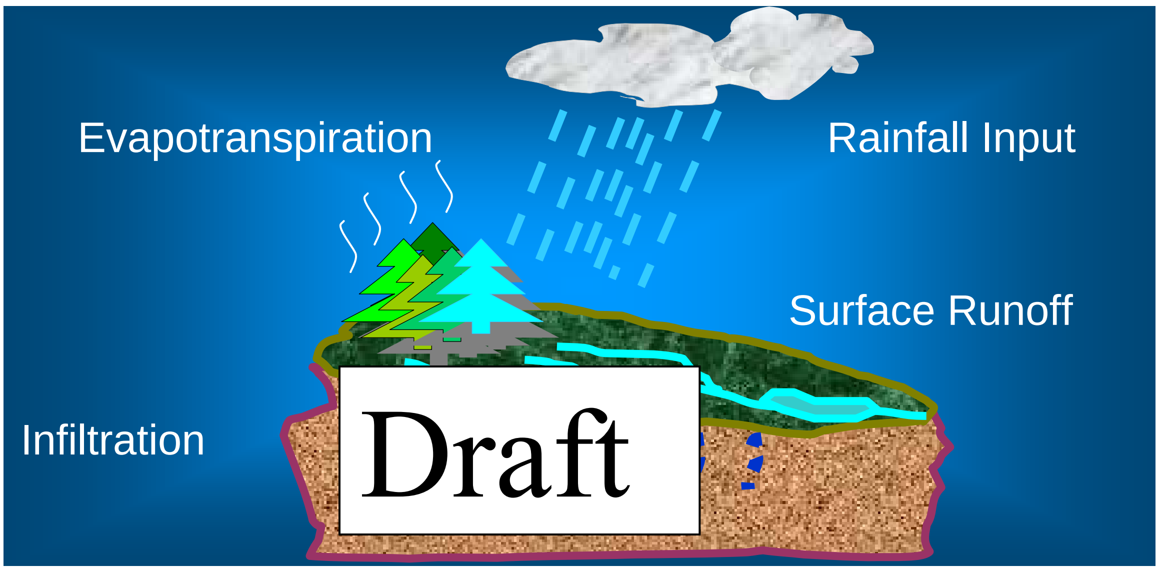
Geospatial Stream Flow Model (GeoSFM) Users Manual



Version 1.0

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

Document accompanying *Geospatial Stream Flow Model Training Manual* and *Geospatial Stream Flow Model Technical Manual*

Revision History:

Jan 2006 –Version 1.0 release

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Overview

The monitoring of wide area hydrologic events requires the manipulation of large amounts of geospatial and time series data into concise information products that speak to the location and magnitude of the event. To perform these manipulations, scientists at the US Geological Survey's Center for Earth Resources Observation and Science have implemented a hydrologic modeling system. The system consists of a data assimilation component which generated data for a geospatial stream flow model (GeoSFM) that is run operationally to identify and map wide-area stream flow anomalies. GeoSFM integrates a geographical information system (GIS) for geospatial preprocessing and post-processing tasks and hydrologic modeling routines implemented as dynamically linked libraries (DLLs) for time series manipulations. Model results which include daily maps depicting the status of stream flow and soil water conditions are disseminated through a variety of media including Internet map servers and flood hazard bulletins.

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Above is a list of all data files contained on the GeoSFM CD. The *GeoSFM Users Manual* is accompanied by the *GeoSFM Training Manual* and the *GeoSFM Technical Manual*.

1.0 GeoSFM Setup

Model Overview

GeoSFM was developed by scientists at the USGS Center for EROS in Sioux Falls, SD. The development of the model was driven by the need to establish a common visual environment for the topographic analysis, data assimilation, time series processing and results presentation activities that go into the monitoring of hydrologic conditions over wide areas. Many of the datasets involved in these processes are raster grids. The spatially distributed nature of the raster grids used in these processes pointed to the adoption of a customizable geographic information system with excellent raster functionality. The ArcView 3.x GIS series was adopted for the implementation because it provided a visual, customizable development environment with excellent support of raster operations. An ArcView extension was developed (in Avenue) for the geospatial processing operations and for the initiation of time series analysis tasks. Routines for performing the hydrologic computations involved in mass balance and routing were developed in a mixed programming environment (C/C++ and Visual Fortran) and compiled as dynamically linked libraries (DLL). These DLLs are called up directly from within ArcView scripts thus eliminating the need to develop a separate interface for hydrologic routing operations.

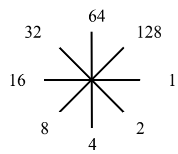
Specific data values referenced in this document are related to the exercises outlined in the *GeoSFM Training Manual*.

