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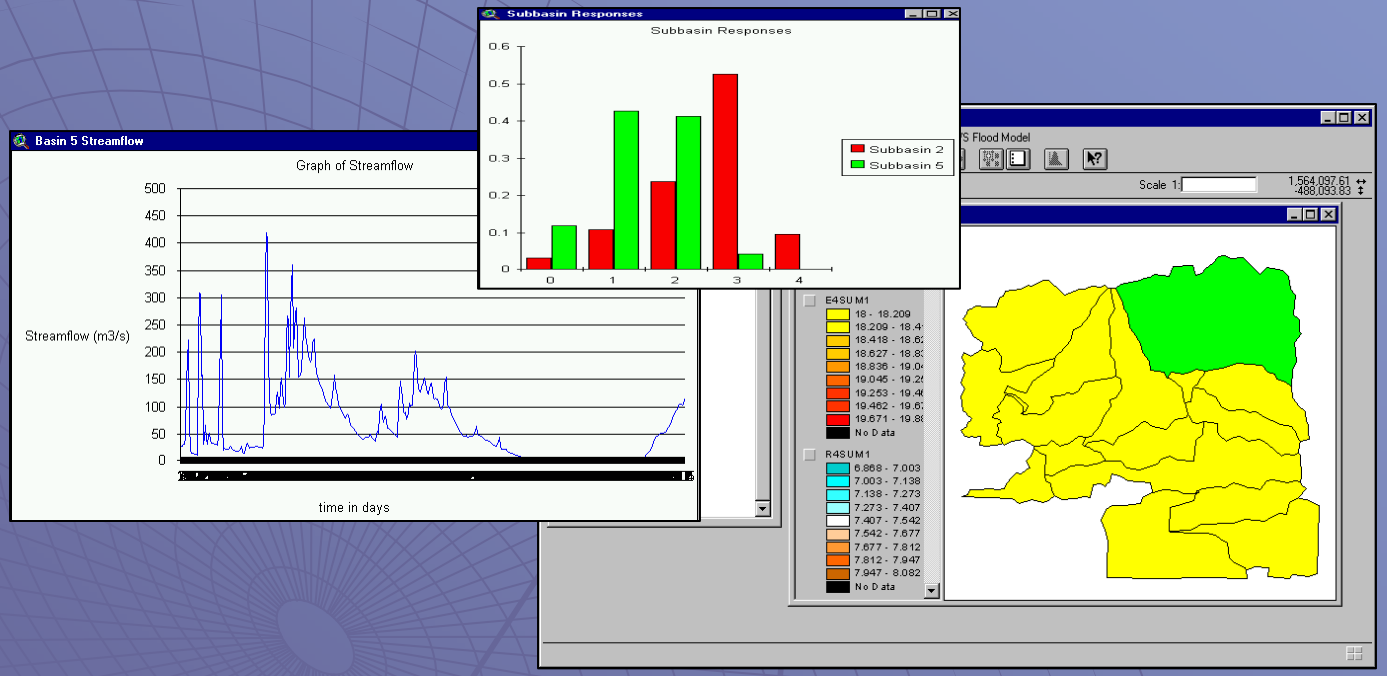
Stream Flow Model

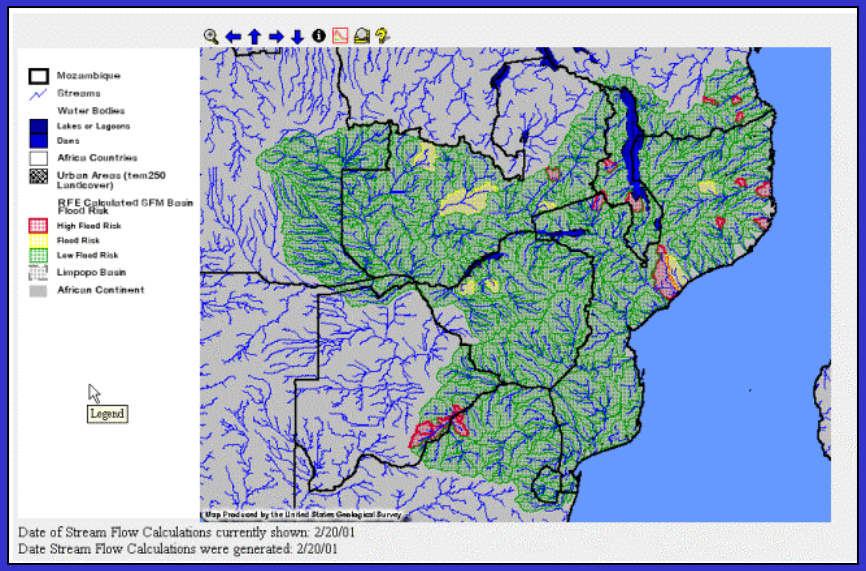


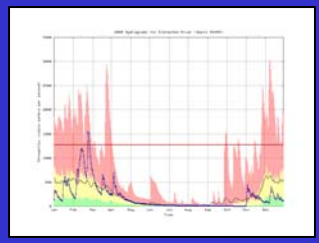
Training Center

U.S. Geological Survey
Center for Earth Resources
Observation and Science (EROS)
Sioux Falls, South Dakota, USA

USGS / FEWS NET

Stream Flow Model





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Outline:

Data Compilation

- Preparing ArcView
- Acquisition of data and data preparation

Using the GUI to simulate stream flow with the SFM

- Generating input files
- Computing Subbasin Response & Flow Statistics

Description of the Stream Flow Model

- Water Balance
- Lumped and Distributed Routing
- Updating

Description of the Stream Flow Model :

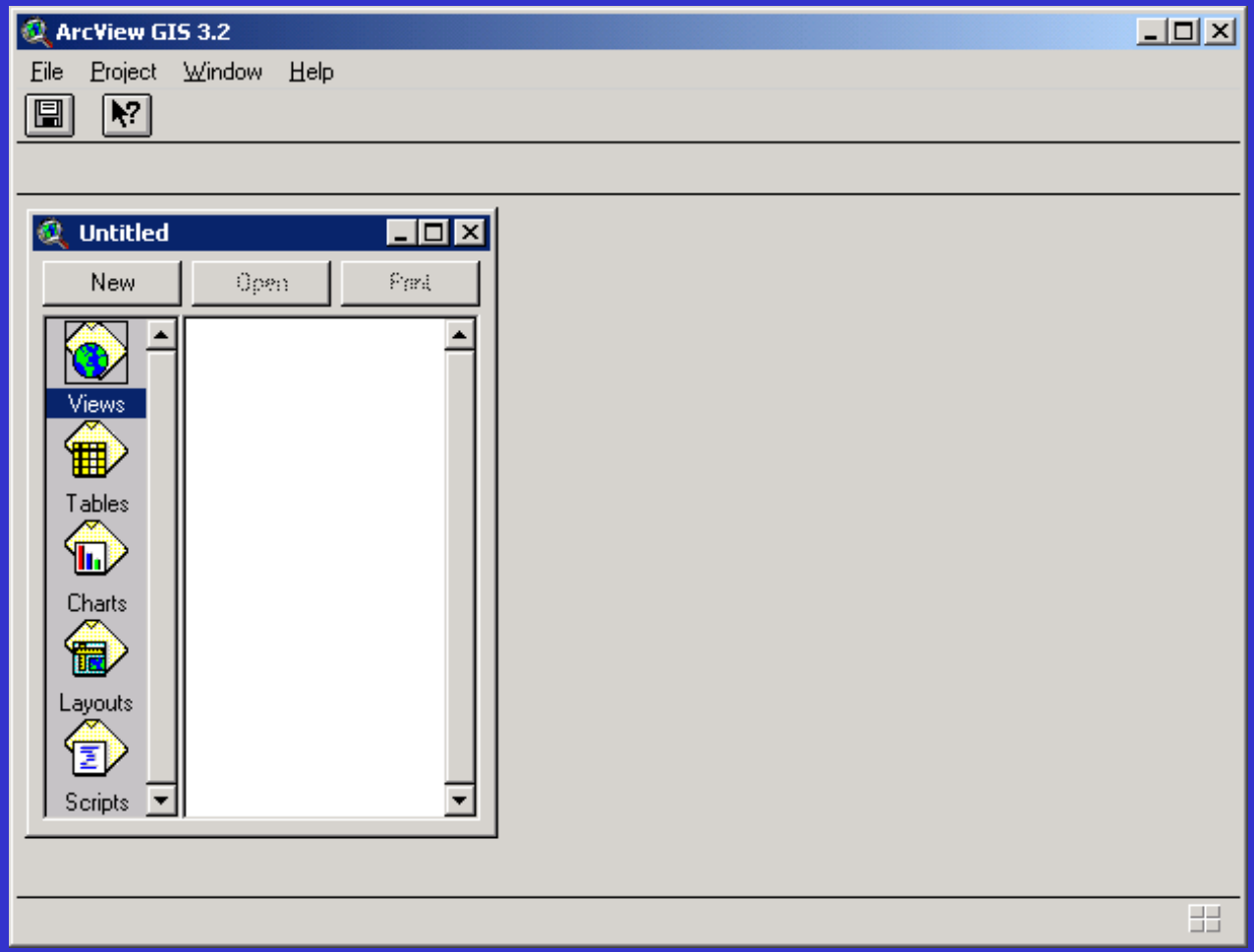
The static data describing the physical characteristics of the watersheds and the precipitation and evaporation data for the watersheds are read and stored in arrays during the model's initialization phase. The application then creates the files required to maintain the simulated stream flow and soil moisture contents.

Many characteristics describing the physical nature of the watershed are included in the input files. Additional characteristics are derived from this information and used by the model to simulate stream flow and soil-water conditions.

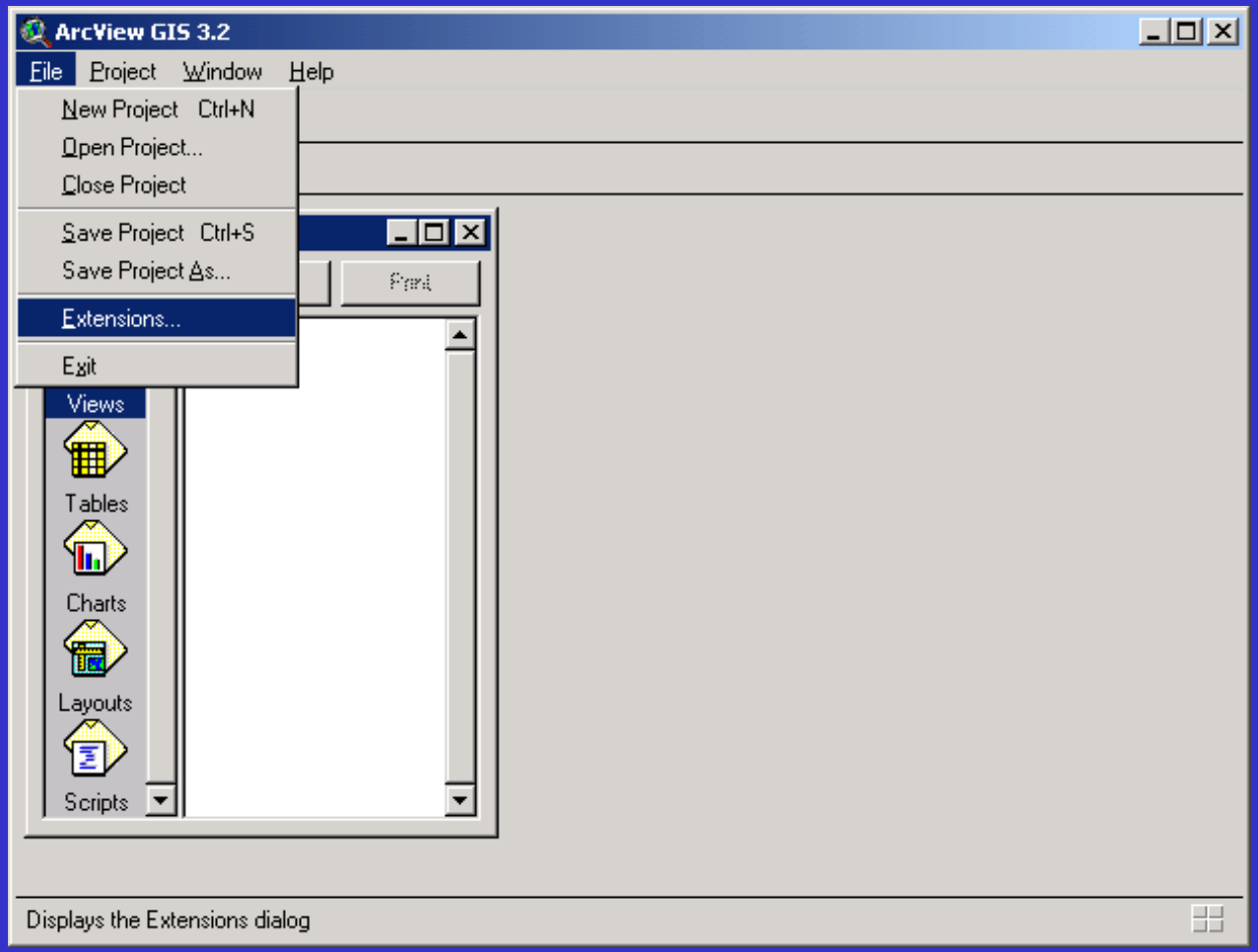
Preparing ArcView:

- The SFM uses ArcView's "Spatial Analyst" extension
- SFM & GUI are included in the "fewsflood.avx" extension
- The "fewsflood.avx" extension must be copied to the folder "/ESRI/AV_GIS30/ARCVIEW/EXT32" prior to execution. (exact path to the EXT32 directory may vary)
- Create a folder that will be the flood model work area
- Copy the contents of the CD to the flood model folder
- Change the write permissions on all files by un-checking the "read only" box under the file properties

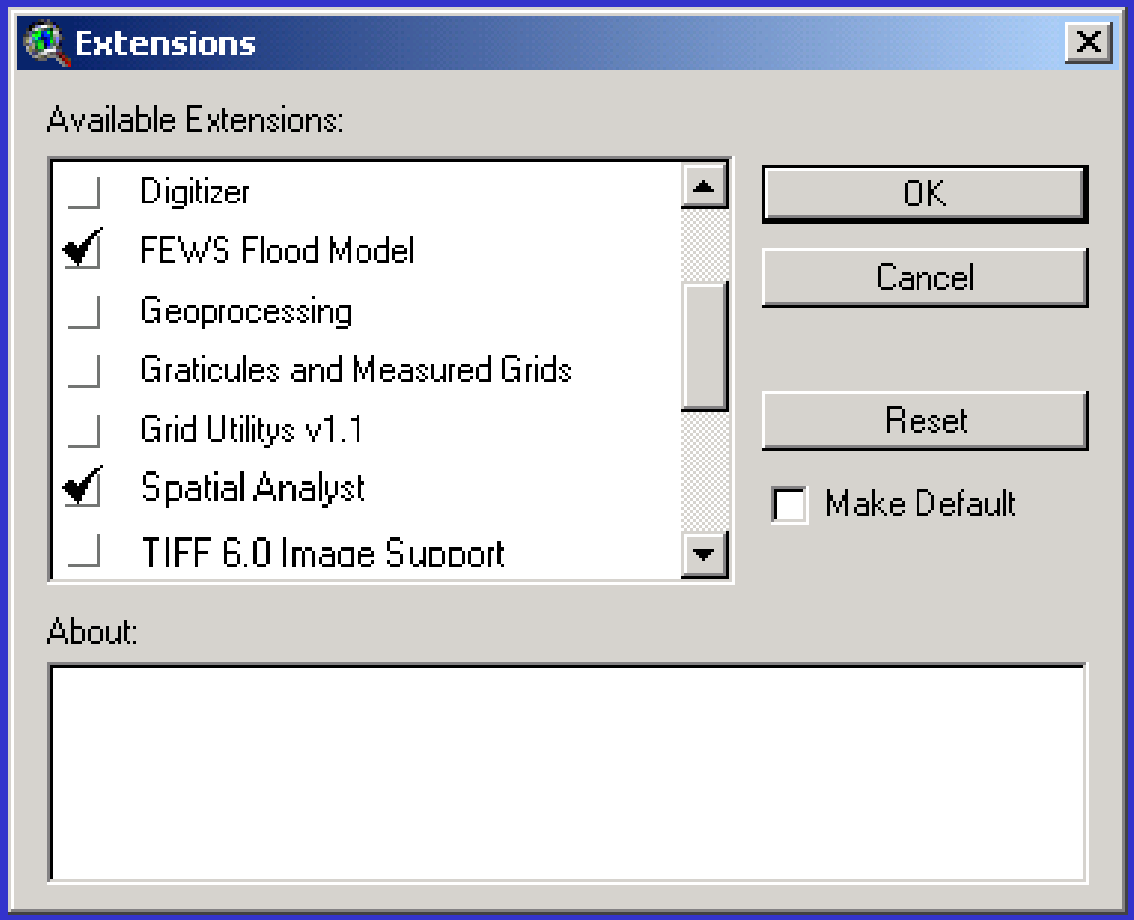
Start ArcView and Open a New Project:



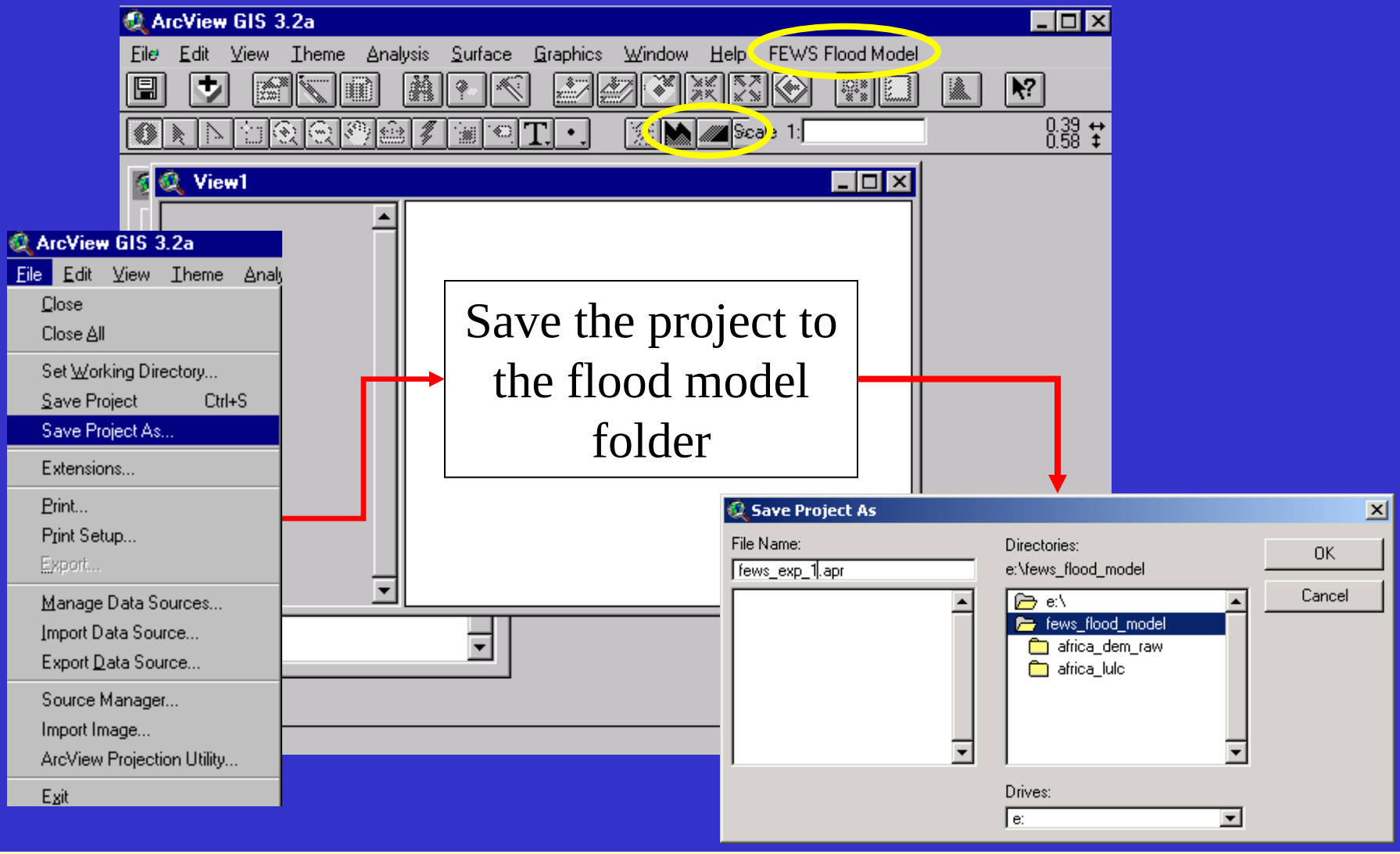
Access ArcView Extension Window:



Activate the FEWS Flood Model and Spatial Analyst Extensions :



FEWS Flood Model menu and additional tools :



Data Compilation :

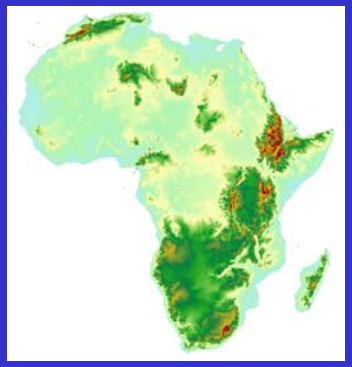
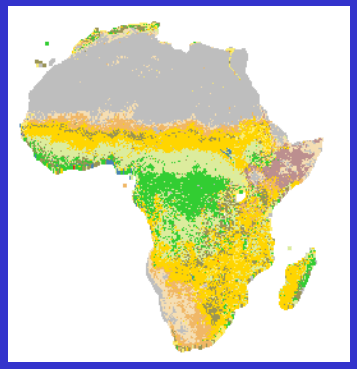
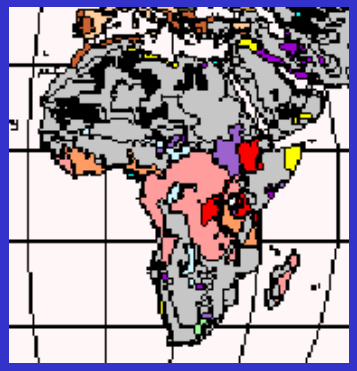
SFM simulates daily stream flow using two primary input files

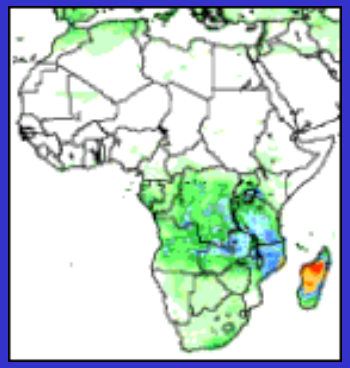
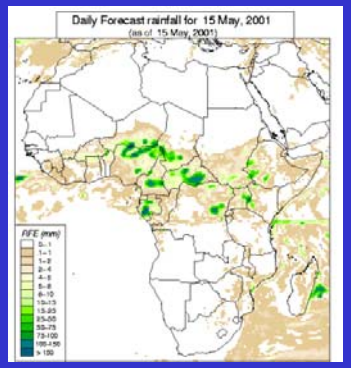
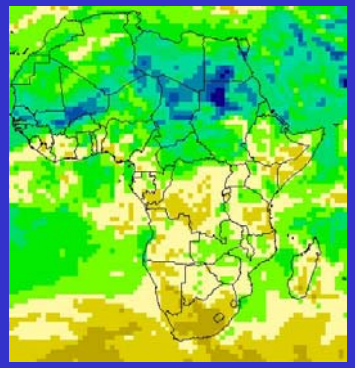
1. A file containing parameter values describing the physical characteristics of the basins being modeled.
2. A file containing values for forcing variables describing daily precipitation and potential evapotranspiration occurring over the watersheds.

Data needed to create the input files is available as GIS layers

A primary function of the SFM GUI is the creation of input data files using these GIS layers

GIS layers necessary for developing input files :

Digital Elevation Model (DEM)	Land Use/ Land Cover	Soils
		

Rainfall Estimates (RFE)	Precipitation Forecasts	Potential Evapotranspiration
		

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GIS Data Sources :

Digital Elevation Model (DEM)

HYDRO 1km dataset - http://edcdaac.usgs.gov/gtopo30/hydro/africa.html

Land Use / Land Cover

USGS Land Cover dataset - http://edcdaac.usgs.gov/glcc/glcc.html

Soils Data

FAO Digital Soils Map of the World

Rainfall Estimates (RFE)

NOAA Climate Prediction Center

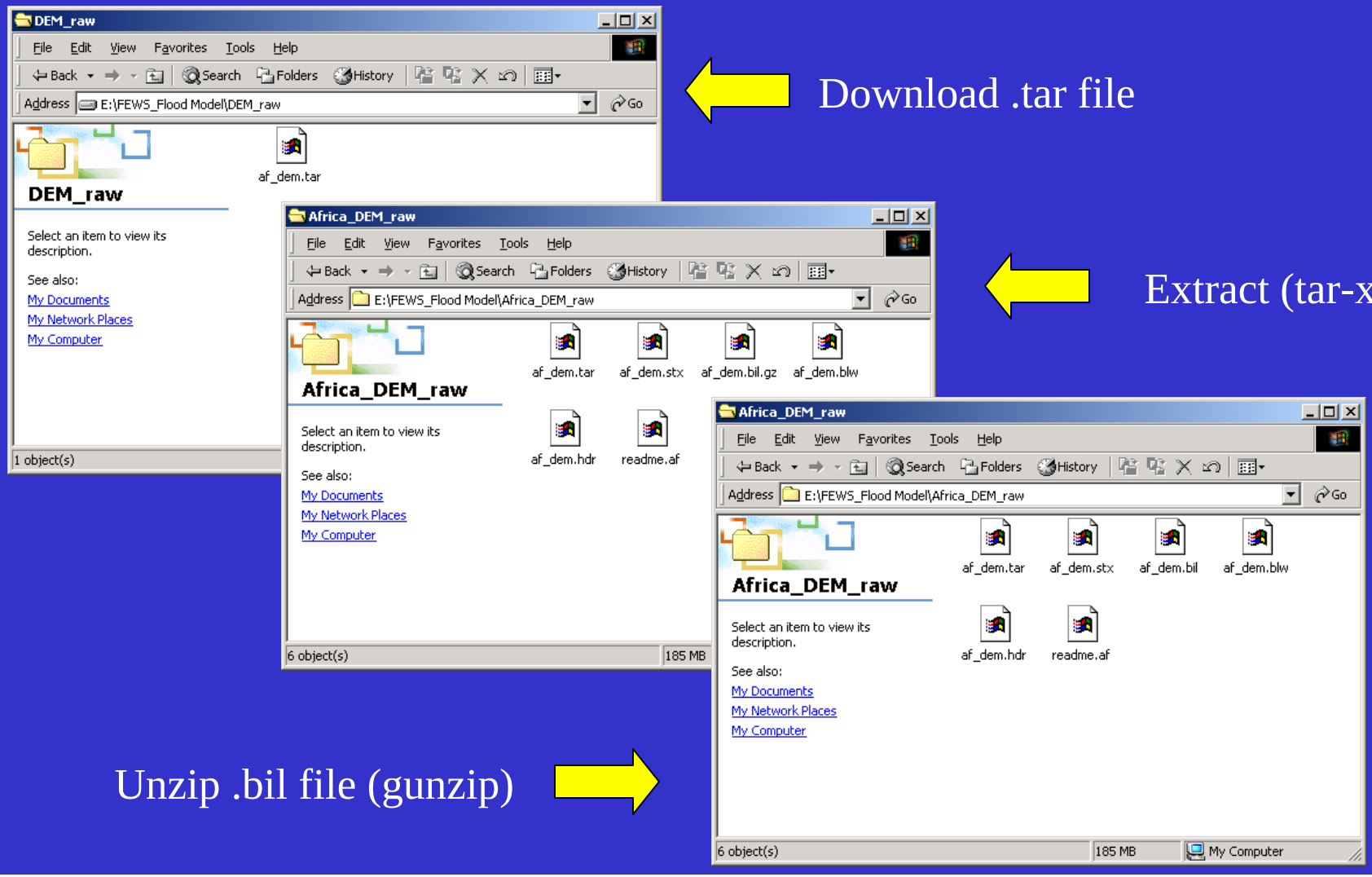
Precipitation Forecast

U.S. Air Force Images

Potential Evapotranspiration

NOAA Climate Prediction Center

Data Preparation : Digital Elevation Model (DEM)



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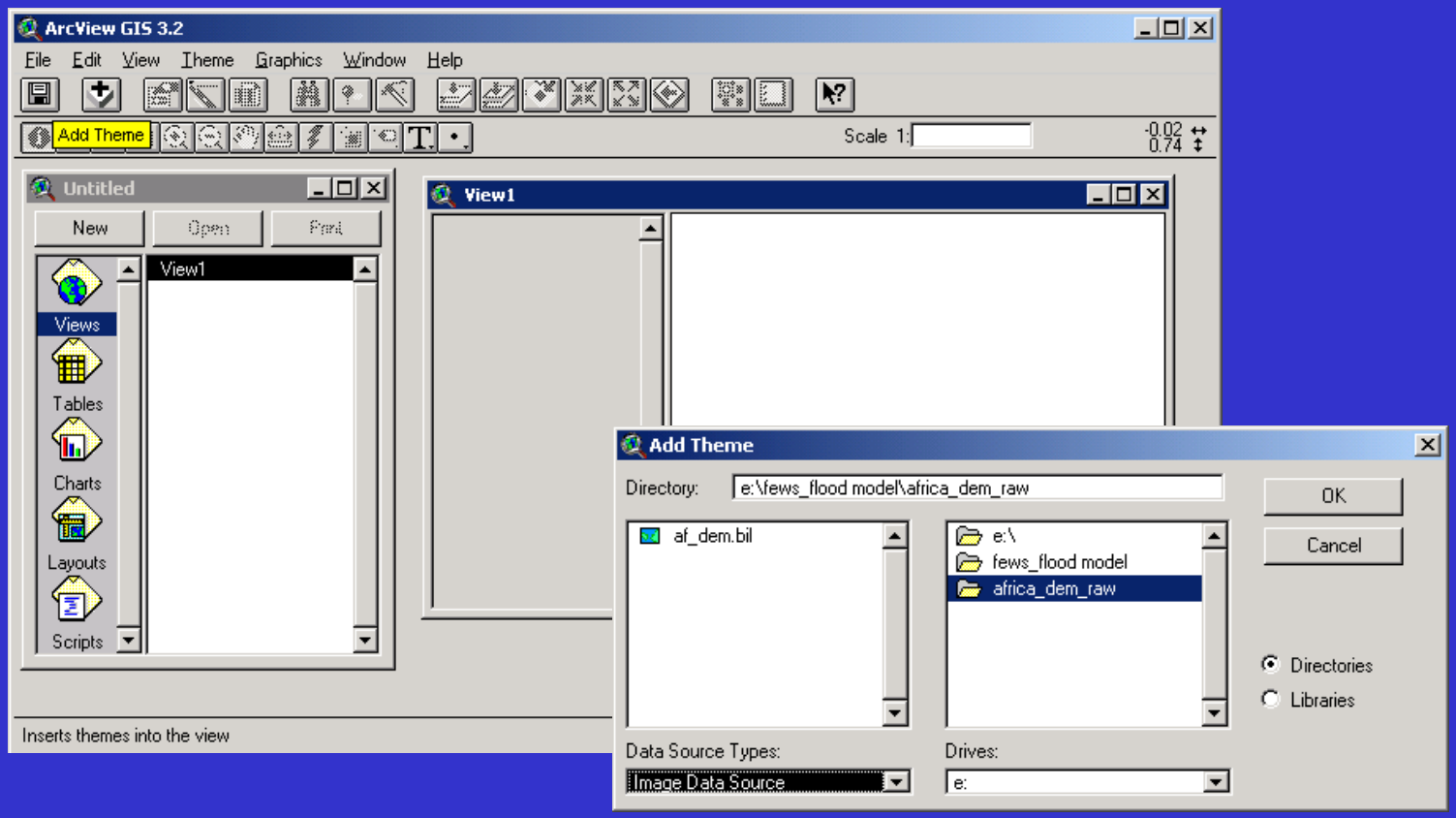
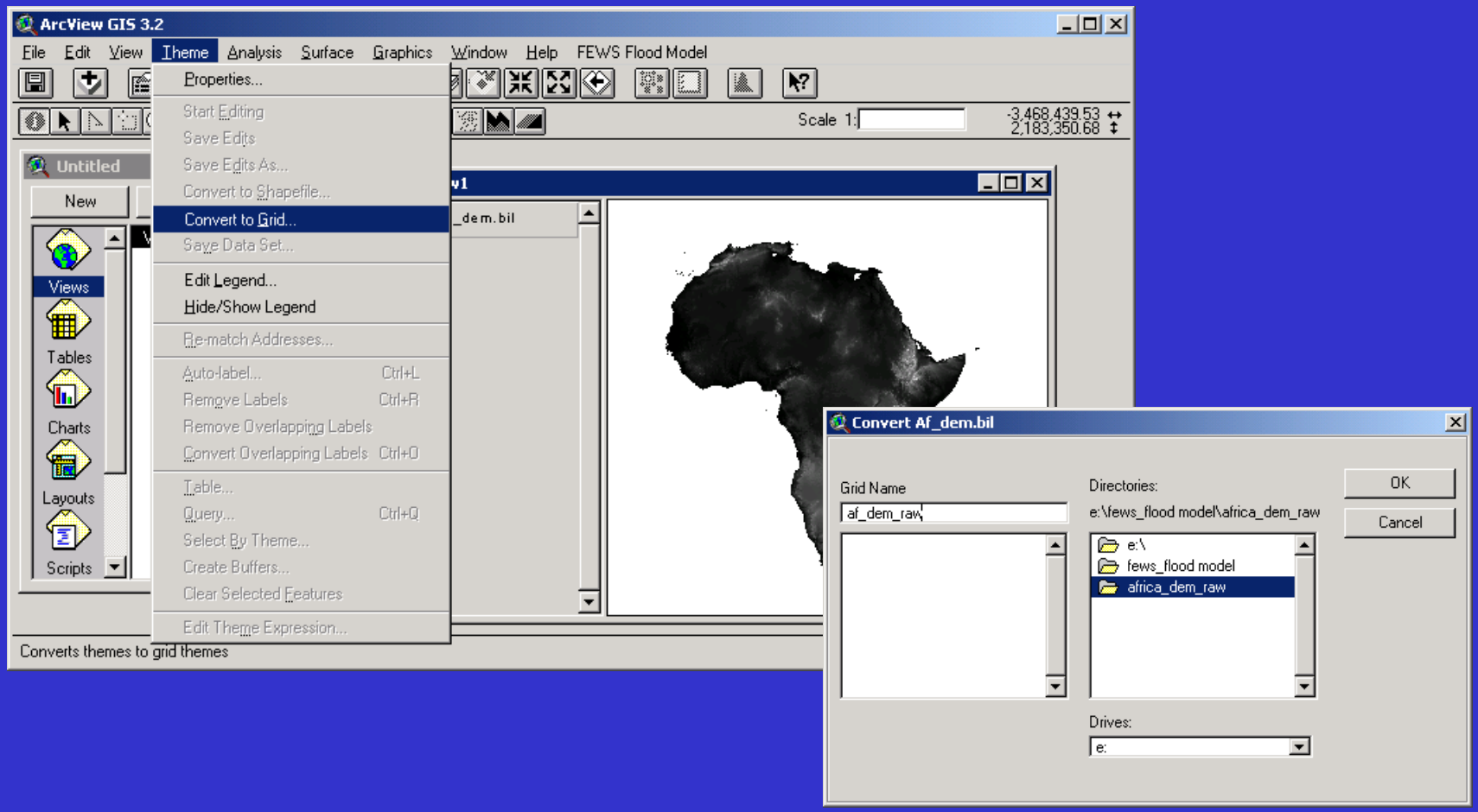
Data Preparation : Digital Elevation Model (DEM)

Add theme as an image data source to the previously saved project



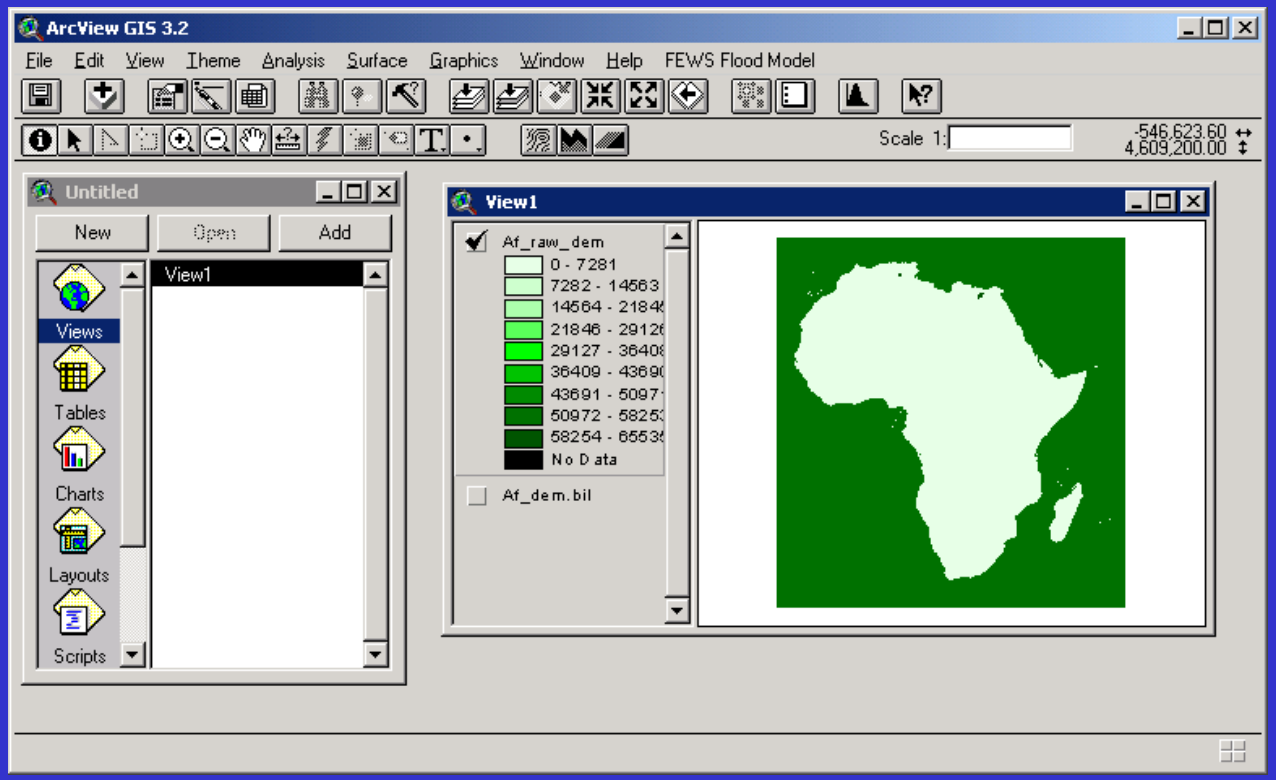
Data Preparation : Digital Elevation Model (DEM)

Convert the DEM image to a grid



Data Preparation : Digital Elevation Model (DEM)

The grid conversion processes in ArcView does not support conversion of signed image data; therefore the negative 16-bit image values will not be interpreted correctly. After converting the image to a grid a fix can be accomplished using the following rule: if the grid value is greater than or equal to 32768, convert the grid value by subtracting 65536.



