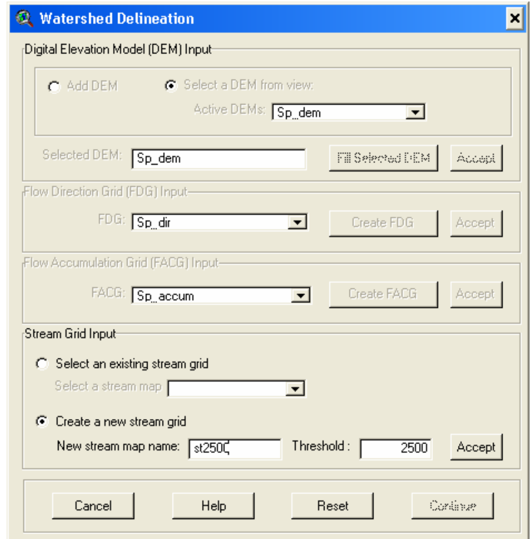
1. Open up your view. Take a look at the data you have available to you to familiarize yourself with the area. This is accomplished by turning on the layer (check the box next to the legend), then change the color ramps and display schemes of the GIS layers by double-clicking on them and manually adjusting the legend.

2. Make sure the *uspb.shp* layer is turned on and is located at the top of the list of available GIS layers. The uppermost themes are displayed on top of the other themes, and this will enable us to see the location of this point, which is the watershed outlet for our first modeling exercise.

3. Start the AGWA tool by clicking on the **AGWA Tools** menu item and then on **Delineate watershed**. Read through the options available for delineation and discretization. Select **Create a new watershed** and click **Continue**.

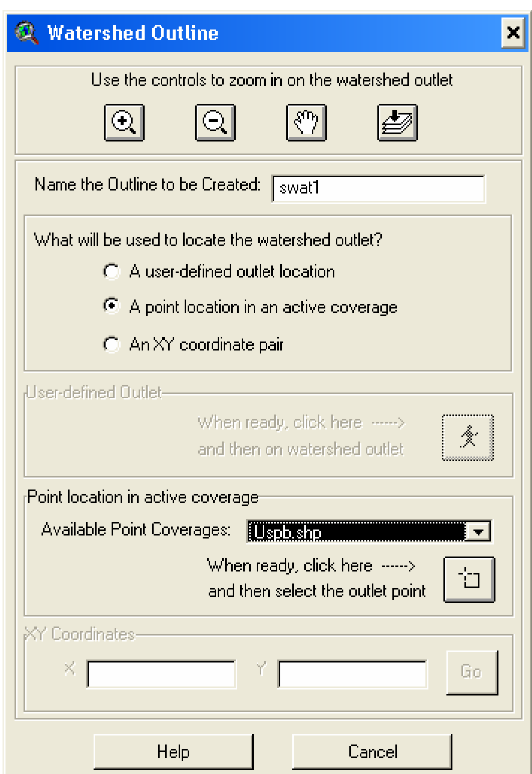
4. In the next window, define the delineation inputs – select the DEM, flow direction and flow accumulation maps with the drop-down windows. Click **Accept** to move on to the next input. Select **Create a new stream grid** to create a new stream map. Enter “st2500” as the name and a threshold of 2500. Click **Accept** to generate a new stream map. Once AGWA has generated the stream map, click **Continue**.

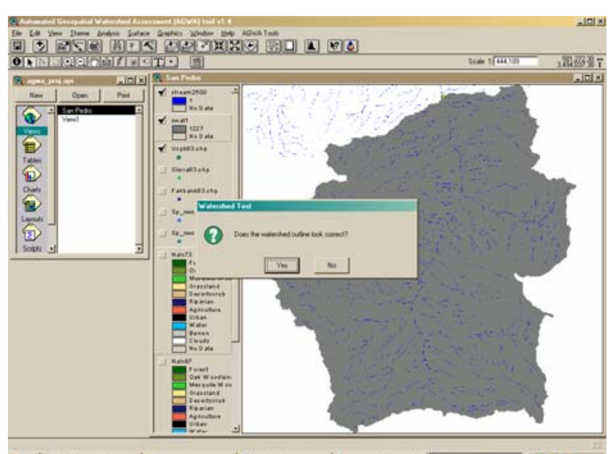


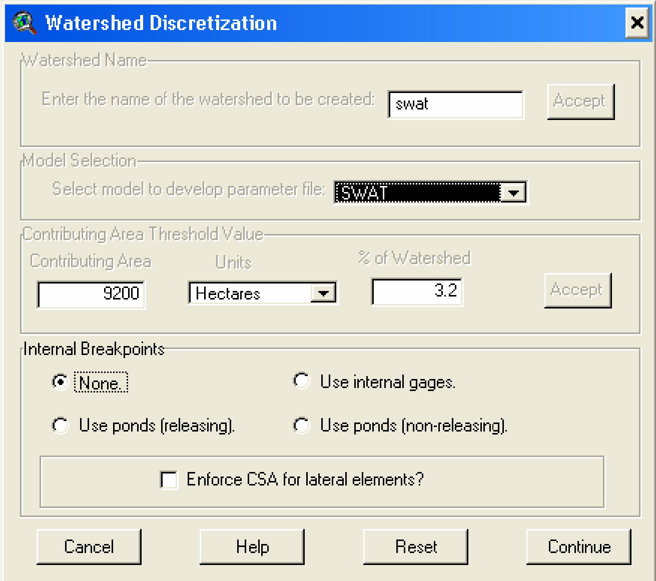


5. On the next screen, named **Watershed Outline**, use the Zoom tool to zoom in on the watershed outlet *uspb.shp* if you like. Enter a name, *swat1*, for the new watershed outline. Then select **A point location in an active coverage** to locate the watershed outlet. Under **Available point Coverages**, select the shapefile *uspb.shp*. Use the draw tool to select the outlet point by drawing a small box around the point. AGWA will now begin delineating the watershed.

6. AGWA will generate a grid that delineates the outline of the watershed contributing runoff to the upper San Pedro River Basin from the point marked by the *uspb.shp* shapefile. AGWA will ask if the watershed looks OK. Click **Yes** if it looks like the image below, otherwise start over to make sure all values were entered correctly.





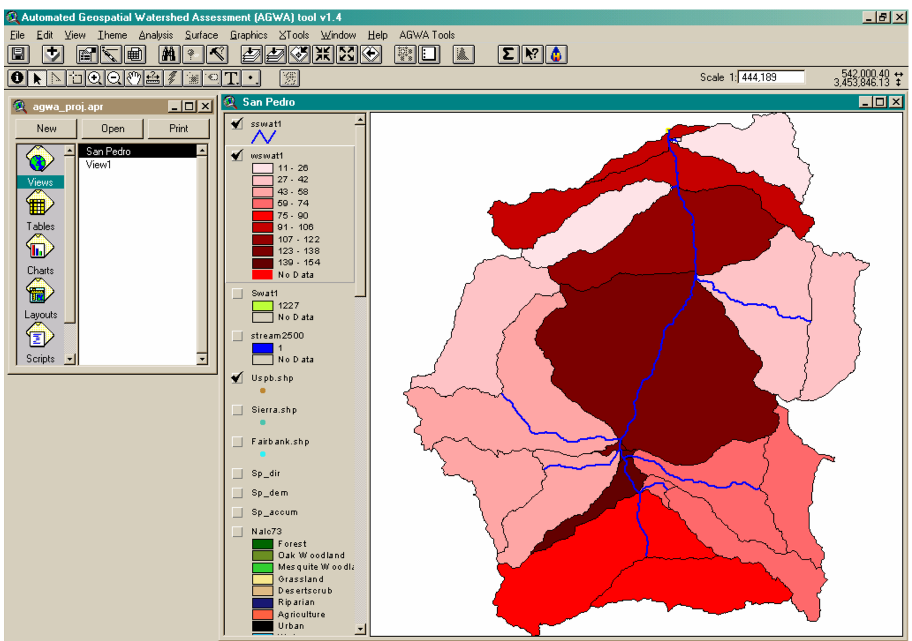


If the watershed is correct, AGWA takes you to the Watershed Discretization window. Enter a name, *swat1*, for the discretized watershed and click **Accept**. Select **SWAT** in the Model drop-down box.