1.1 Model Installation

Files	Description
geosfm.avx v.1.0	Geospatial Stream Flow Model (GeoSFM) ArcView Extension model. The model interface.
Geosfm.dll	Geospatial Stream Flow Model – Dynamically Linked Libraries (.dll.) Hydrologic (water balance and routing) component.
Geosfmcalib.exe	Geospatial Stream Flow Model Calibration – Calibration module.
Geosfmgzip.exe geosfmtar.exe	GeoSFM Utilities – Freeware used for unzip and tar of downloaded files.
Geosfmpost.exe	Geospatial Stream Flow Model Calibration – Calibration module.
Geosfmstats.dll	Geospatial Stream Flow Model – Dynamically Linked Libraries (.dll.) Used for time series analysis.
INSTALL.bat	Copies all GeoSFM files and registers the .dll files to the local computer.

1.2 Complete Terrain Analysis

The analysis of topographic data for hydrologic modeling applications relies on the simple principle that water flows in the direction of steepest descent. Hence by comparing the elevation of a given cell with that of the eight surrounding cells, it is possible to determine which direction incident drops of water would flow. Flow direction in GeoSFM is assigned using the eight direction pour point model in which each grid cell is assigned one of eight compass directions depending on which of its eight neighboring cells it discharges flow into.



32	64	128
16		1
8	4	2

The computation of a flow direction grid paves the way for the determination of other parameters of hydrologic interest such as upstream contributing area, distance to the basin outlet and the slope of the land surface. It also allows for the definition of hydrologic modeling units such as catchments and river reaches. Routing parameters are extracted for each of the resulting catchments and river reaches from the data derivatives of terrain analysis as well as the soil and land cover datasets. The extracted parameters are stored in ASCII files formatted to GeoSFM specifications. For any given river basin application, the terrain analysis only is performed once during the model creation phase. The GIS data layers and ASCII files resulting from the analysis are stowed away for use in future flow simulations.

1.2.1 Elevation Processing

The direction and rate of movement of water over the land surface is influenced very heavily on underlying topography. In this age of digital geocomputation, the digital elevation model (DEM) has consequently become the single most important input in the setup of hydrologic models. The division of river basins into catchments with associated river reaches, and the parameterization of these modeling units from DEM data have been automated in many hydrologic models including GeoSFM. While the model supports the use of DEMs of any resolution, the 1-kilometer resolution Hydro1k DEM produced at the U.S. Geological Survey's Center for Earth Resources and Observation Science (EROS) is used in GeoSFM because of its global coverage. Hydro1K is a hydrological corrected DEM which implies that it is devoid of spurious pits that interrupt hydraulic connectivity over the land surface. These pits are artifacts of the interpolation procedure used in the creation of DEMs, and they result in breaks in the flow network unless they are removed. Hydro1k data for the whole world are available for download over the Internet at http://edcdaac.usgs.gov/gtopo30/hydro/.

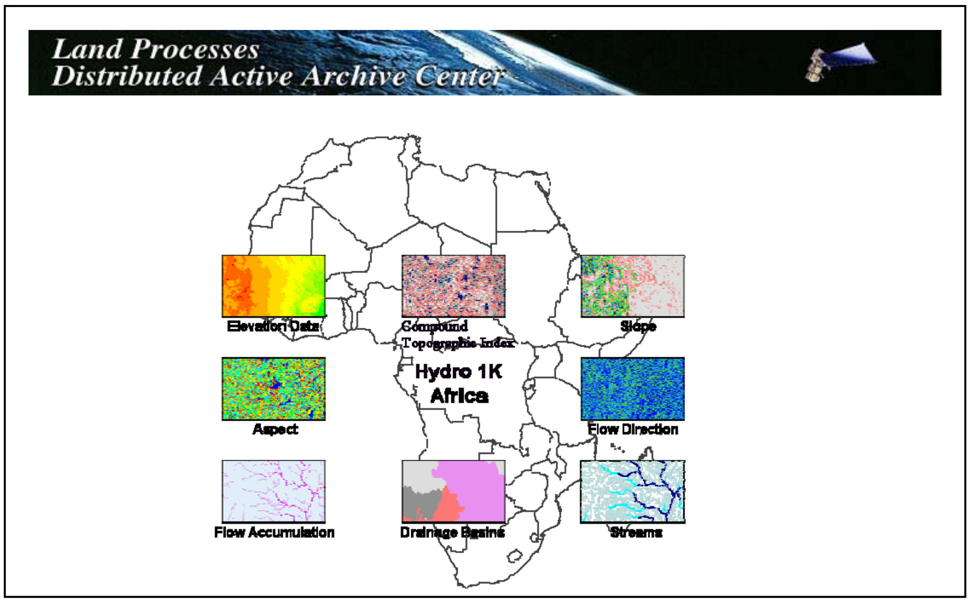
Elevation Input Data

Input Grid	Description	Unit
elevations	Hydrological corrected Digital Elevation Model – source HYDRO1K DEM	meter

Downloading/Correcting HYDRO1K DEM

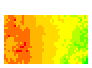
The GeoSFM uses a digital elevation model for the delineation of hydrologic modeling units. The HYDRO1K is used in the training exercises in the *GeoSFM Training Manual* because of its availability. The download process documented below captures data needed to complete exercise one outlined in the *GeoSFM Training Manual*. This exercise was developed for the Limpopo Basin in southern Africa.