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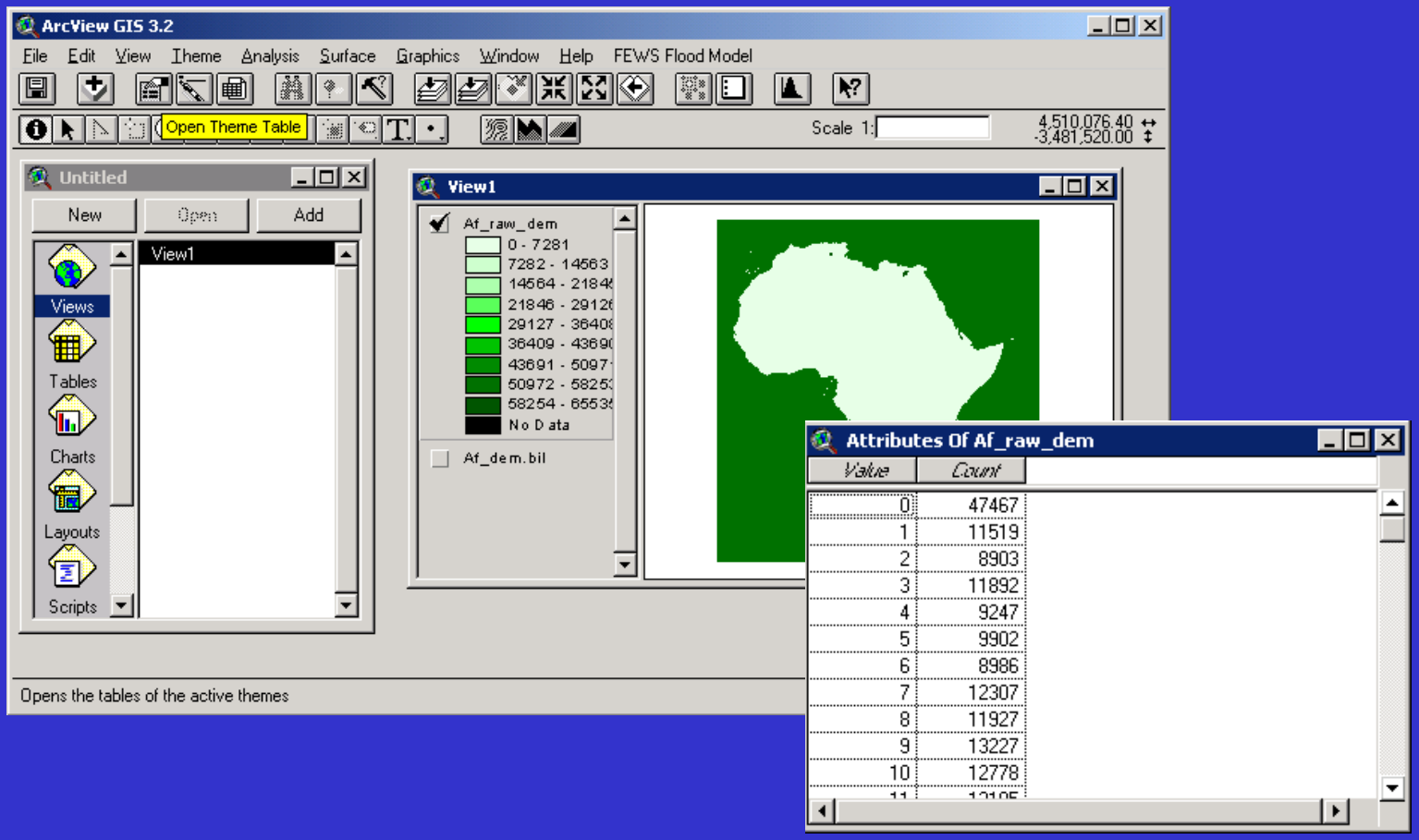
Data Preparation : Digital Elevation Model (DEM)

Open the attribute table for the DEM grid



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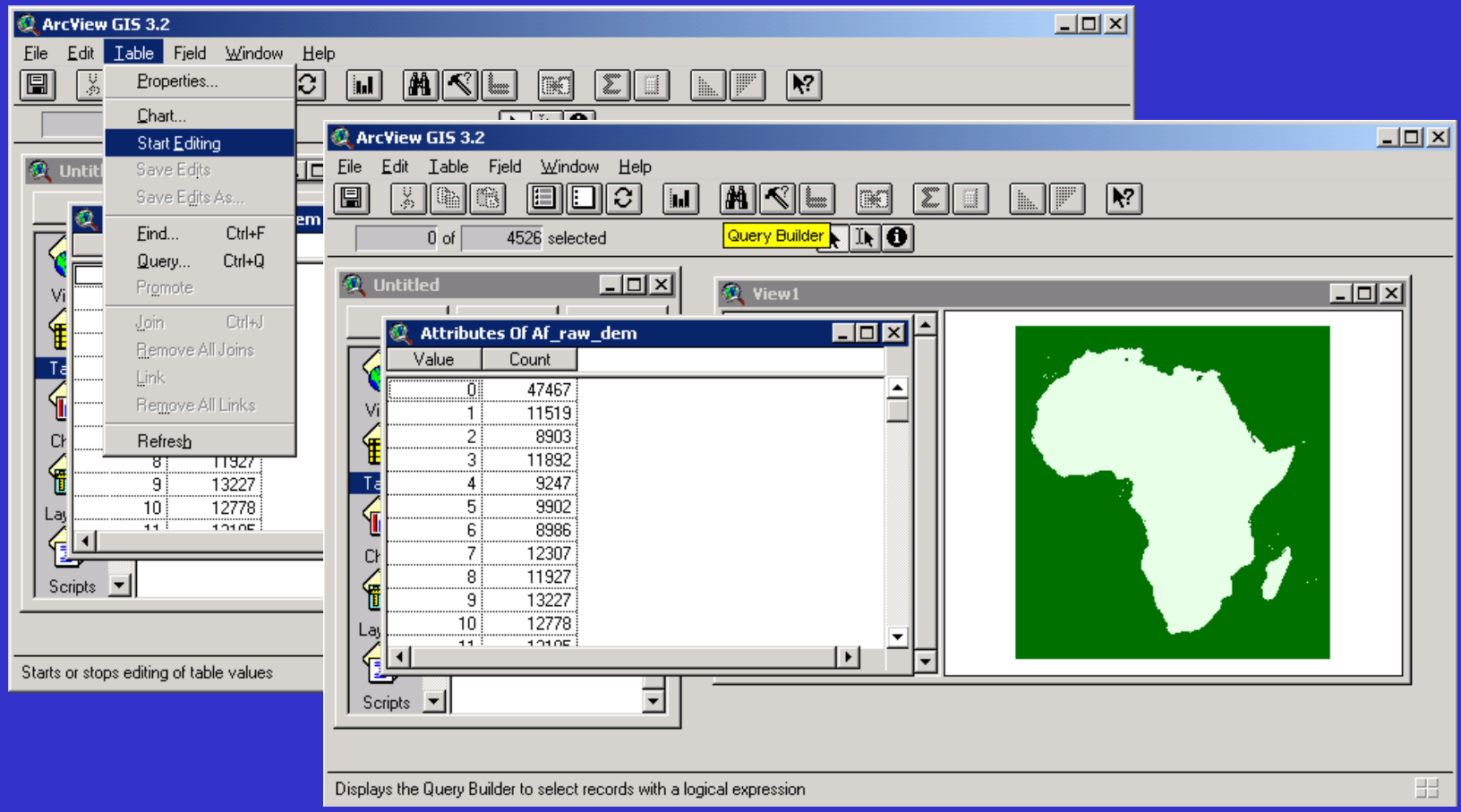
Data Preparation : Digital Elevation Model (DEM)

Select ‘start editing’ from the table menu and open the query builder



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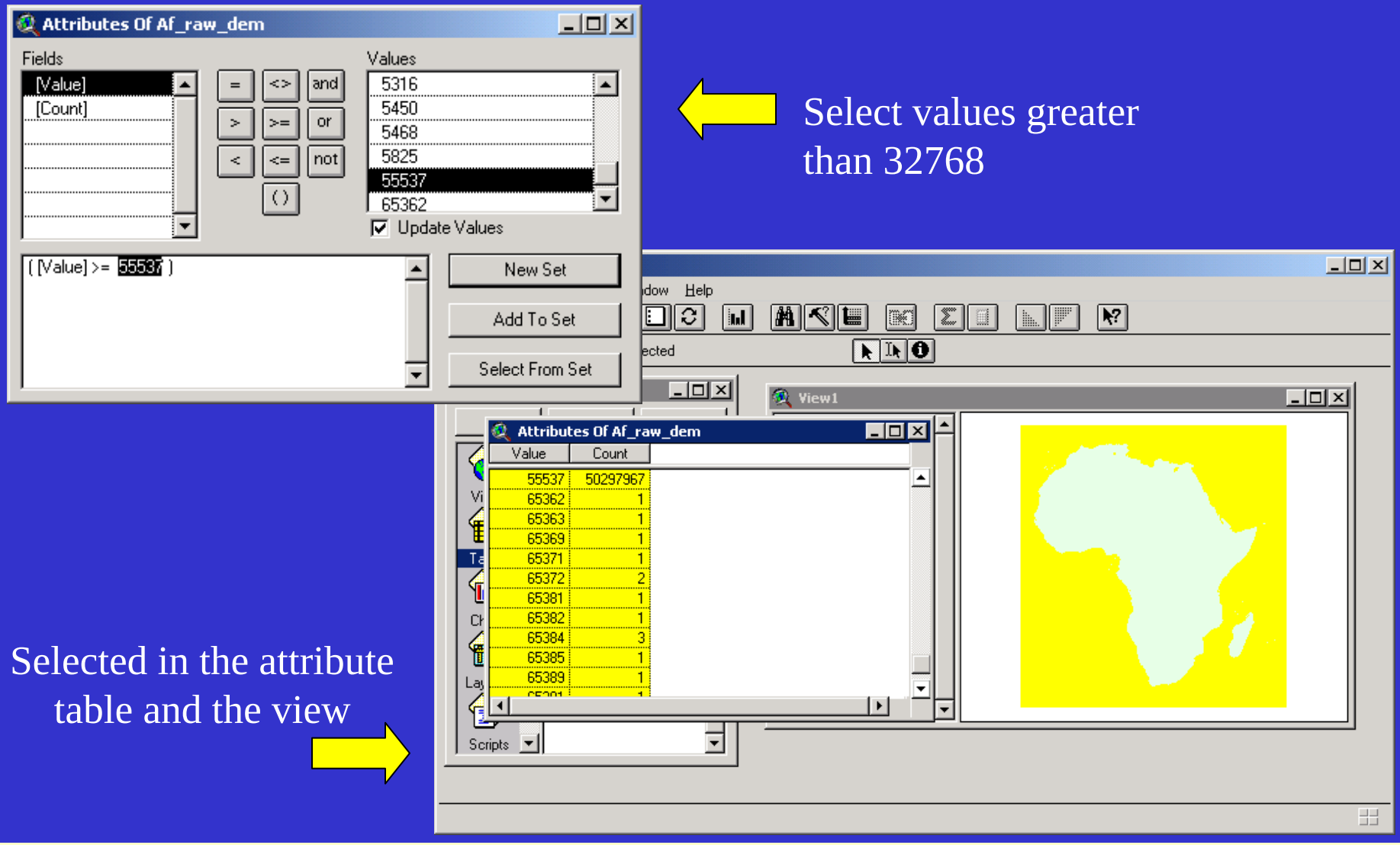
Data Preparation : Digital Elevation Model (DEM)



Select values greater than 32768

Selected in the attribute table and the view

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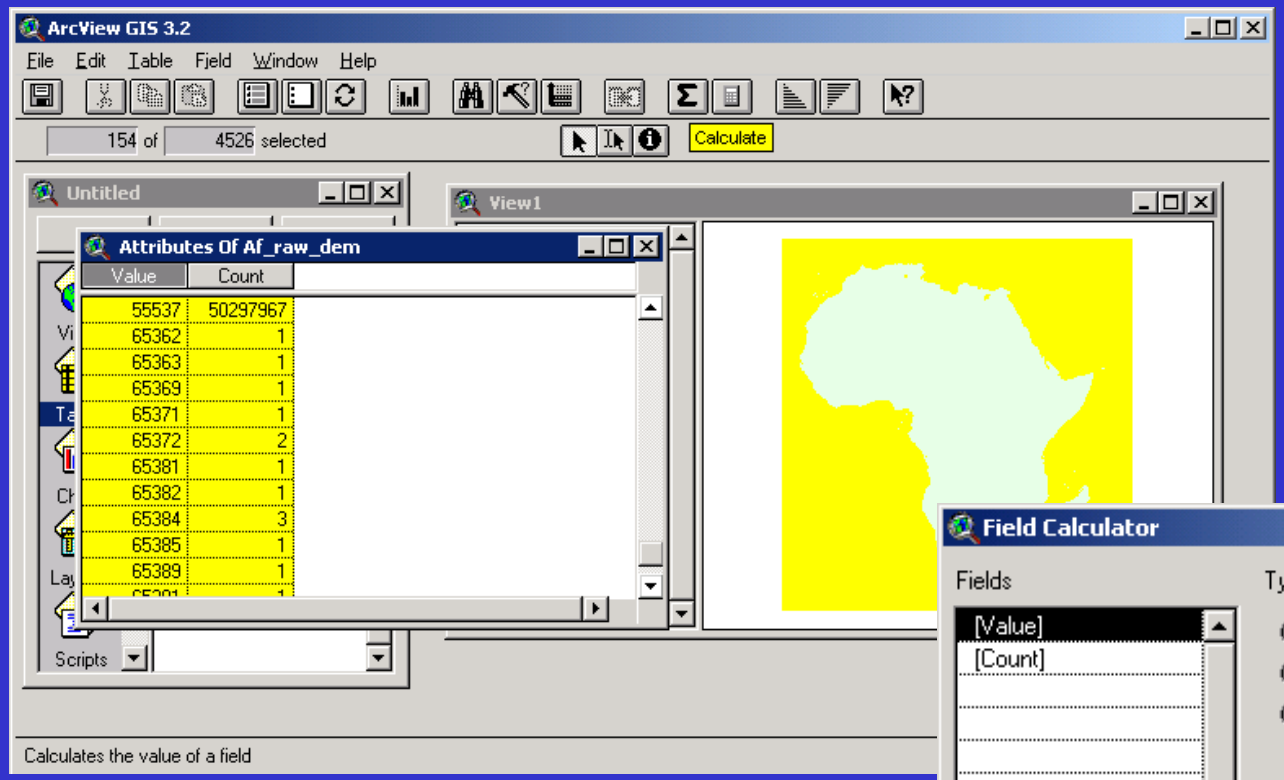
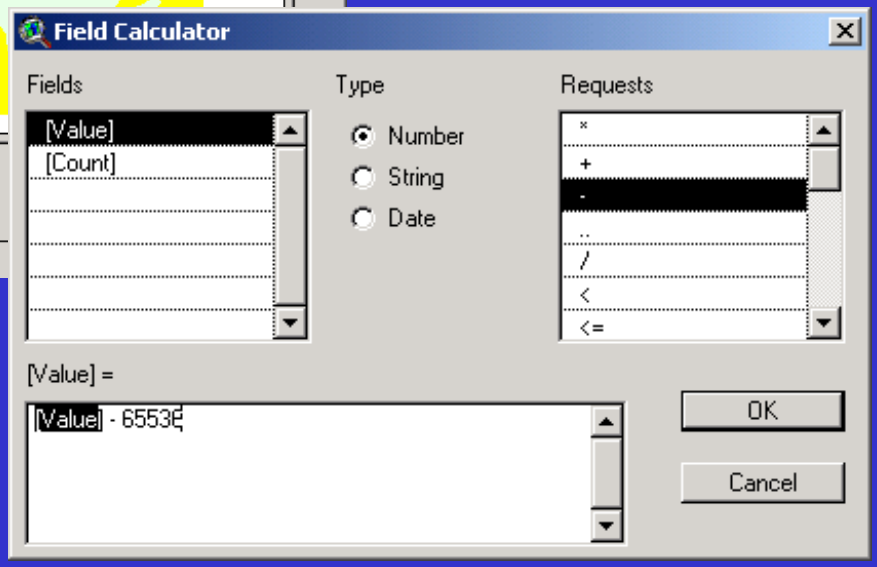
Data Preparation : Digital Elevation Model (DEM)



Select the 'value' field in the attribute table and open the calculator



Calculate the value equal to the current value minus 65536

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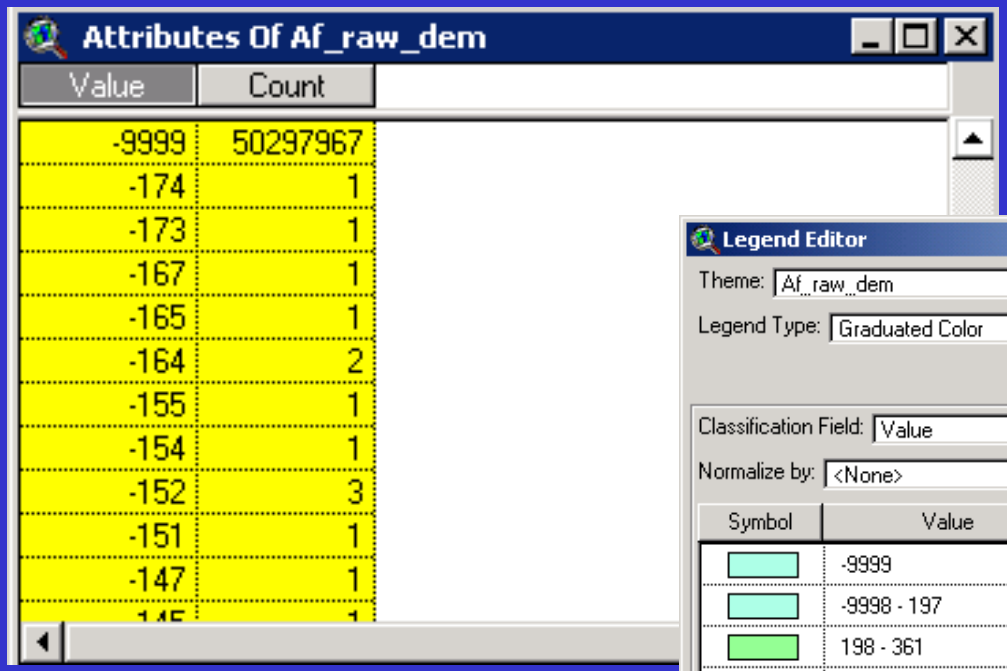
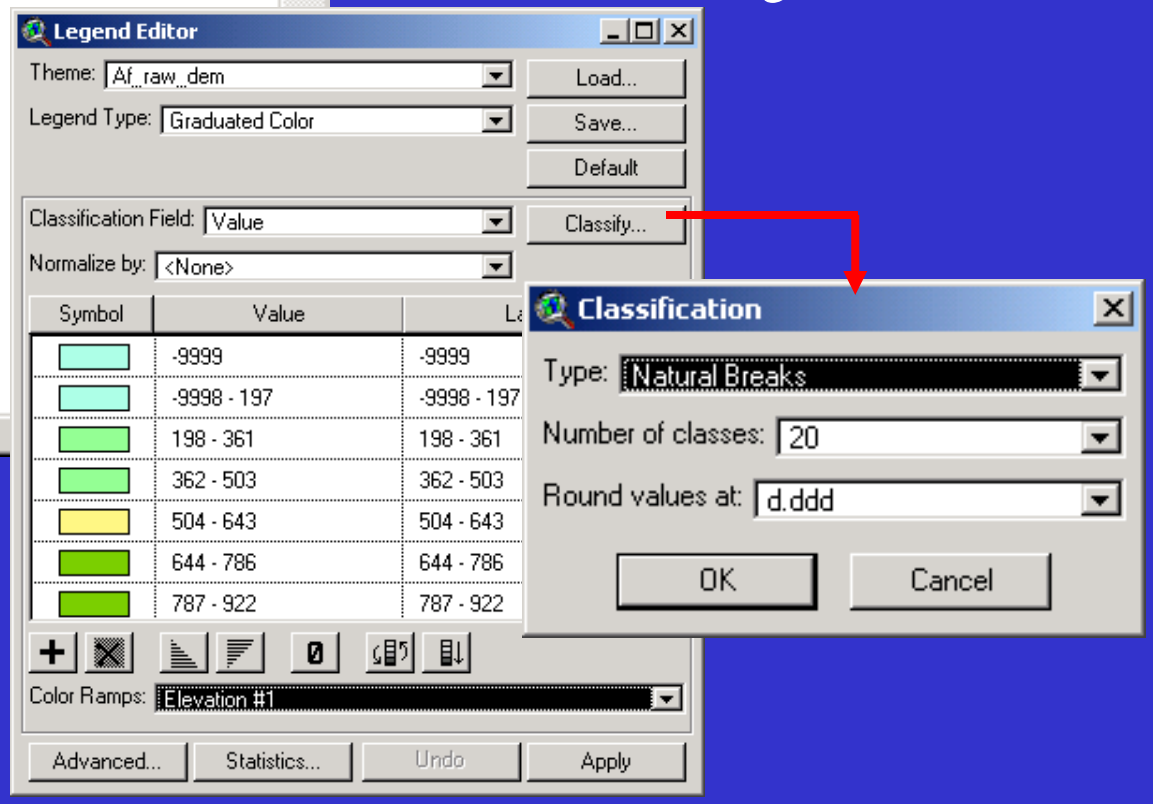
Data Preparation : Digital Elevation Model (DEM)



Results of the calculation to correct for the signed integer data



Open the legend editor for the grid and change the color ramp to “Elevation#1”, set the classification to “natural breaks” with 20 classes

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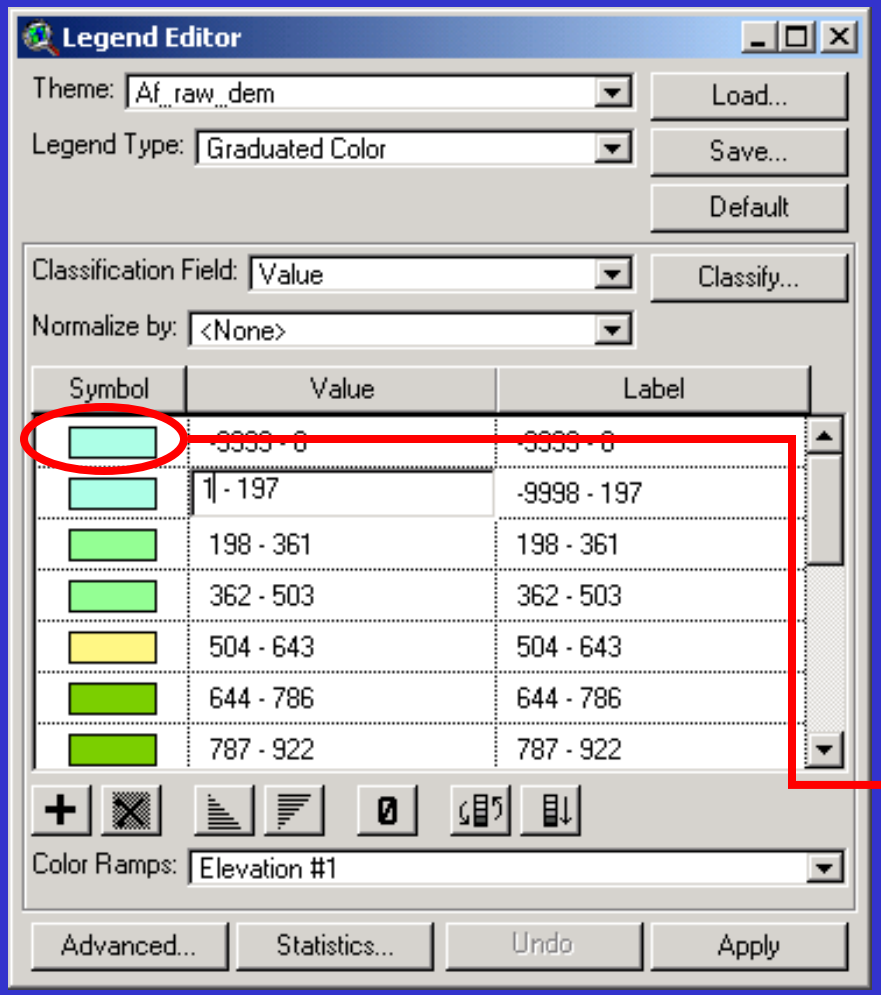
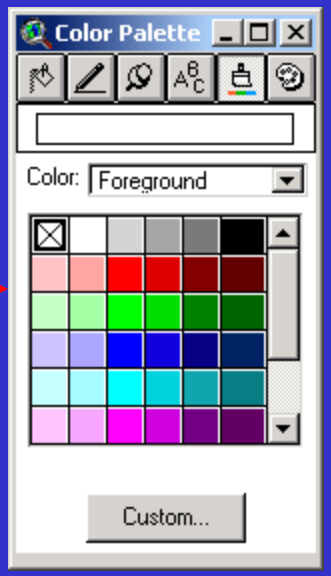
Data Preparation : Digital Elevation Model (DEM)



Manually change the value range from "-9998 – 197" to "1 – 197"

Double-click on the symbol window and change the foreground color to transparent. Choose apply.



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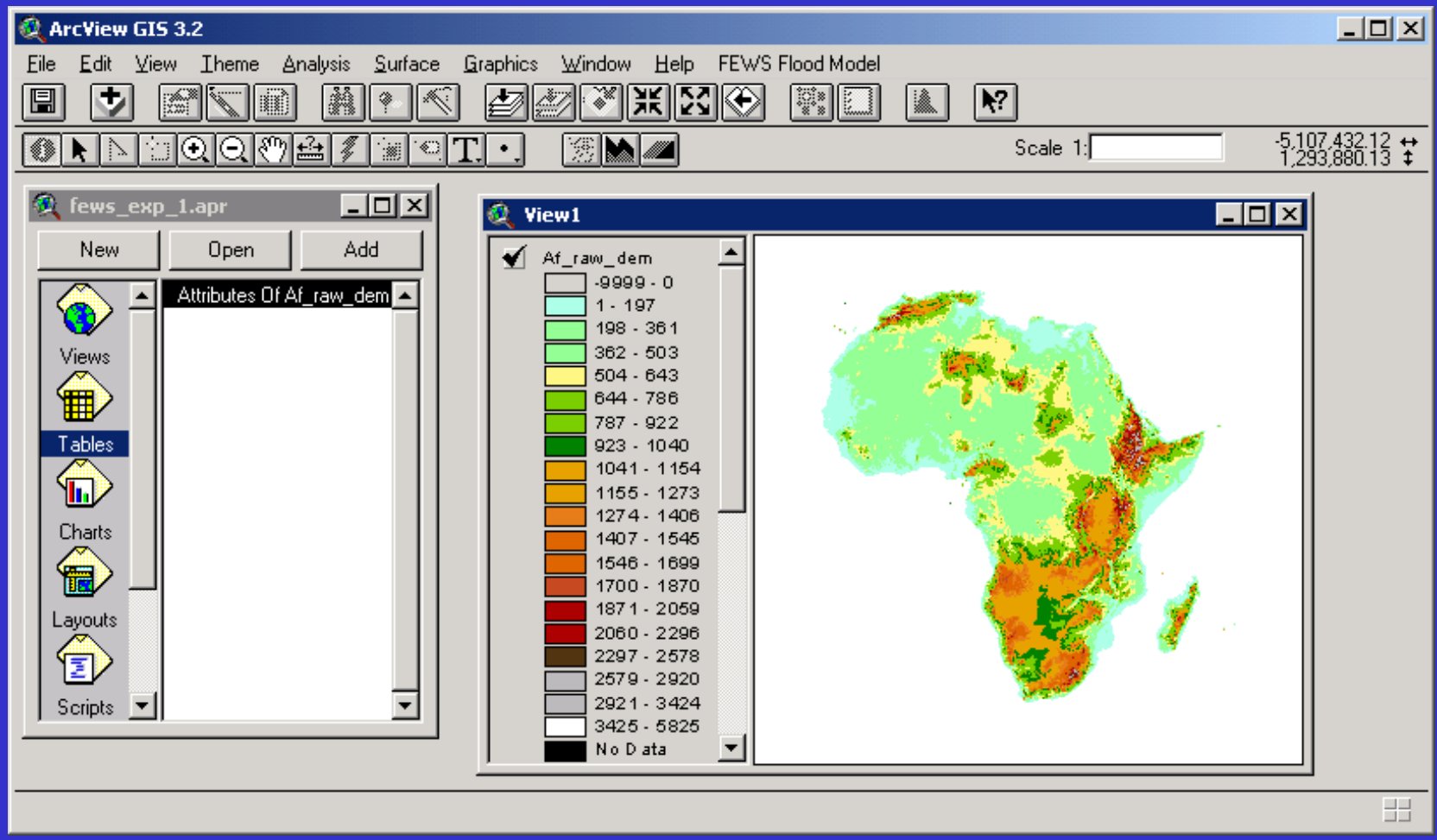
Data Preparation : Digital Elevation Model (DEM)

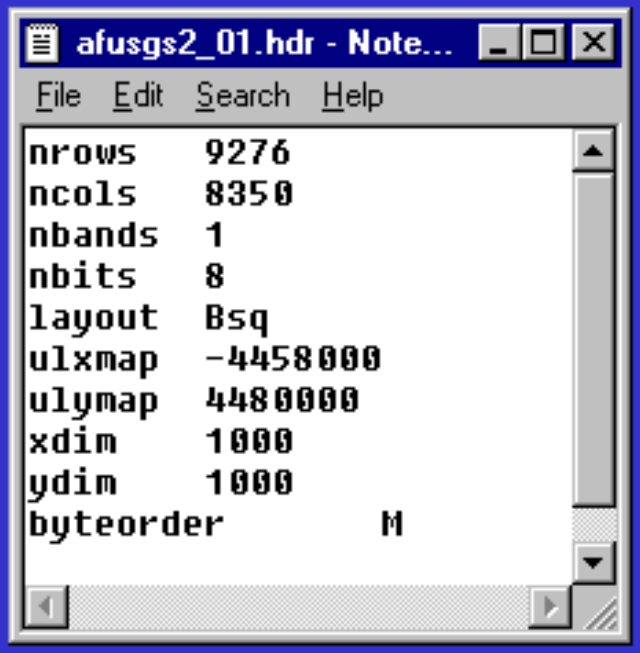
Select ‘save project’ from the file menu



Data Preparation : Land Use / Land Cover

The file **afusgs2_0l.img** has a band sequential multi-band image format. Like the .bil file format used to transport the DEM data, this format requires a header file for ArcView to use the image directly. The data file name must be changed to **afusgs2_01.bsq** and the header file created. The header file information is shown below and must be named **afusgs2_0l.hdr**.

After changing the file name and creating the header file ArcView can directly use the land use and land cover image



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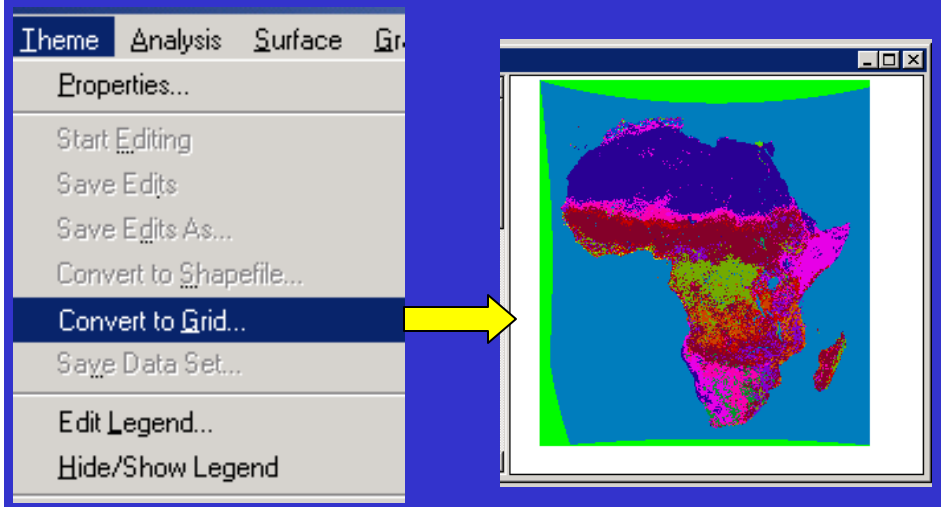
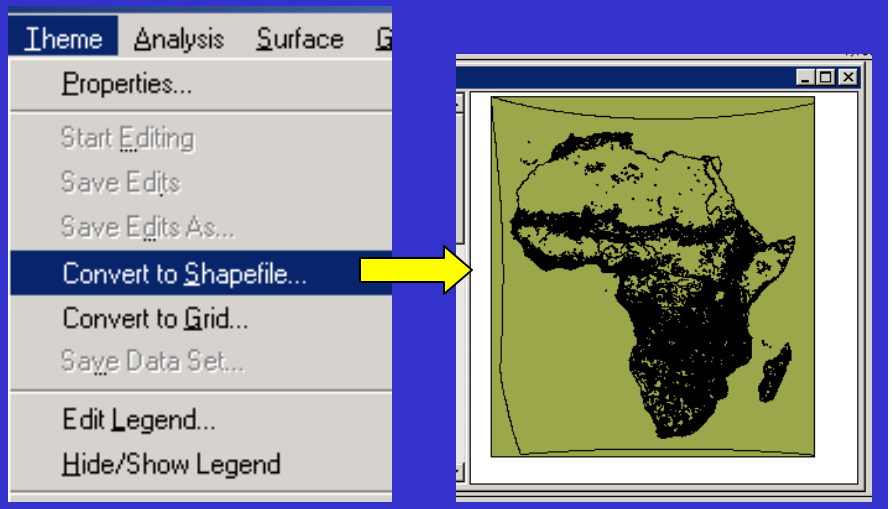
Data Preparation : Land Use / Land Cover

- To use the individual pixel values the image must be converted to a grid
- Unlike the DEM data, the SFM does not directly use the land use land cover data
- Land use land cover data must first be combined with soil data
- The SFM uses this combined theme

The land use land cover image is converted to a grid using the "Convert to Grid" option in the "Theme" menu.

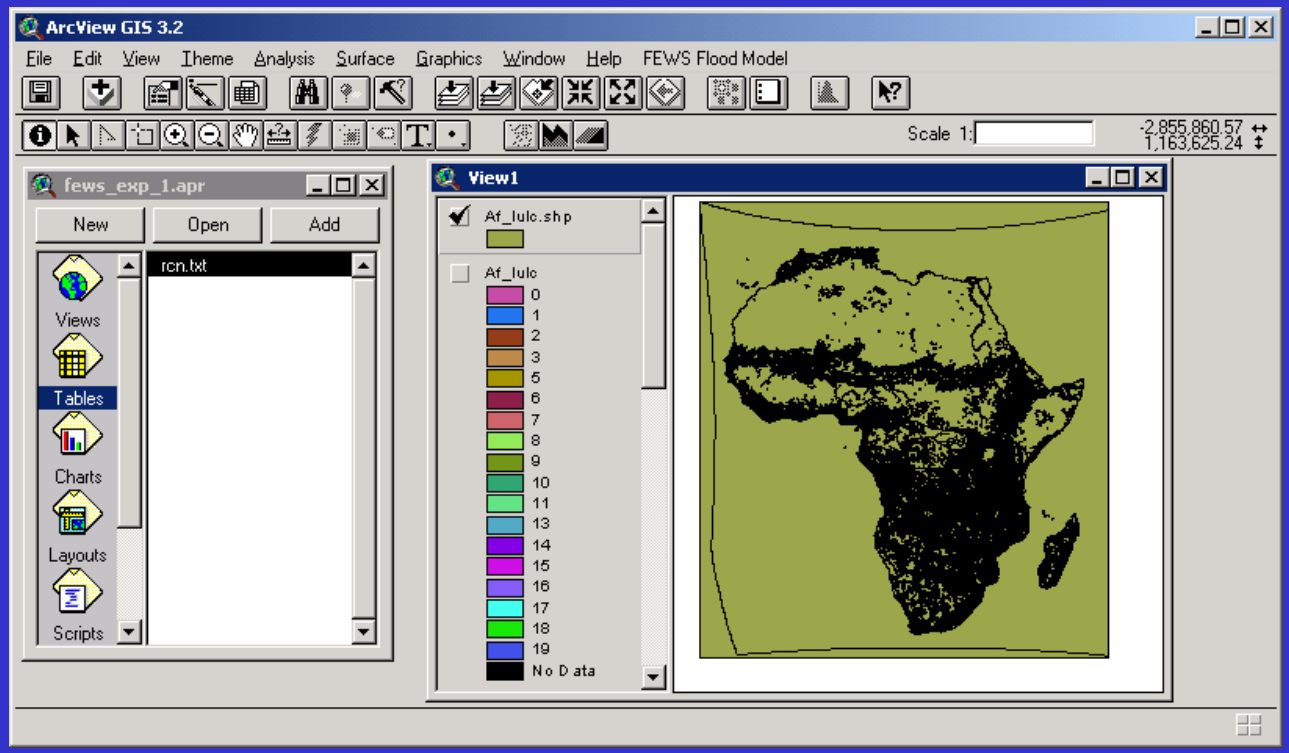


The grid is then converted to an ArcView polygon shapefile using the "Convert to shapefile" option.



Data Preparation : Land Use / Land Cover

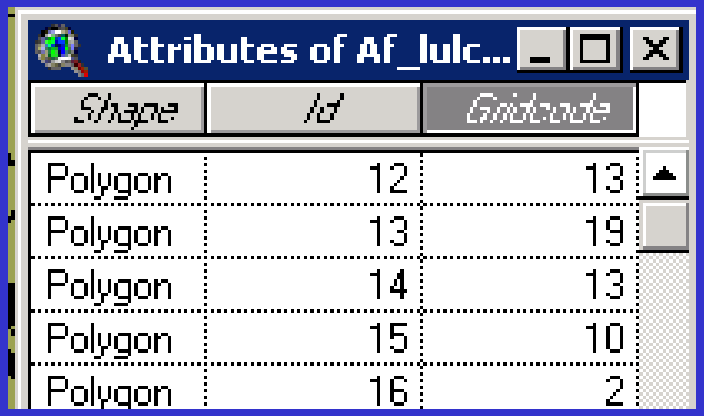
The shapefile is shown as a single symbol, that is, all polygons in the shapefile are assigned the same color. It is recommend that you do not attempt to display the land use land cover shapefile for Africa using any other legend type. The number of polygons in this shapefile makes changing of the legend type a time consuming process.



Data Preparation : Land Use / Land Cover

The shapefile lacks attributes and only contains two data elements

1) polygon identifier (Id)
2) Gridcode



The gridcode is the "Value" field from the grid theme attribute table

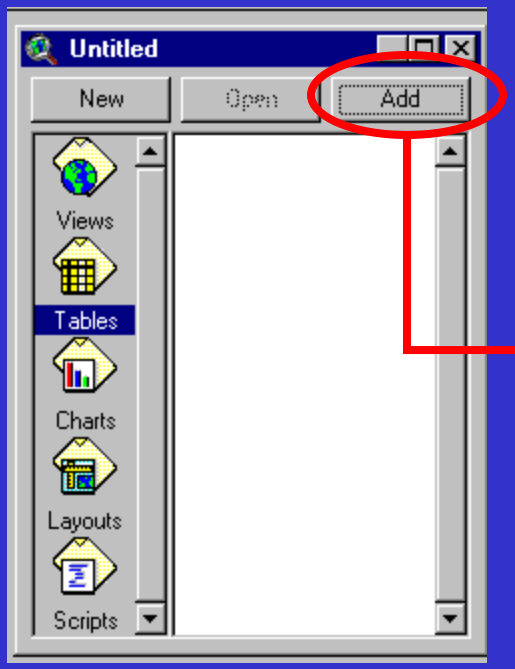
The usefulness of the land cover and land use data stems from the attributes carried in the theme attribute table

The join function is used to combine the land use attribute table and the response coefficients table

Data Preparation : Land Use / Land Cover

Importing the text file into ArcView:

Select the tables icon and choose "add"



Add the "rcn.txt" file as an ArcView table

rcn.txt

Value	Count	Lu_code	Description	Hyd_a_me
1	7682	100	Urban and Built-Up Land	7
2	623556	211	Dryland Cropland and Pasture	7
3	22982	212	Irrigated Cropland and Pasture	6
5	232015	280	Cropland/Grassland Mosaic	6
6	1516263	290	Cropland/Woodland Mosaic	5
7	1842393	311	Grassland	6
8	2547286	321	Shrubland	4
10	8287280	332	Savanna	4
11	1396525	411	Deciduous Broadleaf Forest	5
13	3495040	421	Evergreen Broadleaf Forest	5
16	40585806	500	Water Bodies	10

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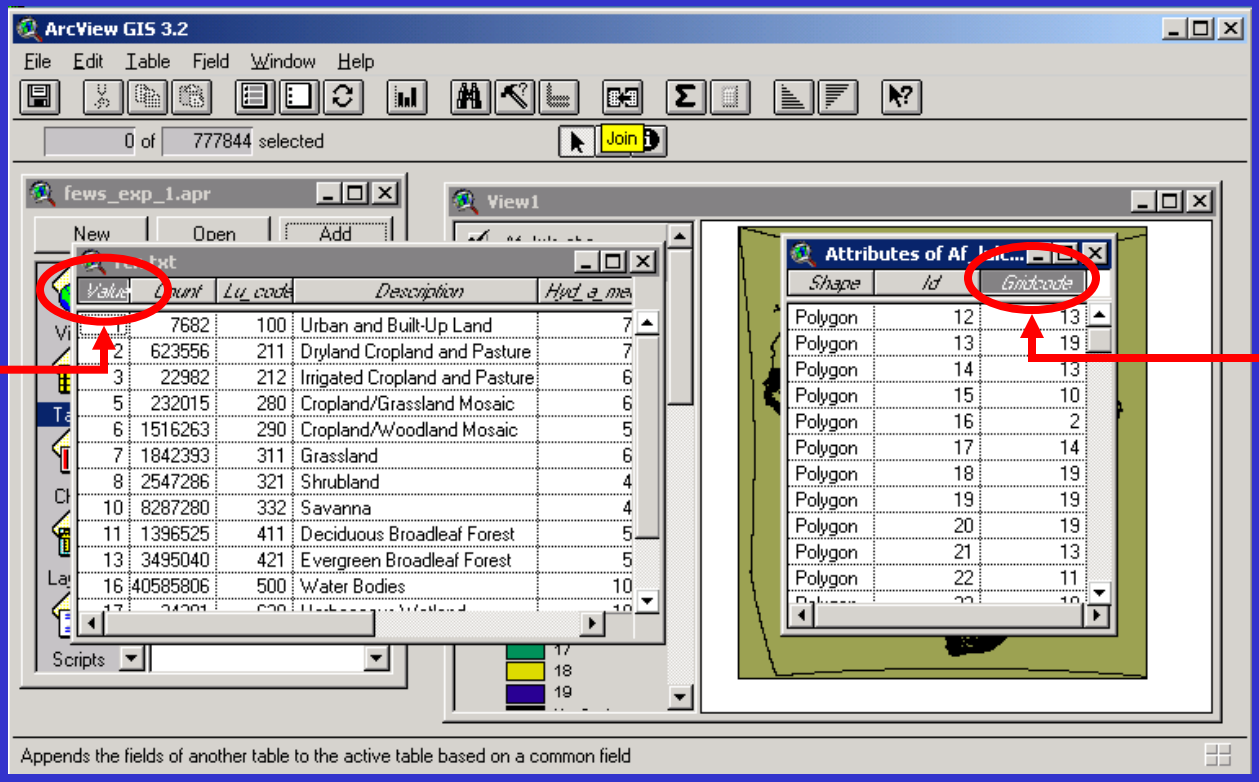
Data Preparation : Land Use / Land Cover

Joining the text file with the land use shapefile:

With the "value" field selected in the source table (rcn.txt) and the "gridcode" field selected in the destination table (attributes of af_lulc), choose the join button.

source table field



destination table field

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Data Preparation : Land Use / Land Cover

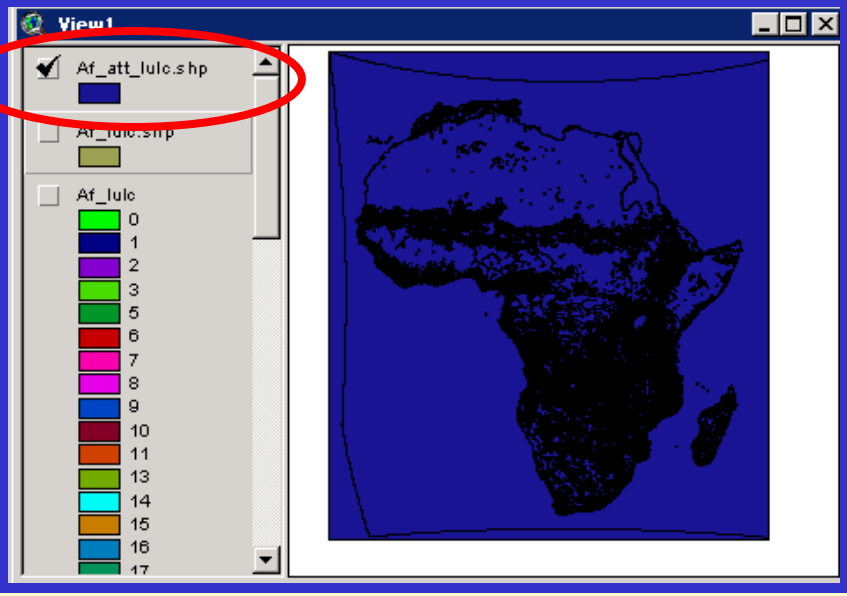
Results of the join operation:

Attributes of Af_lulc.shp

Shape	Id	Gridcode	Count	Lu_code	Description	Hyd_a_mean	Hyd_b_mean	Hyd_c_mean	Hyd_d_mean	V
Polygon	1	0								
Polygon	2	19	9608907	770	Barren or Sparsely Vegetated	75	80	85	90	
Polygon	3	19	9608907	770	Barren or Sparsely Vegetated	75	80	85	90	
Polygon	4	13	3495040	421	Evergreen Broadleaf Forest	55	66	74	79	
Polygon	5	11	1396525	411	Deciduous Broadleaf Forest	55	66	74	79	
Polygon	6	2	623556	211	Dryland Cropland and Pasture	71	80	86	86	
Polygon	7	19	9608907	770	Barren or Sparsely Vegetated	75	80	85	90	
Polygon	8	19	9608907	770	Barren or Sparsely Vegetated	75	80	85	90	
Polygon	9	13	3495040	421	Evergreen Broadleaf Forest	55	66	74	79	

Create a new shapefile using the "Convert to shapefile" option on the "Theme" menu.