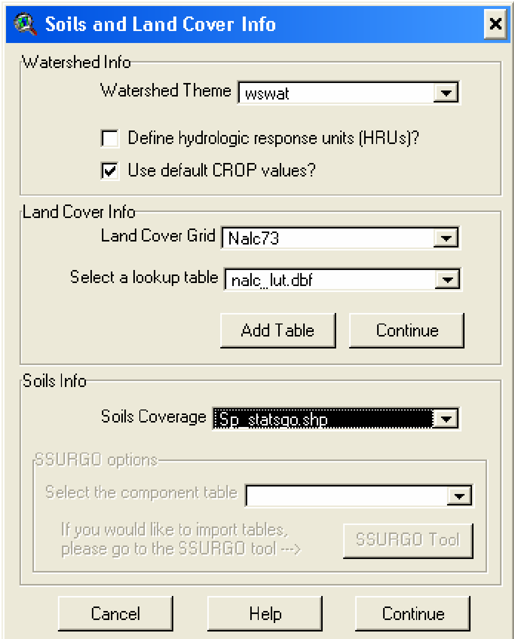
AGWA subdivides watersheds into hydrologic elements based on the contributing source area (CSA) approach, where the channels are defined as a function of the contributing area, or the total area required for channelized flow to occur. Smaller CSA values results in a more complex watershed. The default CSA is set to 2.5% of the watershed. Change the CSA to 9200 and change the units to hectares. Click **Accept**.

Under **Internal Breakpoints**, select **None** and leave the **Enforce CSA** box unchecked. Click **Continue** to discretize the watershed.

7. Select **Default Relationship** for the Hydraulic Geometry Relationships, and click **Process**. AGWA will now complete the watershed discretization, creating the individual planes and channels for the simulation. Your final watershed should look like the one below. The actual colors may be different, but the configuration of the planes should be the same. If it is very different, you may want to start again to make sure the values were entered correctly.



Step 2: Characterize the watershed elements for SWAT model runs

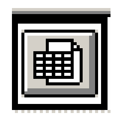


1. Each of the watershed elements needs to be characterized according to its unique properties of land cover and soils. These properties are used by AGWA to create input parameters for either SWAT or KINEROS. To start this process, select **AGWA Tools>Run Landcover and Soils Parameterization**.

   Note that in the previous steps AGWA has created a subwatershed with the *swat1* name and placed a “w” in front of the discretized watershed map (*wswat1*). A channel map is also in the view named *sswat1*.

2. Fill in the land cover & soils dialog box as shown in the image to the left, then press the **Continue** button. If you did not add the nalc_lut.dbf table to the project, use the **Add Table** button. AGWA will now prepare the *wswat1* watershed for running SWAT by intersecting the watershed with the 1973 land cover map and STATSGO soils data.

3. At this point the watershed has been subdivided into model elements and these elements have been characterized according to their land cover and soil properties. AGWA has added a few items to the watershed’s data table that will be used to provide input to the SWAT model. You can see these changes by selecting on the legend for wswat1 and then clicking on the **Table** icon at the top of the ArcView screen that looks like the image to the right.



Step 3: Prepare rainfall files

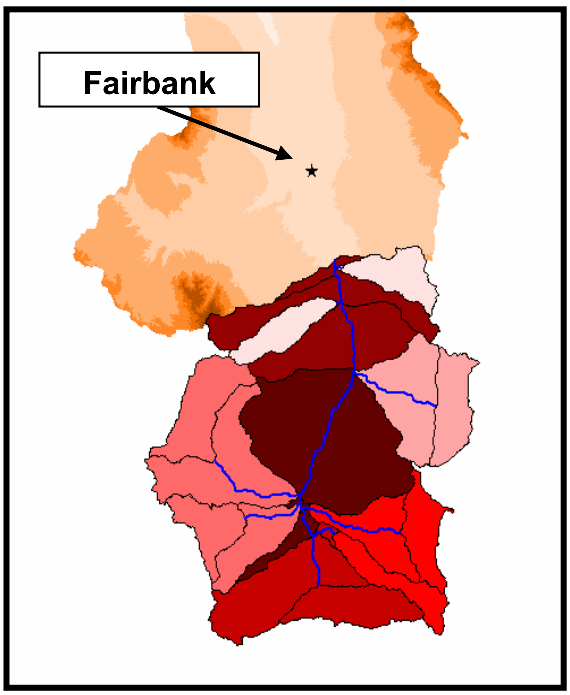
1. AGWA provides a means for preparing rainfall files in SWAT- or KINEROS-ready format. For SWAT, the user must have a dbf file containing the daily estimates of rainfall for the rain gages within the study area. Rainfall data for gages within the San Pedro are provided to you in the *sp60_73.dbf* file.

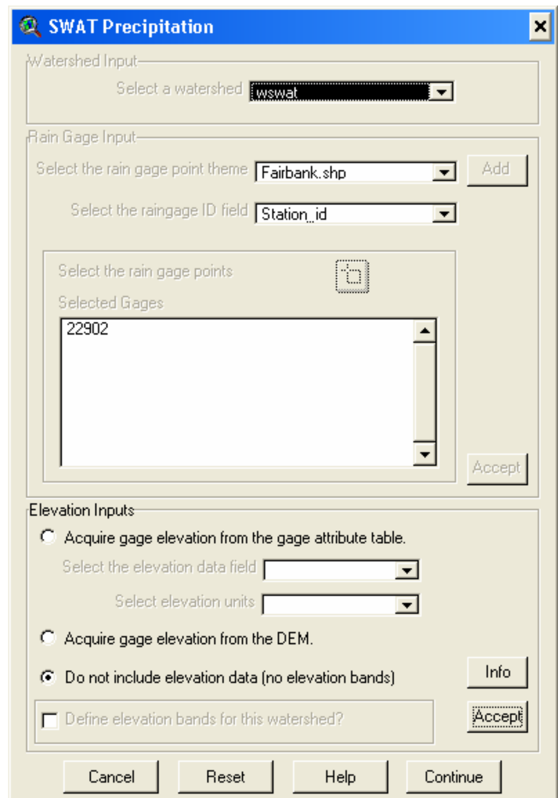
2. When AGWA is used expressly as a hydrologic modeling tool it is critical that the rainfall data be spatially distributed across the watershed. A large body of literature exists regarding the crucial nature of spatially distributed rainfall data. Given a number of rain gages scattered throughout the study area (see the *nws_gages* data layer), AGWA will generate a Thiessen rainfall map and distribute observed rainfall on the various watershed elements using an area-weighting scheme. Feel free to use the *nws_gages* file in concert with the *sp60_73.dbf* file to generate rainfall data, but we are NOT using this option right now.

Note on rainfall input: The process of creating area-weighted rainfall files is very time-consuming (it can take several hours to characterize a complex watershed for many years of rainfall) and we are avoiding it during this exercise. Instead, we will use a single rain gage to generate a uniform rainfall file across all the model elements. This is clearly a huge deviation from using observed data, but there is a sound reason for doing so in change detection work. We are interested in the impacts of land cover change on hydrologic response, but the spatial variability in rainfall can have confounding effects on the analysis, overwhelming the isolated changes within the subwatershed elements. Using homogeneous rainfall serves to isolate the effects of land cover change independent of the rainfall.

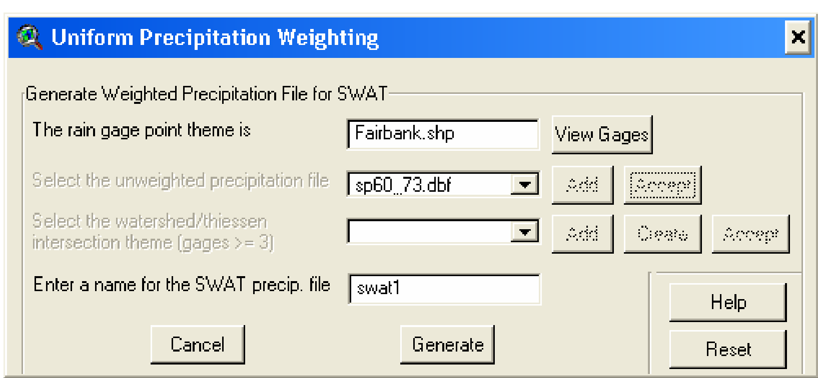
** Optional ** You can try using 2 different sources of rainfall data for SWAT: uniform and distributed rainfall. In this example you will use a single gage (uniform), but you could also try running SWAT with the *nws_gages* shapefile (distributed) and use all available gages for the same time period. In this way you can investigate the impacts of rainfall input on hydrologic modeling.