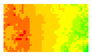
These data are available from the U.S. Geological Survey's Center for Earth Resources Observation Science (EROS) at http://edcdaac.usgs.gov/gtopo30/hydro/africa.html. This website will bring you to the *Land Processes Distributed Active Archive Center* page, from this page scroll down to the list of downloads. (Data for other regions is found at the following website http://edcdaac.usgs.gov/gtopo30/hydro/.)



The African HYDRO1k can be downloaded in its entirety or individual layers can be downloaded by selecting the data layer above. Detailed descriptions of the techniques used in the development of the HYDRO1k data set can be found in the Readme file.

Download the entire HYDRO1k data set for Africa as a tar file (215.5 MB)

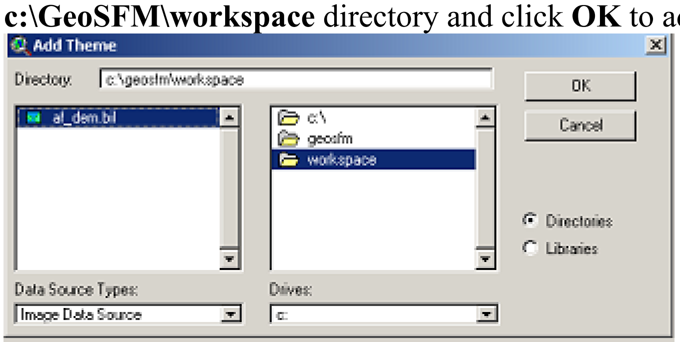
 Download HYDRO1k DEM for Africa as a tar file (34.0 MB)

 Click on –**Download HYDRO1k DEM for Africa as a tar file (34.0MB)**. Save the file to your workspace, **c:\GeoSFM\workspace**. Use WinZip to select and extract all files to your workspace. Extract the **af_dem.bil** from the **af_dem.bil.gz file**. If you do not already have WinZip installed you can download a free trial version from http://www.winzip.com/winzip/download.htm.
Extracted files:

- **af_dem.gz**
  - **af_dem.bil**
- **af_dem.blw**
- **af_dem.hdr**
- **af_dem.stx**
- **readme.af**

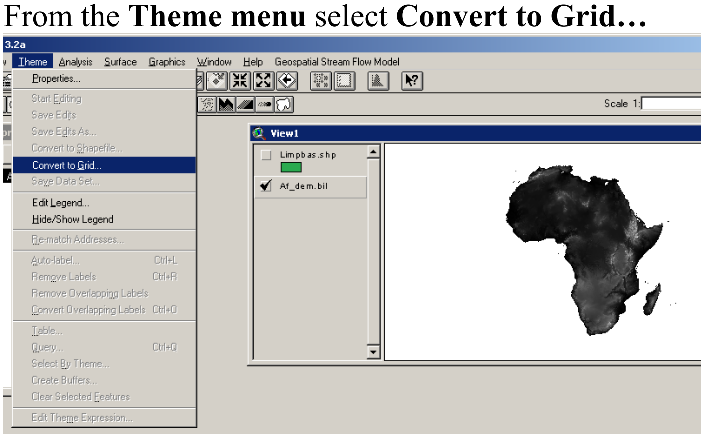
Next, you need to add the Dem data to the ArcView project and correct/convert into a grid for use in exercise one as outlined in the *GeoSFM Training Manual.*

Add the Digital Elevation Model to the View using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Image Data Source**. Click on the **af_dem.bil** file from the **c:\GeoSFM\workspace** directory and click **OK** to add the DEM to the **View**.

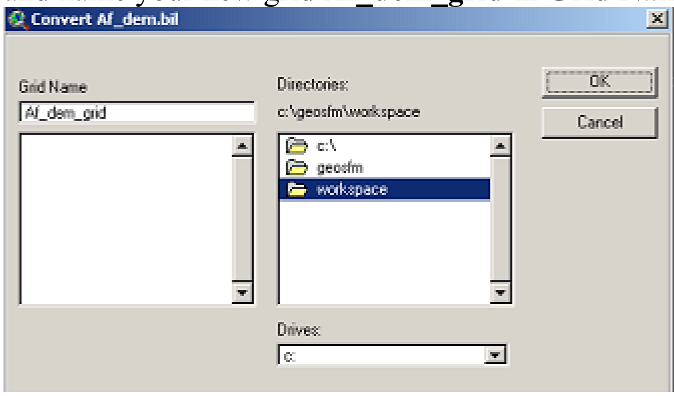


Next, the DEM will need to be converted to a grid. Select the theme **Af_dem.bil** so that it appears in a raised box. Checking the little box next to the theme name will make it visible.