This will create a new theme with an attribute table containing the response coefficients.



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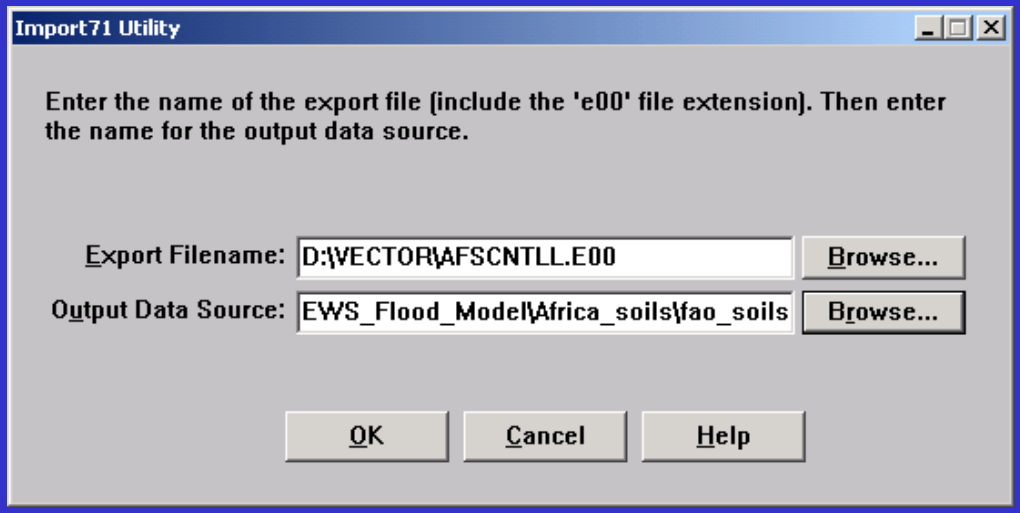
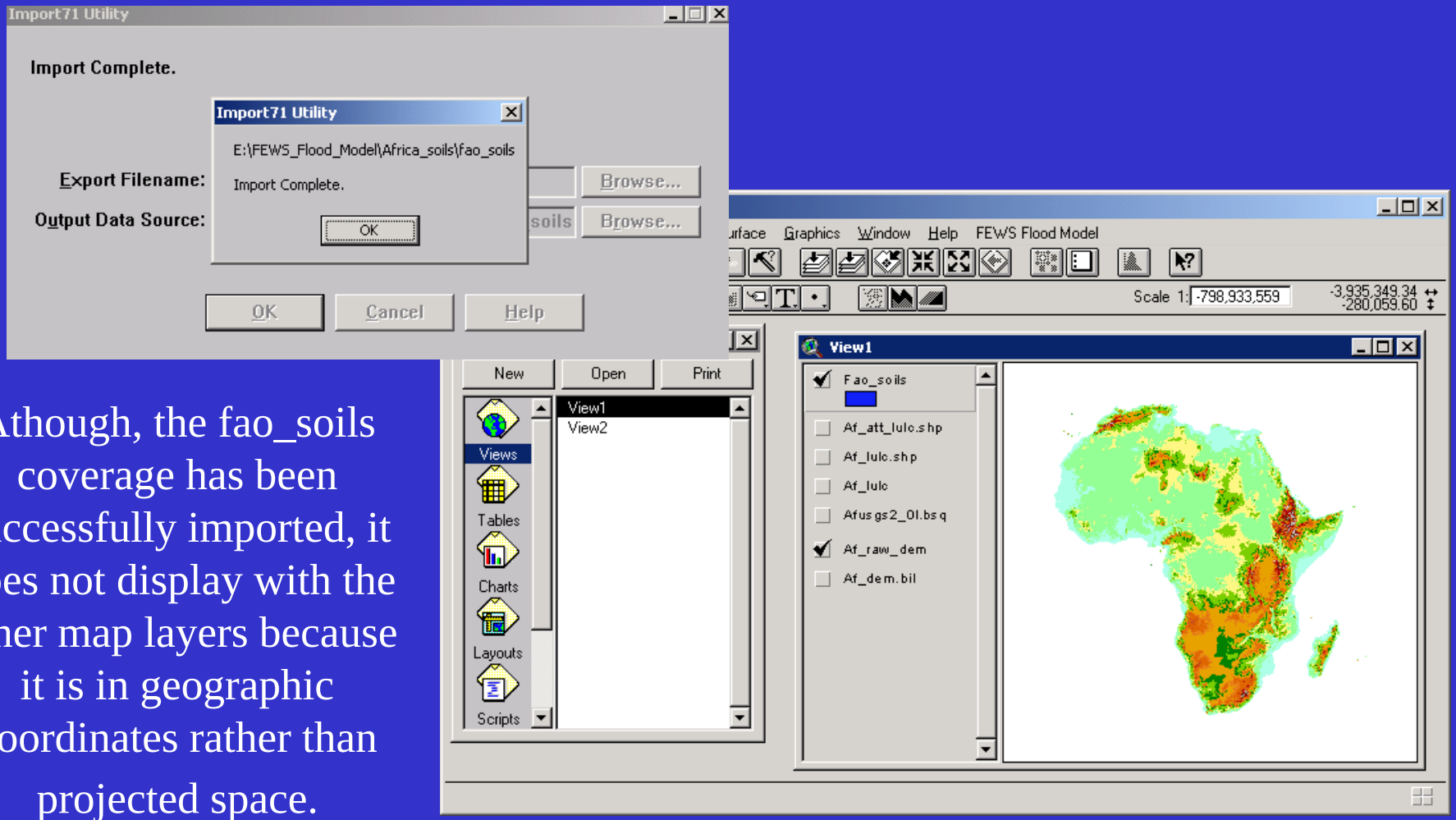
Data Preparation : Soils

- FAO furnishes the soils data in ARC/INFO export files
- The ArcView utility "Import71" can be used to import these coverages into ArcView
- "Import71" is accessible through the "ArcveiwGIS32" menu: **programs > ESRI > ArcViewGIS3.2 > Import 71**
- Executing the import command activates the "Import71 Utility" window.

Select an export file and provide an output file name



Data Preparation : Soils



Athough, the fao_soils coverage has been successfully imported, it does not display with the other map layers because it is in geographic coordinates rather than projected space.

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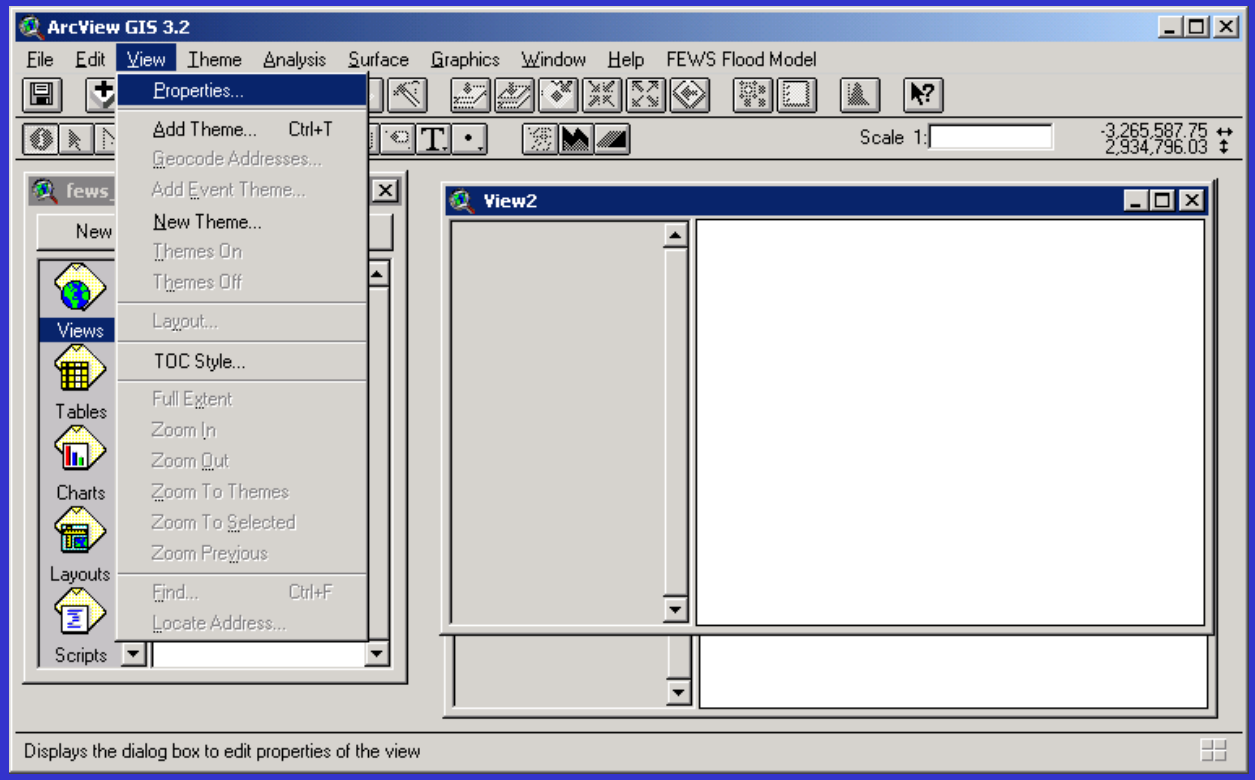
Data Preparation : Soils

Project the FAO soils data to match other layers:

First open a new view. The map projection function is found in the "View Properties" window activated using the "View Properties" item on the "View" pull-down menu.

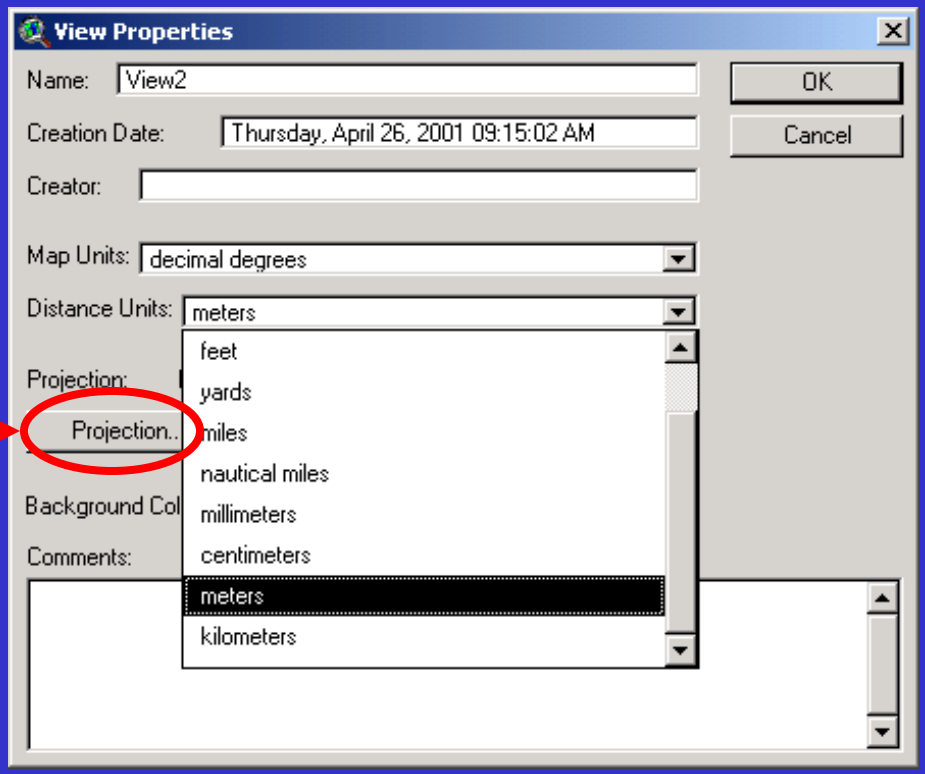


Data Preparation : Soils

Project the FAO soils data to match other layers:

From the "View Properties" change the distance units to meters.

Choose the "projection" button to activate the projection properties window.

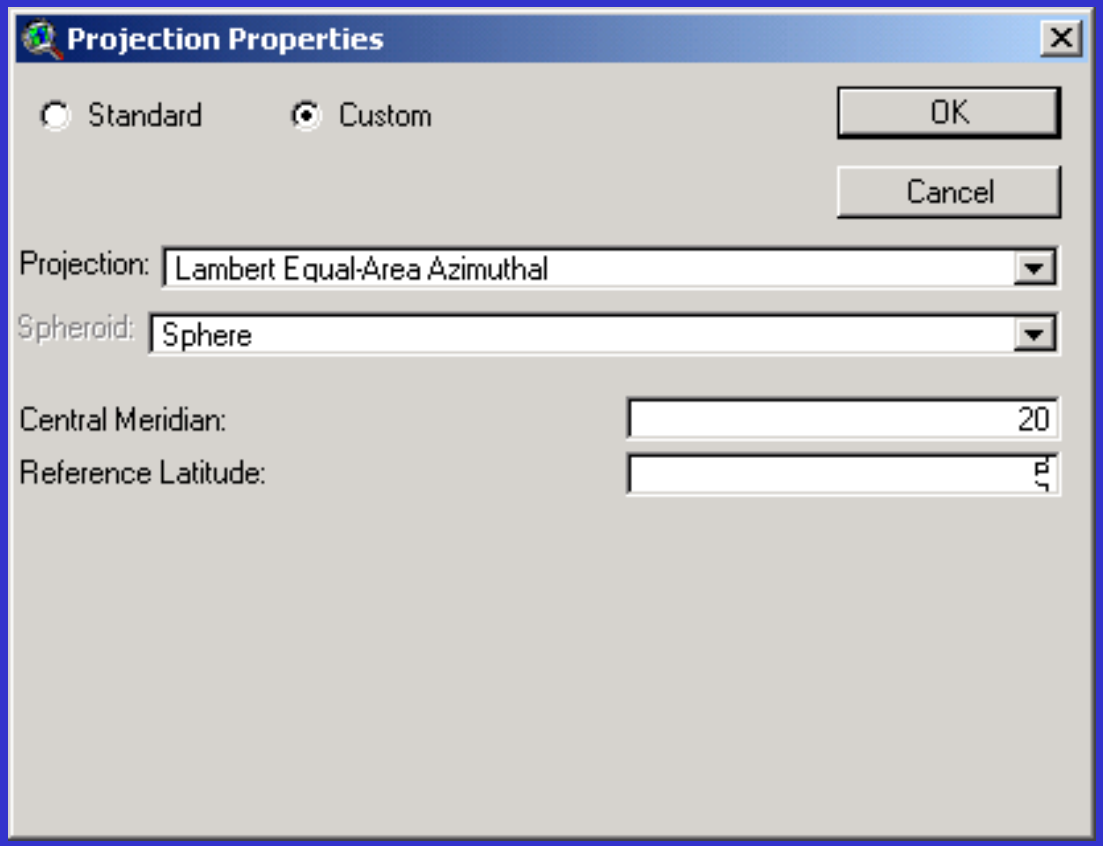


Data Preparation : Soils

Project the FAO soils data to match other layers:

Select “custom” projection and change the projection type to “Lambert Equal-Area Azimuthal”.

Set the central meridian and reference latitude to 20 and 5 respectively.

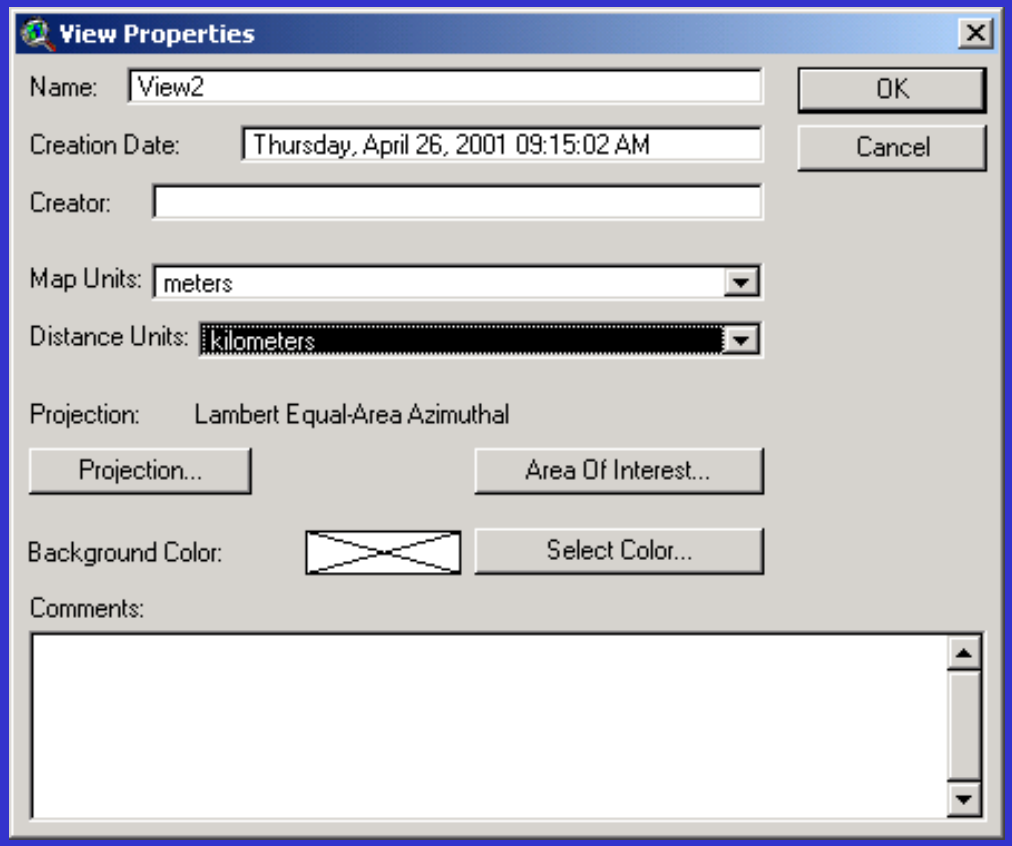


Data Preparation : Soils

Project the FAO soils data to match other layers:

From the view properties, change the map units to “meters” and the distance units to “kilometers”.

Choose ok.



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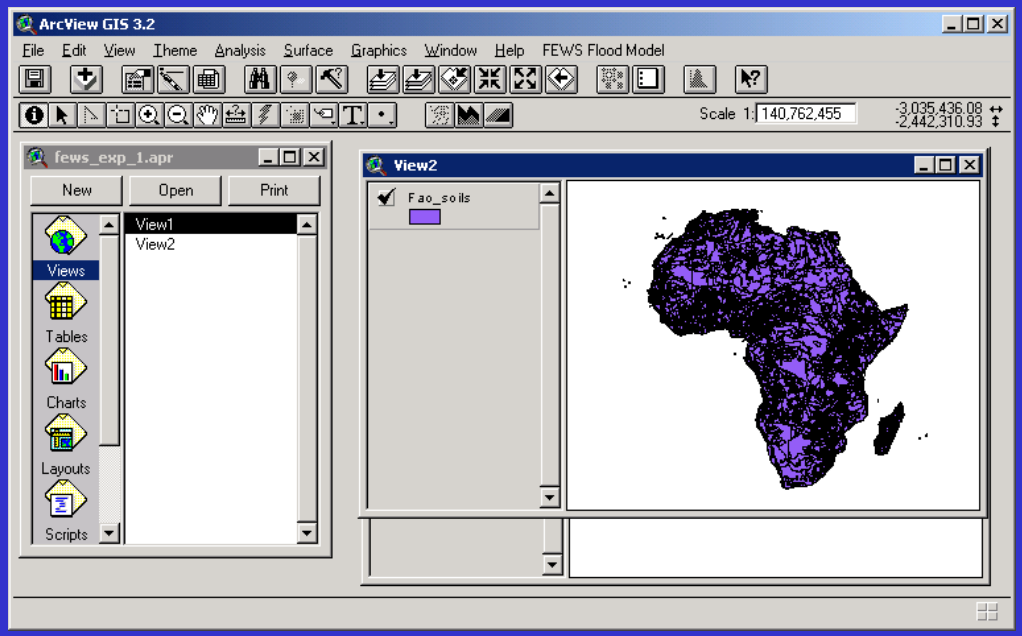
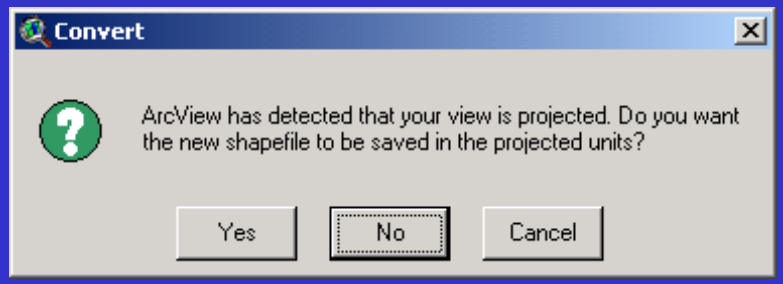
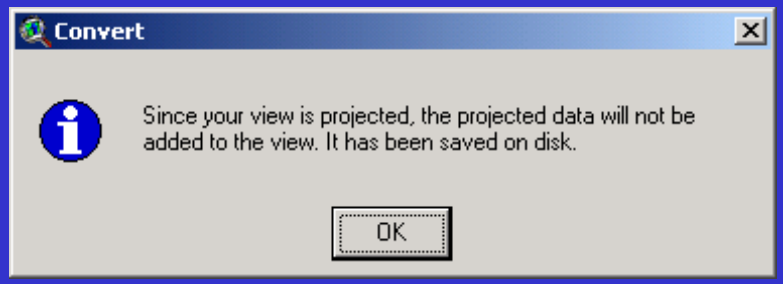
Data Preparation : Soils

Project the FAO soils data to match other layers:

Use the "Add Theme" button to add the "Fao_soil" file to the view. To make the FAO Digital Soil data usable without always changing the projection save the projected version using the "Convert to shapefile" on the "Theme" pull-down menu. ArcView will display two warning messages. Select “yes” to save in the projected units and “ok”.







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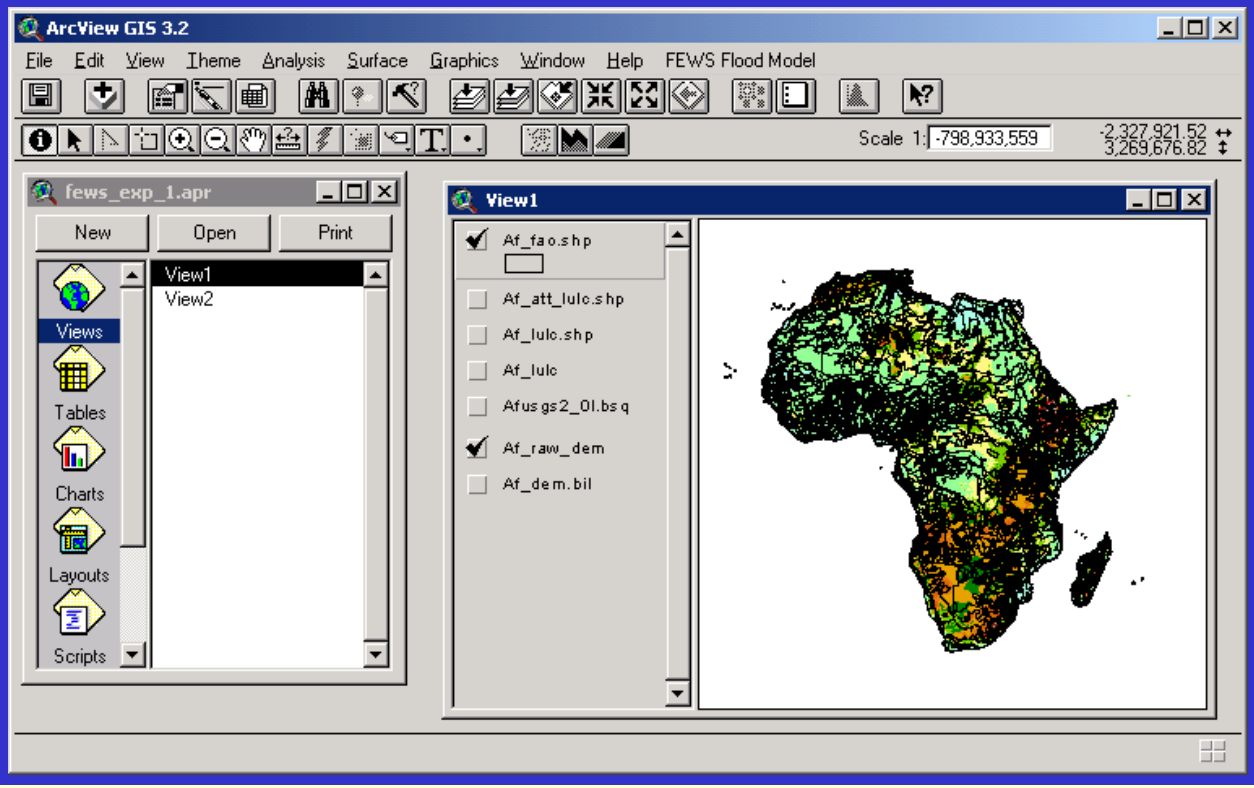
Data Preparation : Soils

Project the FAO soils data to match other layers:

The new projected shapefile can now be added to the view containing other data layers and it will overlay properly. The example below shows the FAO soils data displayed with a transparent fill over the top of the DEM data.

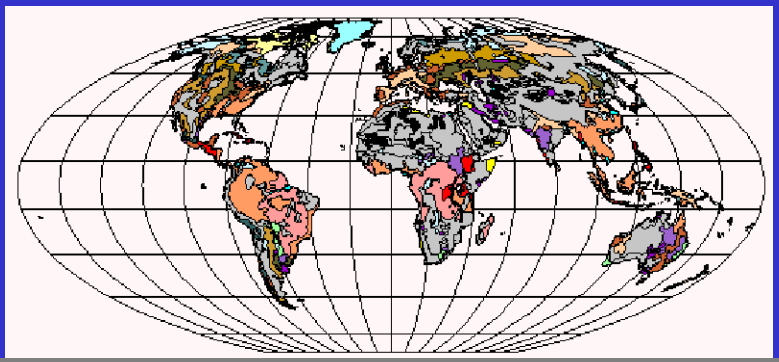


Data Preparation : Soils

The converted shapefile contains only basic information.

The theme table contains the following:

- area
- perimeter
- FAO soils number
- FAO soils id
- Soil number (Snum)
- FAO mapping unit
- Phase1
- Phase2
- Misclu1
- Misclu2
- Permafrost
- Country code
- Country short name
- Country name
- Soil information
- Soil association



The FAO soils database contains additional data that can be used to attribute the shapefile.

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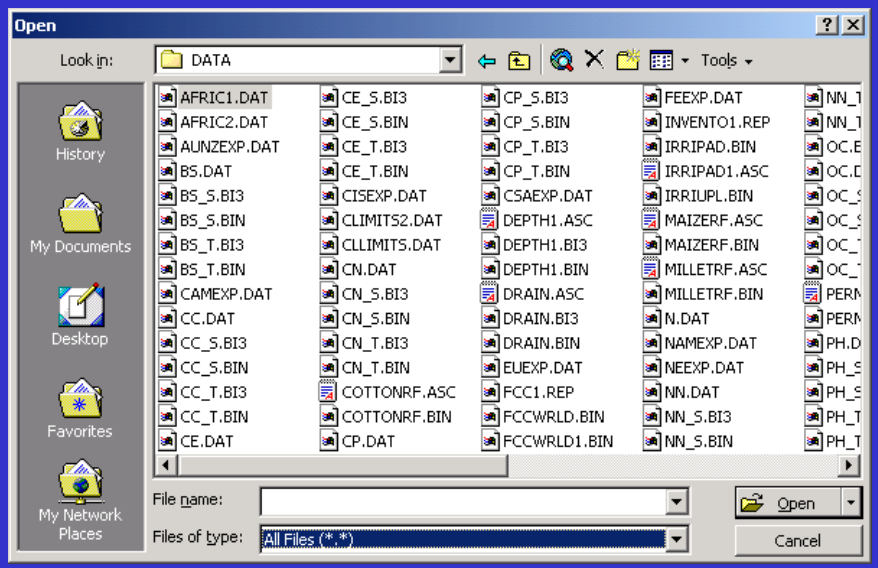
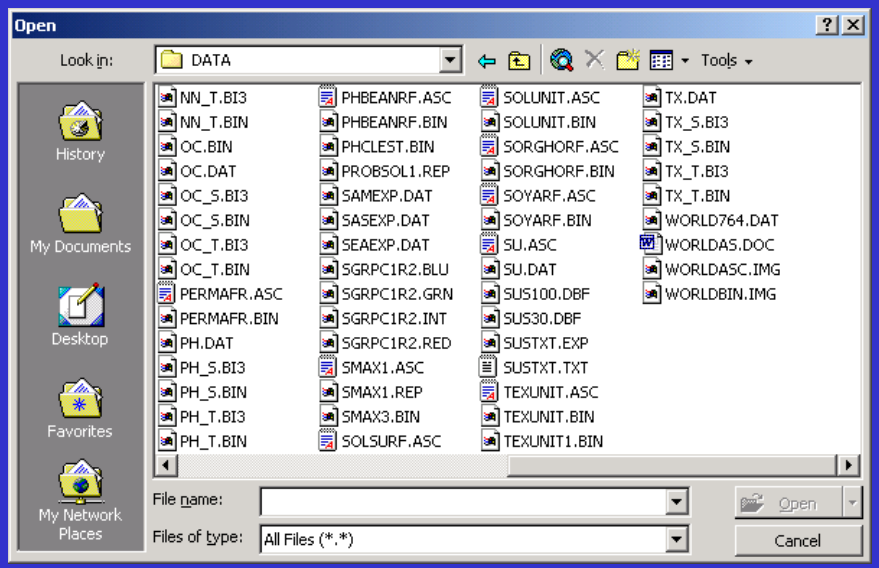
Data Preparation : Soils

Descriptive data contained in the FAO soils "DATA" directory:





Files "DEPTH1.ASC," "TEXUNIT.ASC," "SMAX1.ASC," and "DRAIN.ASC" contain information that can be used to compute data elements needed by the SFM.

To add attributes to the FAO soils shapefile, the FAO data file is read into a spreadsheet program, calculations to add additional data values are performed, and the data file is saved as a tab delimited text file.

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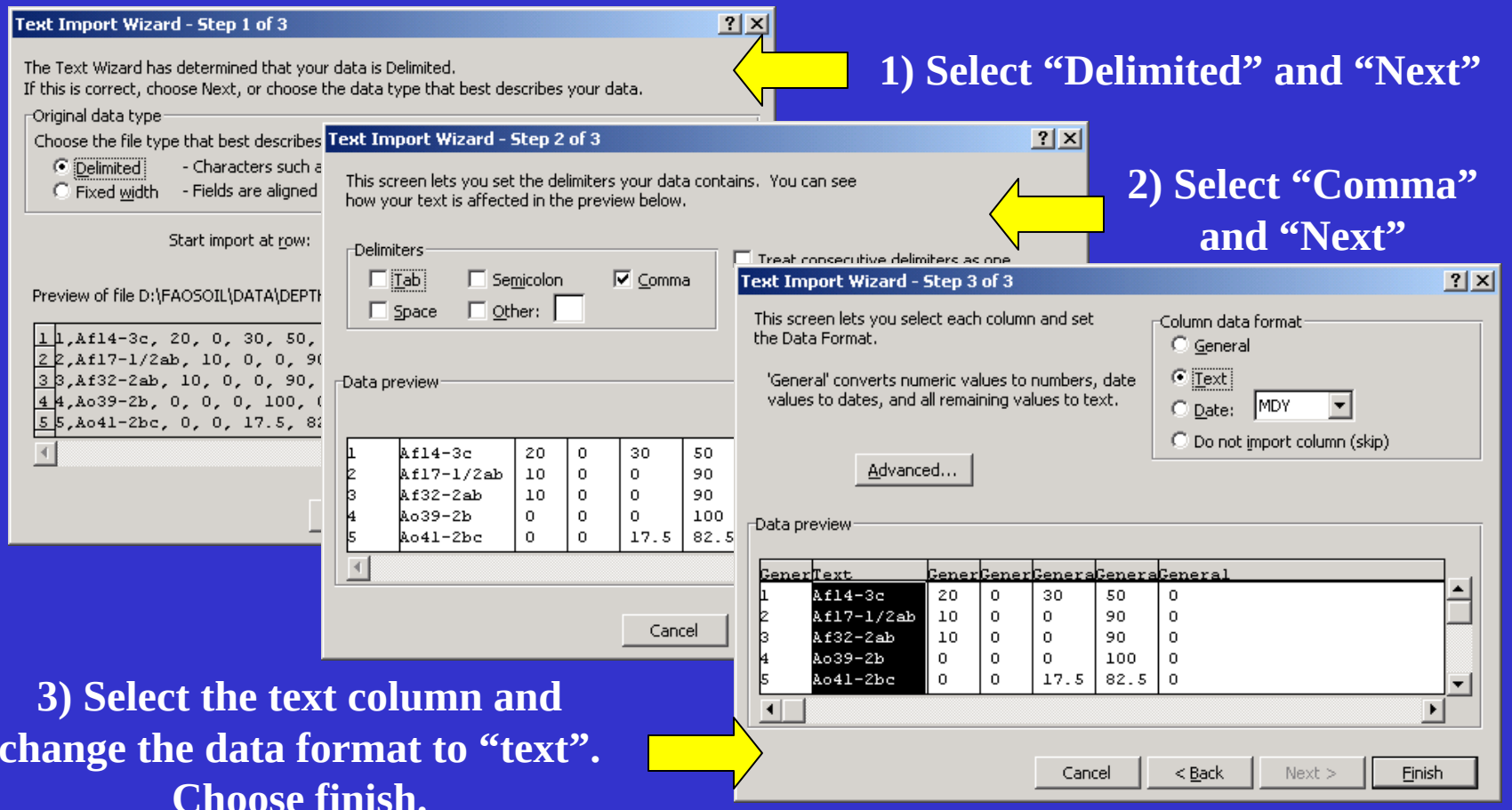
Data Preparation : Soils

Attributing the FAO soil shapefile with other FAO soil data files:

Opening the “DEPTH1.ASC” file in EXCEL will activate the "Text Import Wizard”



1) Select “Delimited” and “Next”

2) Select “Comma” and “Next”

3) Select the text column and change the data format to “text”. Choose finish.