3. To generate uniform rainfall data, select **AGWA Tools>Write SWAT Precipitation file**. Select the *wswat1* watershed. Select *fairbank.shp* as the rain gage point theme, select the field containing the gage identifiers (Station_id) and use the selection tool to select the raingage in the view (the figure to the left displays the location of the gage). The Station_id will be displayed in the text area. Click **Accept**. Select **Do not include elevation data (no elevation bands)**, click **Accept** and **Continue**.





4. Fill in the next screen so it looks like the one below and click **Generate**. Because we are creating a uniform precipitation file, we do not need to select a Thiessen polygon/watershed intersection theme. AGWA will save the .pcp file as *swat1.pcp* in the *rainfall* folder in your project.



Step 4: Write output and run SWAT

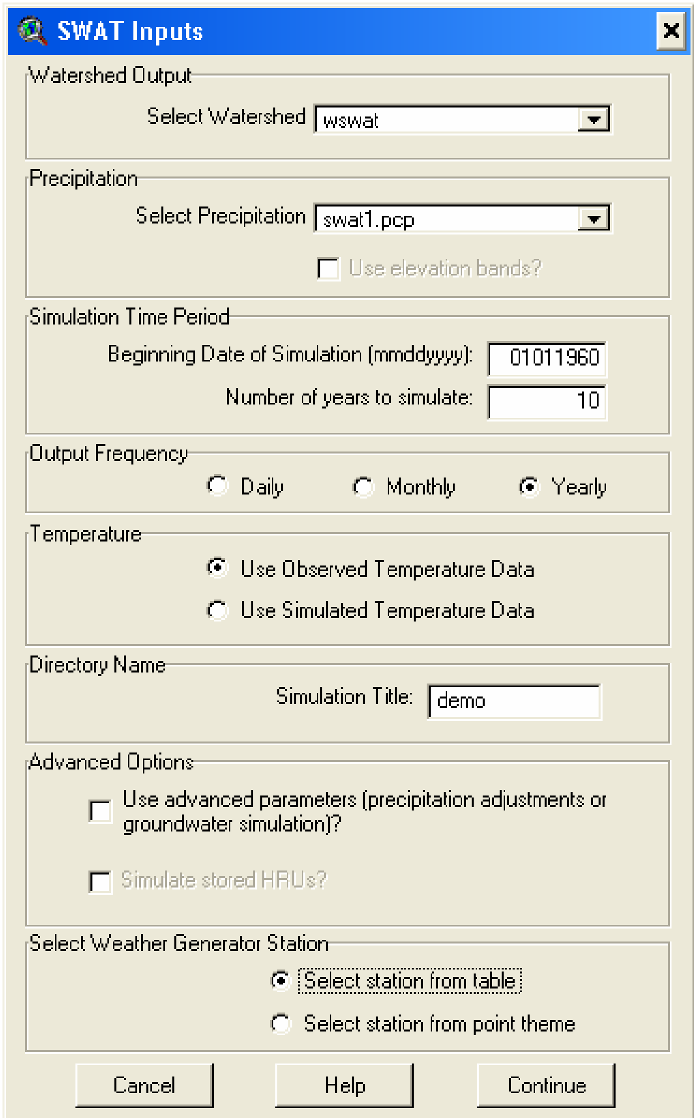
1. At this point all the pieces are in place to run SWAT. The next step is to go to **AGWA Tools>Write Output and Run SWAT**. Fill out the next screen so it looks like the one below.

2. Once you select the watershed, select the precipitation file that you have created for the watershed. If you have generated multiple rainfall events, they will all be shown in this dropdown list.

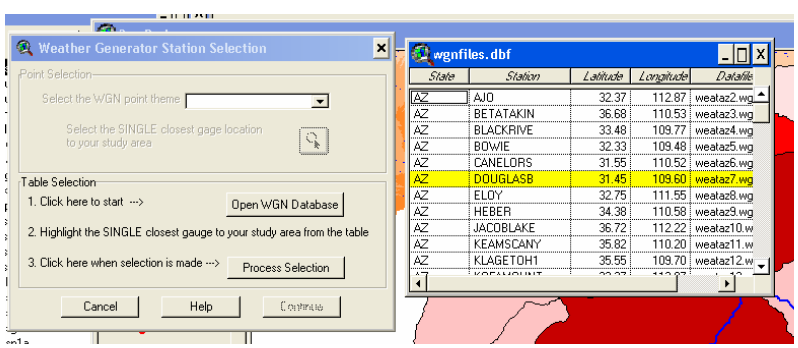
3. There are 14 years of data in the rainfall record you created earlier. You can change the start and end dates for the simulation so long as they fall between January 1, 1960 and Dec 31, 1973. For simplicity, keep the default start date as January 1, 1960 and simulate 10 years of runoff. Select the yearly output frequency.

4. Select **Use Observed Temperature Data**. When asked, find the temperature file, *sp60_73.tmp* in the *c:\agwa\datafiles* directory.

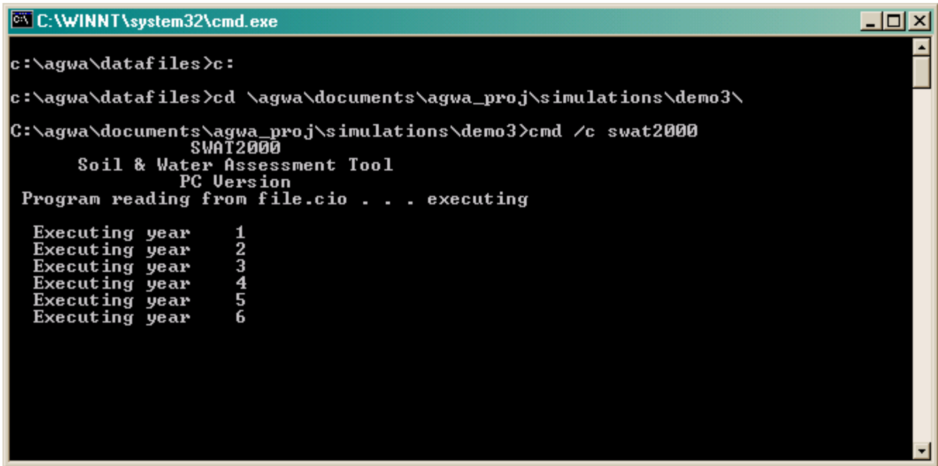
5. Enter *demo* as the name for the simulation. This is the simulation name and consequently will also be the directory name the SWAT results are placed in within the *simulations* directory. Leave the **Use Advanced Parameters…** box unchecked.



6. In the weather generator panel, select **Select station from table**. The weather generator selection window will open. Click **Open WGN Database** to select the station closest to the watershed in question. ***Note:*** *AGWA will show the name, latitude and longitude of the available stations, but it is the responsibility of the user to choose an appropriate station.* For the San Pedro Basin, choose the ***DOUGLASB*** station (see below). Click **Process Selection**, then **Continue** to return to the SWAT Input window.