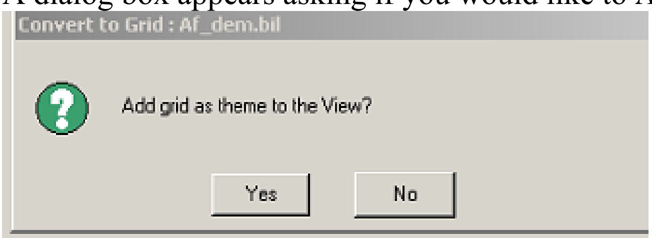
From the **Theme menu** select **Convert to Grid…**



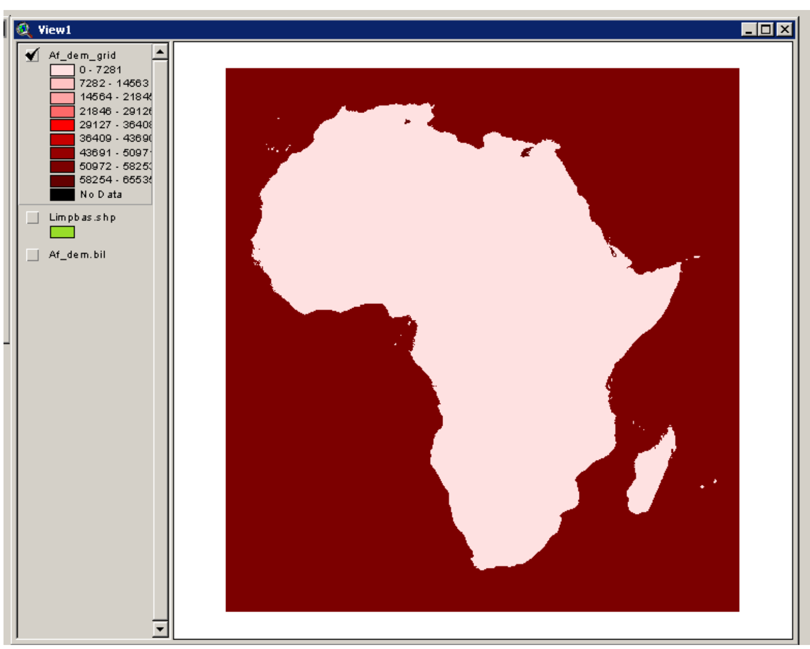
The **Convert Af_dem.bil** dialog box appears. Navigate to the **c:\GeoSFM\workspace** directory and name your new grid **Af_dem_grid** in **Grid Name.** Then click **OK.**



A dialog box appears asking if you would like to **Add grid as theme to View.** Click **Yes**.

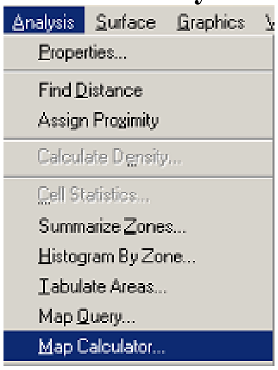


New **Af_dem_grid** theme shown below.



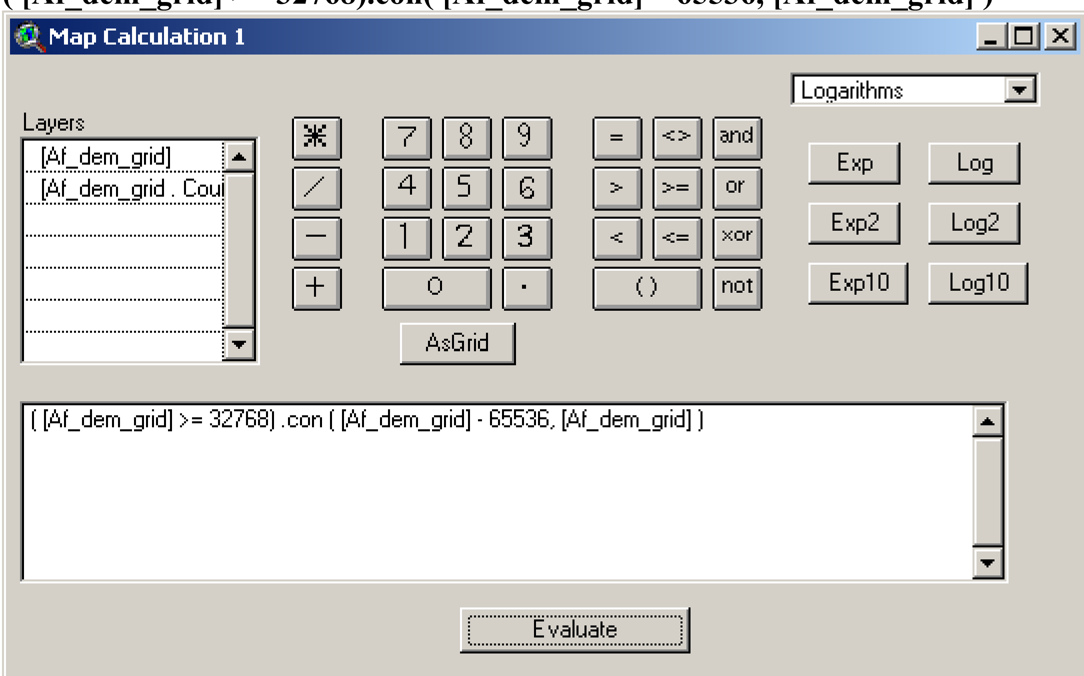
After adding the grid to the **View** you will need to perform some map calculations to produce a corrected elevations grid. The high values are introduced into the DEM to avoid having to store negative values in the .bil format. To correct the DEM, you need to run the following 3 calculations.