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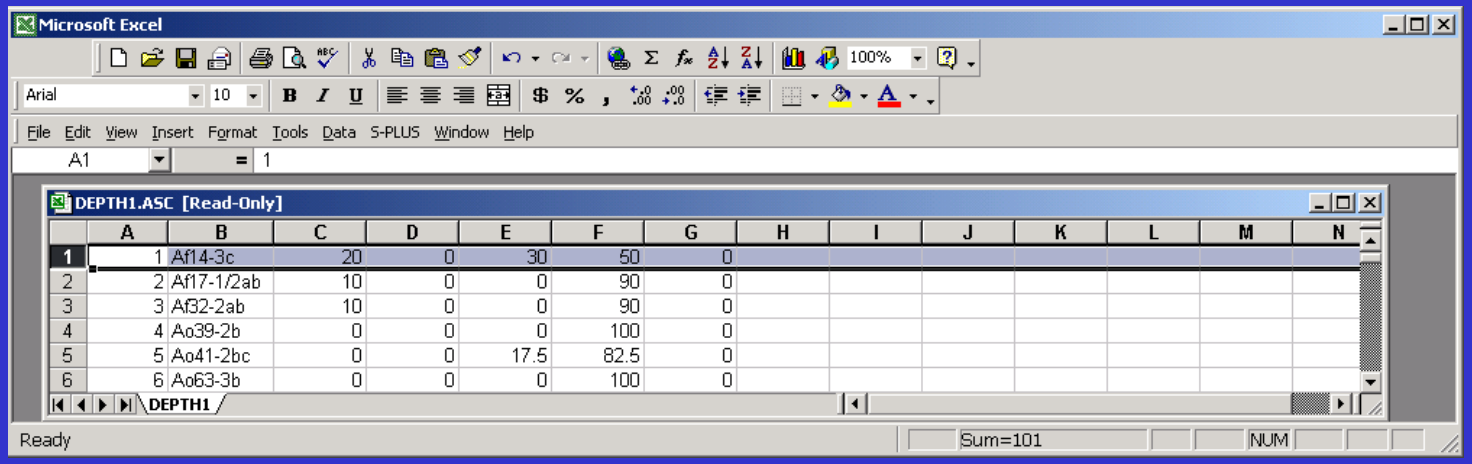
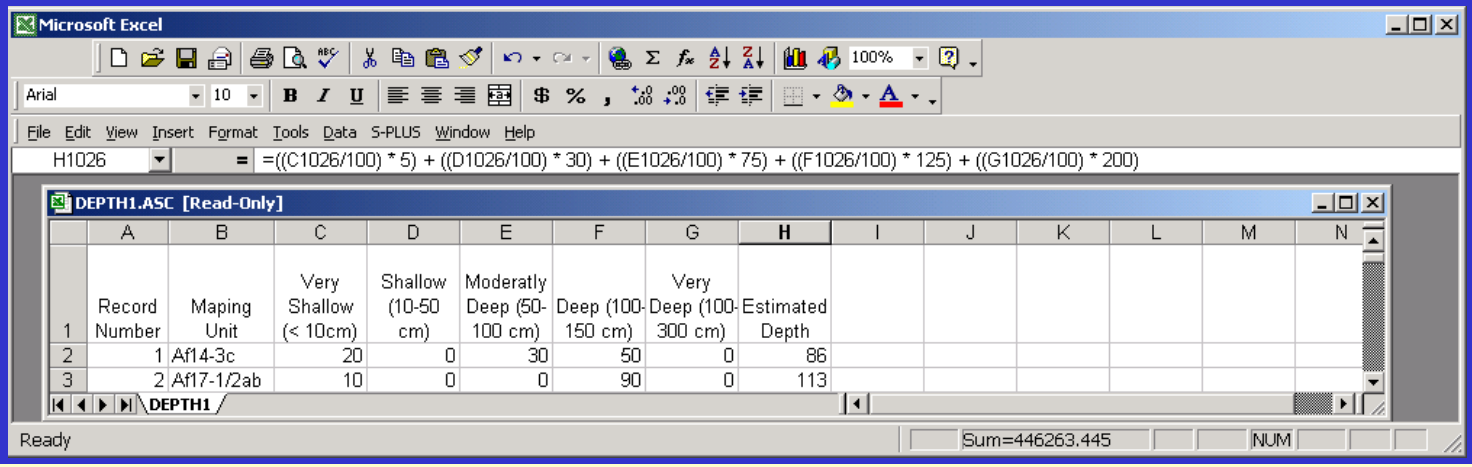
Data Preparation : Soils

Imported text file



	A	B	C	D	E	F	G
1	1	Af14-3c	20	0	30	50	0
2	2	Af17-1/2ab	10	0	0	90	0
3	3	Af32-2ab	10	0	0	90	0
4	4	Ao39-2b	0	0	0	100	0
5	5	Ao41-2bc	0	0	17.5	82.5	0
6	6	Ao63-3b	0	0	0	100	0

Text file with column headings, including the calculated "Estimated Depth"



	A	B	C	D	E	F	G	H
1	Record Number	Maping Unit	Very Shallow (< 10cm)	Shallow (10-50 cm)	Moderatly Deep (50-100 cm)	Deep (100-150 cm)	Very Deep (100-300 cm)	Estimated Depth
2	1	Af14-3c	20	0	30	50	0	86
3	2	Af17-1/2ab	10	0	0	90	0	113

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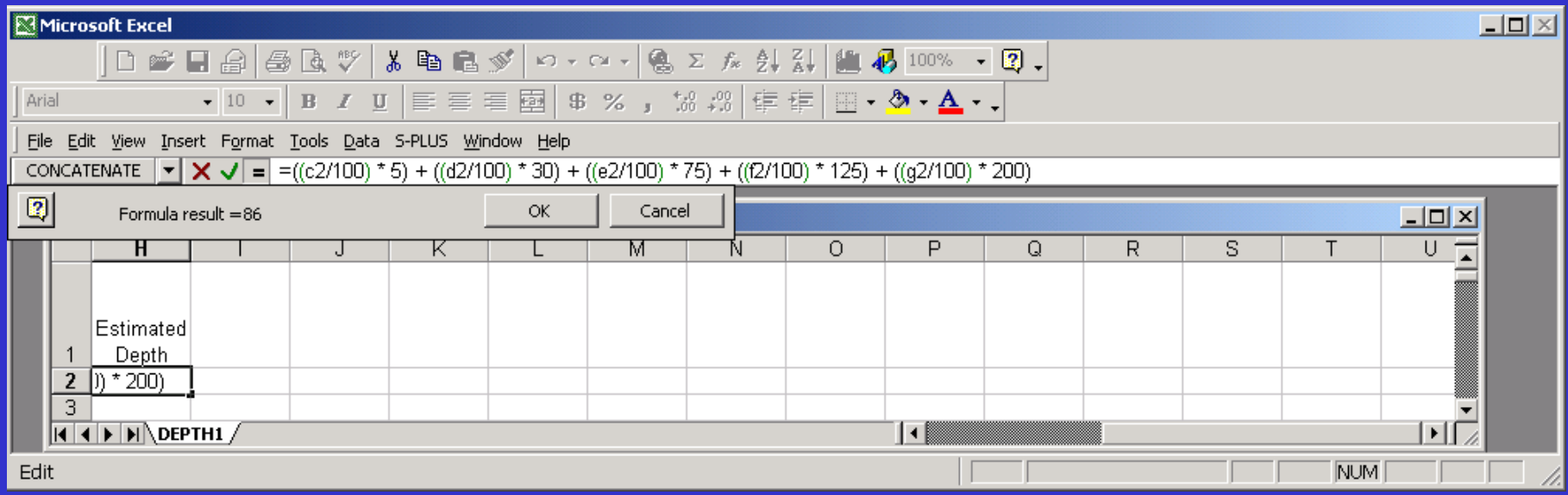
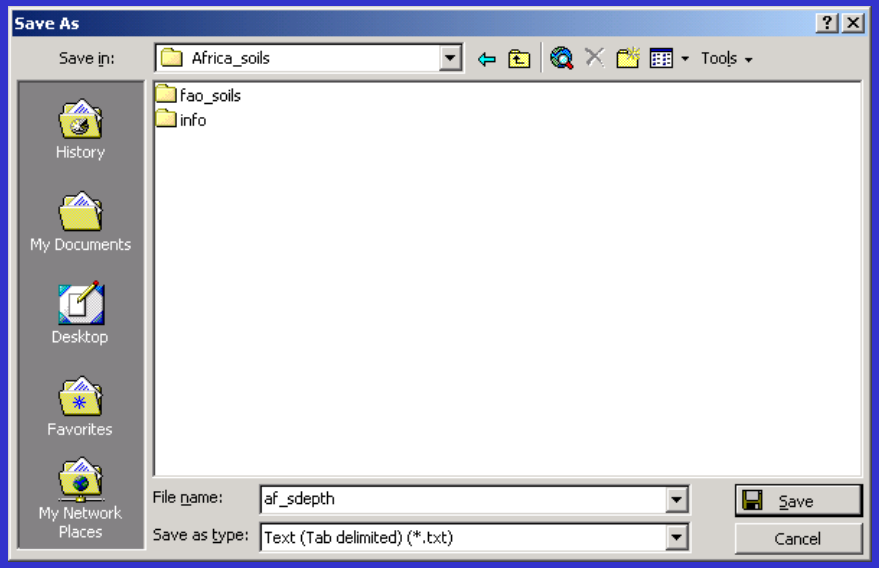
Data Preparation : Soils

Example of using Microsoft EXCEL to make calculations that create data values used by the SFM

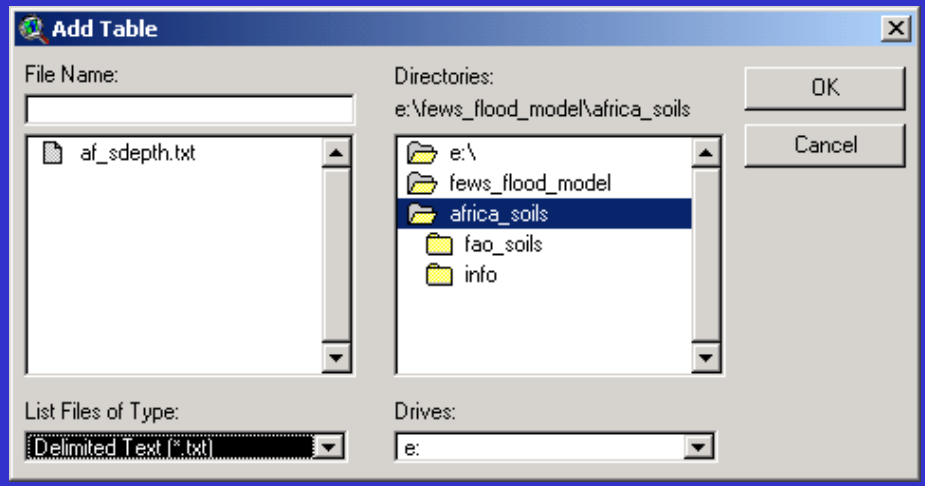


Data Preparation : Soils

Save spreadsheet as a text file



Add the text file as a table in ArcView



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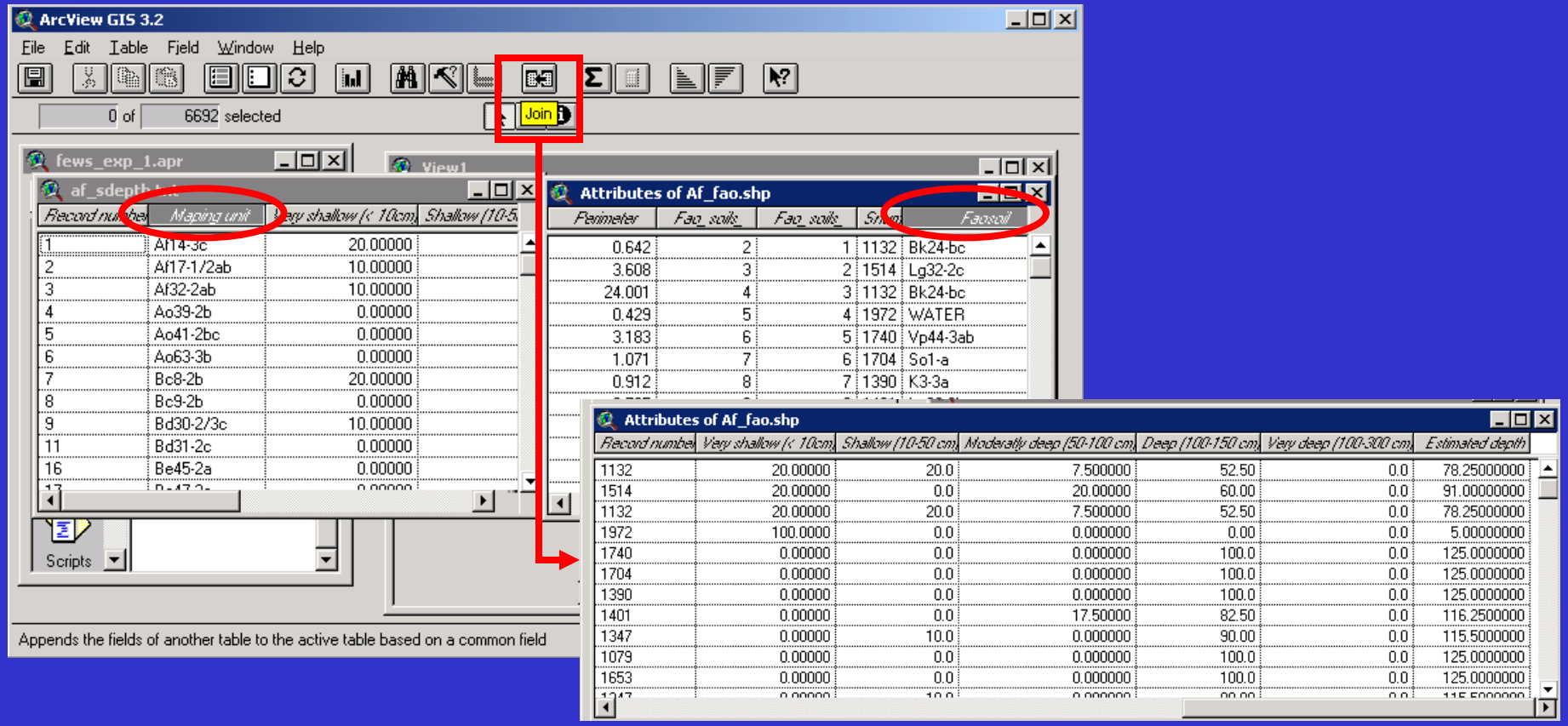
Data Preparation : Soils

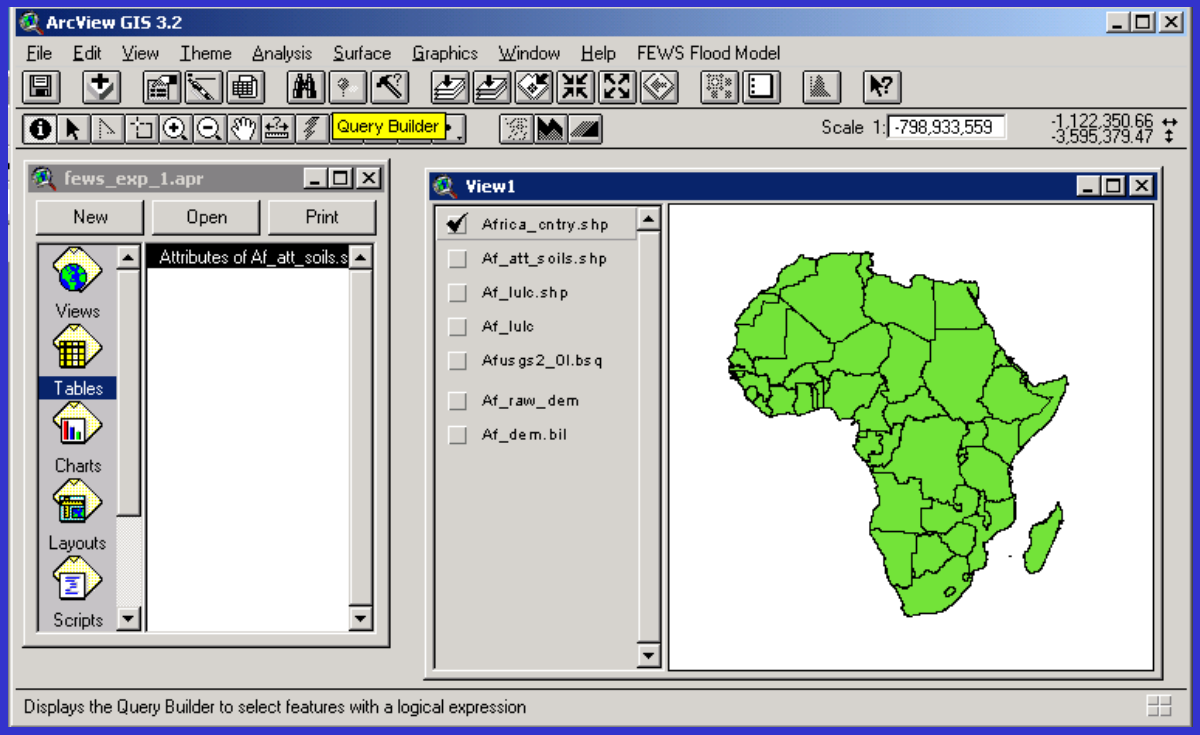
Use the "mapping unit" field in the imported text file and the "faosoil" field in the attributes of af_fao.shp to perform a join in ArcView using the shapefile attributes as the destination table.



Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Country

- Create a shapefile of the desired country in the proper map projection.
- Use the query builder to select a country from the "africa_cntry" shapefile.



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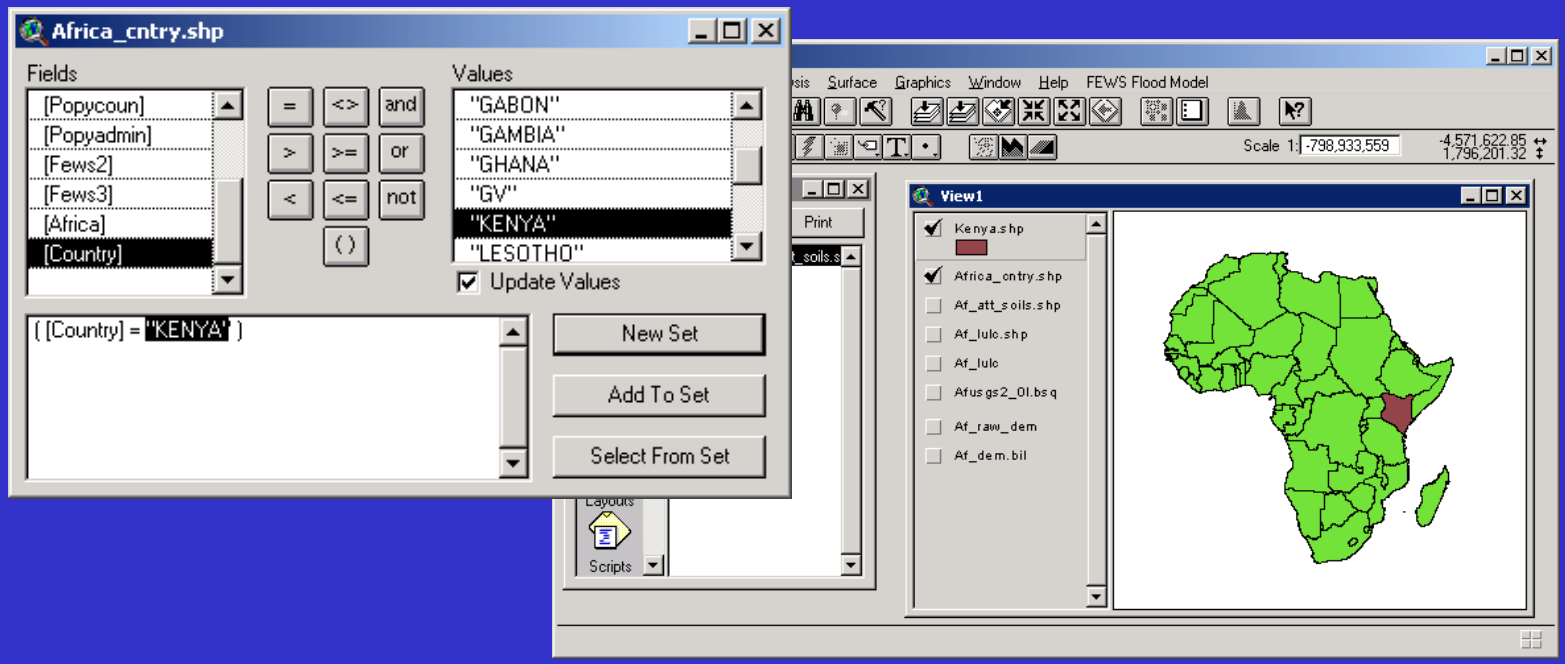
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Country

- Double click on "Country" in the "Fields" column, click the equal sign and double click on the desired country, Kenya in this example.

- Clicking on the "New Set" button will select the identified country.



- Create a new shapefile of the selected country by selecting “create shapefile” from the theme menu.

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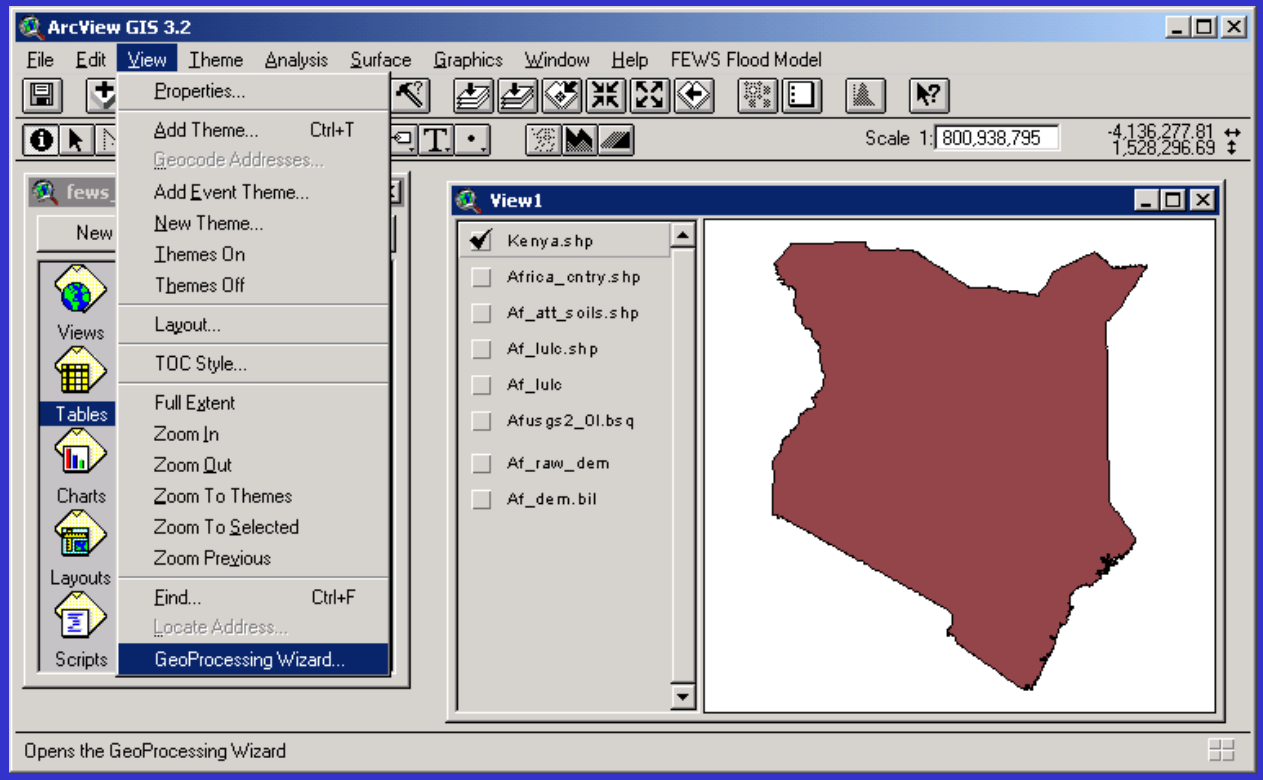
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Country

ArcView window zoomed into Kenya and showing the "GeoProcessing Wizard" entry on the "View" pull-down menu



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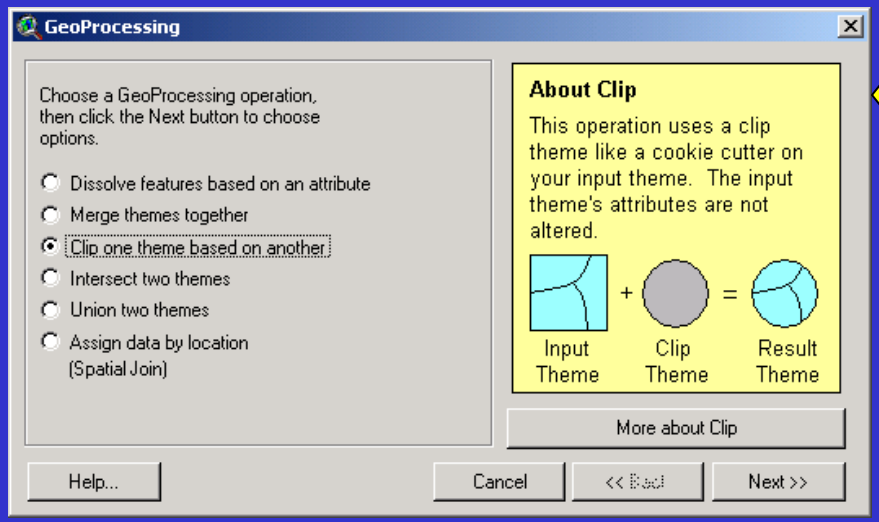
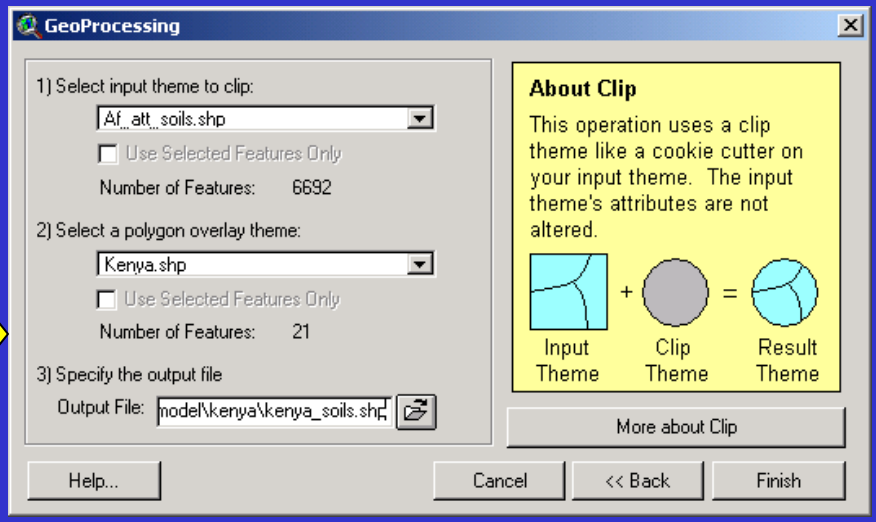
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Country



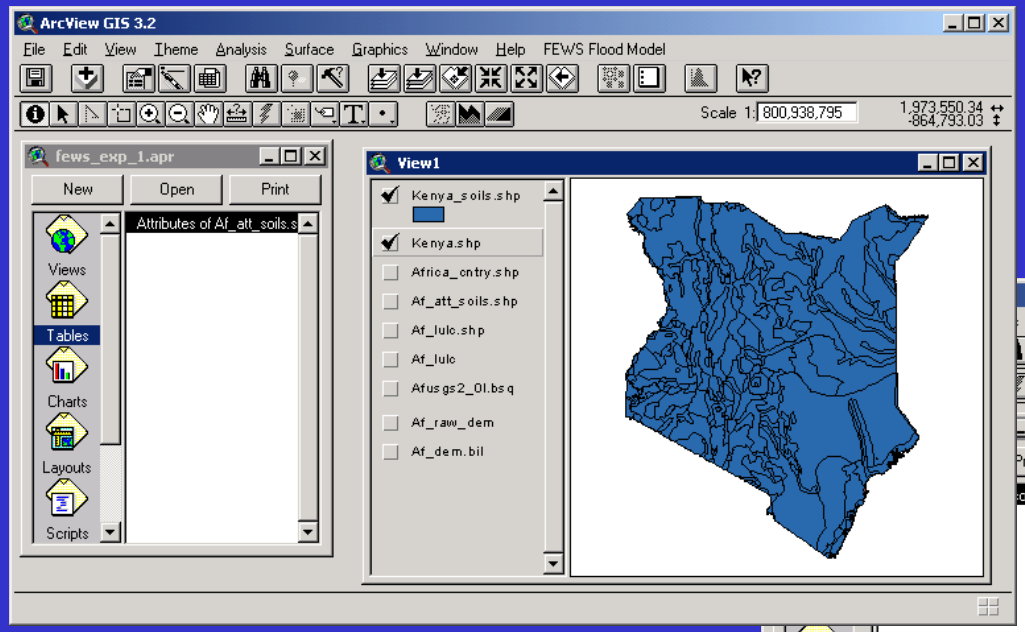
Use the "clip one theme based on another" option from the geoprocessing wizard menu

Select the input theme to clip, the polygon overlay theme to use for the clip operation (the boundary you want to clip to), and provide an output shapefile name



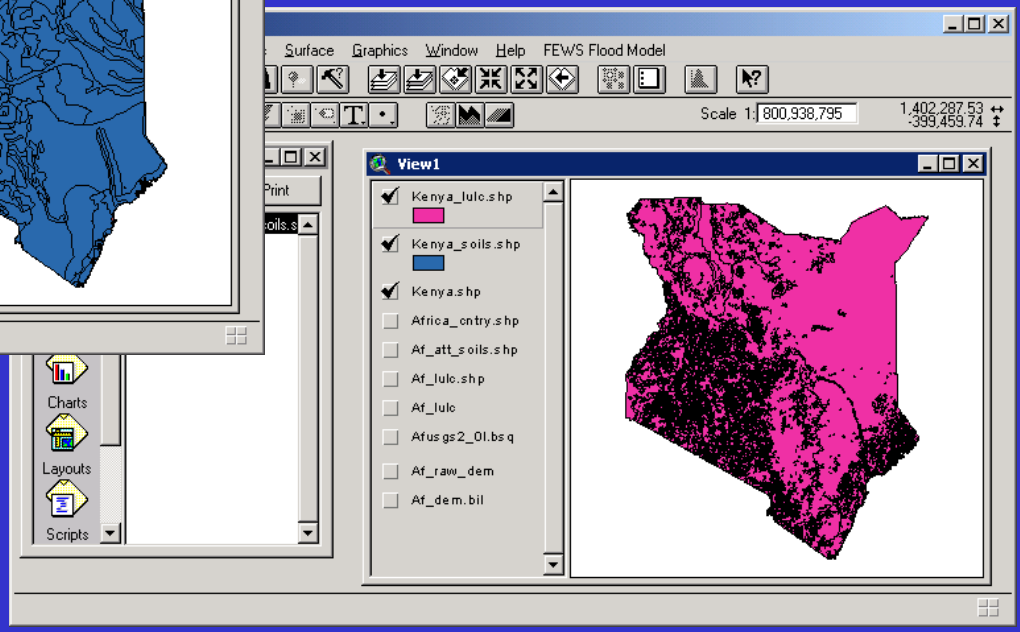
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Country



Clipped soils shapefile

Clipped land use/
land cover shapefile



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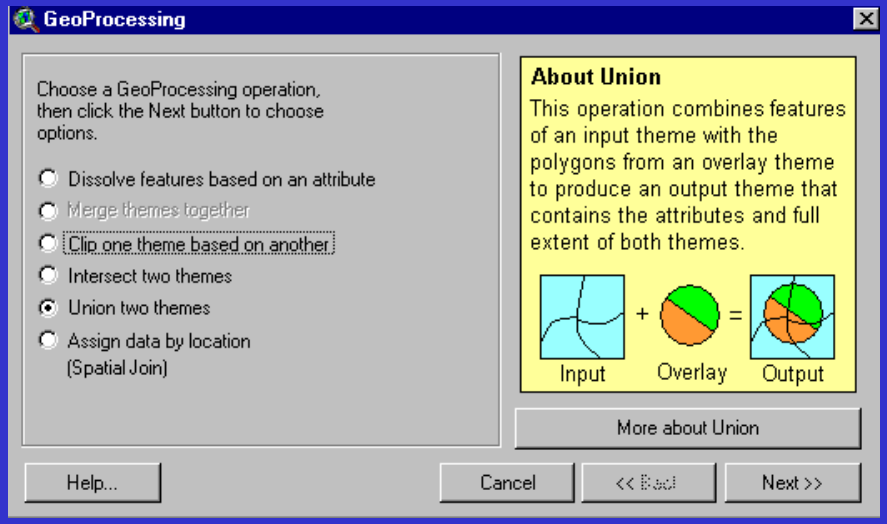
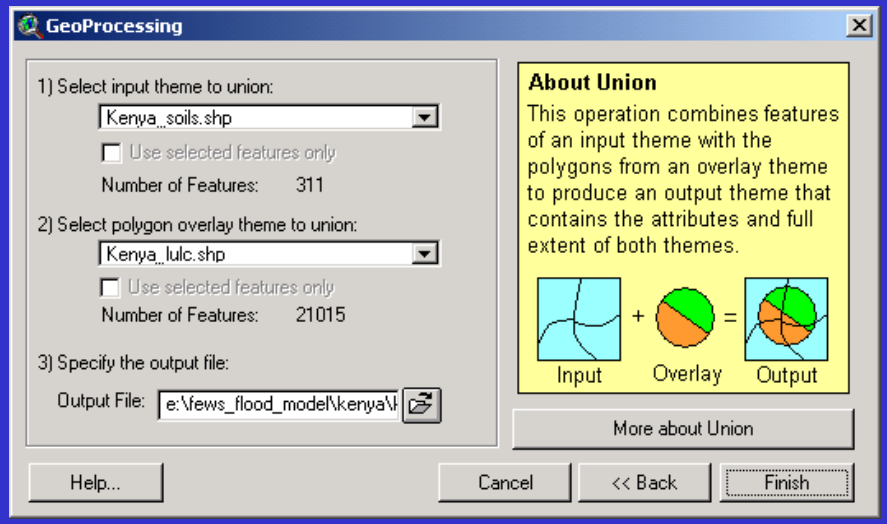
Data Preparation : Additional Geoprocessing Operations

To compute the SCS curve numbers the soils shapefile and the land use/land cover shapefile must be combined.

This is accomplished using the "Union" function in the geoprocessing wizard.

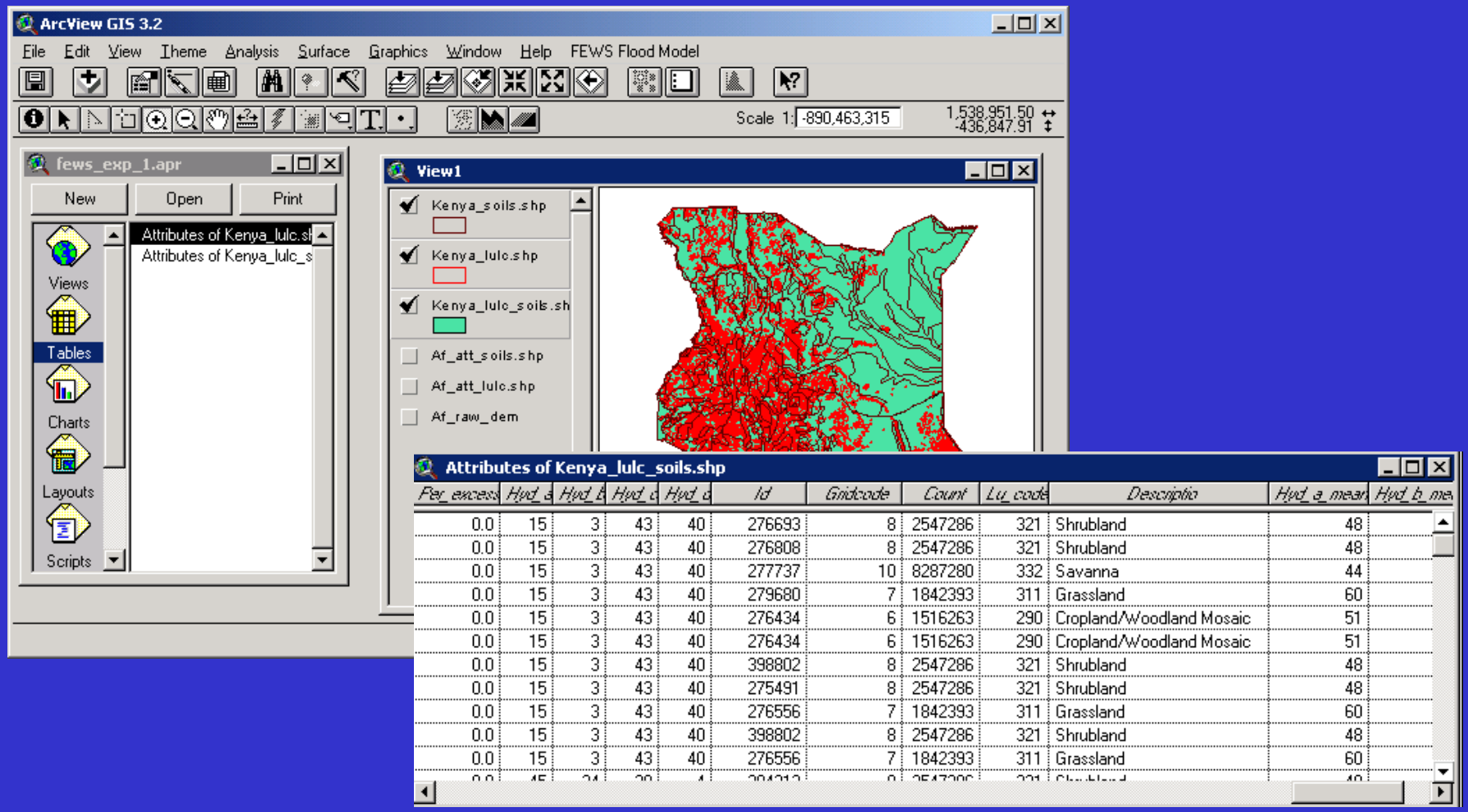




kenya_soils.shp + kenya_lulc.shp = kenya_lulc_soils.shp

Data Preparation : Combining Layers using the Union Operation

The combined soils and land use land cover shapefile for Kenya



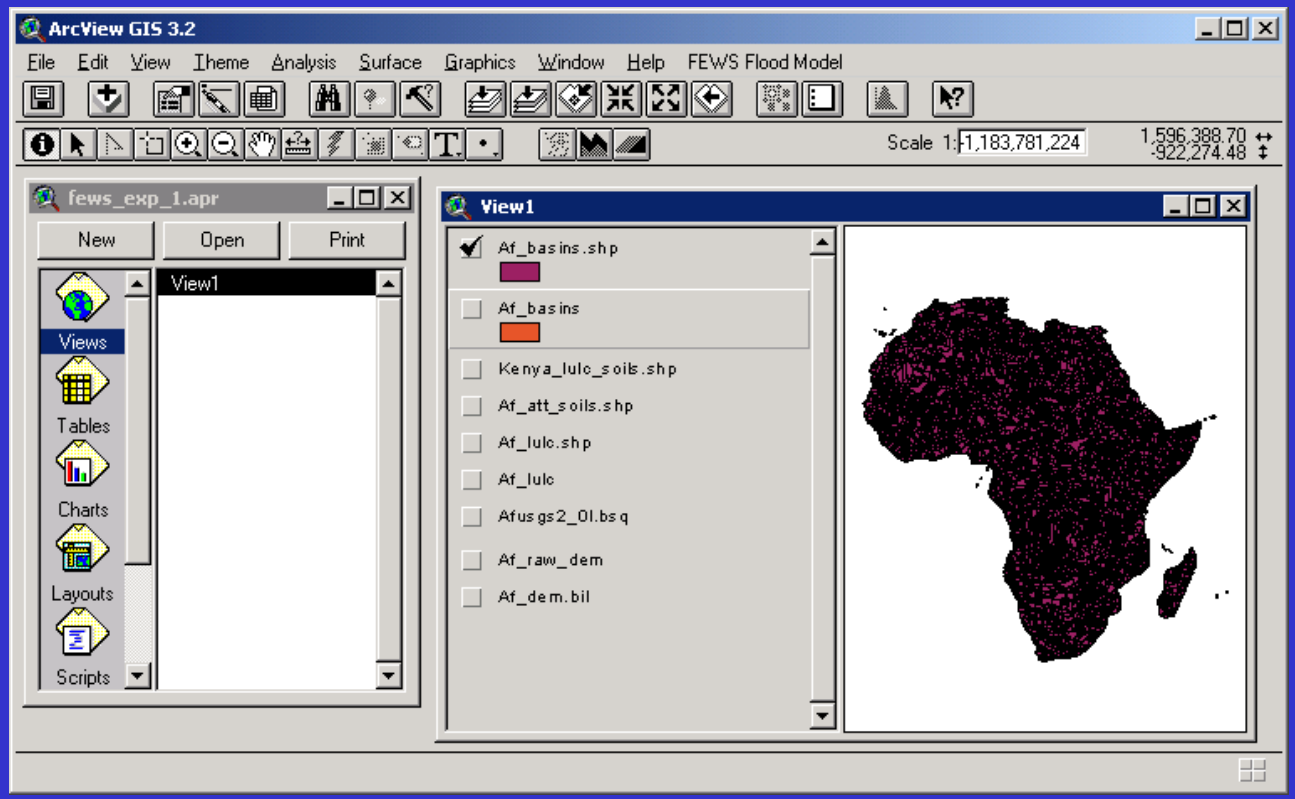
Per_excess	Hyd_a	Hyd_b	Hyd_c	Hyd_d	Id	Gridcode	Count	Lu_code	Descriptio	Hyd_a_mean	Hyd_b_me
0.0	15	3	43	40	276693	8	2547286	321	Shrubland	48	
0.0	15	3	43	40	276808	8	2547286	321	Shrubland	48	
0.0	15	3	43	40	277737	10	8287280	332	Savanna	44	
0.0	15	3	43	40	279680	7	1842393	311	Grassland	60	
0.0	15	3	43	40	276434	6	1516263	290	Cropland/Woodland Mosaic	51	
0.0	15	3	43	40	276434	6	1516263	290	Cropland/Woodland Mosaic	51	
0.0	15	3	43	40	398802	8	2547286	321	Shrubland	48	
0.0	15	3	43	40	275491	8	2547286	321	Shrubland	48	
0.0	15	3	43	40	276556	7	1842393	311	Grassland	60	
0.0	15	3	43	40	398802	8	2547286	321	Shrubland	48	
0.0	15	3	43	40	276556	7	1842393	311	Grassland	60	

Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

Basin boundaries can also be used to clip an area that contains the watershed to be modeled.

The watersheds shown on this theme represent level 6 of the Pfafstetter coding methodology



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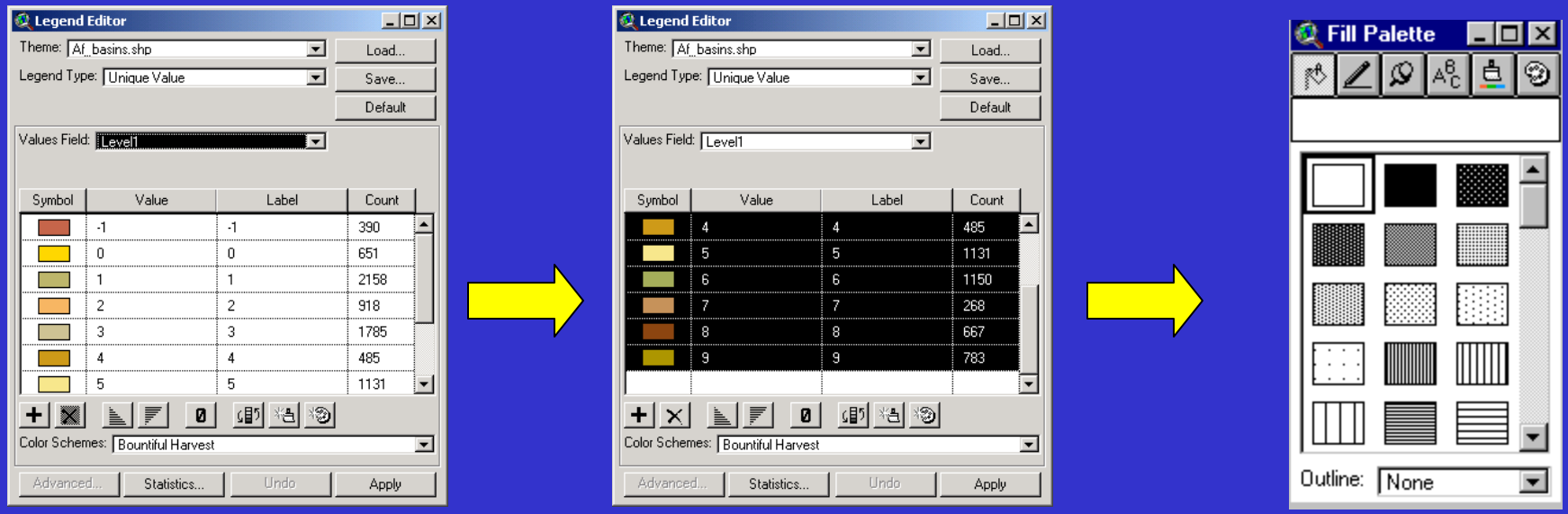
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

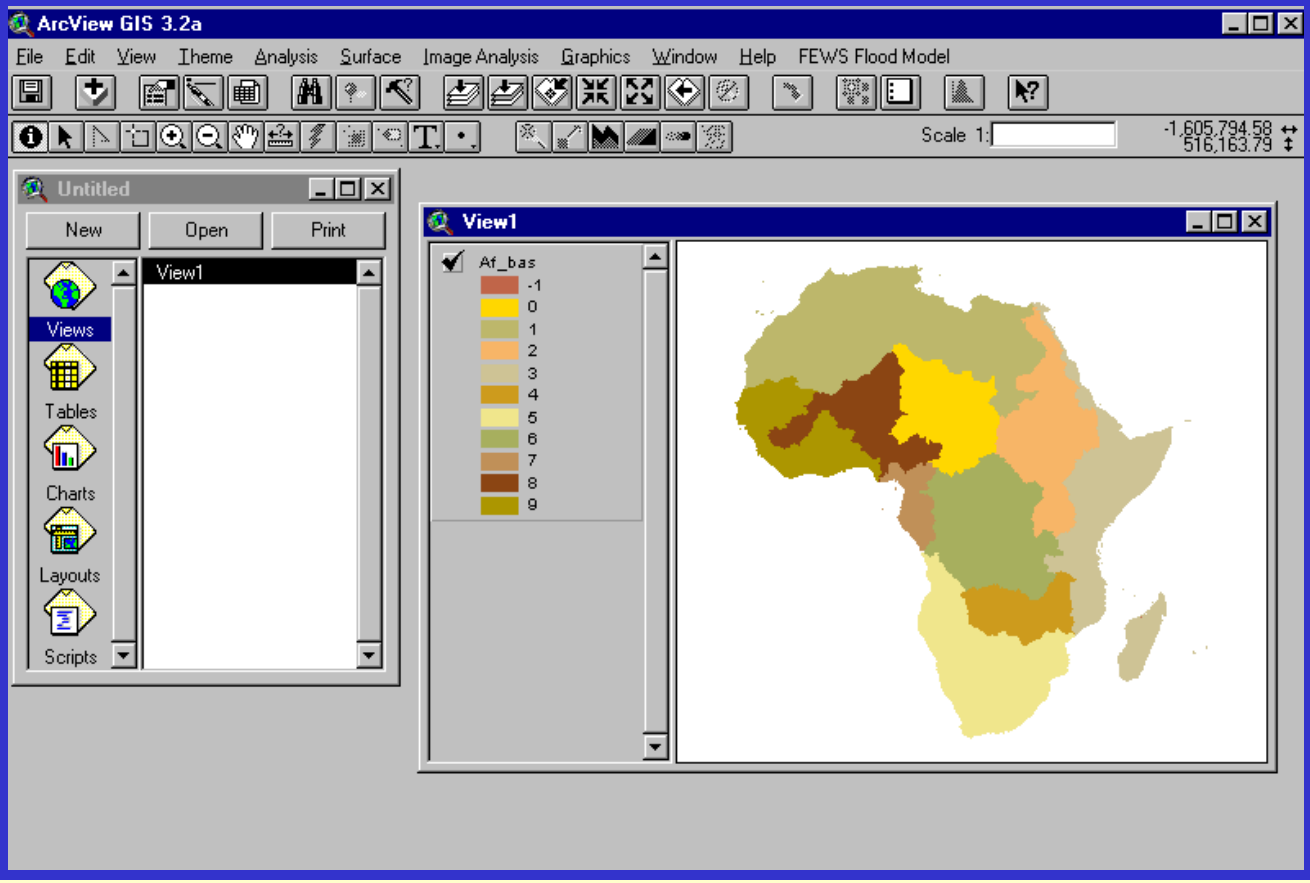
- Open the legend editor by double clicking on the theme in the View's table of contents
- Change the legend type to "unique value" and the values field to "level 1"
- Select all entries by clicking on the first and holding the shift key down while clicking on the last
- While still holding the shift key, double click on the symbol for the last entry to open the fill palette
- Change the outline entry to "none" and click apply



Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

Level 1 watersheds for Africa with no outline



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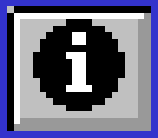
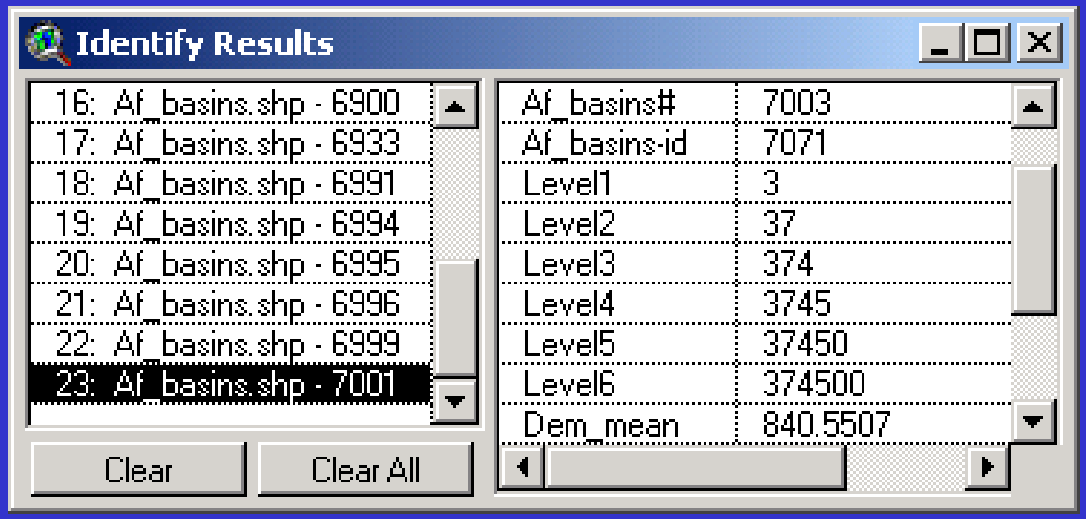
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

The “Query builder” can be used to locate smaller watersheds with which to work. These can also be identified using the ArcView “Identity Tool.” Click on the “Identity Tool” and point on or in the general vicinity of the desired watershed, and click the mouse. The "Identify Results" window displays information about the watershed(s).