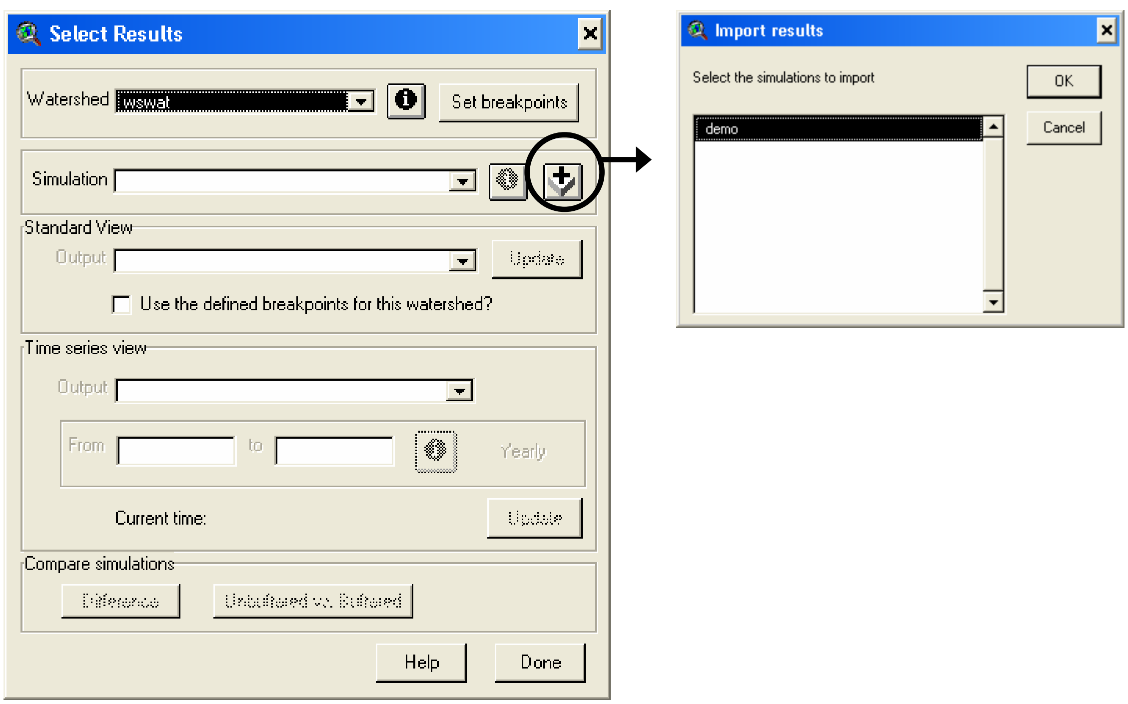


7. Click **Continue** to write the SWAT input files. AGWA will now run SWAT for each of the 10 years, and you should see the black command window as shown below running SWAT. When this window disappears, SWAT has completed running.



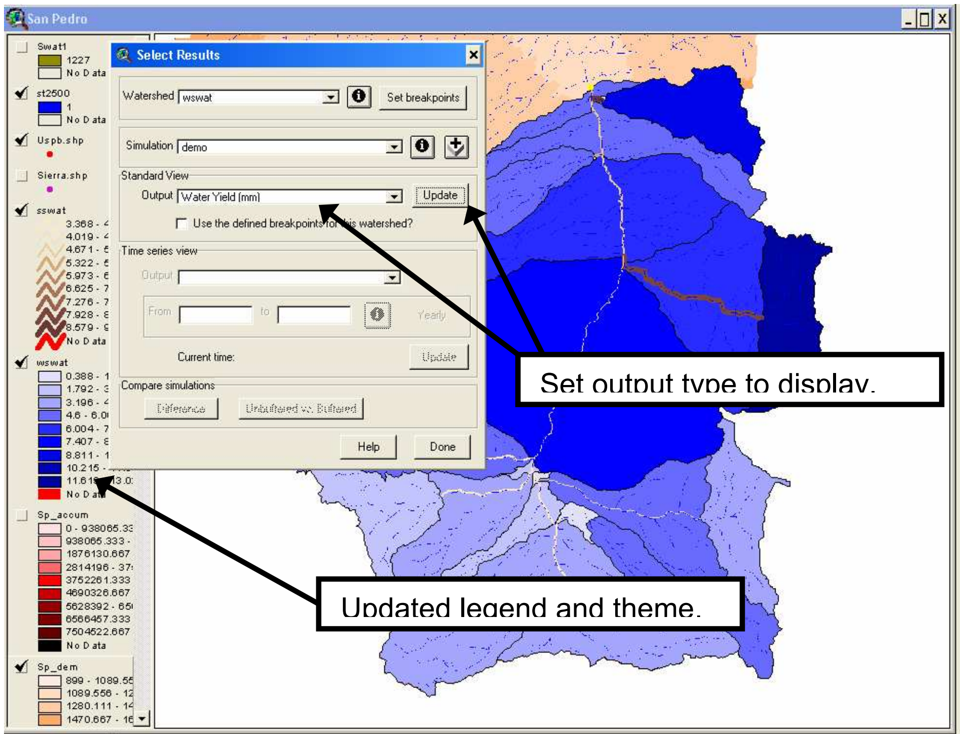
Step 5: View the results

1. After SWAT runs to completion, the SWAT output files must be imported into AGWA before displaying the results. Go to **AGWA Tools>View Swat Results** to display the spatially distributed runoff, infiltration, and other water balance results.



Click on the import button (circled) to select the simulation results. Select “demo” and click **OK** to import the tables. Once the tables have been added to the project, the Simulations drop-down window will be updated. Click on the **Identify** buttons to review the inputs up to this point. This box provides a summary of the data used to provide input to SWAT. In this case, the watershed size was 713218 acres with a CSA of 9200 hectares. 1973 NALC and STATSGO soils were used to parameterize the watershed for a 10 year model run starting in 1960.

2. Experiment with the visualization tool by choosing different results to display using the Standard View options. The results for water yield should look like the image below:



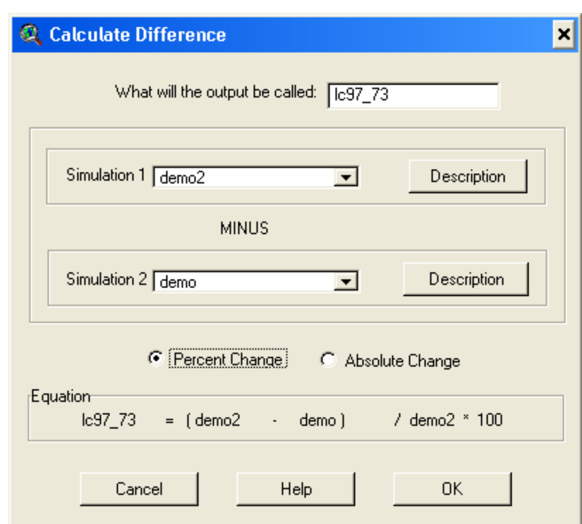
Step 6: Repeat for 1997 land cover

1. You do not have to re-configure the watershed to run the simulation with the 1997 land cover. Start the process at **Step 2: Characterize the watershed elements for SWAT model runs**, from above, choosing the *Nalc97* landcover data this time.

2. You do not have to re-produce rainfall data since the geometric watershed configuration is exactly the same.

3. Repeat the same steps as above to generate 10 years of runoff data for the basin using 1997 land cover, STATSGO soils, and homogeneous rainfall. Save the results as *demo2*.