From the **Analysis menu** choose **Map Calculator…**



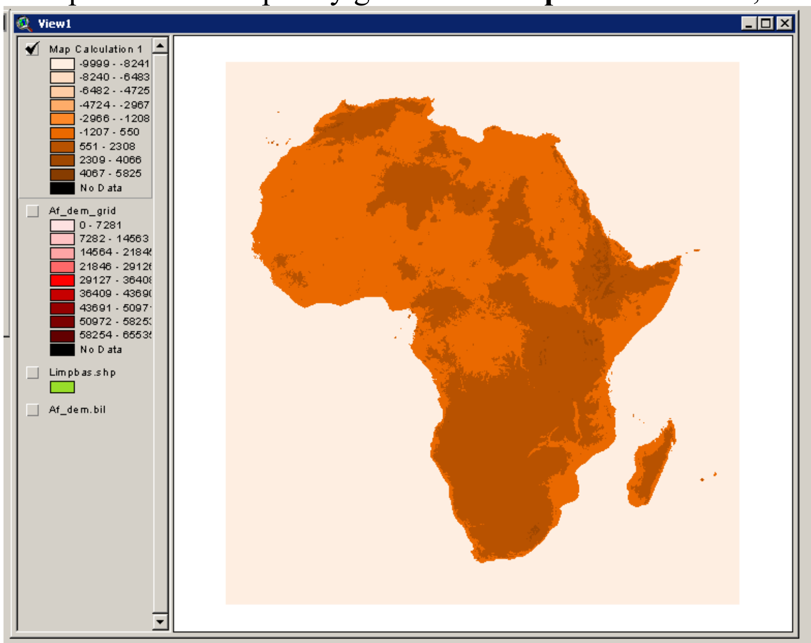
The first correction subtracts 65536 from all the cells with elevation higher than 32768, which restores the original negative values. The result of this computation is that all NODATA cells are assigned values of -9999 while all other cells will have their true elevation (negative or positive).

In the Map Calculator type the following expression exactly as shown:
([Af_dem_grid] >= 32768).con([Af_dem_grid] – 65536, [Af_dem_grid])



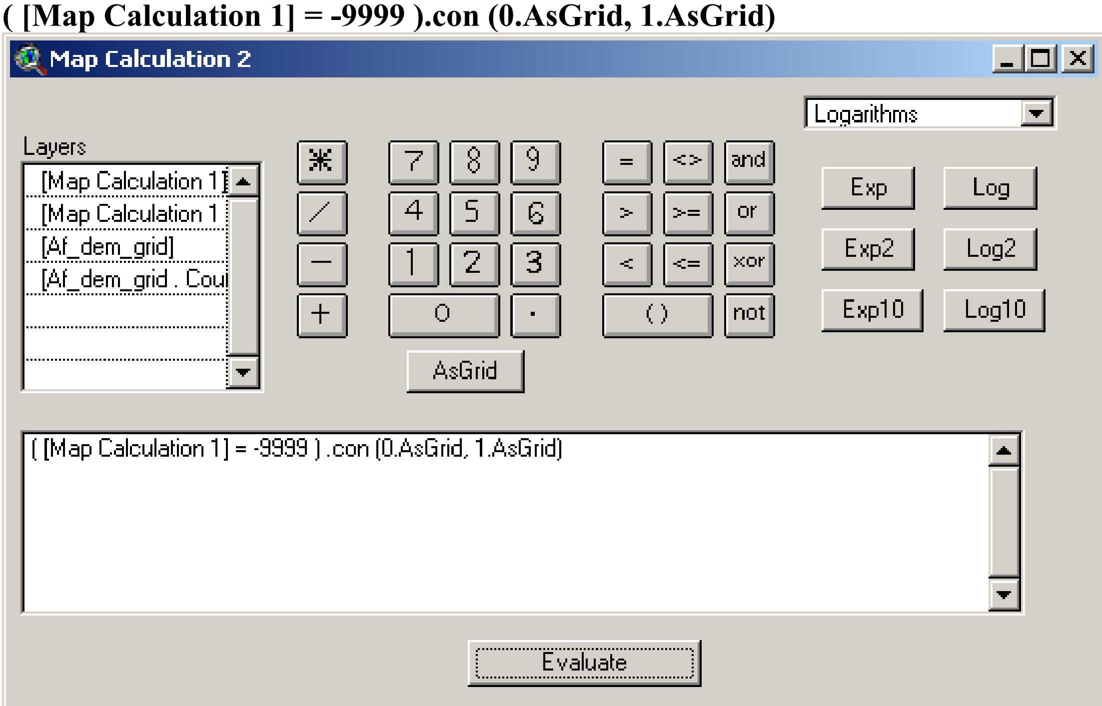
Then click the **Evaluate** button.

This produces a temporary grid called **Map Calculation 1**, seen below.