Identity Tool



By alternating between the "Identity" function and displaying smaller watersheds without an outline, you can locate and select a watershed to model.

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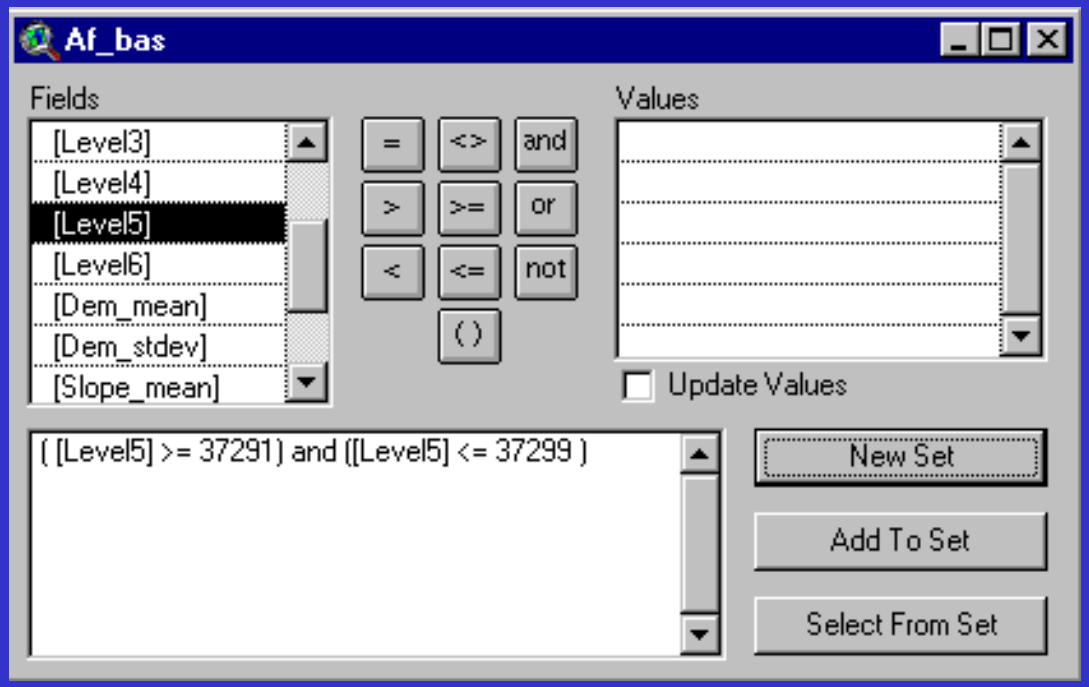
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

With knowledge of the Pfafstetter coding, the query builder can be used to quickly select the desired basins. The Tana watershed in Kenya is used in the following example.



- Open the query builder
- Enter the logical expression selecting level 5 values between 37291 and 37299
- Choose “New Set”

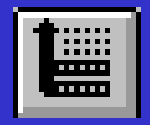
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

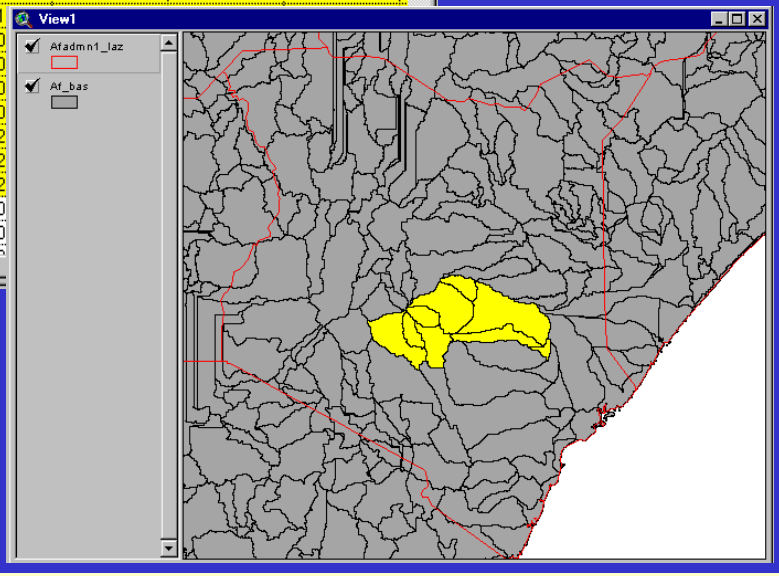
With the basin attribute table open, select the “promote” button to bring the selected basins to the top of the table. Note that the level 5 values are those chosen in the query builder expression. The basins are highlighted in the the both the attribute table and the view.

Attributes of Af_bas

Af_bas#	Af_bas-id	Level1	Level2	Level3	Level4	Level5	Level6	Dem_mean	Dem_stdev	Slope_mean	Slope_stdev	Aspect_mean	Aspect_stdev
6547	6615	3	37	372	3729	37294	372940	595.3560	251.4604	0.9862	1.0191	146.3949	68.0954
6554	6622	3	37	372	3729	37293	372930	294.6371	129.3308	0.3335	0.2530	126.4963	88.0378
6557	6625	3	37	372	3729	37295	372950	865.3016	566.7214	1.6911	1.8492	138.9627	101.6103
6618	6686	3	37	372	3729	37296	372960	1615.7122	833.3080	3.0870	2.2659	114.5553	47.6540
6634	6702	3	37	372	3729	37299	372990	1764.6774	624.0766	2.1182	1.9095	142.5811	90.6034
6637	6705	3	37	372	3729	37298	372980	1606.3895	682.3786	2.1663	2.2559	153.8993	48.6990
6663	6731	3	37	372	3729	37297	372970	1033.4977	231.4133	1			
6677	6745	3	37	372	3729	37292	372920	412.2930	192.9601	0			
6700	6768	3	37	372	3729	37293	372930	294.6371	129.3308	0			
6717	6785	3	37	372	3729	37291	372910	129.9122	22.6579	0			
6747	6815	3	37	372	3729	37291	372910	129.9122	22.6579	0			
6859	6927	3	37	372	3729	37299	372990	1764.6774	624.0766	2			
6861	6929	3	37	372	3729	37299	372990	1764.6774	624.0766	2			
6864	6932	3	37	372	3729	37299	372990	1764.6774	624.0766	2			
6725	6793	3	37	372	3726	37260	372600	519.1917	295.1129	0			
6726	6794	3	37	372	3728	37280	372800	294.2863	135.4624	0			



Promote Button



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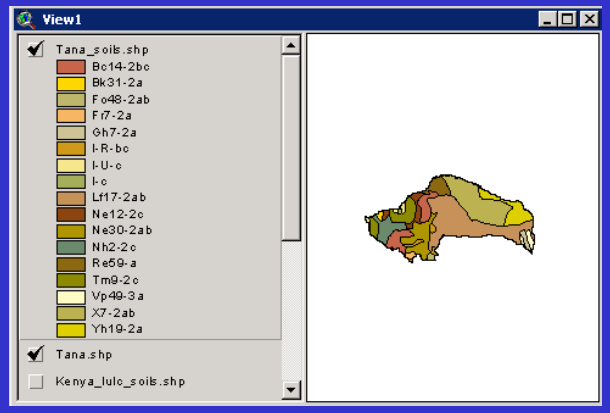
Data Preparation : Clipping Themes from a Larger Data Set

Clipping by Watershed

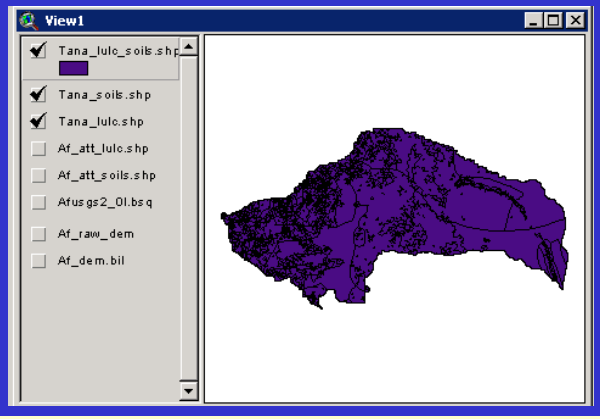
Create a new shapefile that contains only the watershed to be modeled using the "Convert to Shapefile" option in the Theme pull-down menu. As shown in the clipping by country example, the new shapefile can be used to clip the desired areas from other data sets needed to create the input data files for the SFM.

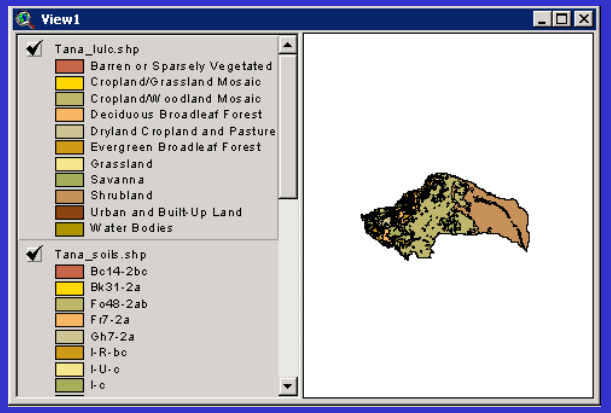


Tana - soils

Tana

soils / land cover





Tana - land cover

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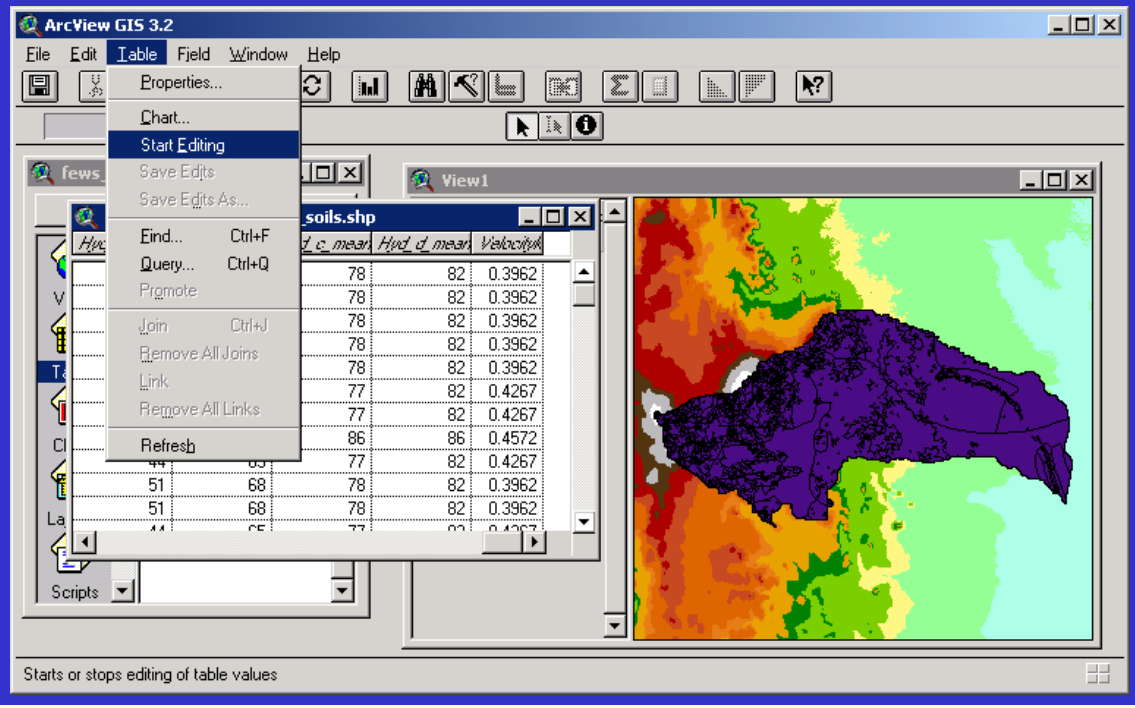
Data Preparation : Computing values for the SCS Curve Number

The SFM uses the SCS curve number during the simulation of stream flow. The SCS curve numbers can be estimated using information available in the FAO soils database and the USGS Land Use/Land Cover database.

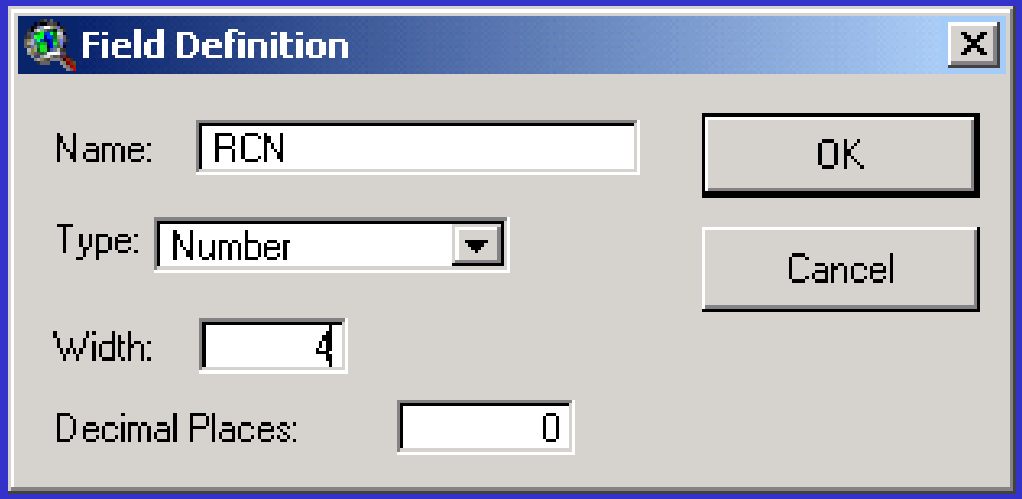
After creating a union of the two covers and opening the theme attribute table, use the Start Editing entry in the Table pull-down menu to make the table ready for editing.



Data Preparation : Computing values for the SCS Curve Number

Editing the attribute table:

- Under the edit menu, select “add field” to open the field definition box
- Name the field "RCN“
- Set the field type to “number
- Set the field width to “4”
- Set the number of decimal places to “0”
- Click on the "OK" button

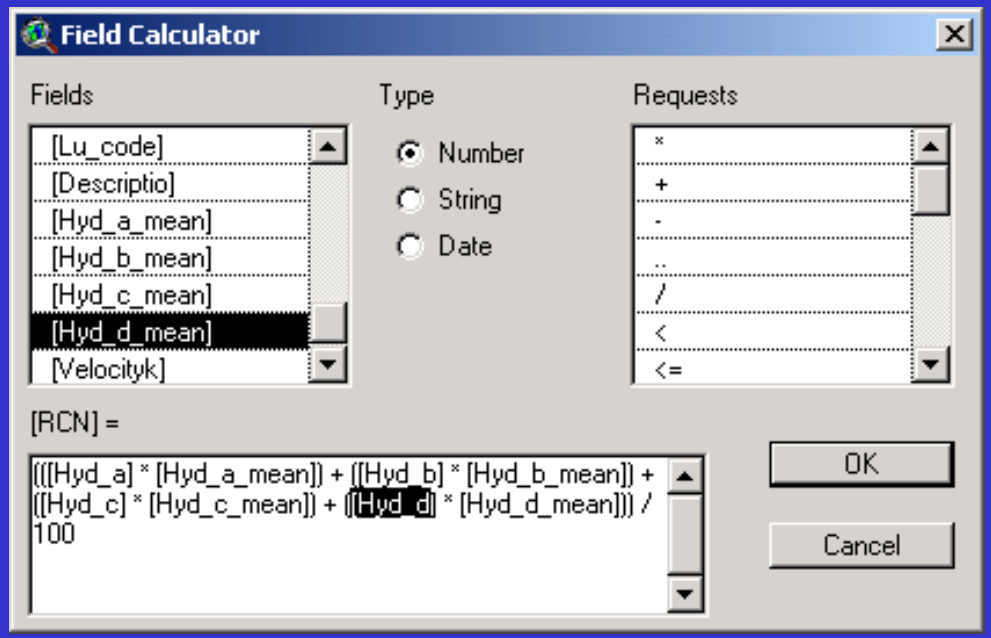


Data Preparation : Computing values for the SCS Curve Number

Populating the new field:

- The column RCN will be added to the table
- Select the column by clicking on the column heading
- Use the calculator button to open the "Field Calculator"
- The "Field Calculator" is used to populate the RCN field

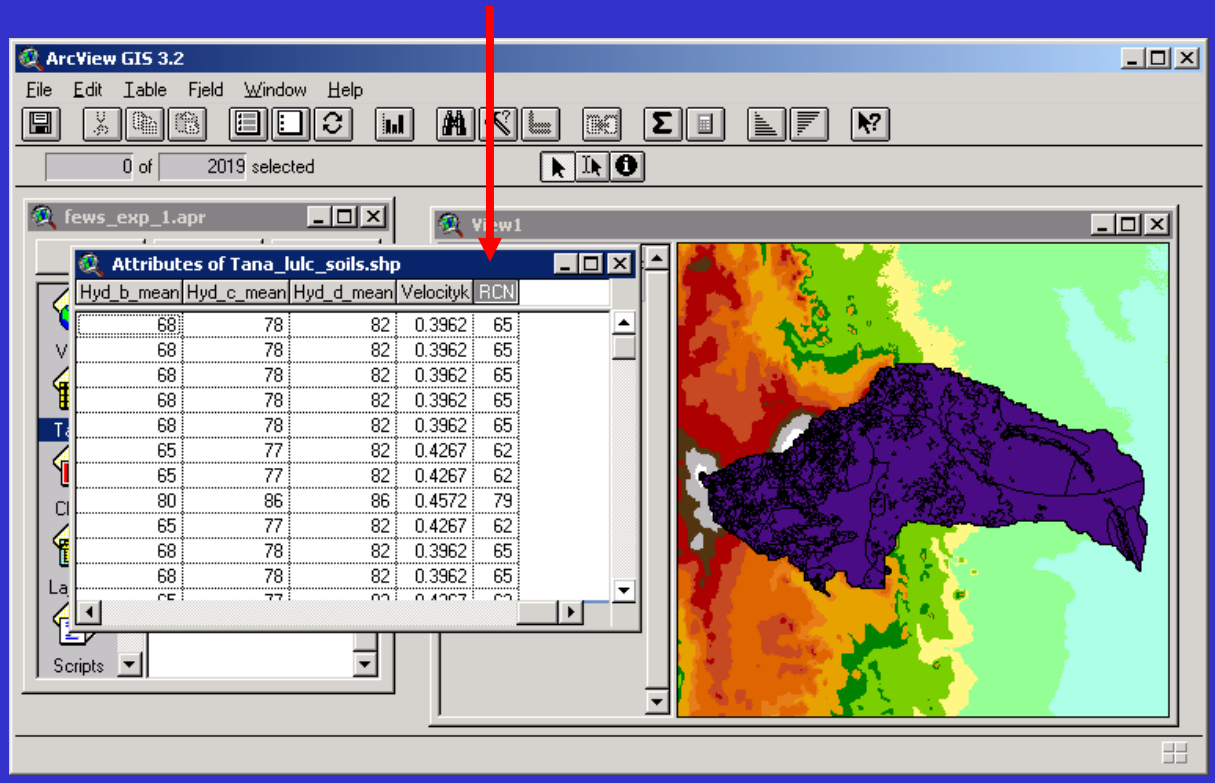
Enter the formula for calculating the RCN field and select ok



Data Preparation : Computing values for the SCS Curve Number

Populating the new field:

The RCN field is populated with the results of the field calculator formula

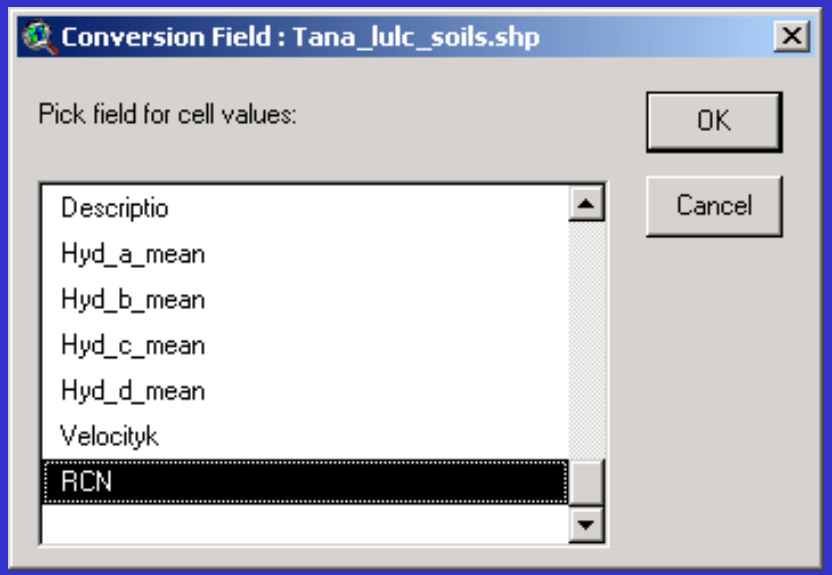


Data Preparation : Computing values for the SCS Curve Number

Creating a watershed grid of SCS curve numbers:

ArcView grid themes are used to create the input data files for the SFM.

- Convert the "tana_lulc_soils" shapefile to a grid of SCS curve numbers
- Make the theme active and select "convert to grid" from the theme menu
- Select RCN as the field for cell values from the conversion field window

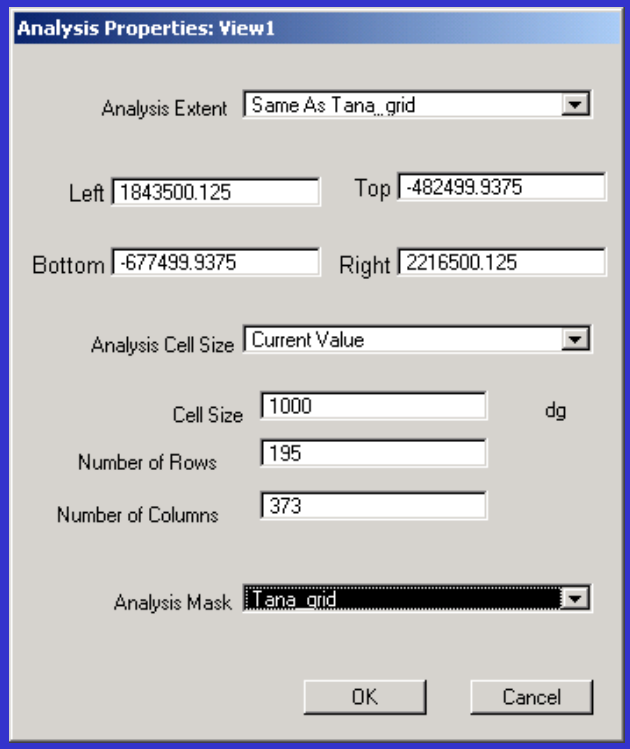


Data Preparation : Clipping a portion of the Africa DEM data set

Reducing the DEM data set to the watershed being modeled:

The clip function discussed earlier is applicable to shapefiles only and cannot be used for clipping gridded data. However, ArcView offers the "Analysis Extent" function to limit the area of a grid theme included in an analysis.

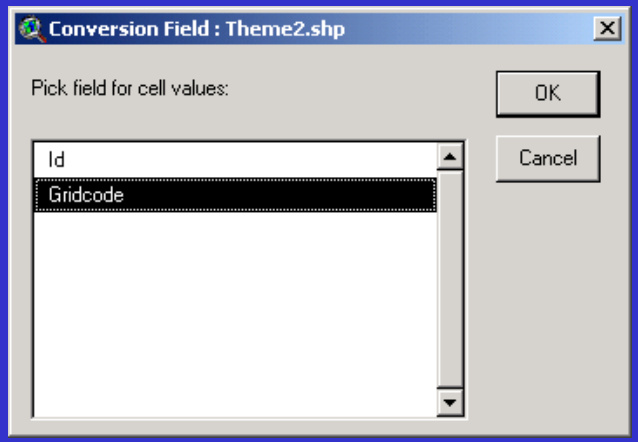
- Convert the shapefile of the watershed being modeled to a grid
- Select “properties” from the analysis menu to set the analysis extent
- For this example, select the tana_grid for both the “analysis extent” and “analysis mask”

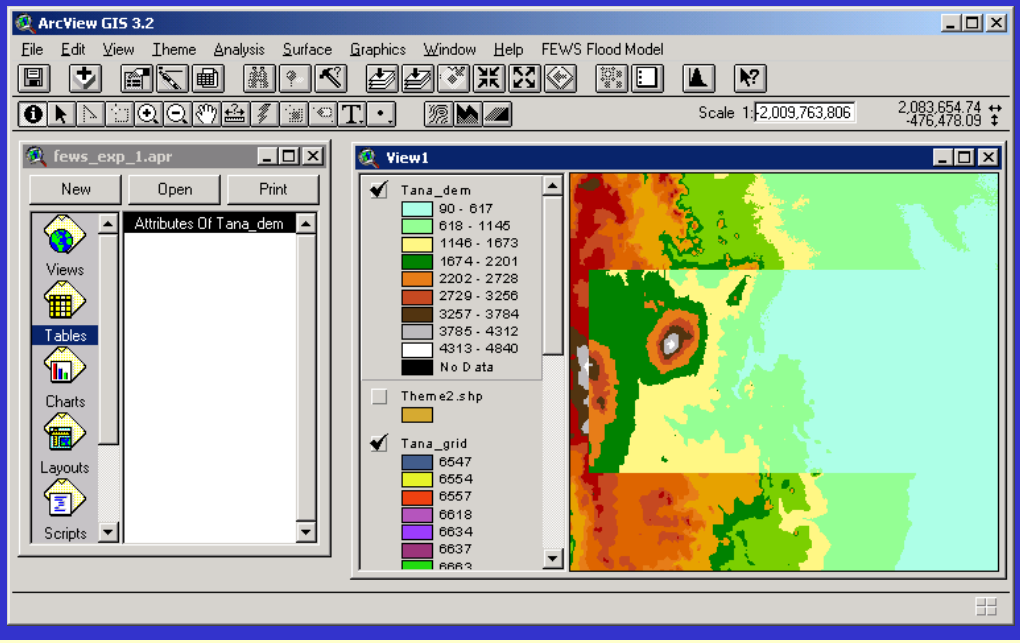


Data Preparation : Clipping a portion of the Africa DEM data set

Creating a grid with the new analysis extent:

- Use "Convert to Shapefile" from the "Theme" menu to create a shapefile of the DEM data for the watershed.
- Convert the watershed shapefile into a grid using the “Convert to grid” function
- Provide a grid name and directory for the output
- Select the “gridcode” field to populate the grid cell value

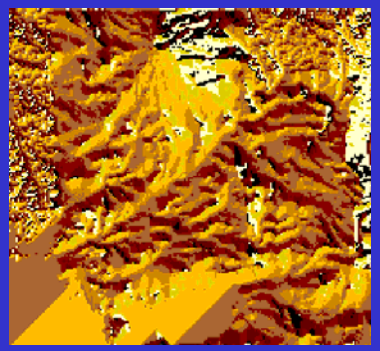




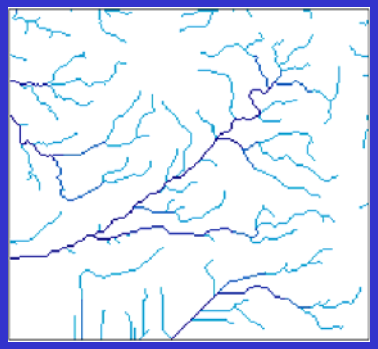
Using the GUI to simulate stream flow with the FEWS SFM :

The SFM GUI uses a number of different functions to create the input-data files, run the model, and permit examination of the simulated stream flow and soil-water conditions.

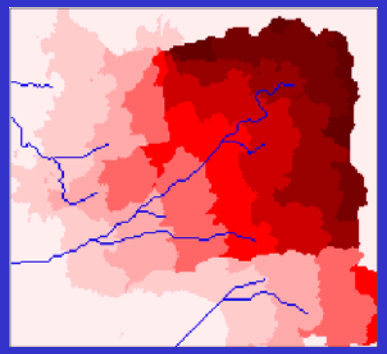
- **Create the input-data files**
  - "Complete Terrain Analysis"
  - "Generate Basin Characteristics"
  - "Generate Basin Response"
- **Convert precipitation and evaporation data**
  - "Interpolate Station Data to Grid"
  - "Generate Rain/Evap. Data File"
- **Define overland flow response for each sub-basin**
  - "Compute Sub-basin Response"
- **Simulate stream flow and soil-water conditions**
  - "Perform Flow Routing"
- **Examine simulated data**
  - "Compute Rain/Evap Statistics"
  - "Compute Flow Statistics"
  - "Flow Percentile Map"
  - "Flooded Area Map"
  - "Plot Hydrographs"



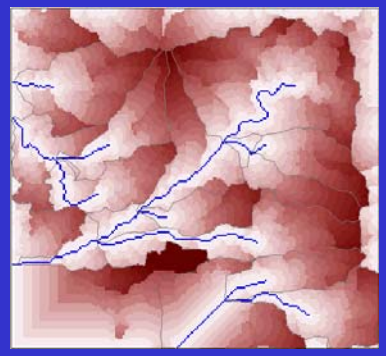
Flow direction



Flow Accumulation

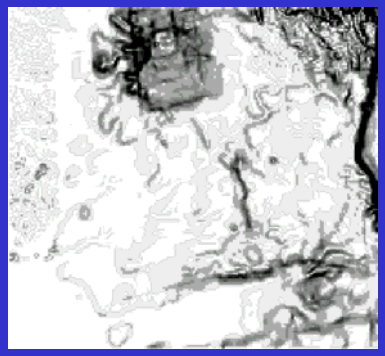


Flow Length

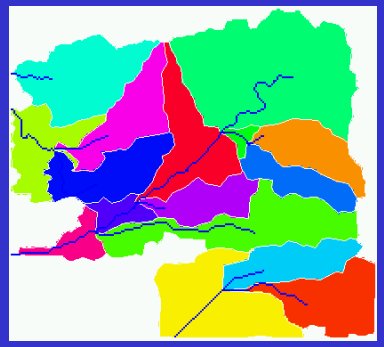


Hill Length

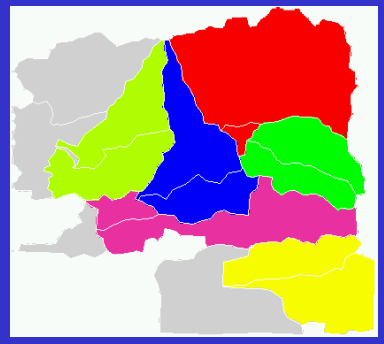
Derivatives of USGS 1 km DEM



Terrain slope



Sub-basins



Sub-basin Linkage

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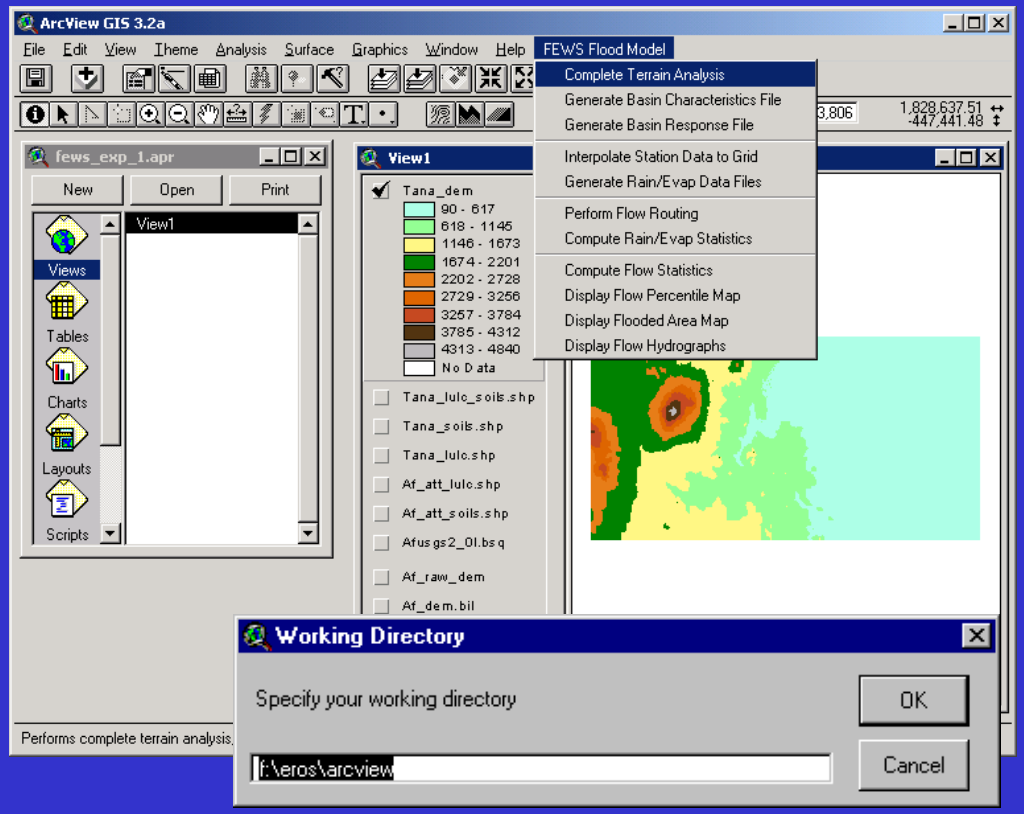
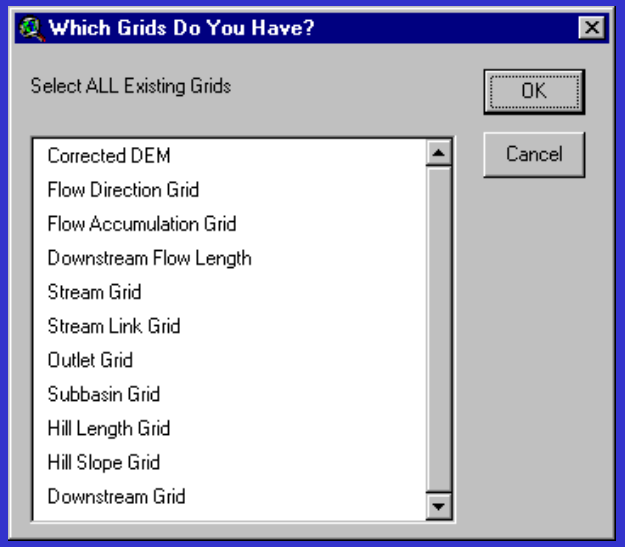
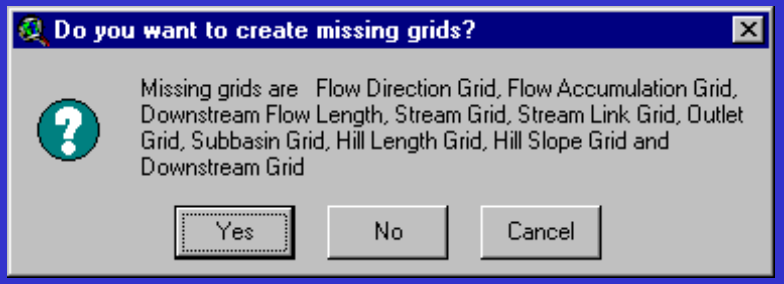
Creating the input-data files:

"Complete Terrain Analysis"

The "Complete Terrain Analysis" function creates grid themes that the function "Generate Basin File" will use to create the SFM input-data file "Basin.txt."







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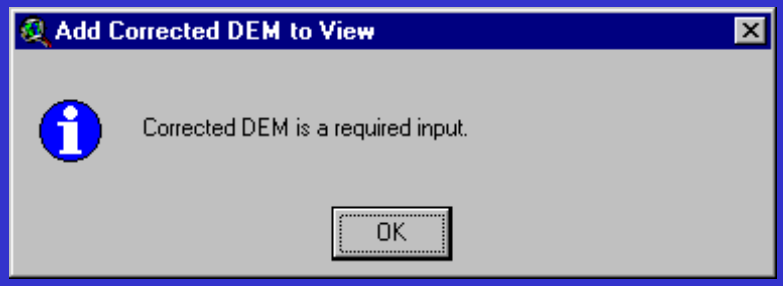
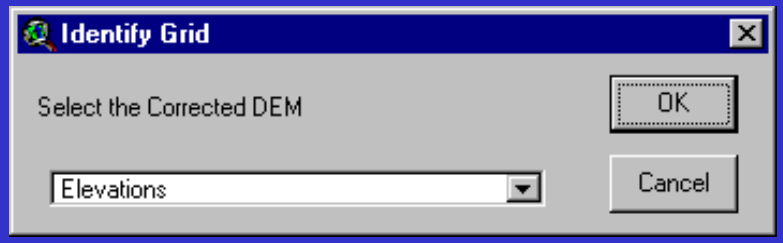
Creating the input-data file basin.txt without having a basin coverage:

"Complete Terrain Analysis"

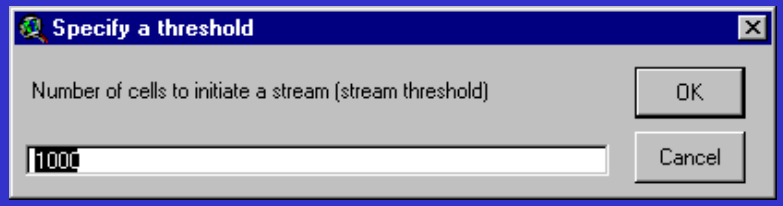
"Complete Terrain Analysis" uses a grid theme of corrected DEM data.