Step 7: Compare the 1997 results with the 1973 results

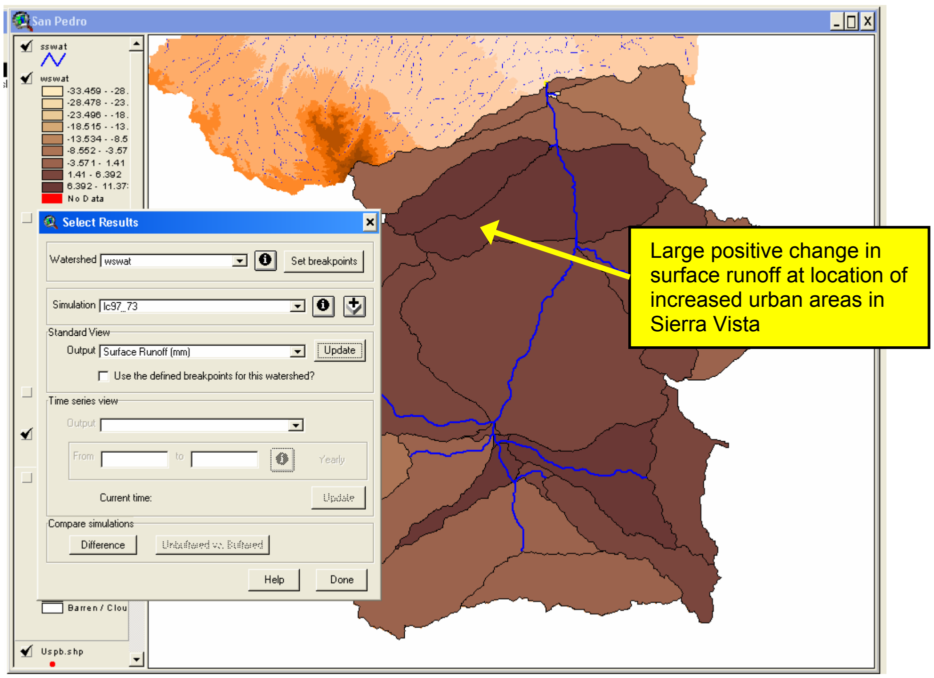


1. Click on **AGWA Tools>View SWAT Results**. Once you have selected “wswat1”, click on the **Import** button to import the 1997 results. Once AGWA has added the tables to the project, the **Difference** button is activated. Click on the **Difference** button, and you will be prompted with the dialog shown to the right. Here we are creating a new data layer with the differences in runoff between the 1997 and 1973 land cover classes. This approach is a simple subtraction, so negative values will occur where runoff is predicted to decrease due to beneficial changes in the land cover.

2. Name the output *lc97-73* to indicate the direction

of subtraction. Here positive values indicate an increase in runoff.

3. Results of the simulated change in surface runoff resulting from land cover changes are shown below:



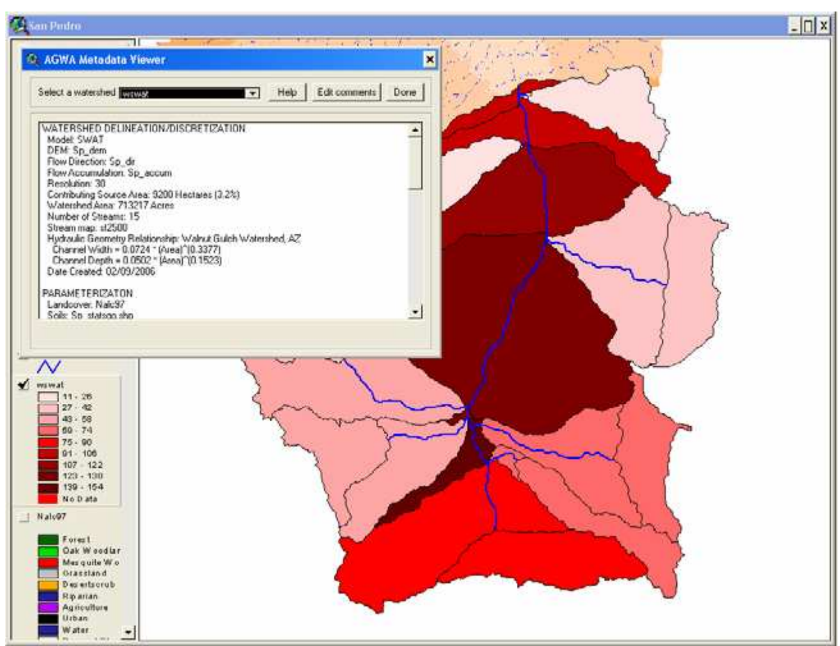
Step 8: View Metadata

1. AGWA metadata contains information regarding watershed delineation and discretization options, landcover and soils parameterization options, and simulation details. This information can be viewed at any time by going to **AGWA Tools>View metadata**.

2. In the Metadata window, select the SWAT watershed from the drop-down menu. The metadata will be displayed in the text area. Scroll through the text area to familiarize yourself with the information.

3. User comments can be added at any time through the viewer. Click the **Edit comments** button to add any comments you'd like to the watershed.

4. Click **Done** to exit the window.



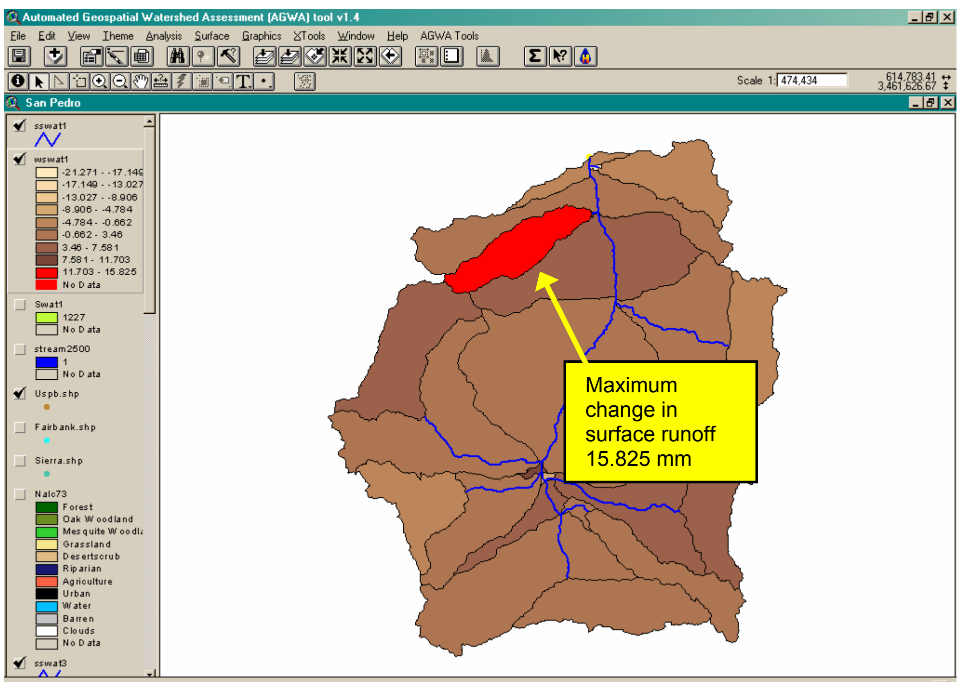
Part II: Modeling Runoff at the Small Watershed Scale Using KINEROS

In the previous section we identified regions that have undergone significant changes both in terms of their landscape characteristics and their hydrology. These basin scale assessments are quite useful for detecting large patterns of change, and we will use the results to zoom in on a subwatershed to investigate the micro-scale changes and how they may affect runoff from simulated rainfall events.

SWAT is a continuous simulation model, and in the last exercise we simulated runoff for 10 years on a yearly basis. KINEROS is termed an event model, and we will use design storms to simulate the runoff and sediment yield resulting from a single storm. In this case, we will use the estimated 10-year, 60-minute return period rainfall.

A quick review of the spatial distribution of changes in surface runoff predicted by SWAT shows that the largest increase occurred in a small watershed draining an area near Sierra Vista that underwent significant urban growth from 1973 to 1997.

The area near Sierra Vista is highlighted in red.



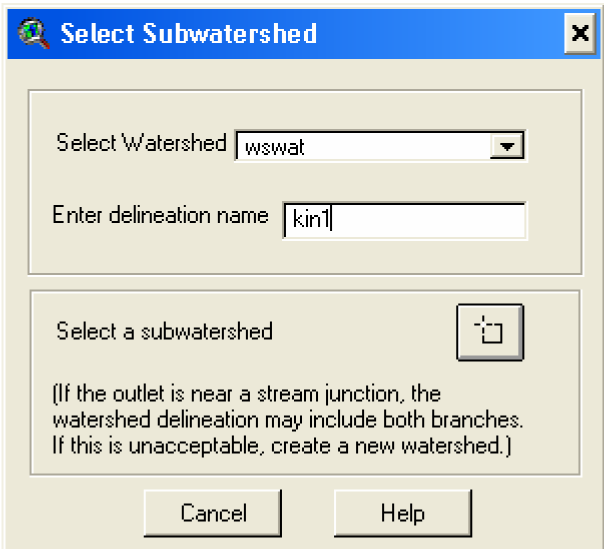
In this exercise, we are going to zoom in temporally and spatially to investigate large-scale changes within the watershed.