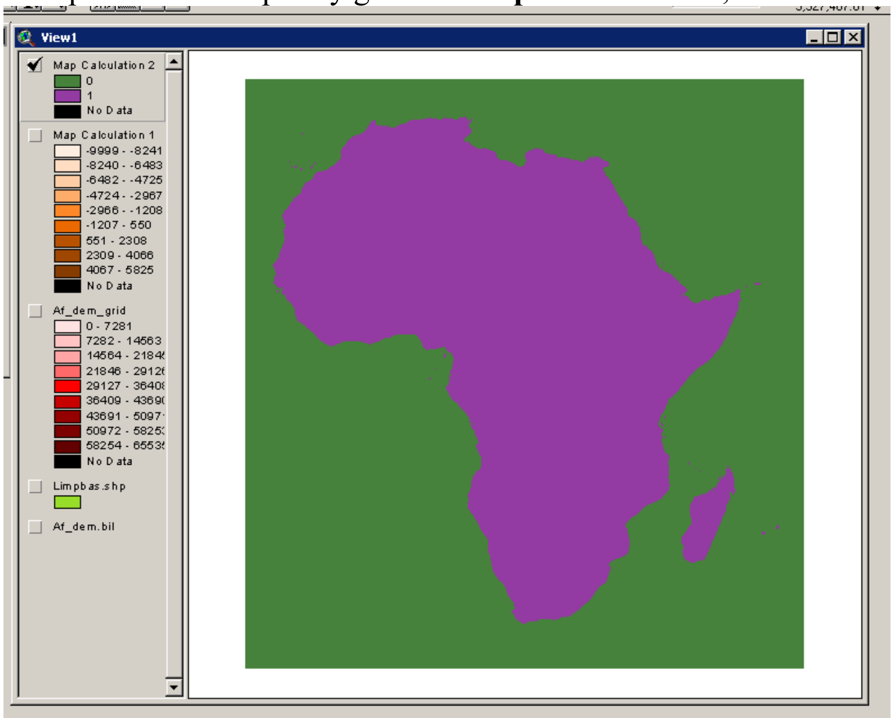
Choose the **Map Calculator** from the **Analysis menu** again to do the second calculation. The second calculation assigns values of zero to NODATA cells and values of one to all other cells so that the NODATA cells can be eliminated in the final step. Type in the following expression exactly as shown:

([Map Calculation 1] = -9999).con (0.AsGrid, 1.AsGrid)



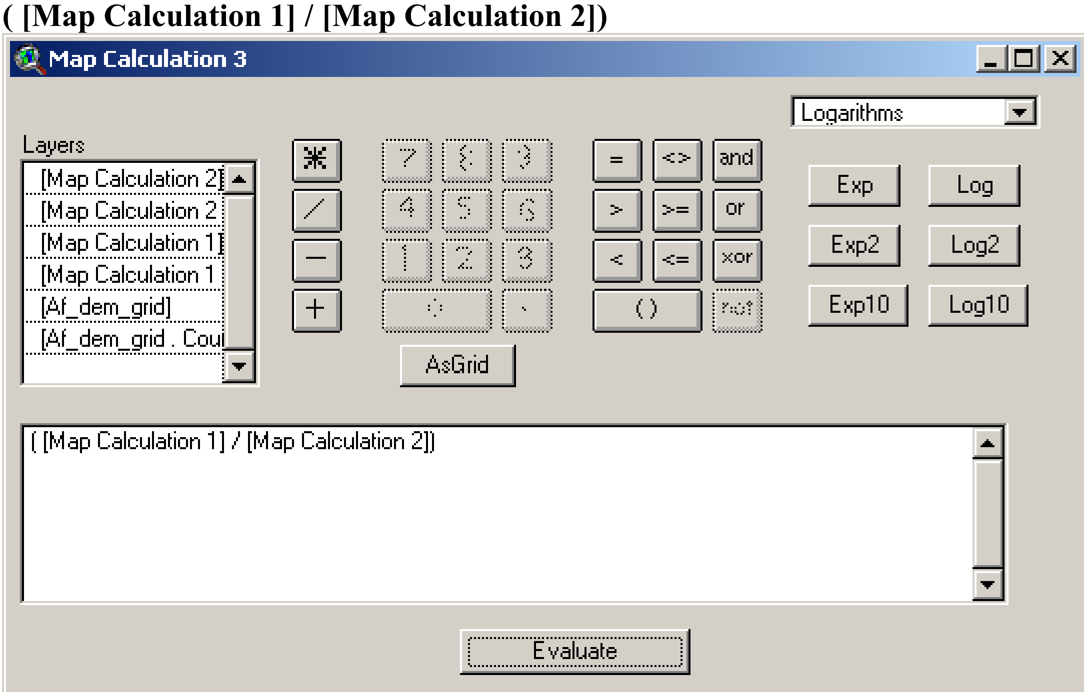
Then click the **Evaluate** button.

This produces a temporary grid call **Map Calculation 2**, seen below.