"Complete Terrain Analysis" first renames the theme of corrected DEM data to "Elevations"



Number of cells that must be contributing flow to a cell before it is considered part of a stream network



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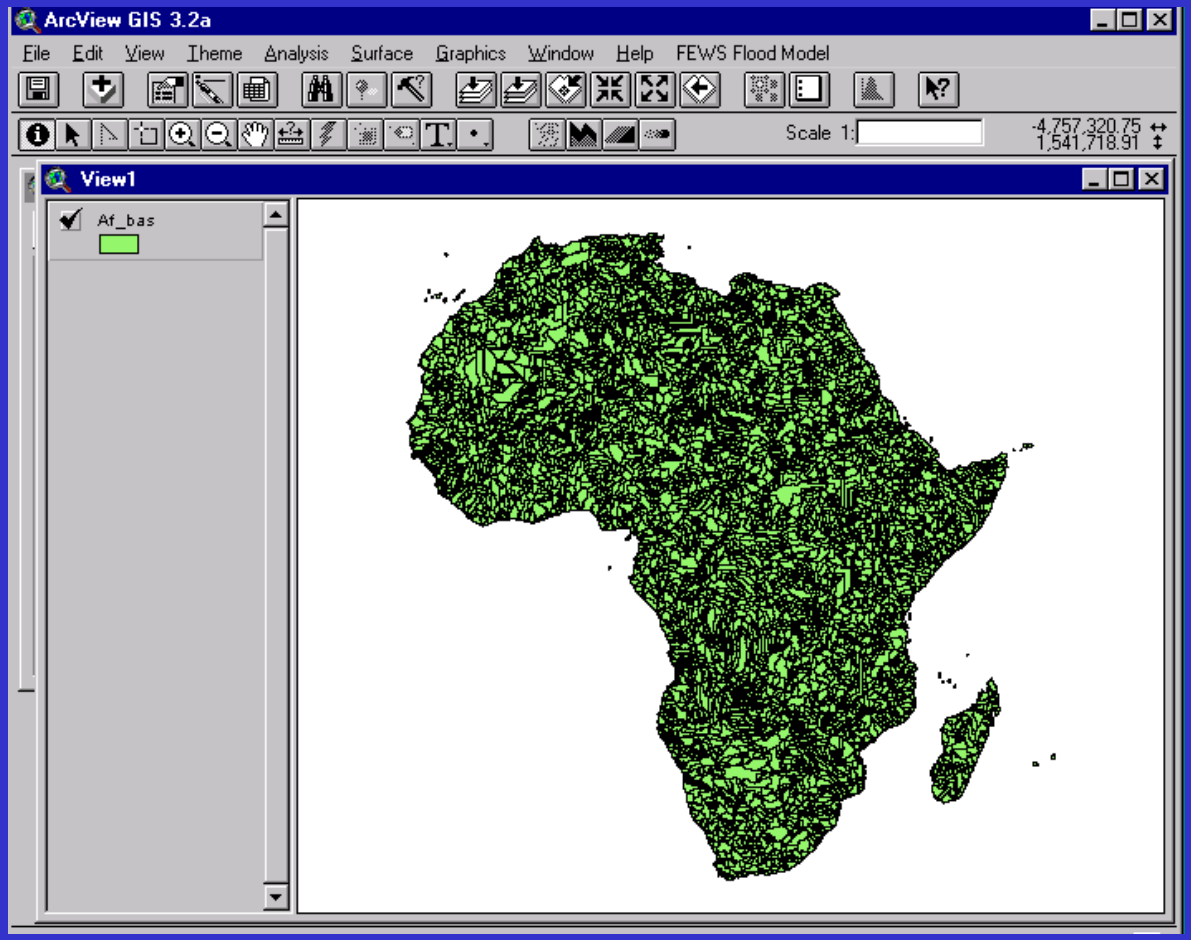
USGS HYDRO1K Dataset



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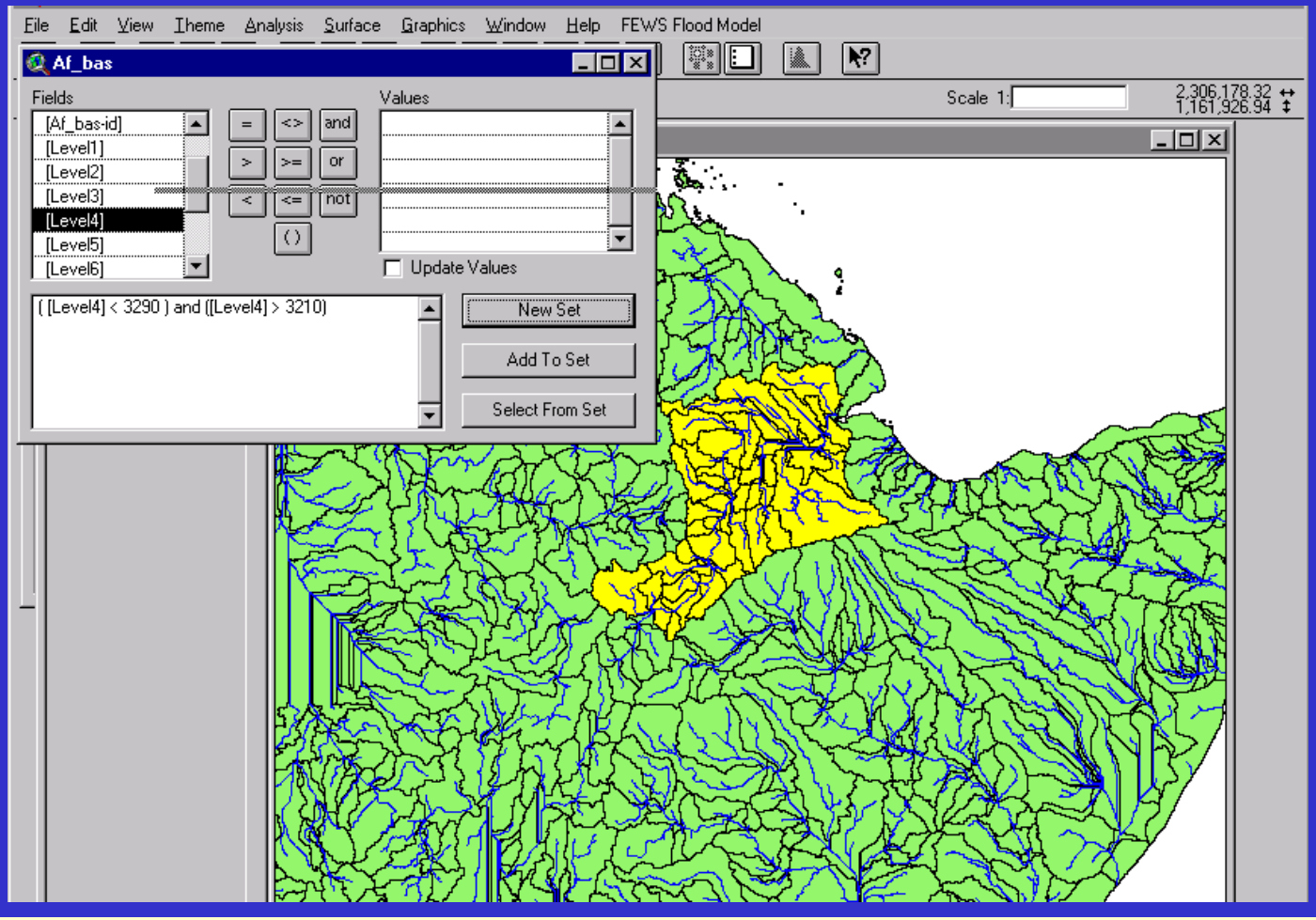
Selecting the Modeling Unit



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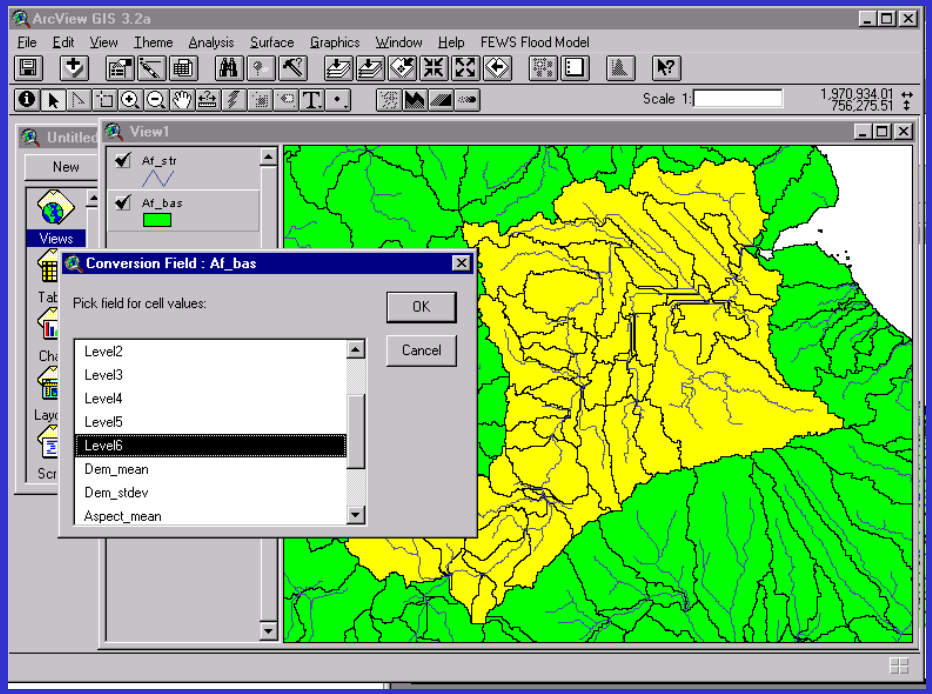
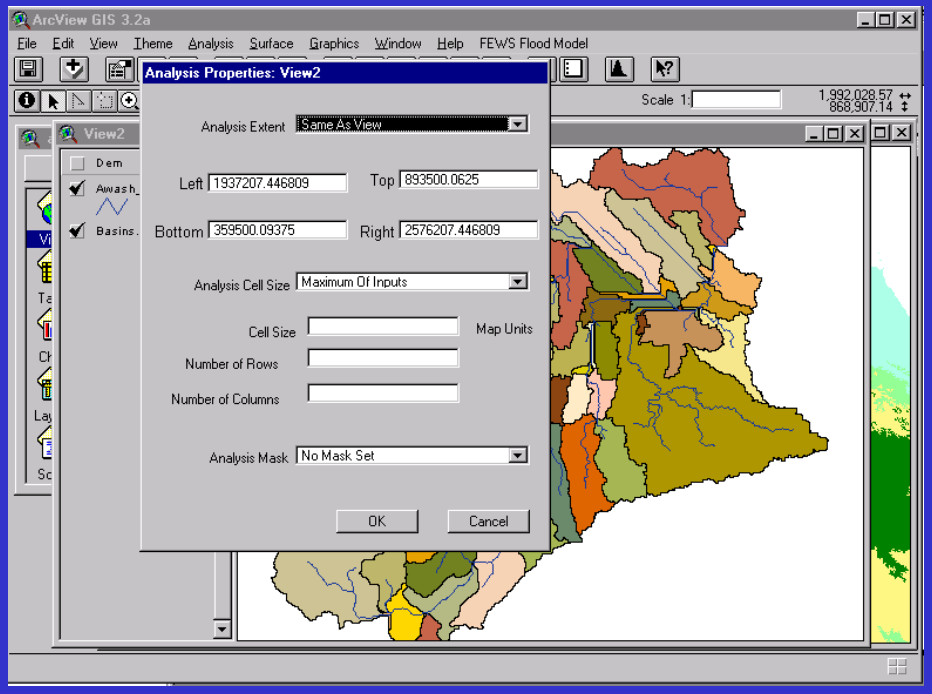
Saving the Unit





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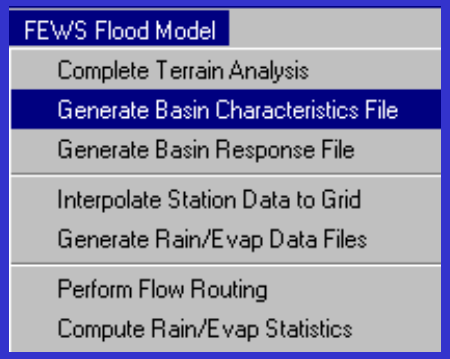
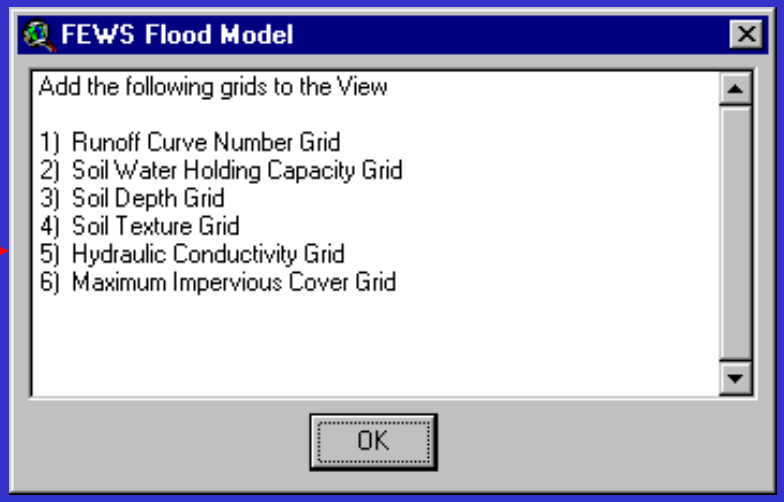
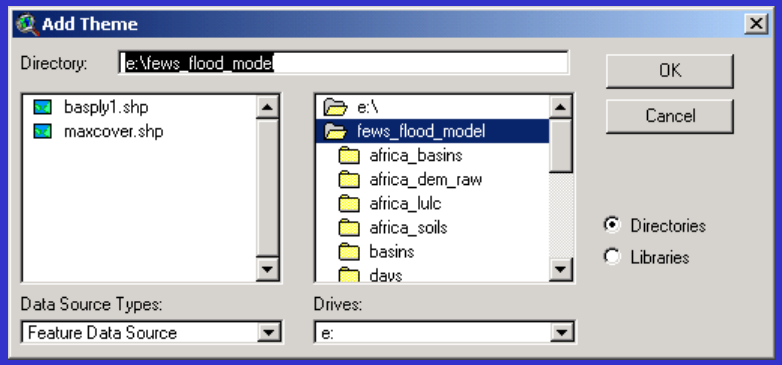
Creating the input-data files:

"Generate Basin Characteristics File"

"Generate Basin File" is the function that creates the SFM input data file "basin.txt."

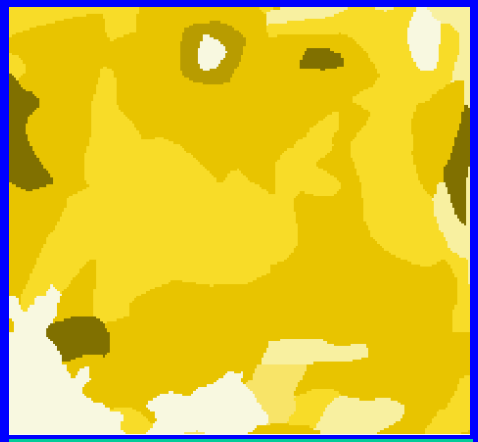






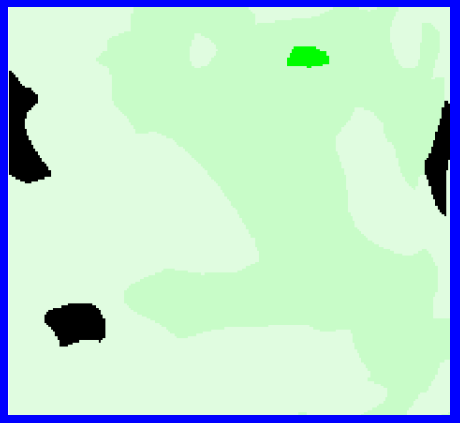
Soil and land cover grid theme types needed to create the input-data file that describes the physical characteristics of the basin

Soil and Land Cover Data

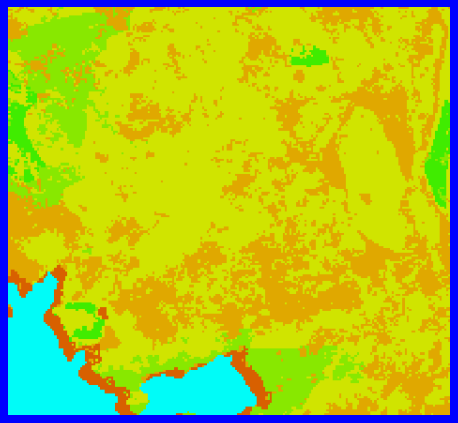


Soil WHC

Soil Depth

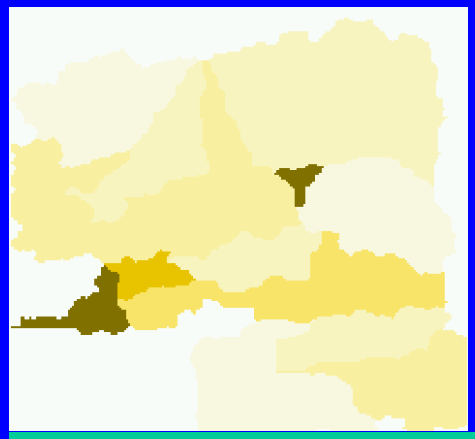


Hydraulic Conductivity



SCS Curve No.

Texture



Maximum Impervious

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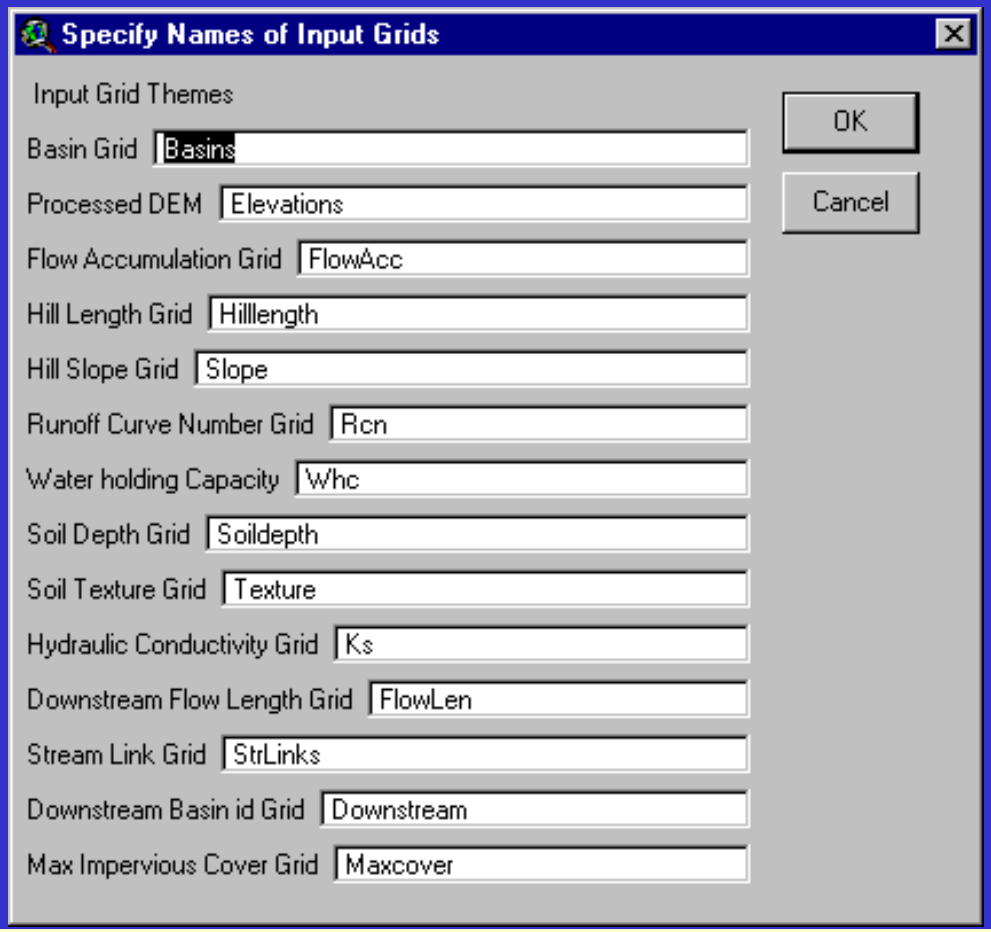
Creating the input-data files:

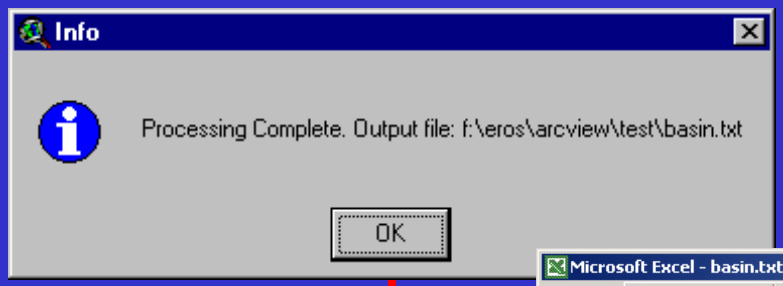
"Generate Basin Characteristics File"

Input grid theme window



Creating the input-data files:

"Generate Basin Characteristics File"



Microsoft Excel - basin.txt

File Edit View Insert Format Tools Data S-PLUS Window Help

Arial 10

R3 =

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Id	SoilWHC	Depth	Texture	Ks	Area	HLength	HSlope	UpArea	RivSlope	Elevation	RCNumber	RivLength	DownID	MaxCover	HasDam
2	1	82.7784	105.71	2	0	2103	28469.1	1.7148	2102	1.025	595.5	69.8	25556.4	7	0.0105	0
3	2	82.3151	97.2434	2	0	4865	28184.9	2.1912	21231	0.723	668.7	71.1	80769.7	7	0.0146	0
4	3	78.9209	95.396	2	0	1909	24882.5	4.5386	1908	1.861	1394.6	57.2	35142.2	2	0.0168	0
5	4	99.3021	121.375	2	0	1089	33891.5	1.0503	1088	0.08	376.5	65.7	1414.2	5	0.0018	0
6	5	99.0161	124.806	2	0	62	9110.4	0.3329	26435	0.113	244.7	67.9	3000	6	0.0645	0
7	6	95.8774	119.14	2	0	6695	18406.2	0.4106	34710	0.139	216	63.9	145610.2	14	0.0184	0
8	7	99.2492	122.009	2	0	1950	23366.9	0.8685	25284	0.475	403.4	69.7	49970.6	5	0.0121	0
9	8	99.5177	118.787	2	0	1580	30433.9	0.6621	1579	0.376	441.9	70.3	32799.1	6	0.0177	0
10	9	99.6046	149.378	2	0	349	5958.5	4.7411	14457	0.615	711.3	45.7	22485.3	2	0.0602	0
11	10	74.6791	94.4346	2	0	2057	37411.3	5.3998	2056	0.952	1615.7	47.9	10485.3	9	0.0043	0
12	11	94.5335	159.133	2	0	3901	21848	2.9295	12051	0.952	1033.6	34.5	76426.6	9	0.0166	0
13	12	98.4706	114.354	2	0	3708	28241.6	0.6249	3707	0.298	412.4	71.1	123254.8	14	0.0299	0
14	13	80.4553	117.94	2	0	1900	29997.5	3.793	1899	0.773	1606.4	53.6	23313.8	11	0.0111	0
15	14	57.6254	132.634	2	0	558	11354.1	0.2552	38976	0.077	132	55.1	25727.9	0	0.0412	0
16	15	83.5767	112.59	2	0	6251	24020.6	3.6743	6250	2.153	1765.3	64.4	108811.4	11	0.0147	0

basin

Ready NUM

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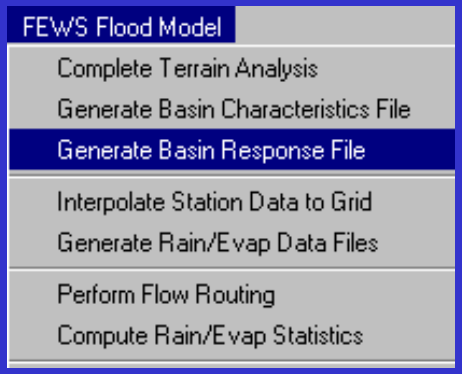
Creating the input-data files:

"Generate Basin Response File"

"Compute Subbasin Response" function creates a set of response coefficients, or unit-hydrograph, for each sub-watershed identified in "Complete Terrain Analysis." These responses are used to estimate the quantity of overland flow that reaches the stream channel in each model time step.



Requires a grid of velocity coefficients. The coefficients are based upon the type of vegetative cover.

Land-UseDescription	Velocity Coefficient
Unknown Land Use	0
Urban and Built-Up Land	6.3398
Dryland Cropland and Pasture	0.4572
Irrigated Cropland and Pasture	2.7737
Cropland/Grassland Mosaic	0.3962
Cropland/Woodland Mosaic	0.3962
Grassland	0.6401
Shrubland	0.4572
Savanna	0.4267
Deciduous Broadleaf Forest	0.4267
Evergreen Broadleaf Forest	0.2134
Water Bodies	14.1122
Herbaceous Wetland	4.7854
Wooded Wetland	3.1394
Barren or Sparsely Vegetated	0.6706

The grid can be created using the land use/land cover theme for the watershed being modeled

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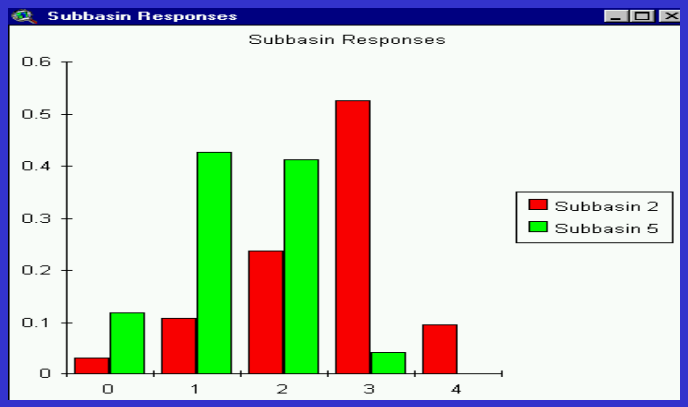
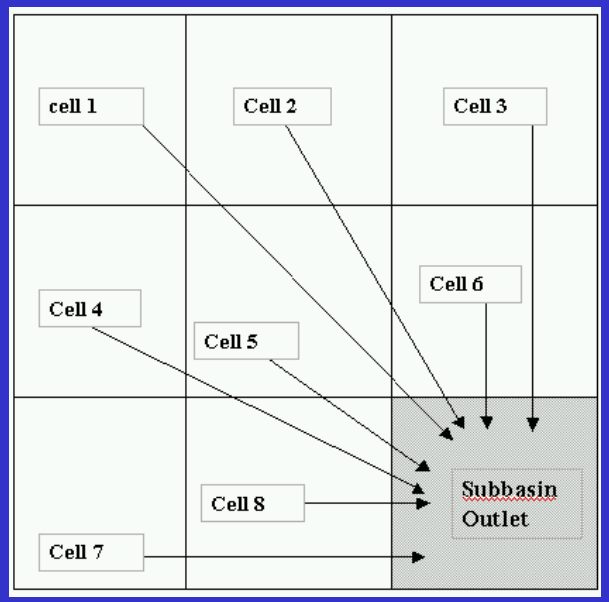
Runoff Response Functions

Flow time from cell to subbasin outlet

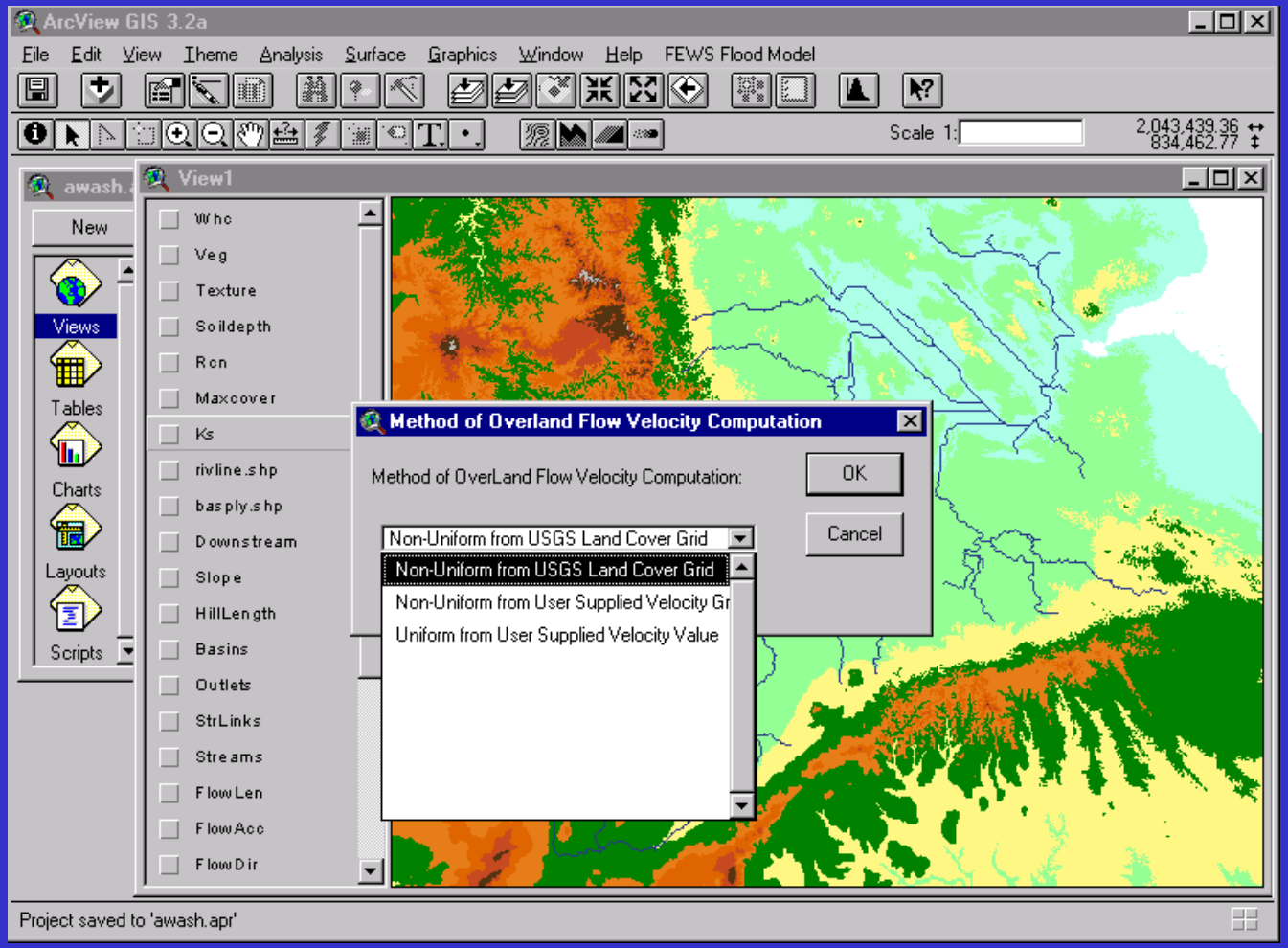
$$t = \sum_{i=1}^{n} \frac{l_i}{v_i}$$

Aggregate flow times for each day





Generate Basin Response File



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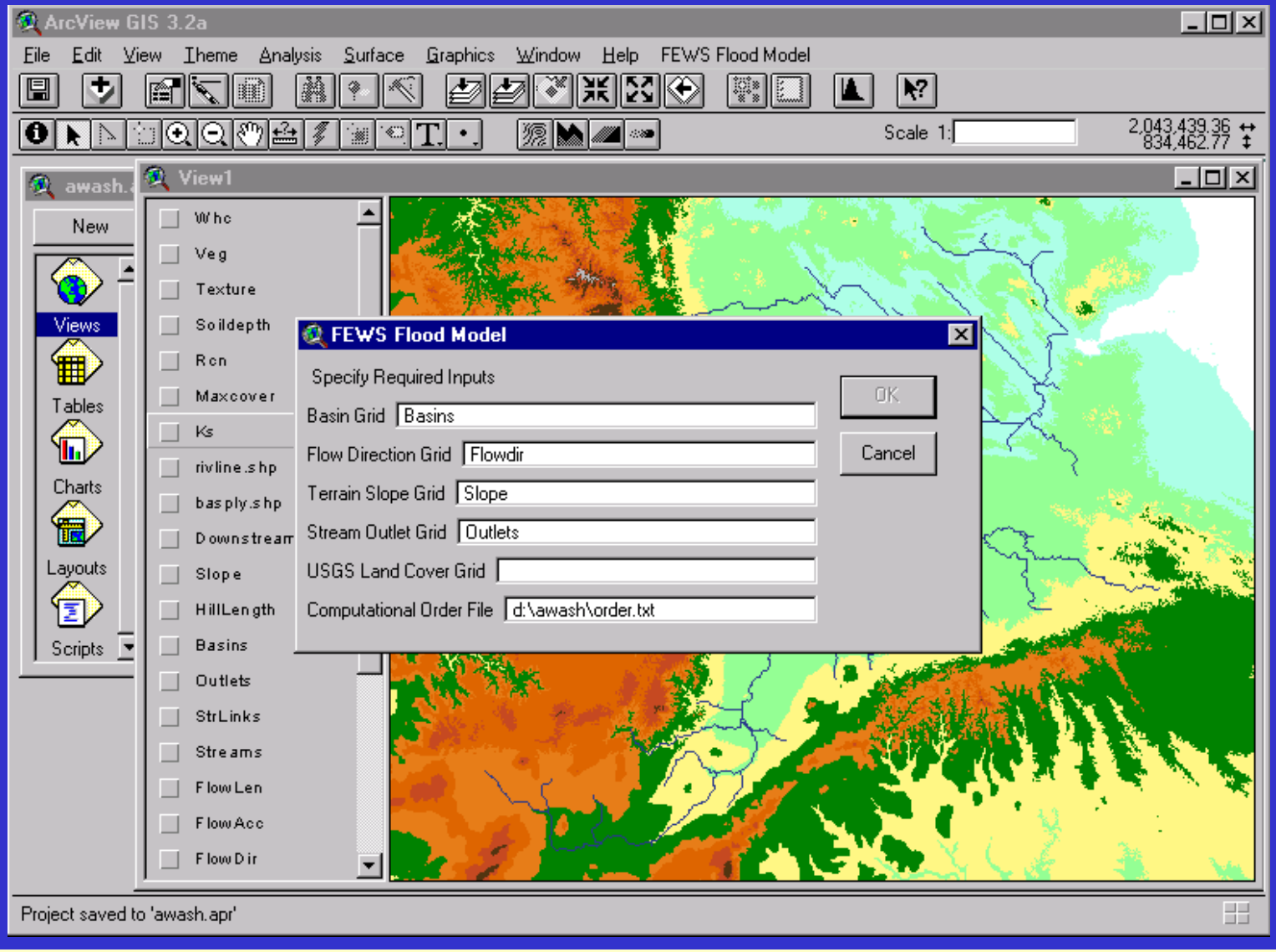
ArcView GIS 3.2a
File Edit View Theme Analysis Surface Graphics Window Help FEWS Flood Model
Scale 1:
2,043,439.36
834,462.77
View1
New
Views
Tables
Charts
Layouts
Scripts
Whc
Veg
Texture
Soildepth
Rcn
Maxcover
Ks
rivline.shp
basply.shp
Downstream
Slope
HillLength
Basins
Outlets
StrLinks
Streams
FlowLen
FlowAcc
FlowDir
FEWS Flood Model
Specify Required Inputs
Basin Grid Basins
Flow Direction Grid Flowdir
Terrain Slope Grid Slope
Stream Outlet Grid Outlets
USGS Land Cover Grid
Computational Order File d:\awash\order.txt
OK
Cancel
Project saved to 'awash.apr'

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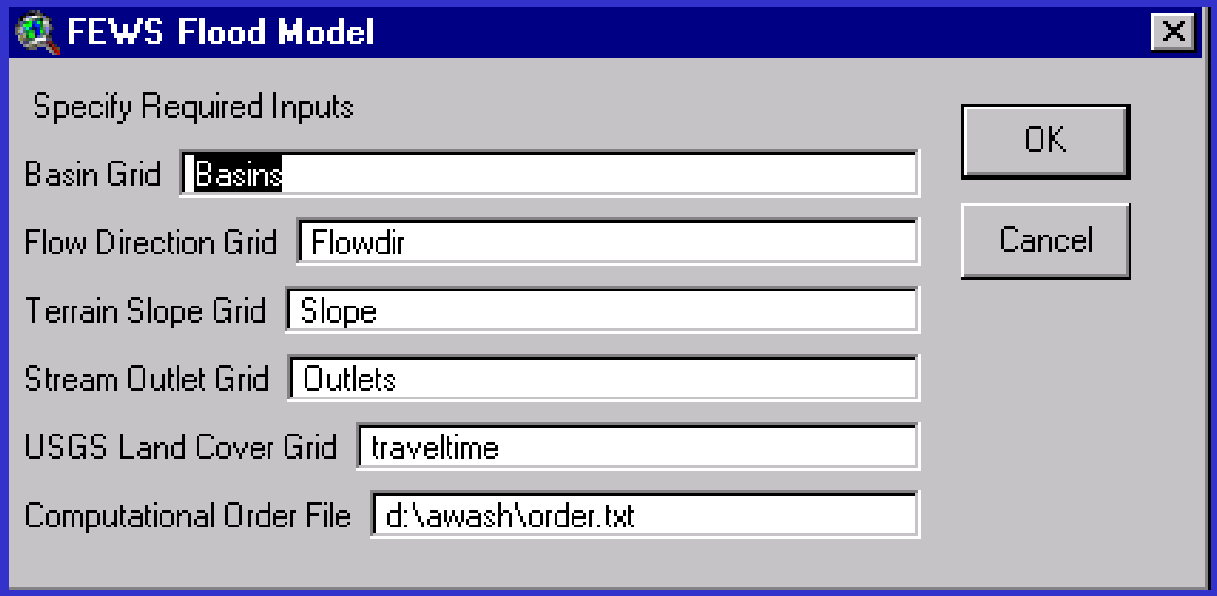
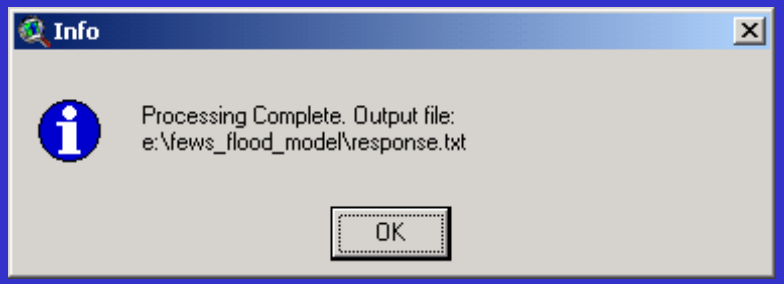
Creating the input-data files:

"Generate Basin Response File"

Input themes used to compute unit-hydrograph response





Window stating the unit-hydrograph response has been completed

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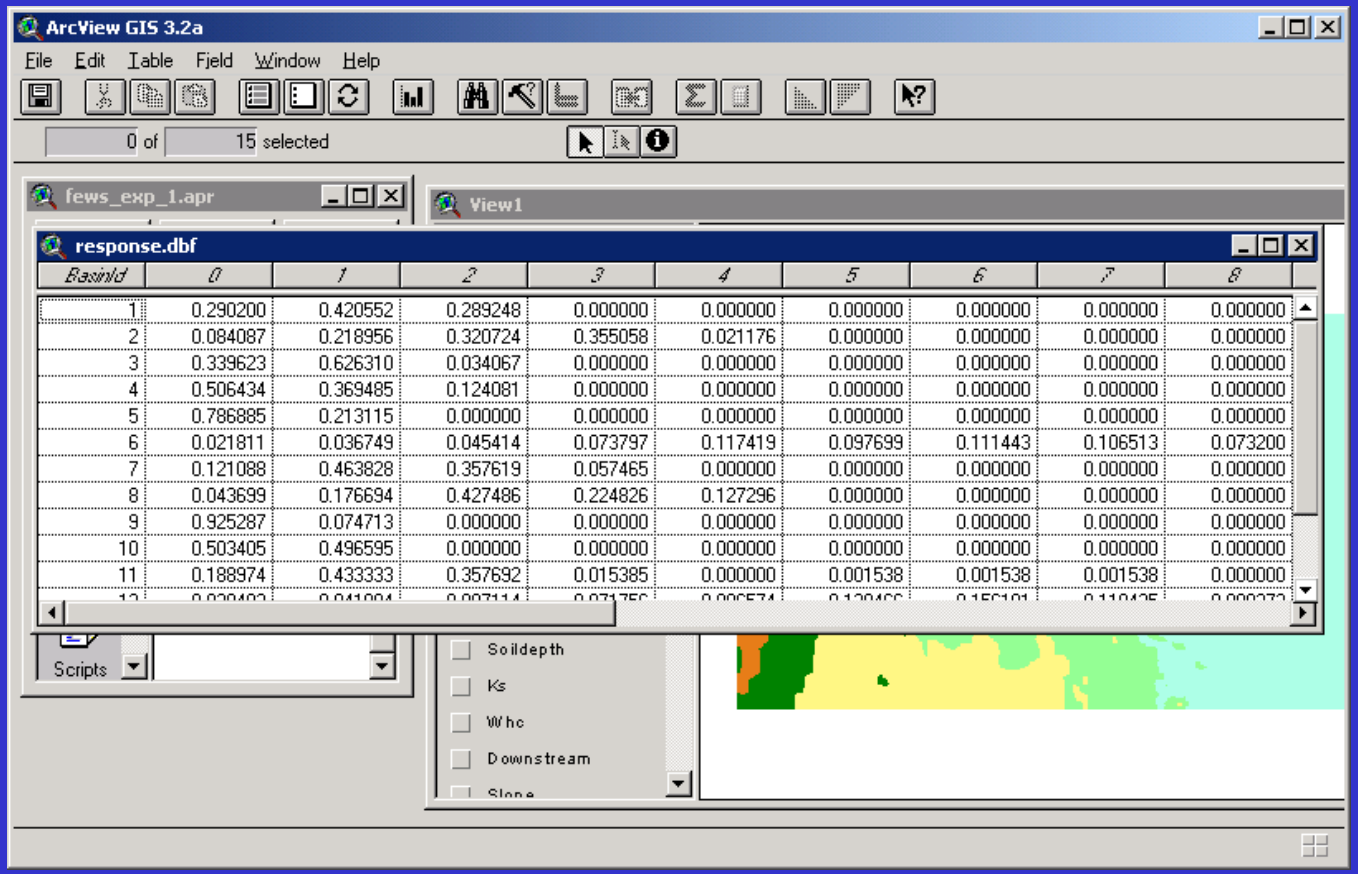
Creating the input-data files:

"Generate Basin Response File"

Outputs a response dBase file called response.dbf.