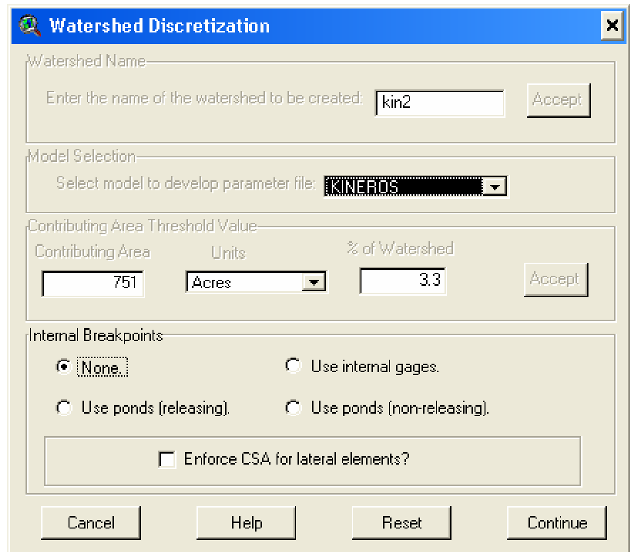
Step 1: Subdividing the watershed

1. As we did for SWAT, the first step is to generate an outline for the watershed in question. You might want to clean up the view a bit by turning off theme layers that are not useful and making sure that the *Sierra.shp* file is at the top of the list of data layers. This point will serve as the watershed outlet for the next exercise.

2. Start the AGWA tool by clicking on the **AGWA Tools>Delineate watershed**. Since we will be looking at a subwatershed in the SWAT watershed, select **Select subwatershed from a SWAT watershed**. Then click **Continue**. The watershed inputs, DEM, flow direction, etc., will be the same as those used for the SWAT watershed.

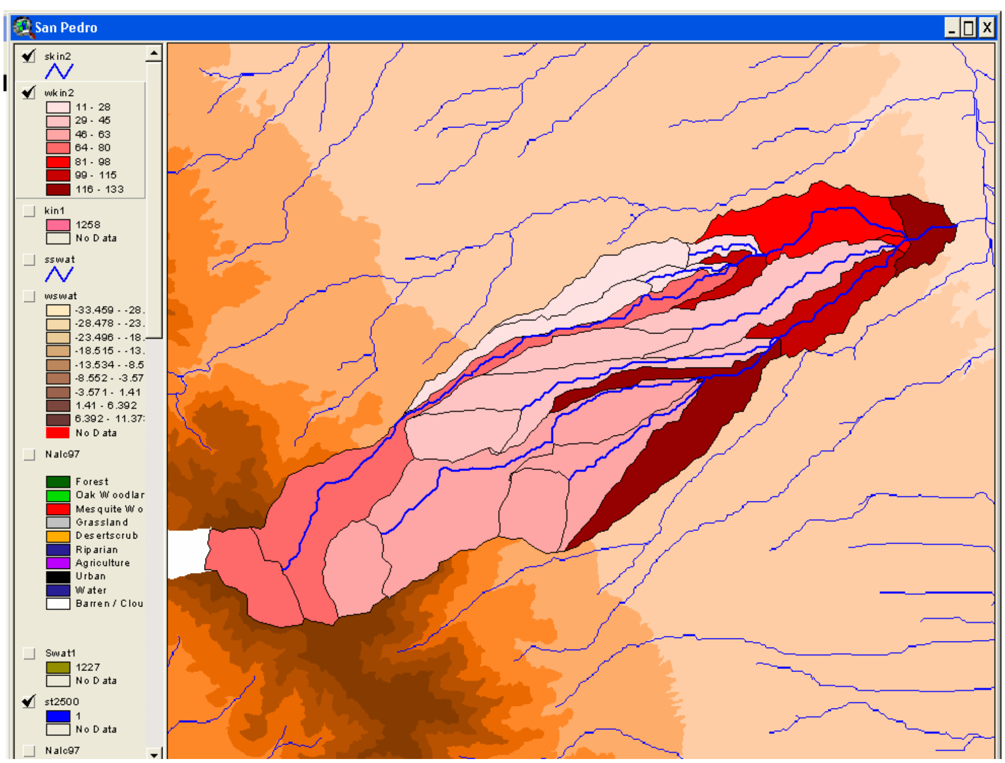
3. In the next screen select the *wswat1* watershed, and name the new watershed *kin1*. Select the SWAT subwatershed with the selection tool (you only need to click once within the subwatershed). A new watershed grid will be generated based on the selected subwatershed.





4. Once the new watershed grid is created, fill in the watershed discretization dialog.

5. For the KINEROS model, set the CSA to 750 acres, and be sure to select the model type as KINEROS, not SWAT. These models require significantly different watershed subdivisions and will not work on each others' watershed geometry. Be sure to select **None** under Internal Breakpoints since we will not be using internal gages or ponds. The final watershed should look something like the image below.



Step 2: Characterize the watershed elements for KINEROS model runs

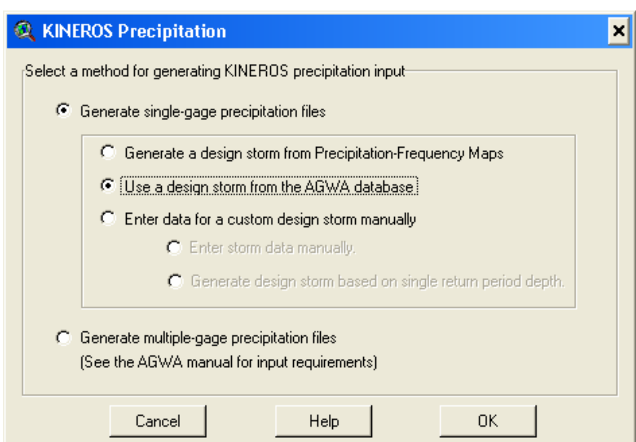
1. As in SWAT, you must intersect the watershed elements with the land cover and soils data to generate parameters for the hydrologic model. Click on **AGWA Tools>Run Land Cover and Soils Parameterization**. Choose the *wkin1*, *NALC73* and *sp_statsgo.shp* layers for the intersection.

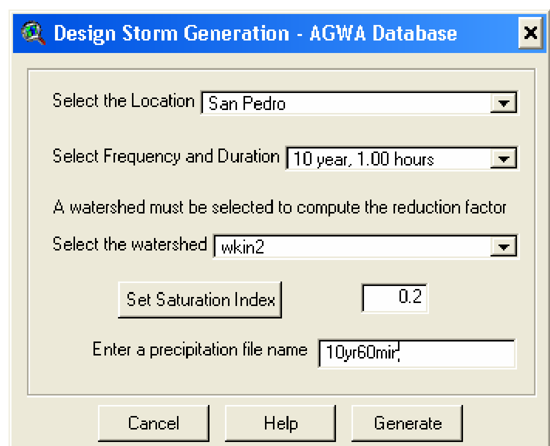
Step 3: Prepare Rainfall Files

KINEROS is designed to be run on rainfall events. AGWA has a number of return period events for southeast Arizona stored in its database. We are going to use one of the pre-defined storms, though AGWA allows you to create rainfall data for KINEROS in 5 ways:

1. Homogeneous design storm from the database (our technique).
2. Homogeneous rainfall input by the user.
3. Homogeneous rainfall input by the user based on a single return-period depth.
4. Homogeneous design storm based on precipitation frequency maps.
5. Heterogeneous rainfall input by the user using multiple gage locations.

1. Click on **AGWA Tools>Write KINEROS Precipitation File**. Select **Generate single-gage precipitation file>Use a design storm from the AGWA database**. Fill in the dialog box so that it resembles the image below on the left. Click **OK** and then fill out the next screen so it looks like the image below on the right. Increasing the watershed saturation index will increase the simulated runoff since losses to infiltration will be lessened. Likewise, increasing the return period will increase the runoff since longer return period storms have greater rainfall depths. We'll pick a middle ground for this exercise (10 year, 1.00 hours with 0.2 saturation). Click **Generate** to continue.