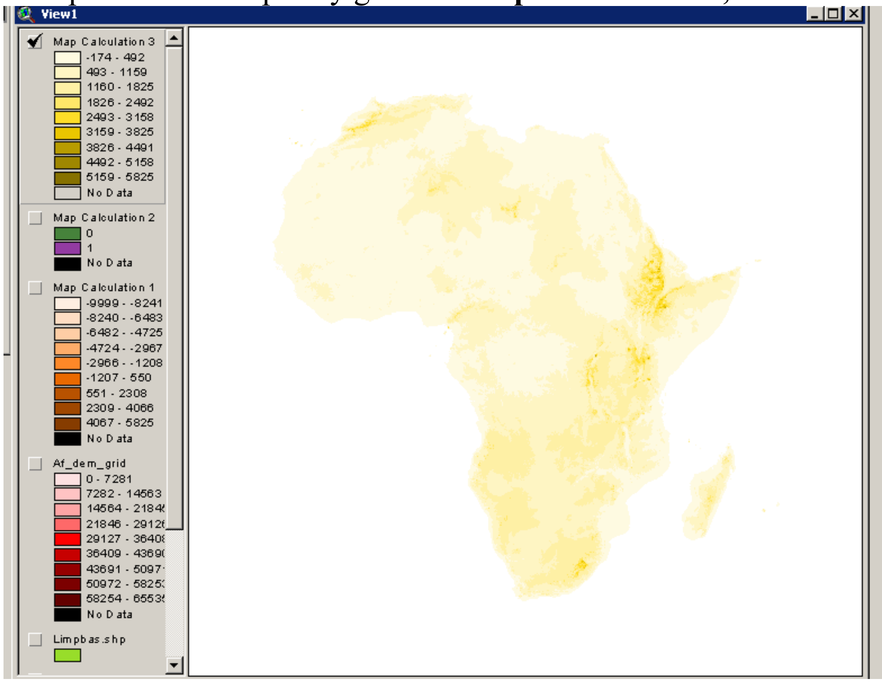


The final computation divides the result of the first correction with the result of the second correction. Zero divides values of -9999 while 1 divides all other values. Division by zero results in a NODATA cell being created while division by 1 leaves the original value unaltered. Choose the **Map Calculator** from the **Analysis menu** again and type in the following expression exactly as shown:

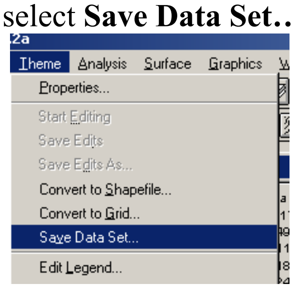
([Map Calculation 1] / [Map Calculation 2])



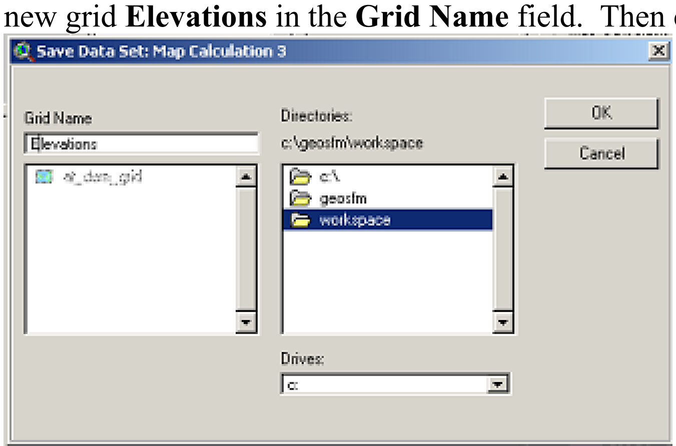
Then click the **Evaluate** button.
This produces a temporary grid call **Map Calculation 3,** seen below.



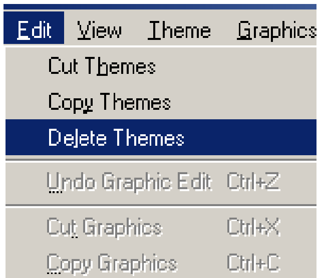
This will be the final elevations grid that you will use for the rest of the exercise, so you need to make it permanent. Select the **Map 3 Theme** so it appears in a raised box, from the **Theme menu** select **Save Data Set…**



In the **Save Data Set Dialog Box** navigate to the **c:\GeoSFM\workspace** directory and name your new grid **Elevations** in the **Grid Name** field. Then click **OK.**



You can now remove all themes by selecting the theme so it appears in a raised box, and then from the **Edit menu** select **Delete Themes.**



Now the permanent **Elevations** grid can be added to the **View** using the **Add Theme** button . You are now ready to begin processing the elevation in section 1.3 of the *GeoSFM Training Manual.*