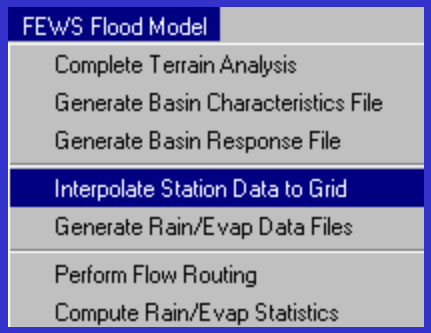


Basinid	0	1	2	3	4	5	6	7	8
1	0.290200	0.420552	0.289248	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.084087	0.218956	0.320724	0.355058	0.021176	0.000000	0.000000	0.000000	0.000000
3	0.339623	0.626310	0.034067	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.506434	0.369485	0.124081	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.786885	0.213115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.021811	0.036749	0.045414	0.073797	0.117419	0.097699	0.111443	0.106513	0.073200
7	0.121088	0.463828	0.357619	0.057465	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.043699	0.176694	0.427486	0.224826	0.127296	0.000000	0.000000	0.000000	0.000000
9	0.925287	0.074713	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.503405	0.496595	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11	0.188974	0.433333	0.357692	0.015385	0.000000	0.001538	0.001538	0.001538	0.000000

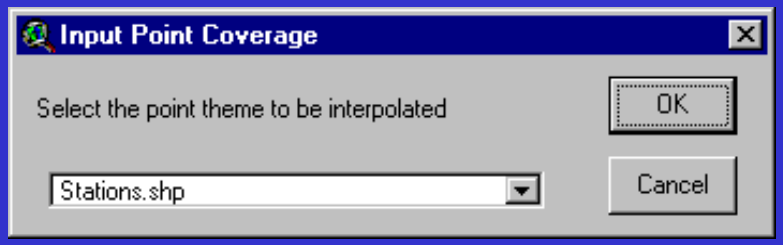
Convert Precipitation and Evaporation Data:

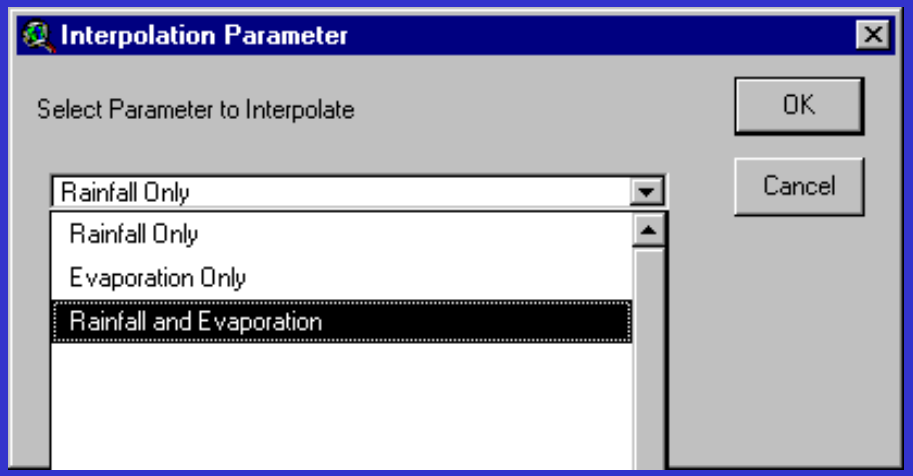
"Interpolate Station Data"

The FEWS SFM uses precipitation and evaporation data to add water to the ground water system and to compute overland flow. The SFM GUI offers a function for interpolating precipitation and evaporation over an area using station data. The function creates grid themes that can be used in creating the precipitation and evaporation input-data files used by the SFM.



Select the input point coverage for interpolating precipitation and evaporation from site-specific data





Select which meteorological parameters to estimate from site-specific data

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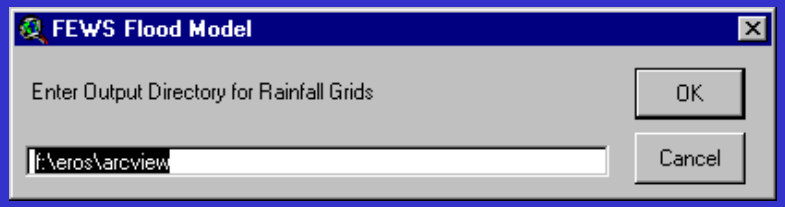
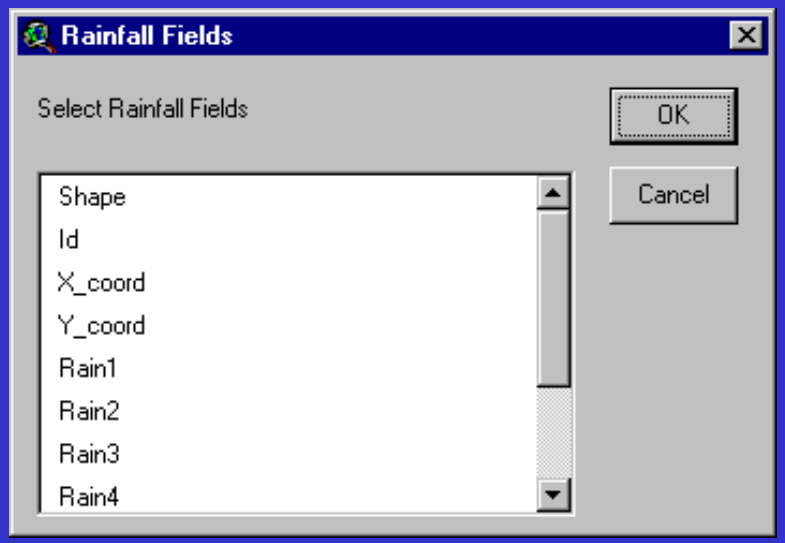
Convert Precipitation and Evaporation Data:

"Interpolate Station Data"

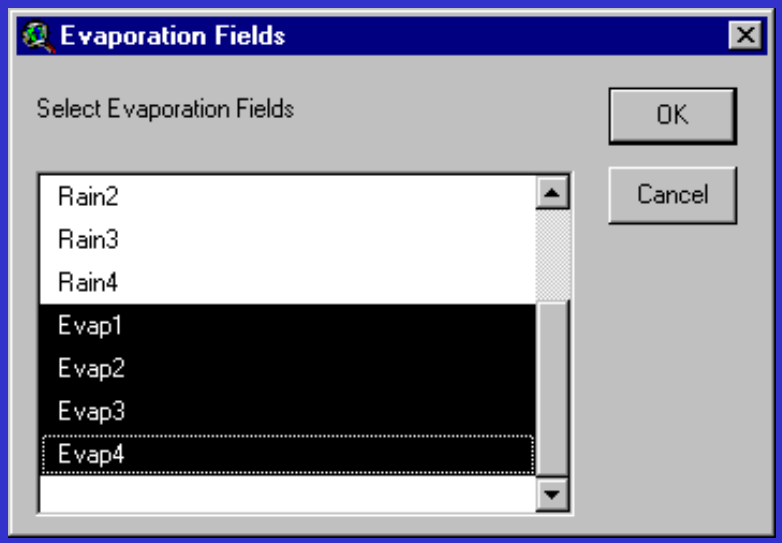
Select output destination for interpolated grids and data fields used in the interpolation.



Rainfall



Evaporation



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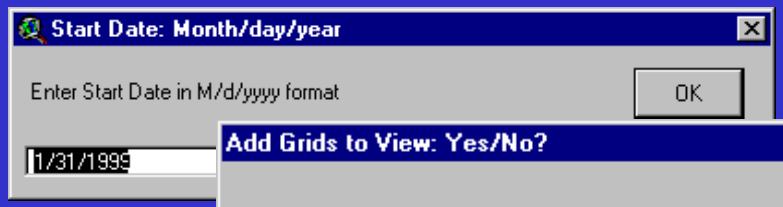
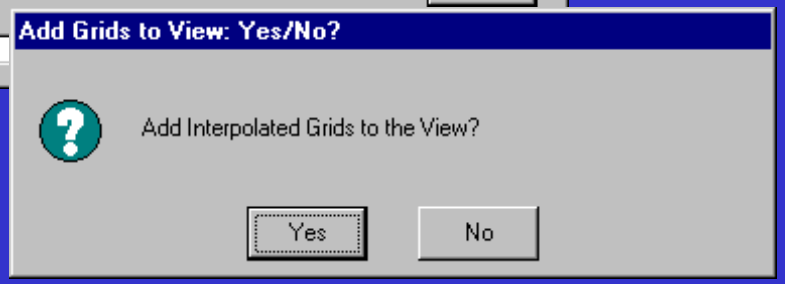
Convert Precipitation and Evaporation Data:

"Interpolate Station Data"

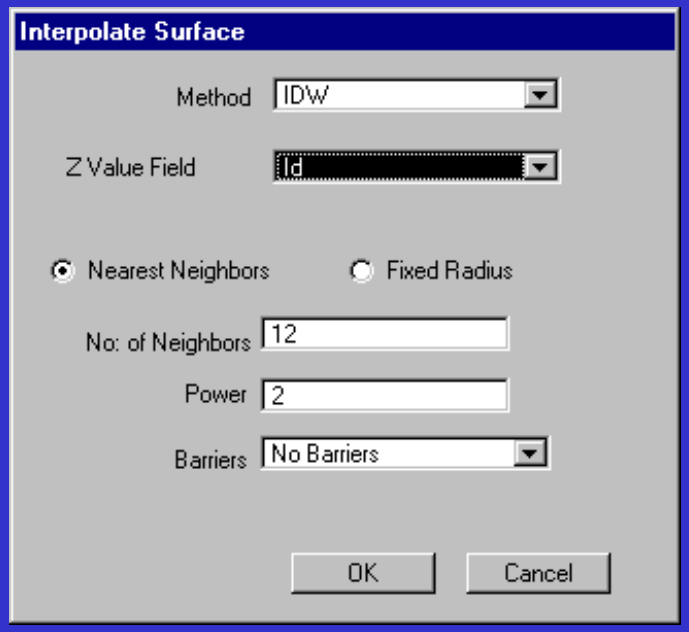
First day of interpolated data

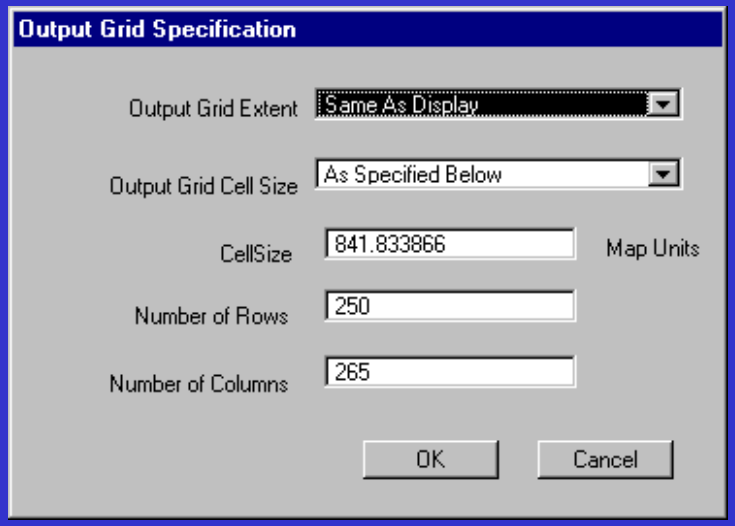


Add grids to the view



Define interpolation method





Set output grid extent and cell size

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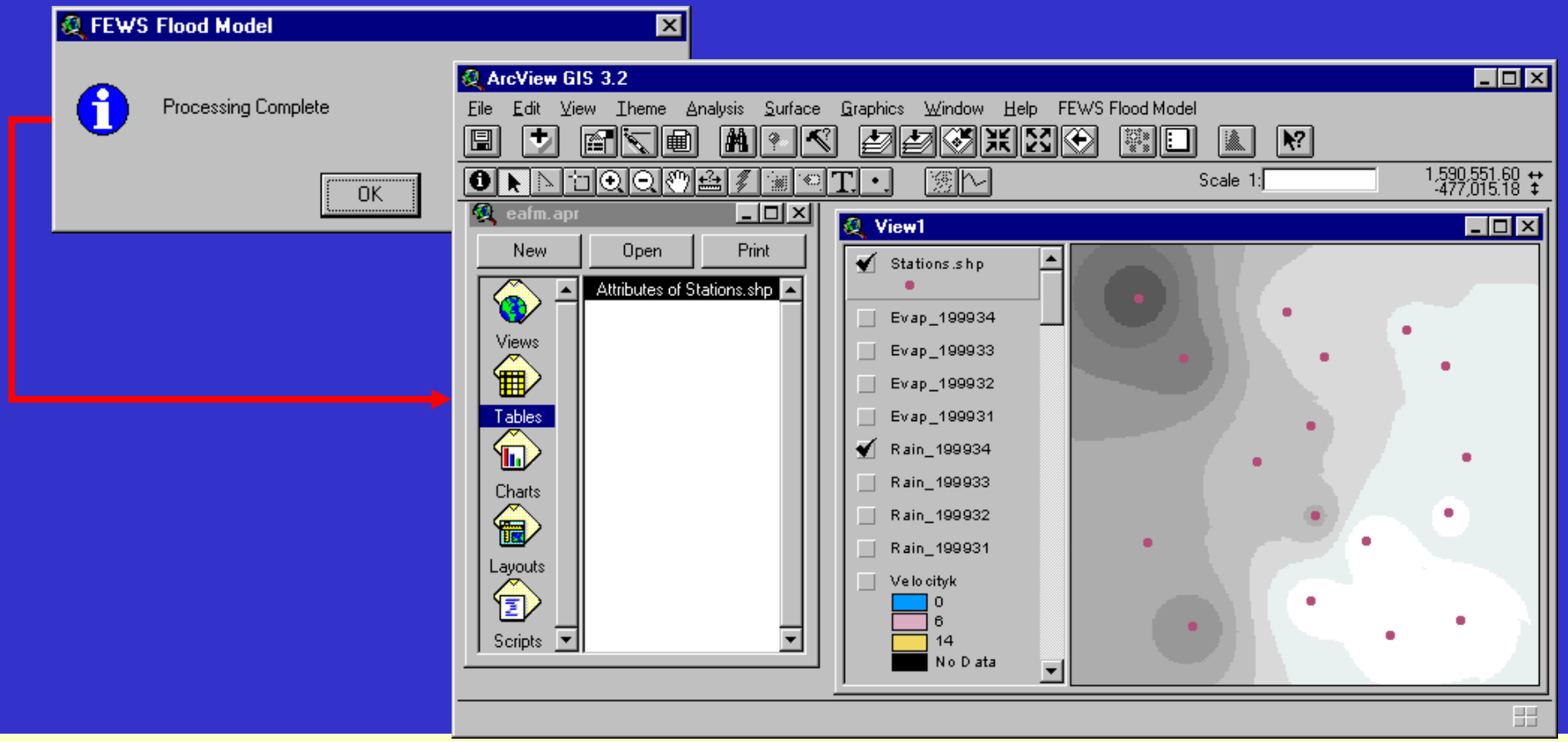
Convert Precipitation and Evaporation Data:

"Interpolate Station Data"

ArcView "Application Window" showing four days of interpolated precipitation and evaporation data and the location of the stations used to create the themes



NOAA RFE Algorithms

- Dekadal RFE since 1995, and from 1998 daily
  - Herman et al., 1997, International Journal of Remote Sensing 18: 2147-2151
- From Jan 2001 NOAA adopted a new method
  - Xie et al, 1997, Bulletin of the American Meteorological Society 78: 2539-2558

Input Data for the Old Algorithm

- GPI rainfall estimate from METEOSAT thermal infrared imagery, 30 minute, 4km
- Interpolated gauge observed rainfall field, data from the Global Telecommunication System (GTS) of the WMO network

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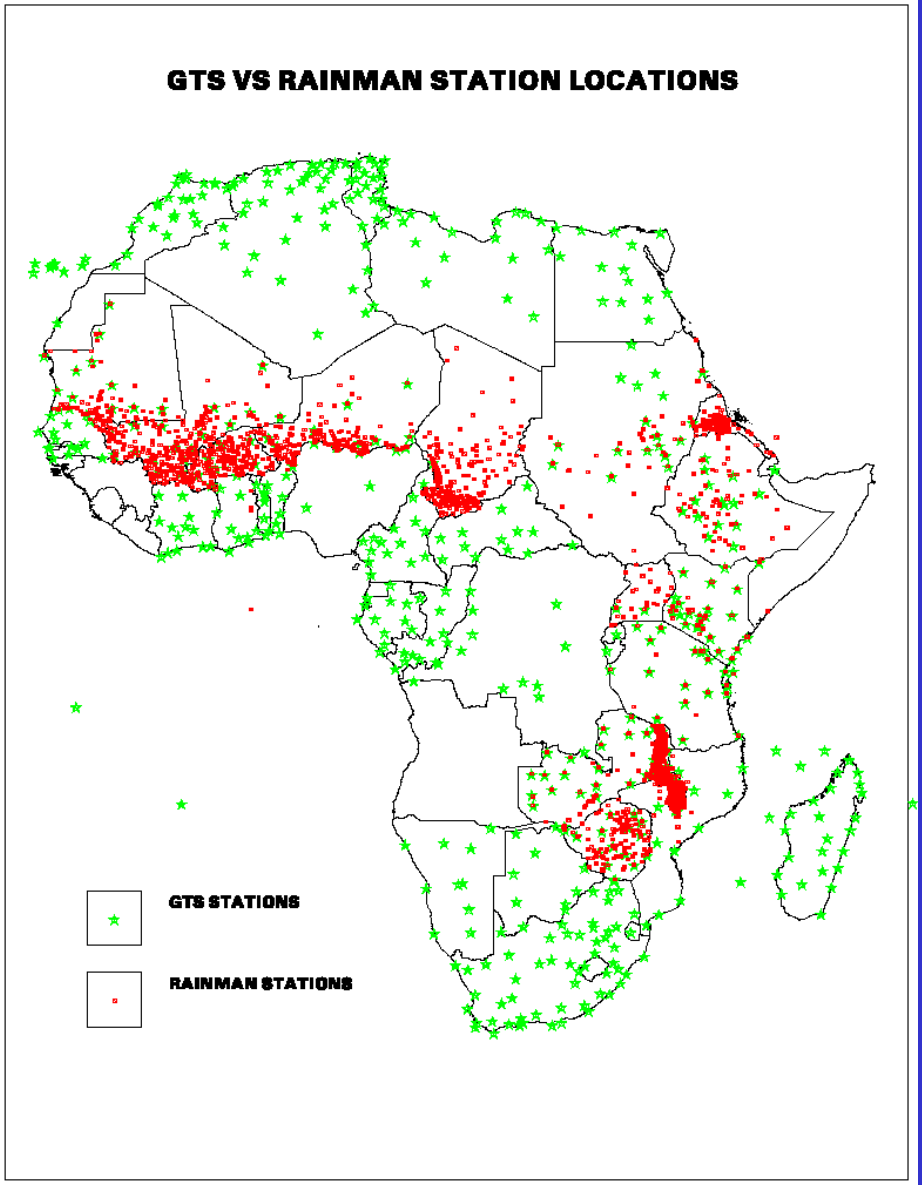

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Input Data for the New Algorithm

- GPI rainfall estimate from METEOSAT, 4km
- Interpolated gauge observed daily rainfall field from the GTS network,
- Special Sensor Microwave/Imager (SSM/I), 4 images daily, 25km
- Advanced Microwave Sounding Unit (AMSU) on board the NOAA-15, 4 images daily, 50km

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Reducing Errors: New Method

- First step, merge the three rainfall estimates from the remotely sensed data SSMI, AMSU, and GPI
  - Maximum Likelihood Estimation Method
- Second step, blend data from step one with data interpolated from the GTS data

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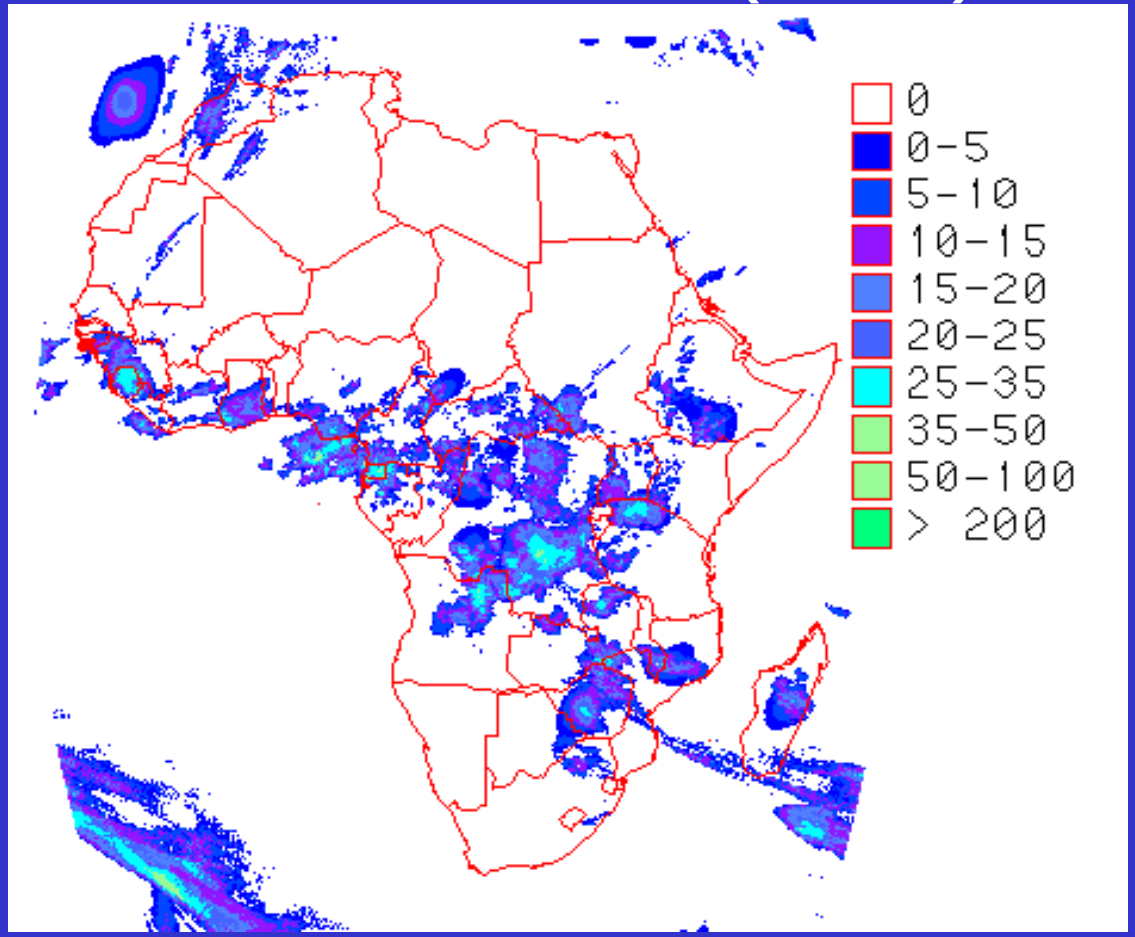
Past Rainfall Estimate (RFE) Product



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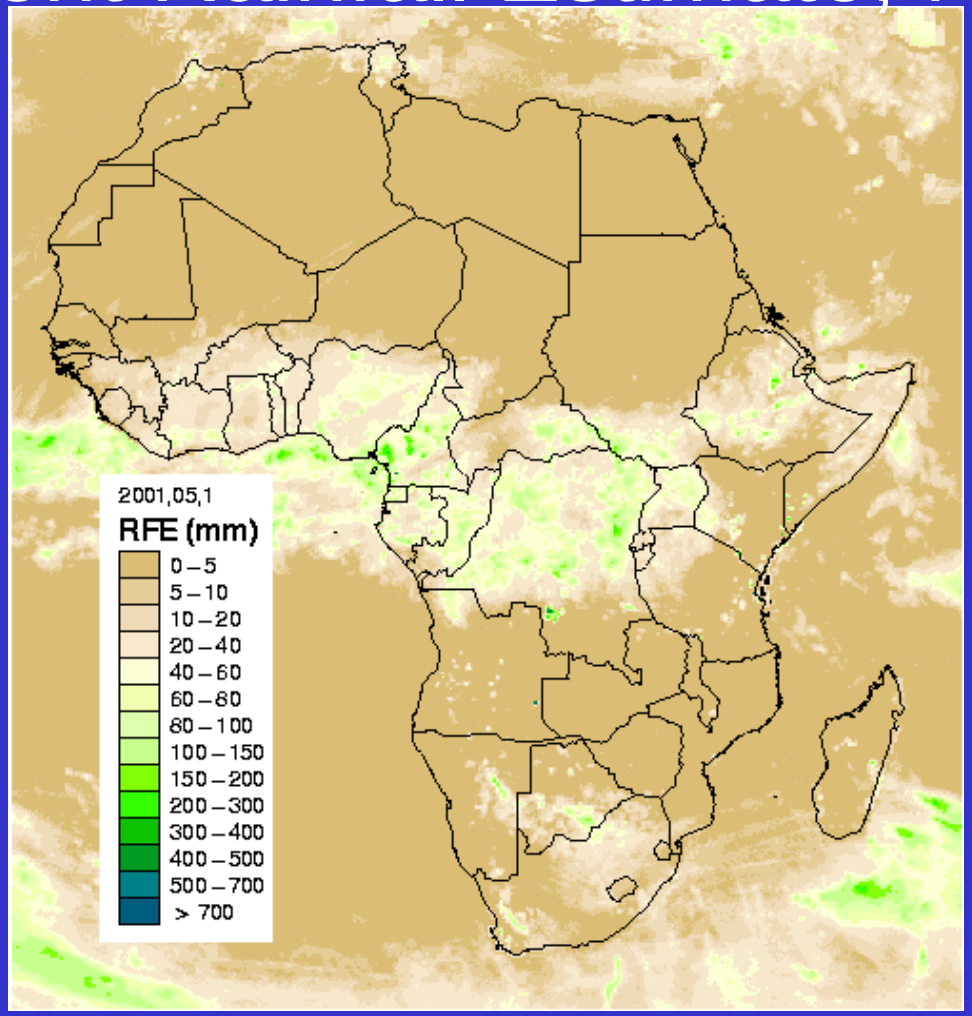
Current Rainfall Estimate, NOAA



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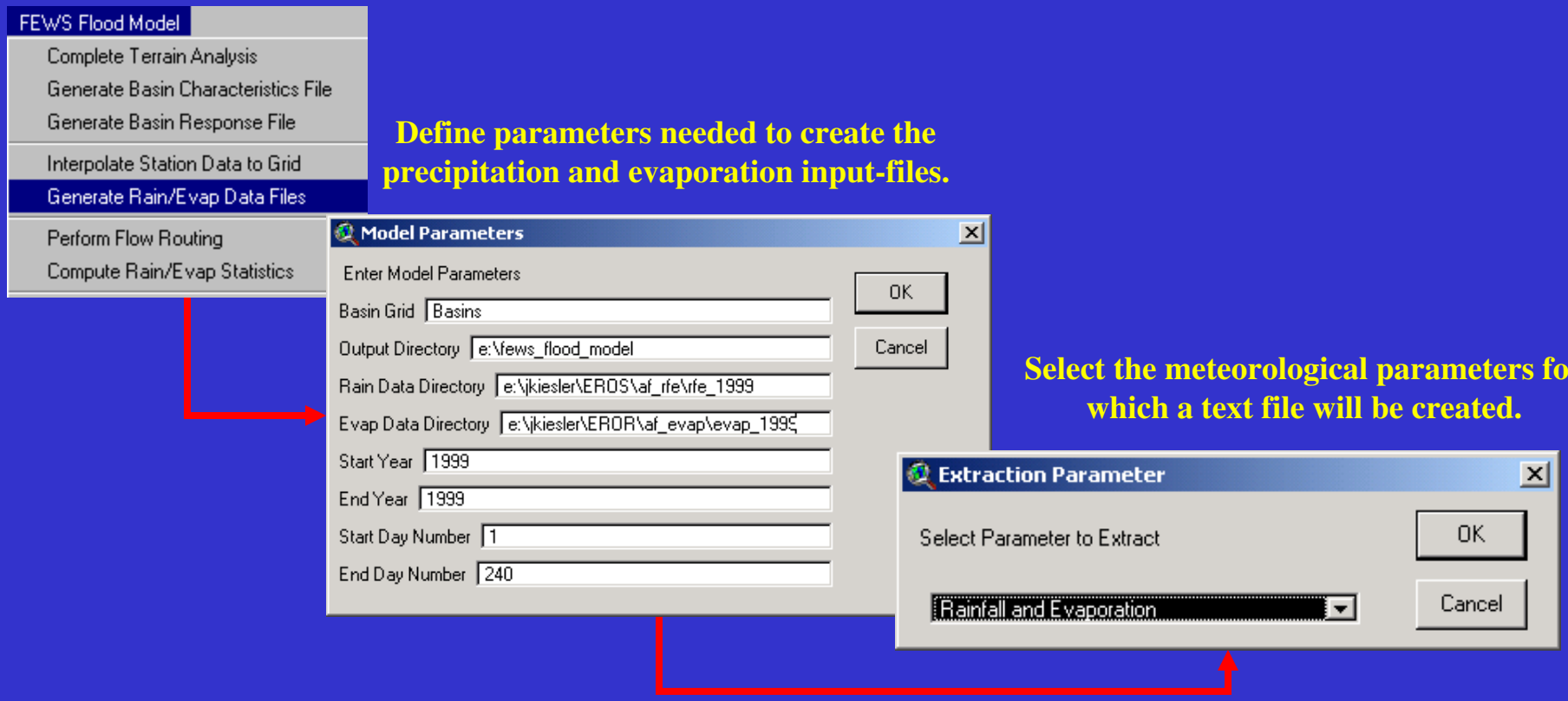
Convert Precipitation and Evaporation Data:

"Generate Rain/Evap. Data File"

The SFM uses two text files of daily precipitation and evaporation data to simulate stream flow. The "Generate Rain/Evap Data File" function of the SFM GUI creates these data files using grids of daily precipitation and evaporation data for the watershed being modeled.



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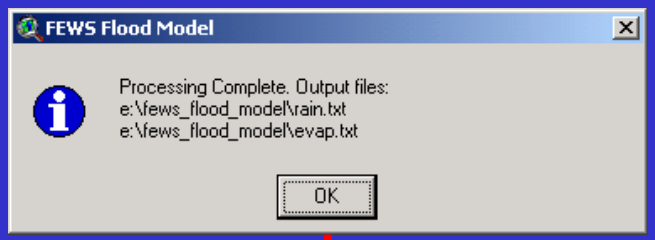
Convert Precipitation and Evaporation Data:

"Generate Rain/Evap. Data File"



Precipitation and evaporation input-data files contain column headings in the frist row and data in the following rows. The starting year and day is in the first column. The following columns contain the precipitation or evaporation data for each sub-watershed. The order of the sub-watersheds starts with the most upstream and ends with the most downstream sub-watershed.

rain.txt

	A	B	C	D	E	F	G	H	I	J	K
1	day	14	6	5	7	2	9	11	15	12	
2	1999001	0	0	0	0	0	0	0	0	0	
3	1999002	0	0	0	0	0	0	0	0	0	
4	1999003	0	0	0	0	0					
5	1999004	0	0	0	0	0					
6	1999005	0	0	0	0	0					
7	1999006	0.1	0	0	0	0					
8	1999007	1.8	0	0	0	0					
9	1999008	0	0	0	0.1	2.8					
10	1999009	0.8	0.1	1.1	0.1	0.7					
11	1999010	2.3	2.9	4.5	5.3	5.5					
12	1999011	0	0	0	0	0					
13	1999012	0	0	0	0	0					
14	1999013	0	0	0	0	0					
15	1999014	0	0	0	0	0					
16	1999015	1	1	1	1	1					

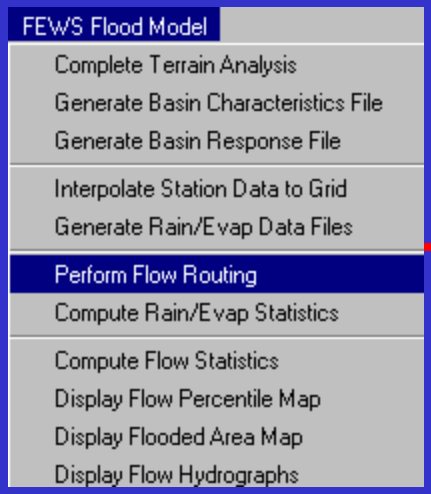
evap.txt

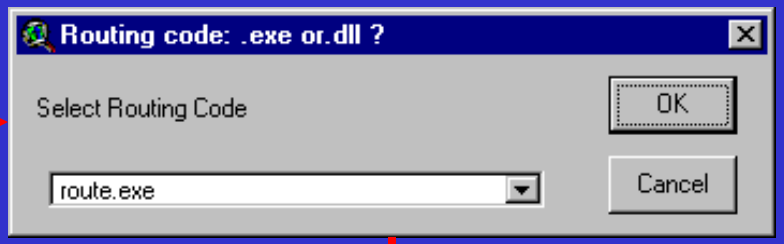
	A	B	C	D	E	F	G	H	I	J	K
1	day	14	6	5	7	2	9	11	15	12	
2	1999001	60	60.2	55.5	54.4	54	52	51.3	51	56.6	54
3	1999002	56	57.5	57.2	54.7	53.9	48	47.3	46.8	52.6	56
4	1999003	60	58.9	57.1	54.7	53.7	45.6	43.2	42.6	54.7	56
5	1999004	67	65.8	54.9	53.1	52.4	48.6	46.8	45.4	59.2	53
6	1999005	61	61.6	54.7	53.1	52.7	49.6	48.5	48.1	56.1	53
7	1999006	31	34.3	39.9	37.4	37.4	32.9	34.3	37.5	31	
8	1999007	36	42.6	53.8	49.6	48.8	39	39	39	37.5	53
9	1999008	38	44.1	53.9	49.6	49	40.9	42.3	44.5	38.5	53
10	1999009	50	54.1	60.9	57.8	56.5	48.6	47.5	45.1	50	60
11	1999010	35	37.8	37.4	35.8	35.7	34.4	35.5	35	34	
12	1999011	38	38.4	37.2	37	37.2	38	38.7	39.3	37.5	
13	1999012	44	41.2	42.5	43.6	43.8	46	46.7	46.9	44.5	
14	1999013	44	45.1	45.2	43.8	43.9	42.4	43.5	44.4	42.5	
15	1999014	51	51	50.1	49.7	49.3	47.6	46.5	43.5	50	49
16	1999015	59	60	54.6	53.1	52.2	47.1	44.3	40.5	55.1	53

Simulate Steam Flow and Soil-Water Conditions:

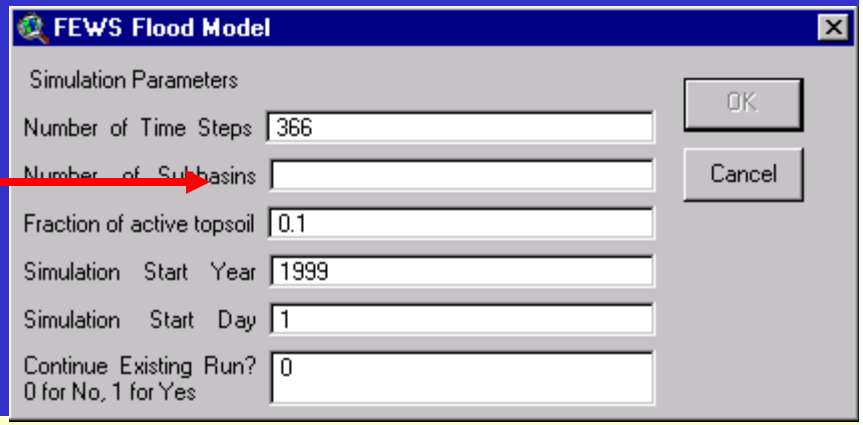
"Perform Flow Routing"

The "Perform Flow Routing" function uses the physical characteristics of the watersheds, unit hydrograph response, precipitation and evaporation to simulate stream flow and soil water conditions.