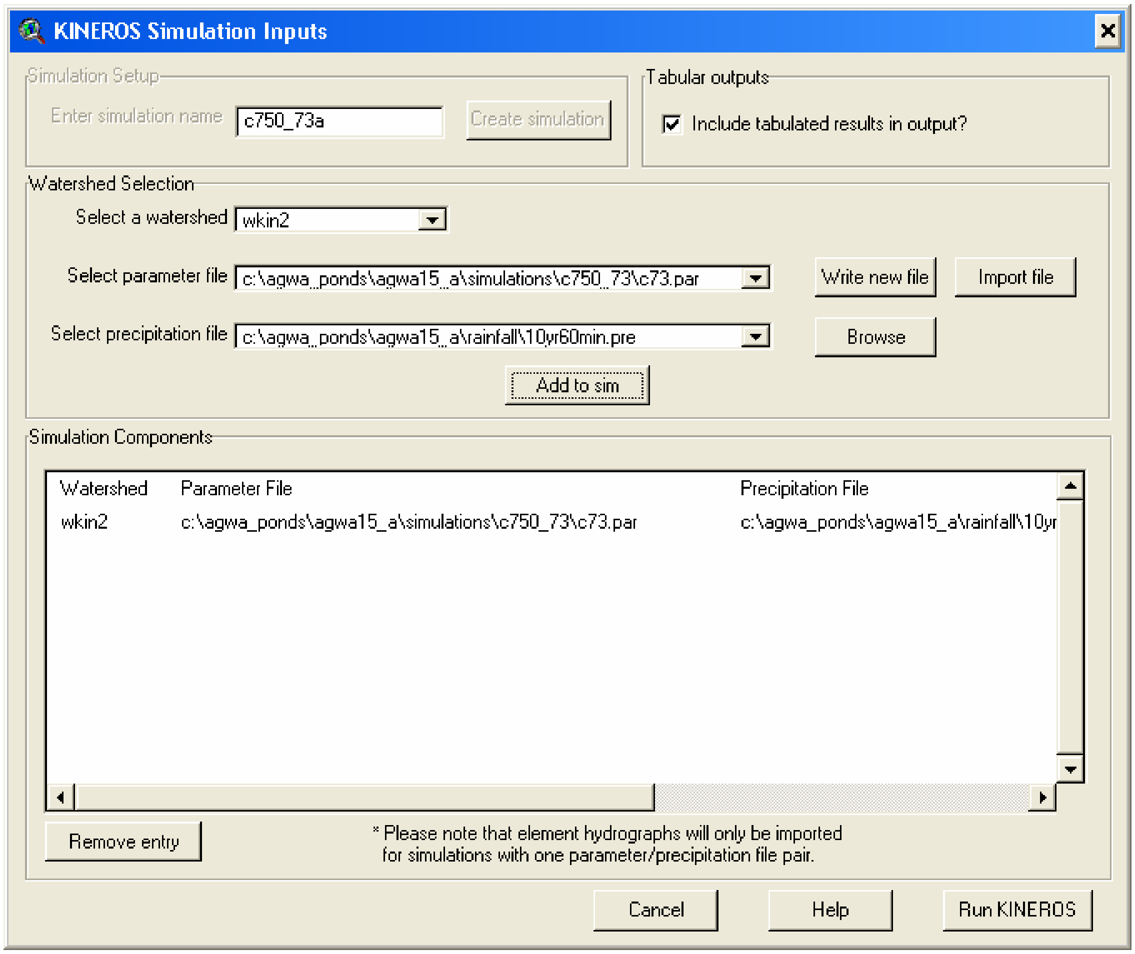




2. Save the precipitation file in the *rainfall* directory as *10yr60min*.

Step 4: Write output and run KINEROS

1. At this point you have all the data you need to run KINEROS on the *wkin1* watershed. Click on **AGWA Tools>Write Output File and Run KINEROS**. Create a new KINEROS simulation called "c750_73". Select the watershed you just created.

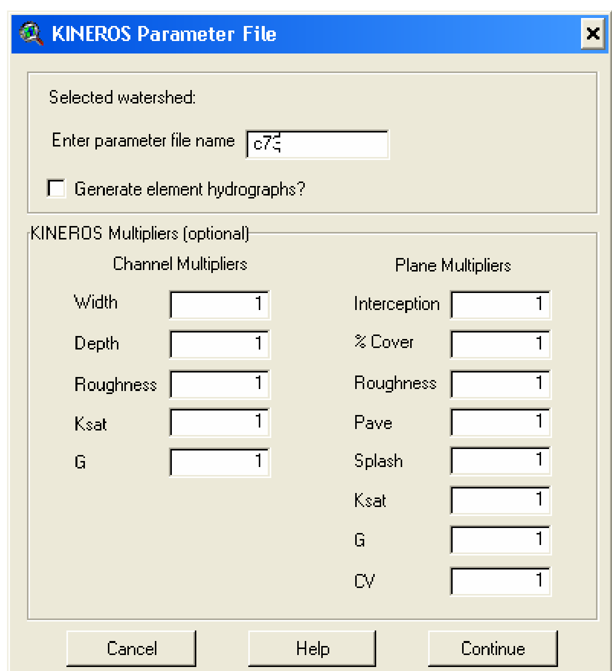


2. AGWA alerts you that no parameter files exist for this watershed. Click 'Write new file' to create a parameter file. Enter 'c73' for the parameter file name.

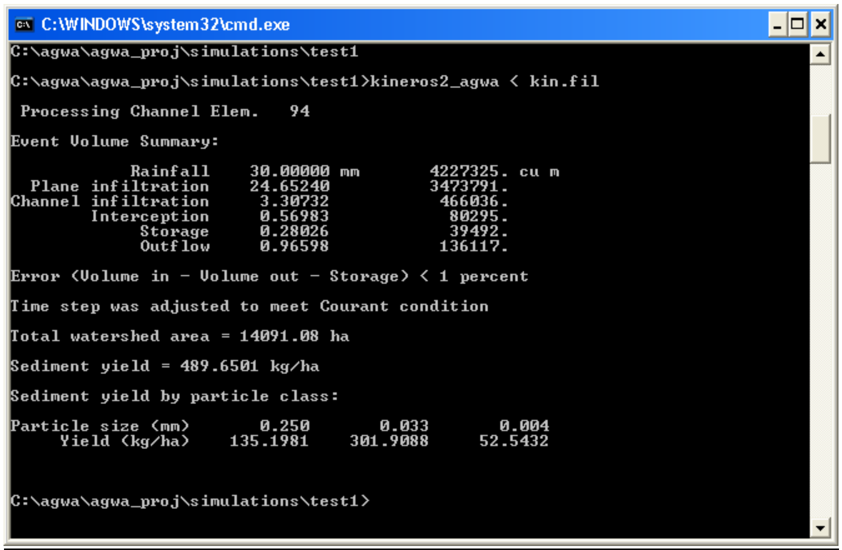
AGWA allows for the use of parameter multipliers in the development of input parameter files for KINEROS. The multipliers can be very useful for calibration and validation studies but are not necessary for our purposes. We will use the default multiplier values of "1", thereby leaving the parameter estimation alone.

Click **Continue** to create the file.