Provide inputs that identify the time step, and beginning and ending dates of the simulation period



Enter the correct number of sub-basins

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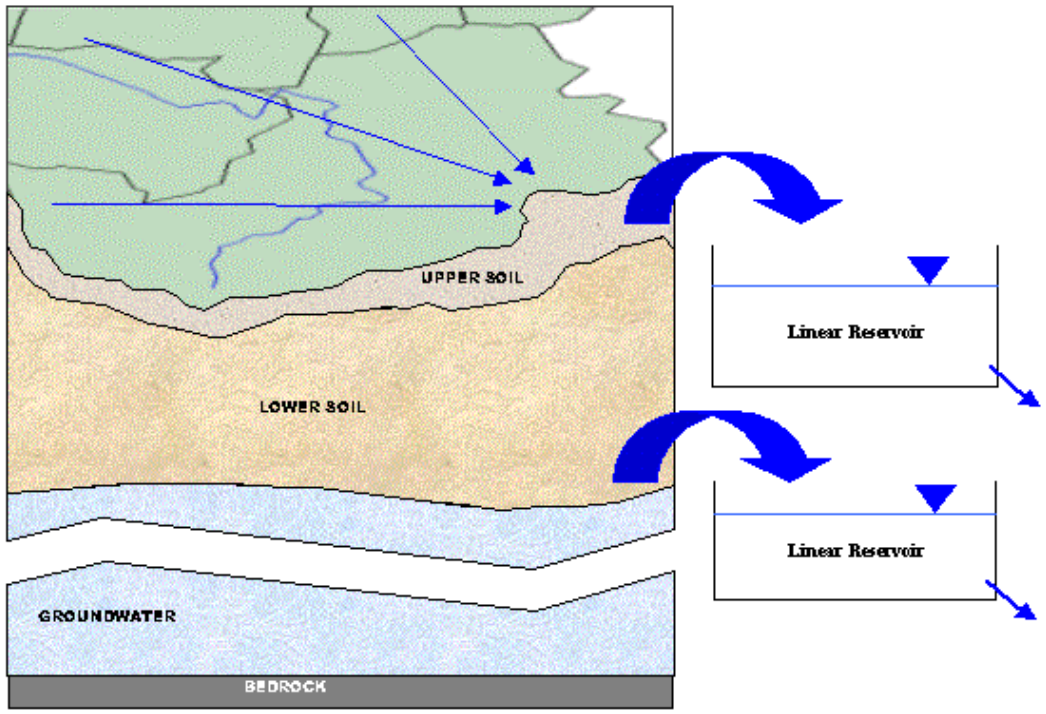
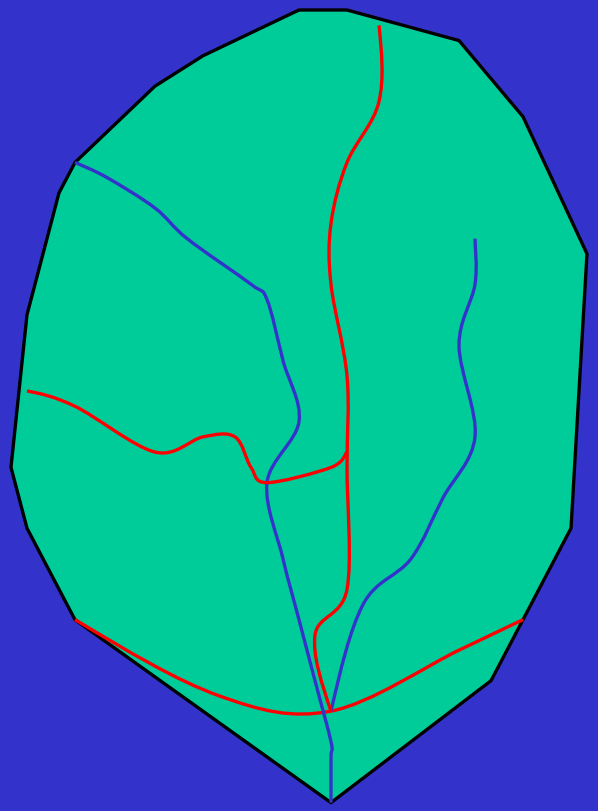
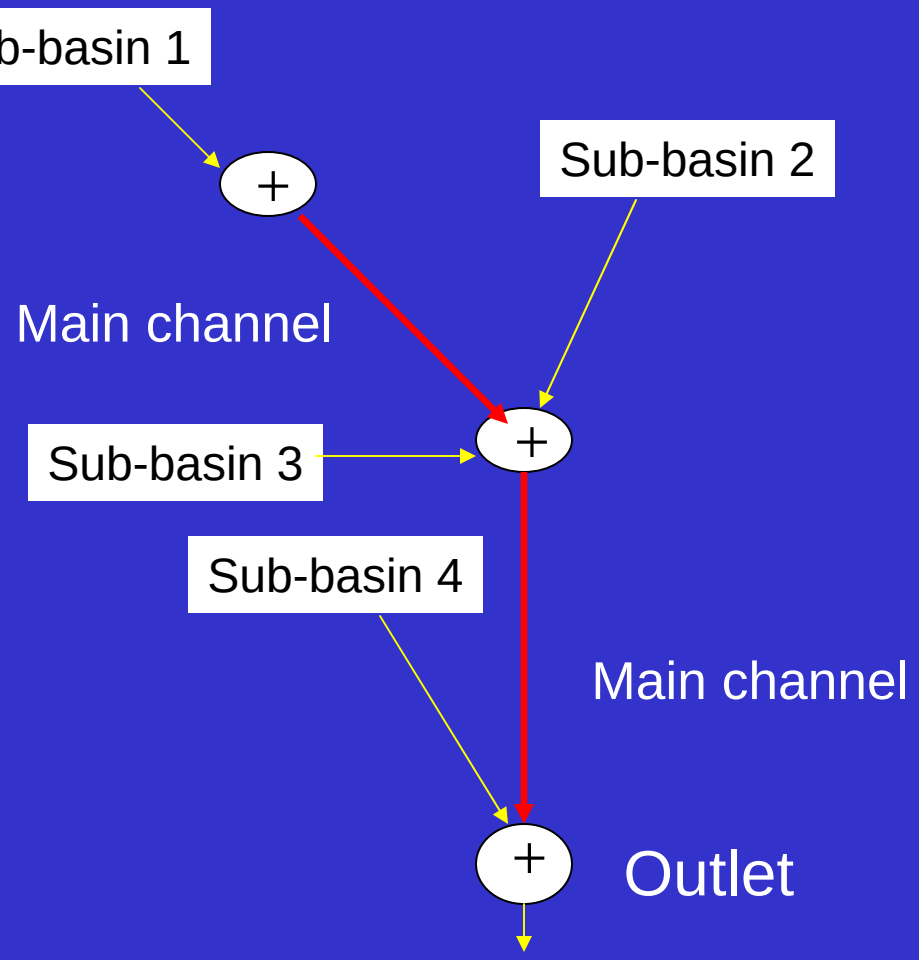
Routing Within Each Sub-basin



Flood Routing Network





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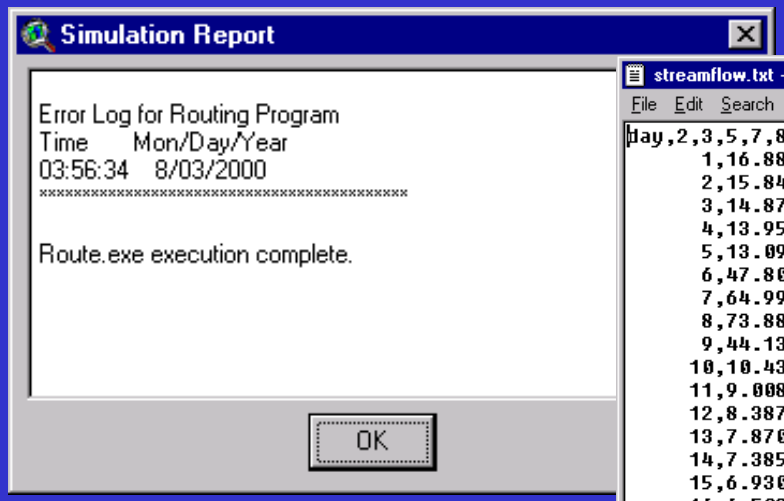
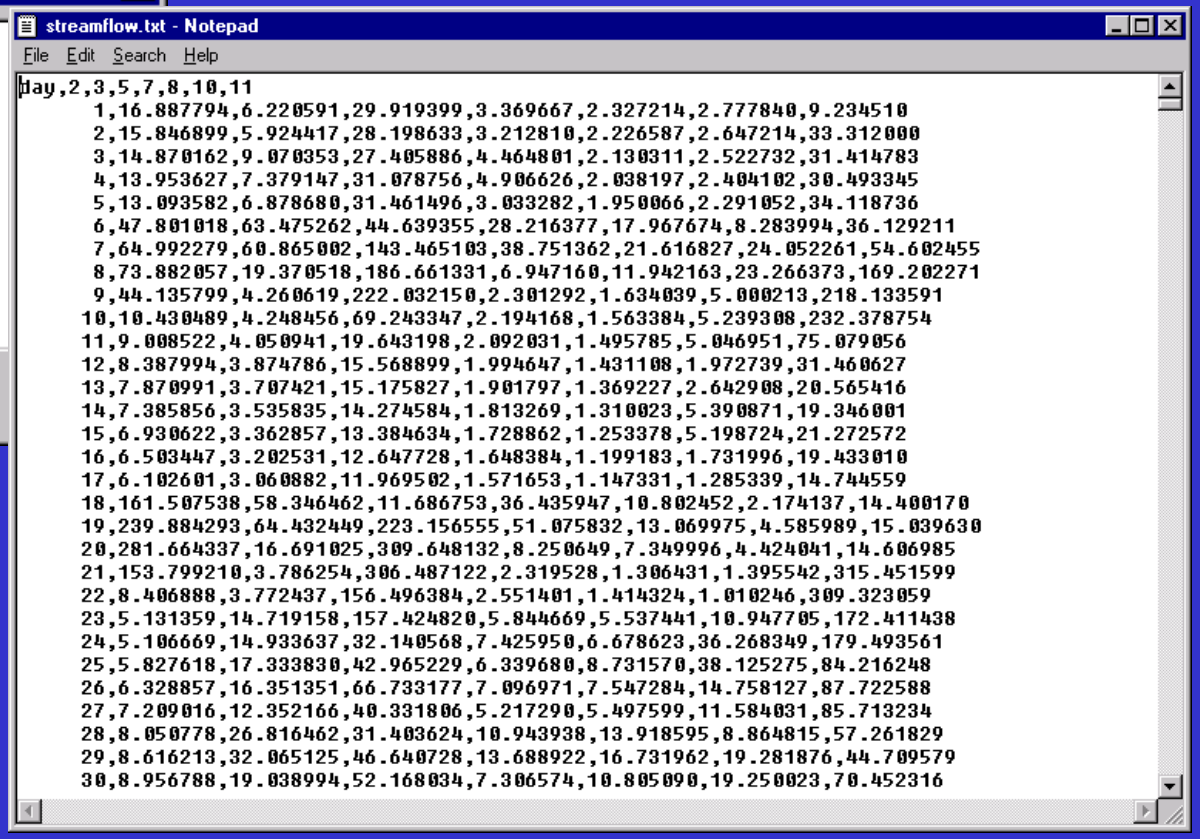
Simulate Steam Flow and Soil-Water Conditions:

"Perform Flow Routing"

Status Window for Model Run



Stream Flow Model Output Data File (streamflow.txt)_



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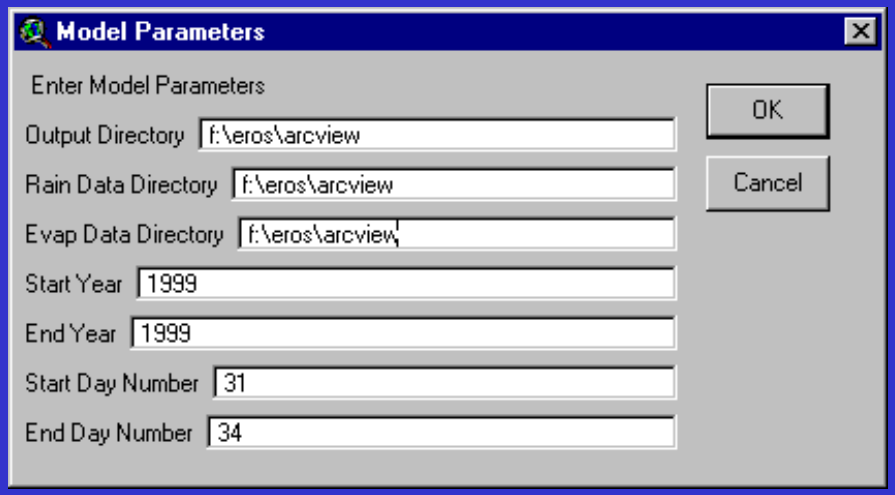
Examine Simulated Data:

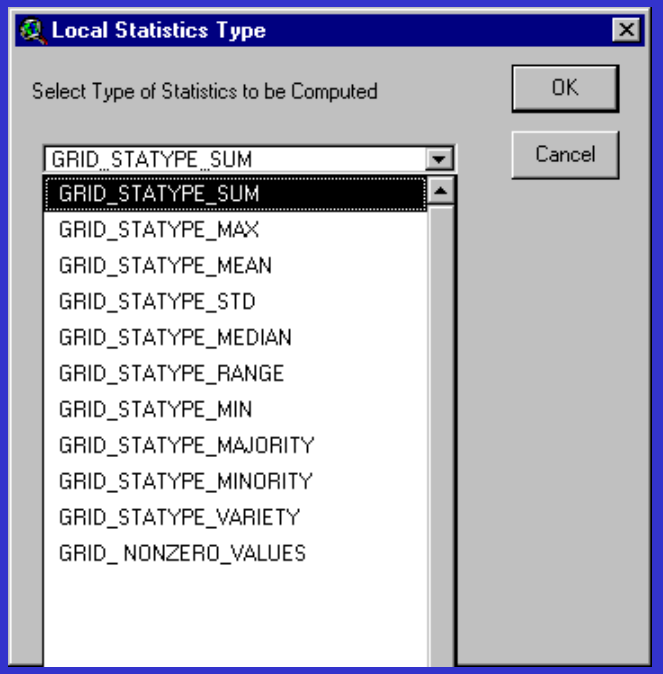
"Summarizing Precipitation and Evaporation Data"

The "SFM" menu contains a function that summarizes the precipitation and evaporation data used during the simulation. The directories where the output is to be, where the precipitation and evaporation data are stored, and the starting and ending dates for the summarization period must be identified.

Define parameters for summarizing precipitation and evaporation input-data files



Select the statistic to use during the summarization



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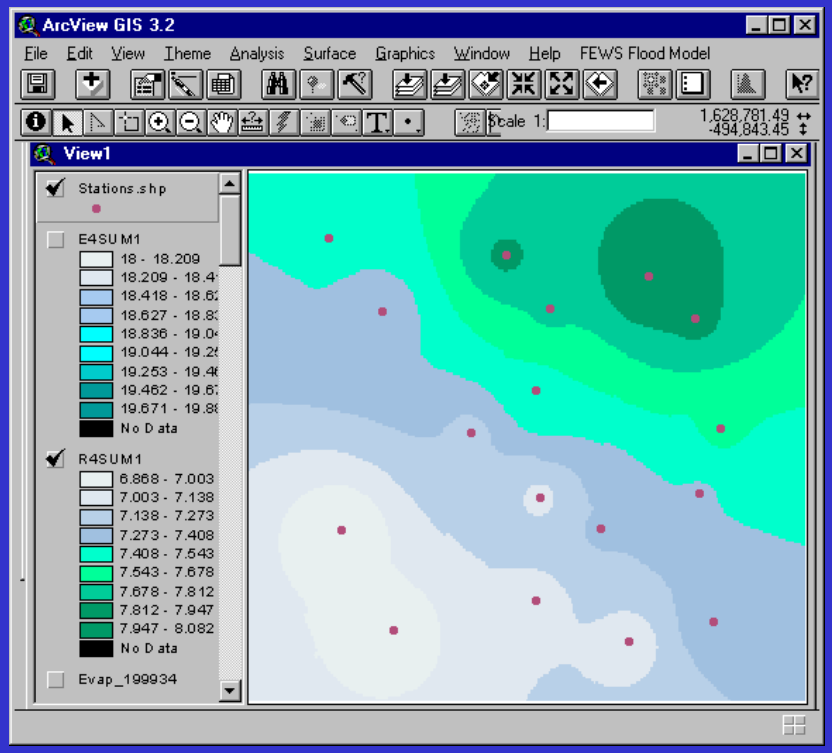
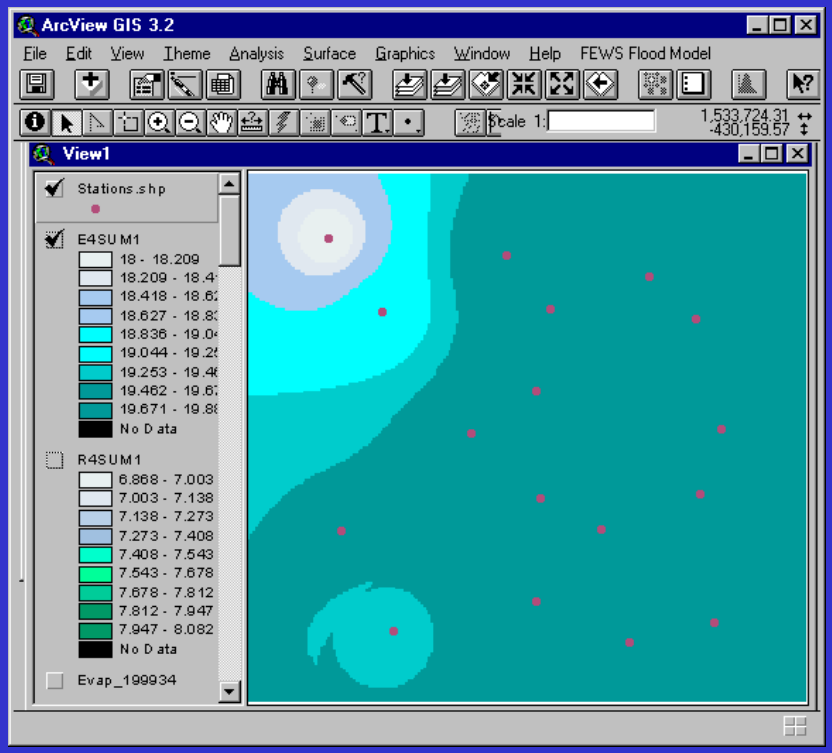
Examine Simulated Data:

"Summarizing Precipitation and Evaporation Data"

Summary of selected precipitation input-data files



Summary of selected evaporation input-data files



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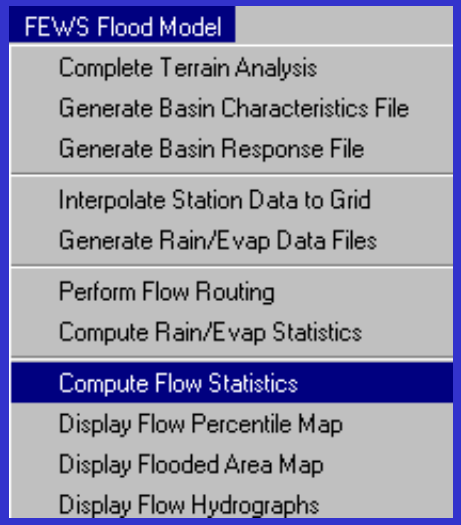
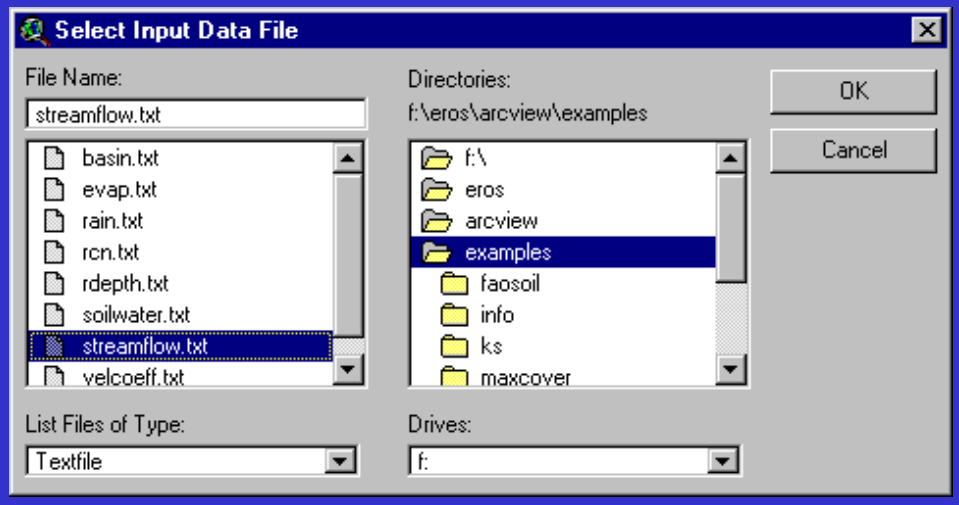
Examine Simulated Data:

"Compute Flow Statistics"

The "Compute Flow Statistics" function computes total, count, mean, maximum, minimum, range, variance, standard deviation, median, and the 25th, 33rd, 66th, and 75th percentiles of the simulated stream flows. The application defines the high flow value to be the 66th percentile, the median flow value is the median, and the low flow value is the 33rd percentile.



Provide Input File



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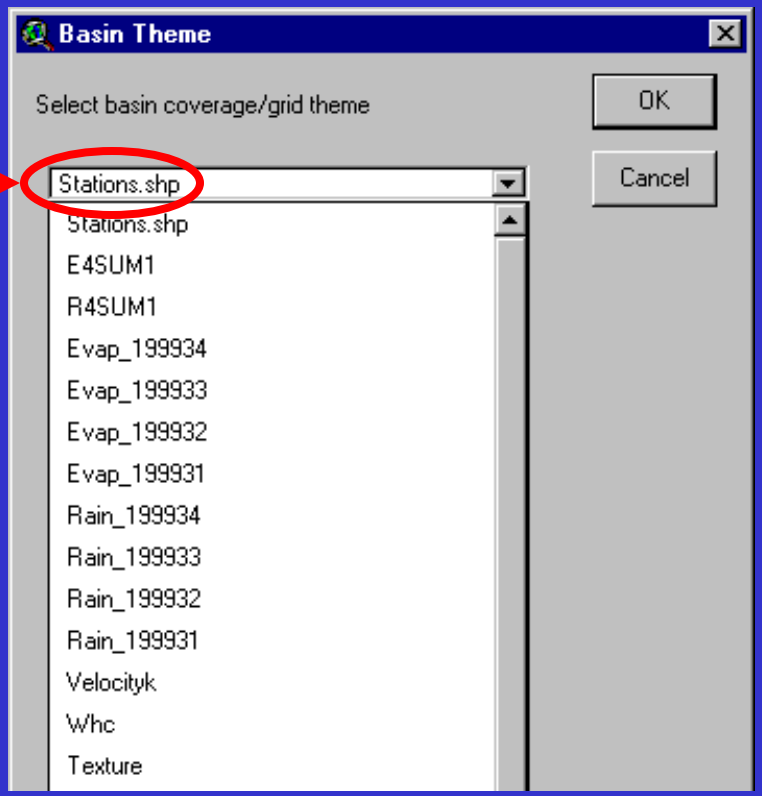
Examine Simulated Data:

"Compute Flow Statistics"

Identify the theme containing the watersheds for which stream flow was simulated



Allows updating of the low and high stream flow threshold values

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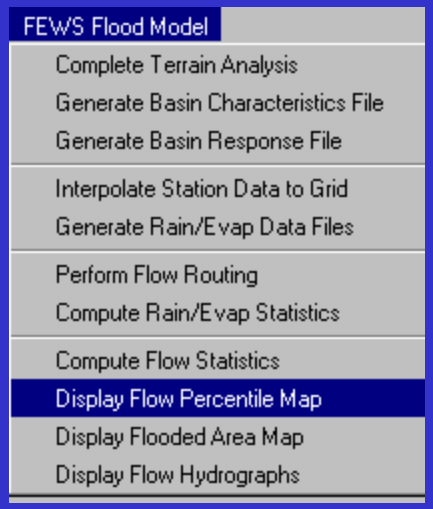
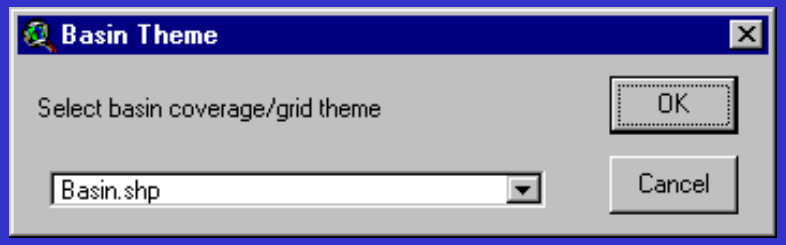
Examine Simulated Data:

"Display Flow Percentile Map"

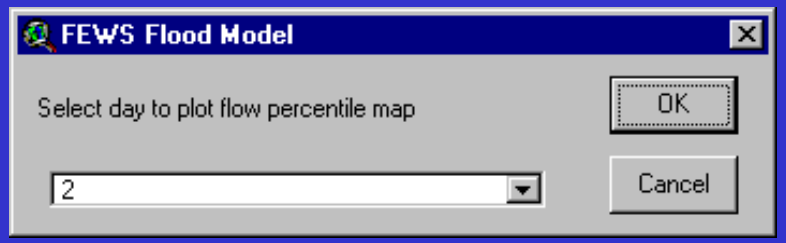
The SFM will produce a map indicating whether the simulated stream flow in the identified watersheds was low, less than the 33rd percentile, normal, between the 33rd and 66th percentiles, or high, greater than the 66th percentile.



Identify the theme containing the flow statistics computed using "Compute Flow Statistics"



Identify which day should be displayed on the map



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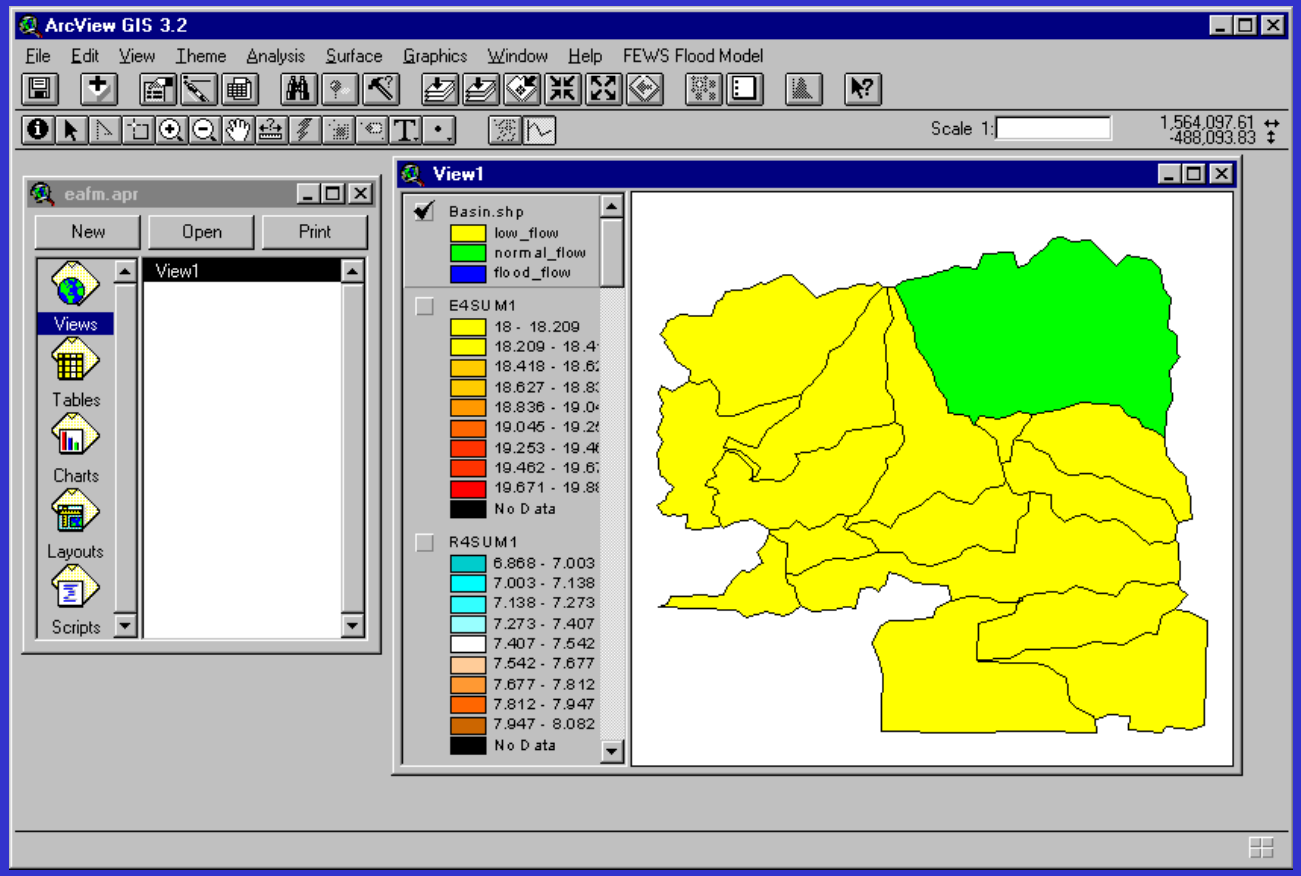
Examine Simulated Data:

"Display Flow Percentile Map"

Example output from "Flow Percentile Map"



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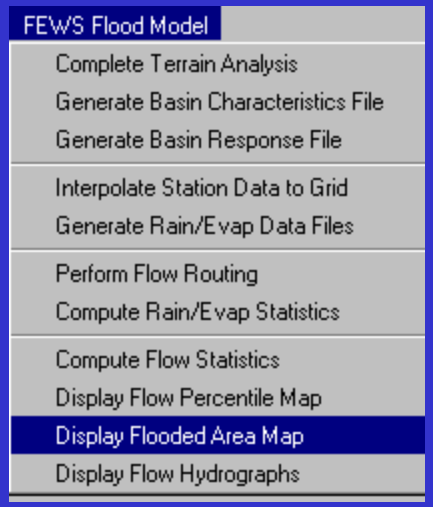
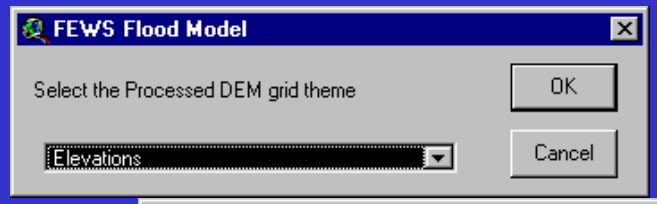
Examine Simulated Data:

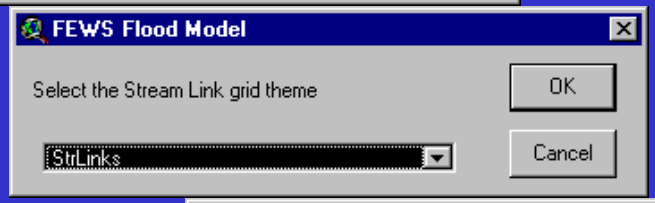
"Display Flooded Area Map"

The SFM interface contains a function, "Flooded Area Map," to display a map showing areas that could be inundated by floodwaters. The function uses the simulated flow depths and the corrected DEM data to identify the area where flooding may occur.



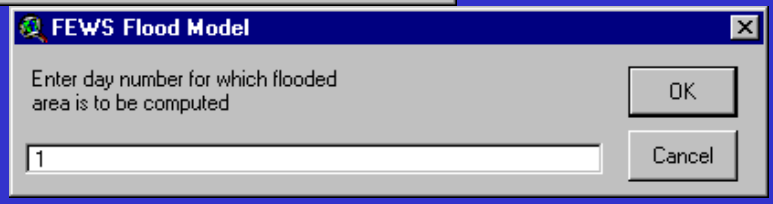


Provide Corrected DEM



Provide Stream Link Grid

Provide Flow Accumulation Grid

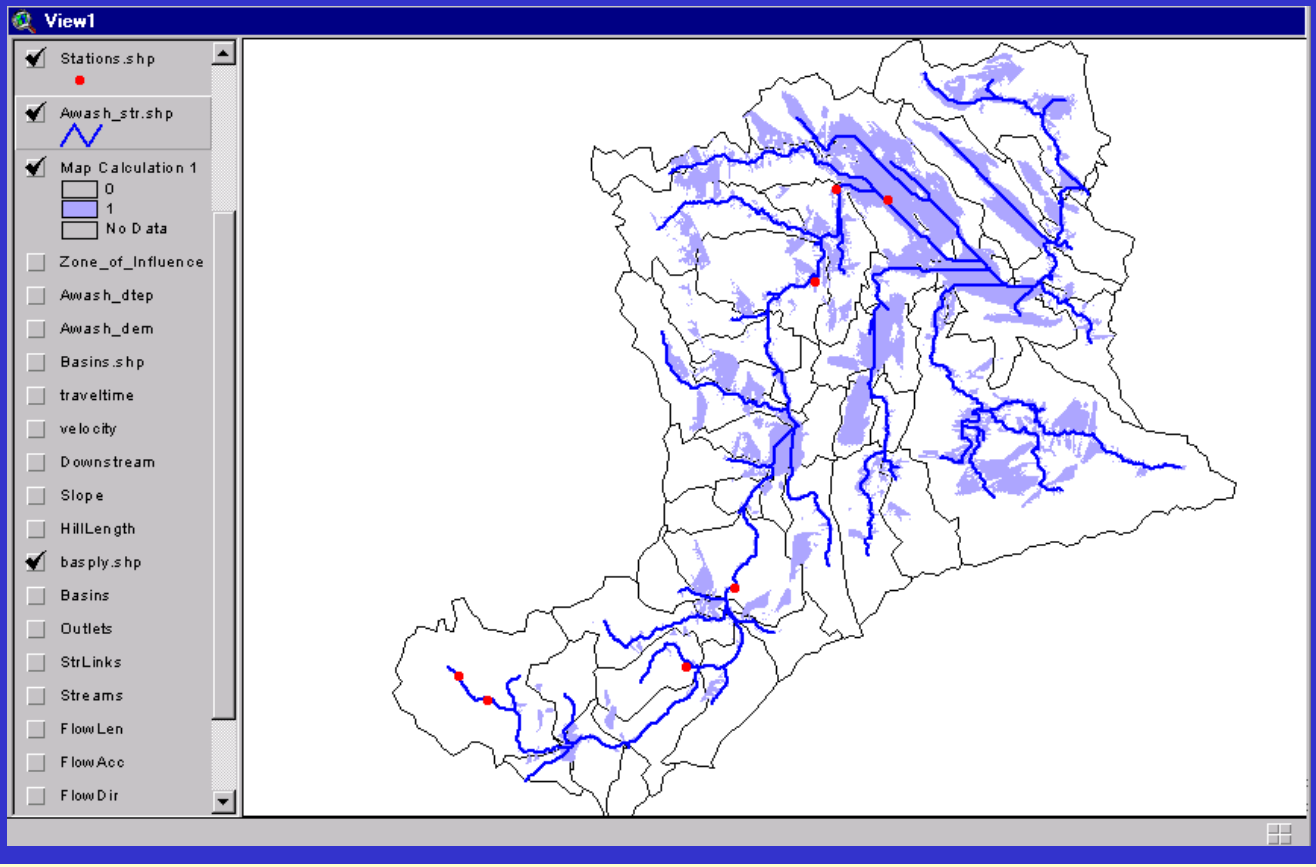


Provide Number of Days for Computing Flooded Area

Examine Simulated Data:

"Display Flooded Area Map"

Example output from "Flooded Area Map"



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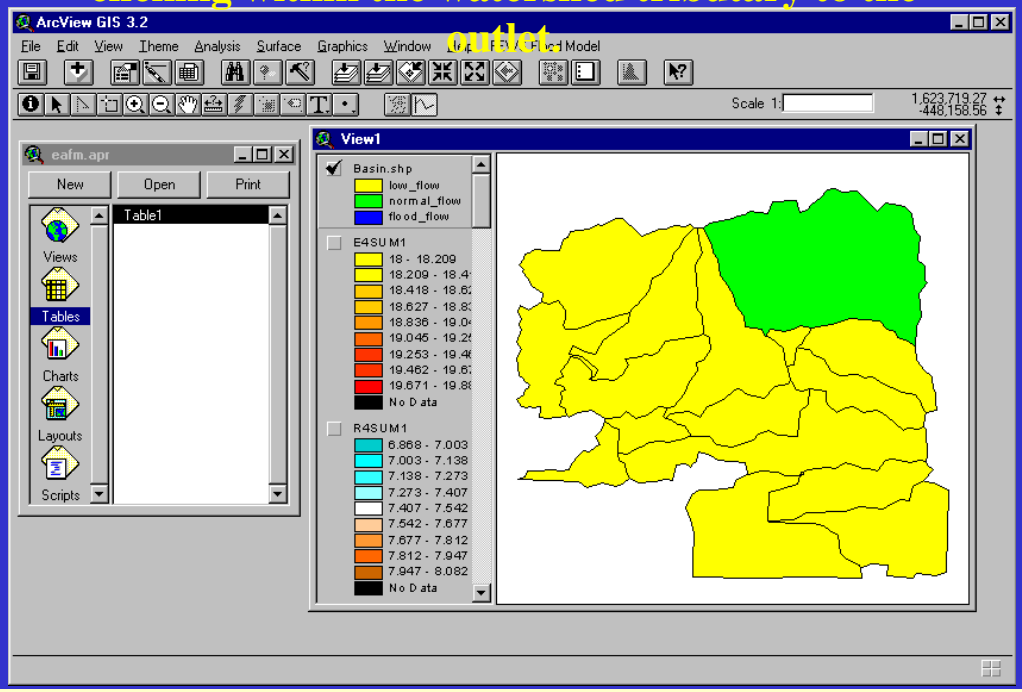
Examine Simulated Data:

"Plot Hydrograph"

The SFM interface has a function to display a hydrograph at the outlet of the identified basins contained in the modeled watershed.

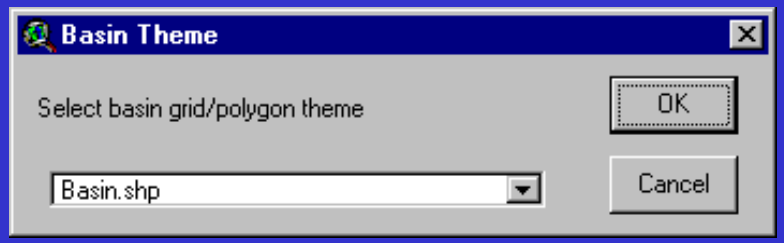
Identify the watershed outlet to display in the hydrograph. The watershed outlet is identified by clicking within the watershed tributary to the outlet.



Examine Simulated Data:

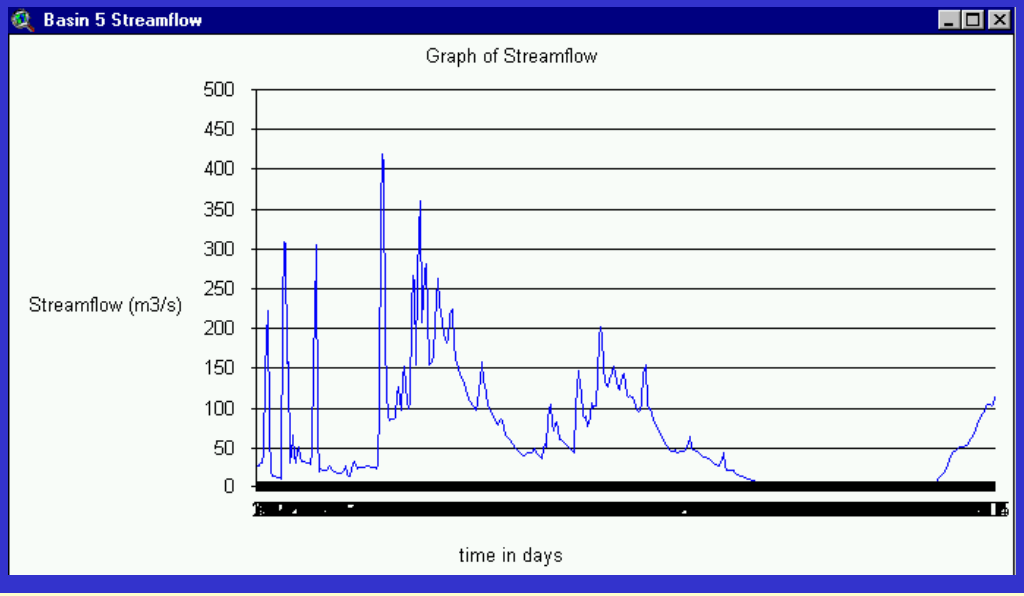
"Plot Hydrograph"

Identify the basin grid theme



Select the grid theme field used to identify the basin

Example of the streamflow output hydrograph



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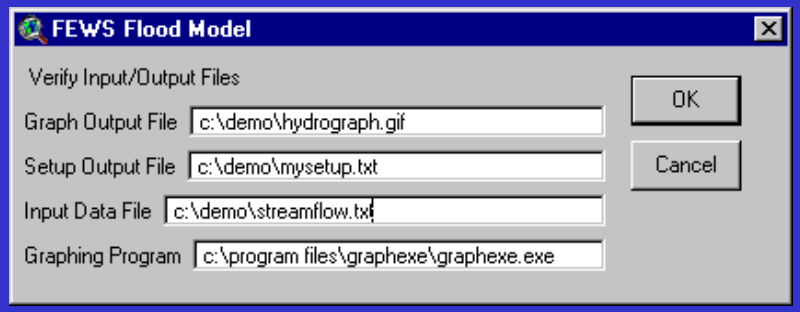
Examine Simulated Data:

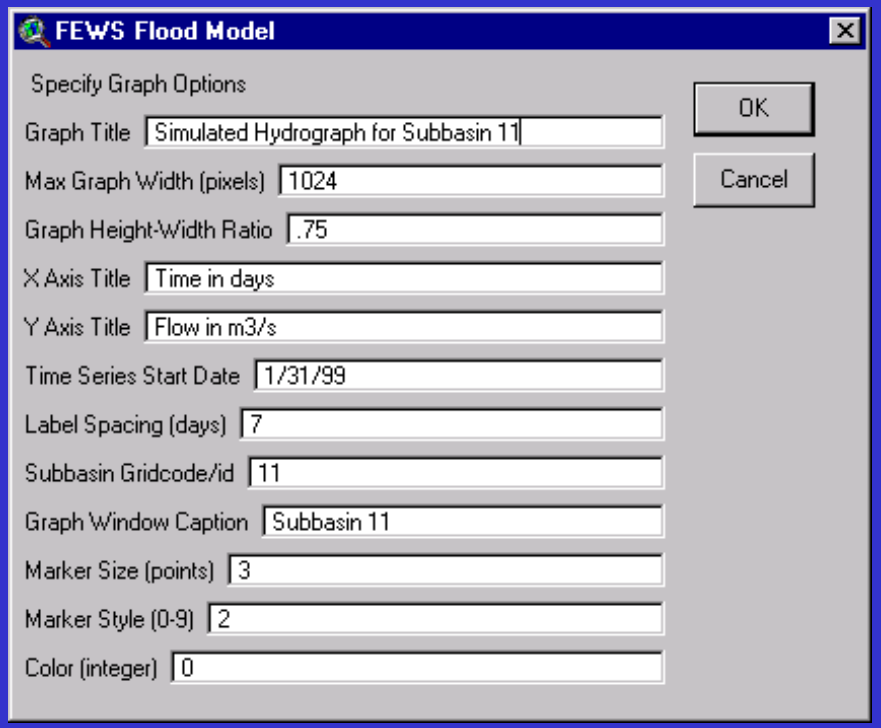
"External Plotting Application"

The SFM menu has two functions for plotting hydrographs. The second requires an executable program that is not part of ArcView.

Enter the location of files required by the external plotting application



Enter the plotting parameters required by the external plotting application



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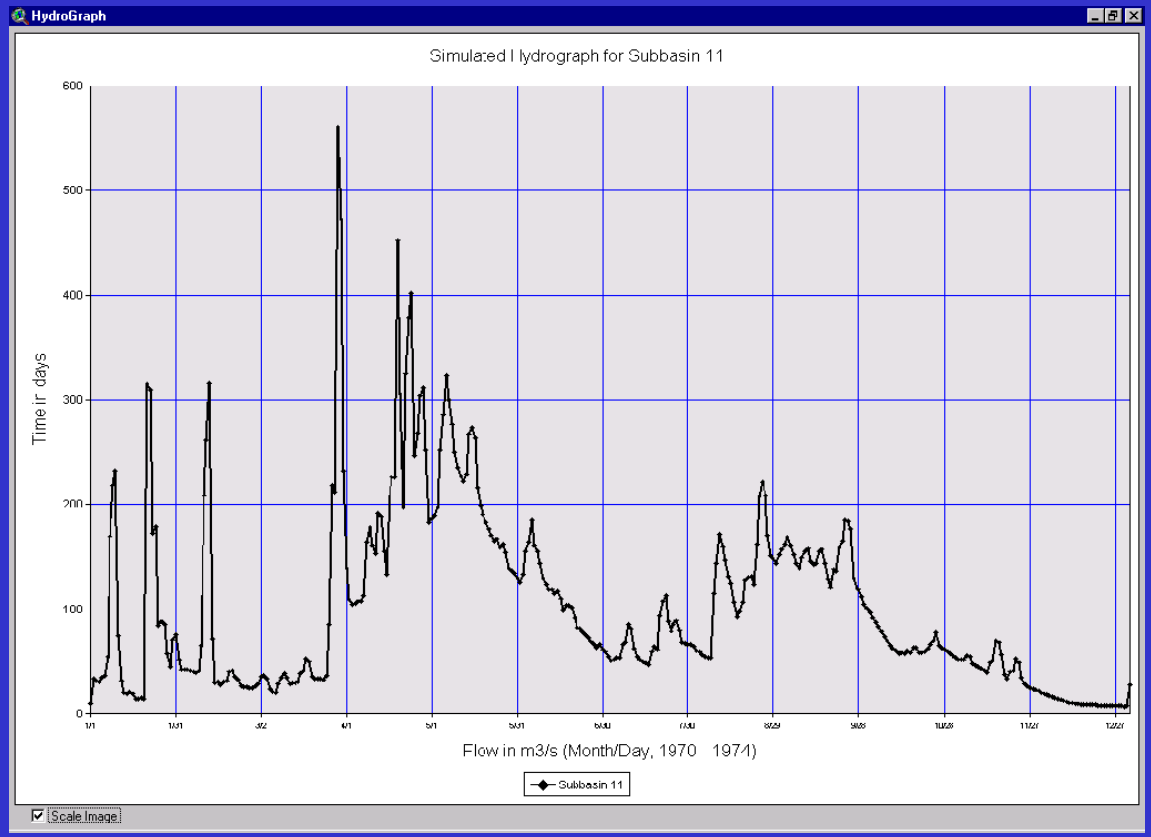
Examine Simulated Data:

"External Plotting Application"

Example hydrograph produced by the external plotting application



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