The new parameter file is added to the drop-down window. Select the file you just created. Then select the precipitation file created

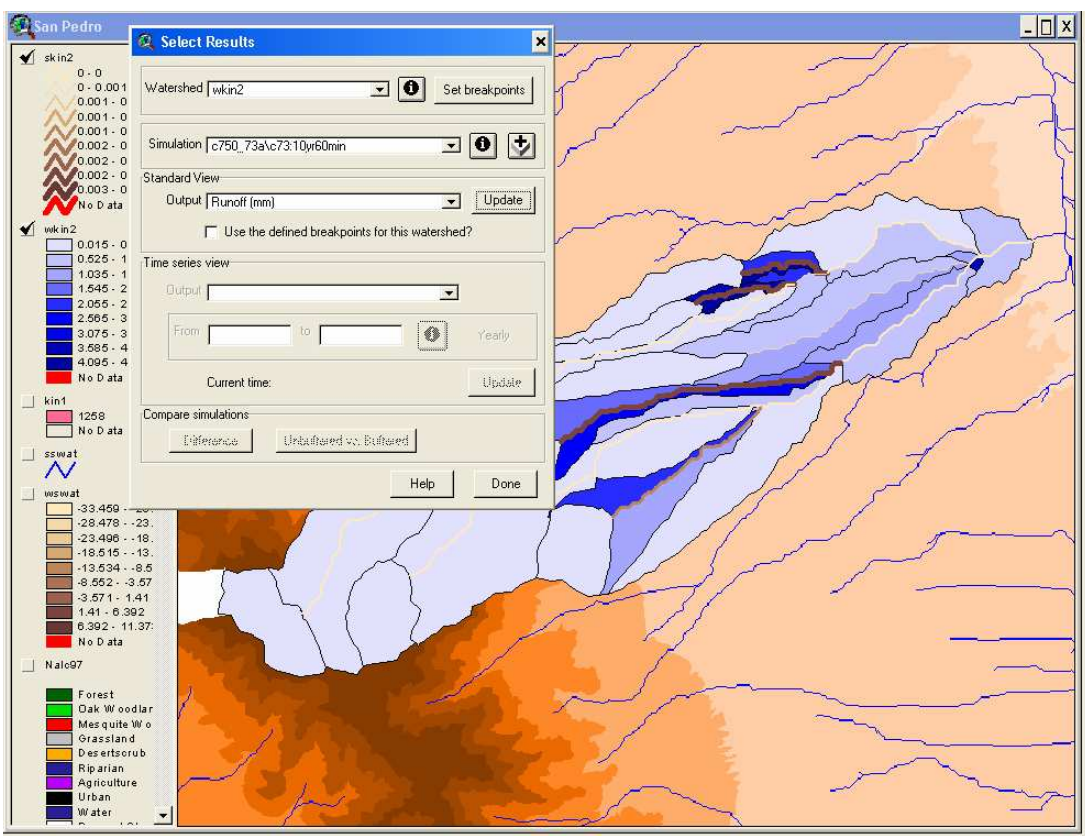


earlier. Click **Add to simulation**. The combination is added to the simulation components text box. Multiple pairs of parameter files and precipitation files can be added to a simulation; but for these purposes, we'll perform separate simulations. Click **Run KINEROS**. Once KINEROS starts running, you will see a black DOS screen like the one shown below.



Step 5: View the results

1. Viewing the KINEROS results is identical to looking at SWAT results. Click on **AGWA Tools>View KINEROS Results** and choose the *wkin1* watershed with the *c750_73\c73:10yr60min* simulation. KINEROS outputs are always identified by the simulation name (directory) then by the combination of the parameter file name and the precipitation file name. Select "Runoff (mm)" for the output.



Step 6: Repeat for 1997 land cover

1. Re-run the land cover and soils parameterization, this time using the 1997 NALC data.

2. You do not need to re-generate a rainfall file.

3. Create a new simulation called c750_97 (**AGWA Tools>Write Output File and Run KINEROS**). Create a new .par file. Name the file *csa750_97.par*.

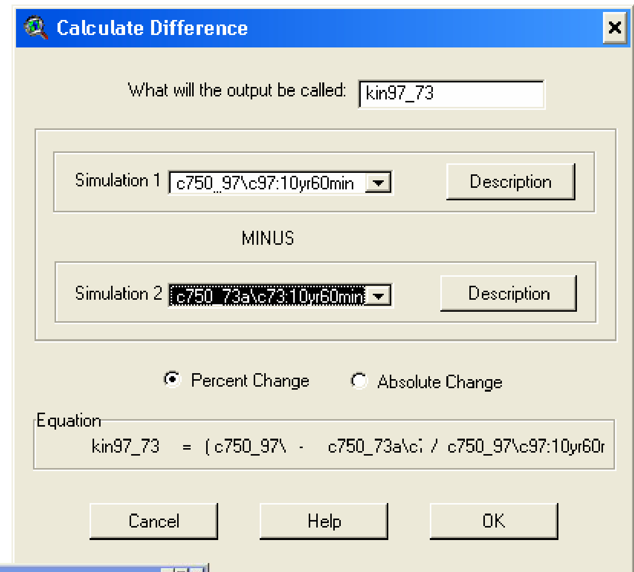
4. View your results. Note that the patterns are similar in display, but the regional magnitudes are different.

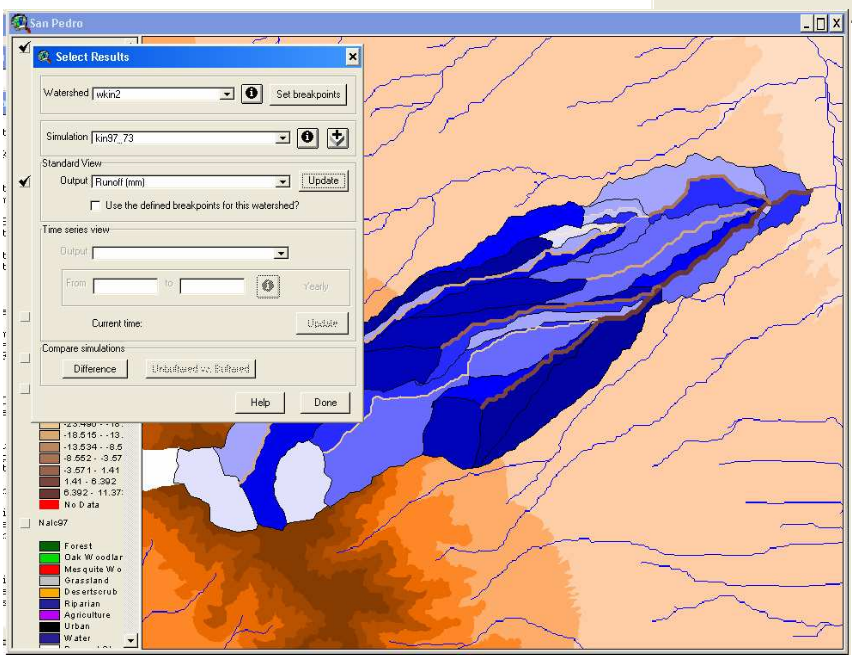
Step 7: Compare 1997 and 1973 results

1. Click on **AGWA Tools>View KINEROS Results** and perform the same steps you did with the SWAT results to visualize the spatial patterns of hydrologic change.

2. Name the output *kin97-73*, and fill in the screen like the one to the right so that you will be viewing the difference between the model results using the 1997 and 1973 land cover data.

3. Your results for runoff should look something like the image below.





What is driving this change in runoff? You can inspect the changes in the underlying land cover and make some correlations. The driving forces behind the change are primarily decreases in cover, surface roughness and infiltration.

Some question to think about that may be answered using this multi-faceted approach:

a. What regions of the basin have undergone significant change in their landscape characteristics?

b. How have these changes in the spatial variability impacted runoff, water quality, and the water balance?

c. Given spatially distributed changes in the water balance, what stresses (or benefits) are placed on the plant community or habitat? Can we identify regions of susceptibility or especially sensitive areas?

d. How may these tools be used in a forecasting model or land cover simulation scenario to identify "at-risk" or sensitive areas?

e. How do the spatial patterns of change affect runoff response? How can we optimize landscape and hydrologic assessment as a function of temporal and spatial scaling?

Some Additional Exercises to Try on the San Pedro

1. Change the CSA to see how altering the geometric complexity impacts the simulation of hydrology and landscape statistics.

2. Use the MRLC from the early 1990s to simulate runoff and compare it with the commensurate 1992 NALC data to see how different land cover classifications affect the results.

3. Use the *nws_gages* coverage to generate spatially-distributed rainfall for input to SWAT. This approach will create a Thiessen map across the watershed and you will notice a distinct south to north gradient in rainfall depths that affects the generation of runoff and also impacts the change statistics.

4. Generate a variety of rainfall events for KINEROS and investigate the relative impacts of land cover change on small vs. large return period storms. You should see a drop in percent change with increasing rainfall. Why?