1.2.2 Defining Basin Extent

Analysis Extent Input Data

Input Shapefile	Description	
Limpbas.shp	Shapefile defining analysis extent	

Analysis Environment Input Data

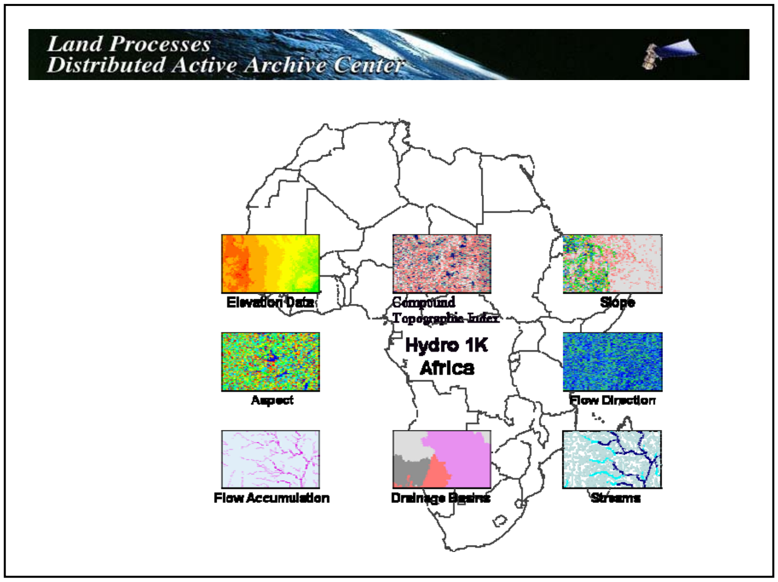
Input Parameters	Description	Unit
Analysis Extent	Boundary defined for analysis area –**same as Limpbas.shp**	meter
Analysis Cell Size	Boundary defined for cell area –**same as elevations**	
Stream Delineation Threshold	Minimum number of cells upstream of a given location for initiating stream. –default 1000–min500	cell

Downloading/Processing Basin Extent

The GeoSFM uses a shapefile to define the analysis extent for use in the modeling process. HYDRO1K Basins data sets are derived using the vector stream networks along with the flow direction data set. Each polygon in the basin data set has been tagged with a Pfafstetter code uniquely identifying each sub-basin. Additional attributes defining the characteristics of each sub-basin have also been developed. These data are available in an ARC/INFO export format and shapefile format. The download process documented below captures data needed to complete exercise one outlined in the *GeoSFM Training Manual*. This exercise was developed for the Limpopo Basin in southern Africa.

These data are available from the U.S. Geological Survey's Center for EROS at http://edcdaac.usgs.gov/gtopo30/hydro/af_basins.asp. (Data for other regions is found at the following website –http:/edcdaac.usgs.gov/gtopo30/hydro/.)

This website will bring you to the *Land Processes Distributed Active Archive Center* page; scroll down to the list of downloads.



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Download the entire HYDRO1k data set for Africa as a tar file (215.5 MB)

 Download HYDRO1k Basins data set for Africa as a tar file in ARCINFO export format (7.4 MB)

 Download HYDRO1k Basins data set for Africa as a tar file in shapefile format (7.4 MB)

 Click on –**Download HYDRO1k Basins data set for Africa as a tar file in shapefile format (7.4 MB)**. Save the file to your workspace, **c:\GeoSFM\workspace**. Use WinZip to select and extract all files to your workspace. Extract all files from the **af_base.tar.gz file**. If you do not already have WinZip installed you can download a free trial version from http://www.winzip.com/winzip/download.htm.

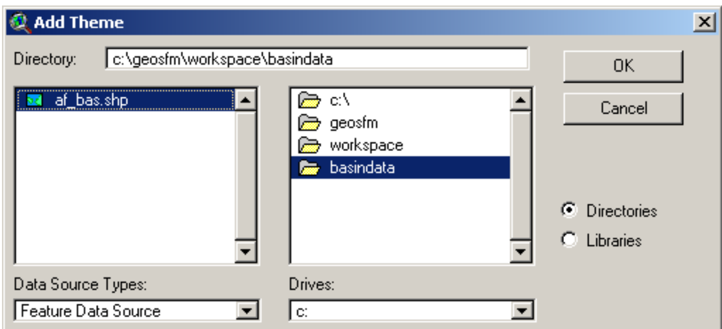
Extracted files:

- af.readme
- af_bas.dbf
- af_bas.prj
- af_bas.shp

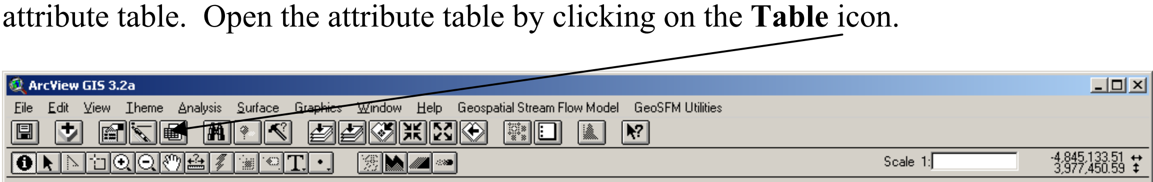
- af_bas.shp.xml
- af_bas.shx

Next, you need to add the Basin data to the ArcView project and select the basins you will need for your area. In this example you will select the basins needed to complete exercise one outlined in the *GeoSFM Training Manual*.

Add the Basin data to the View using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Feature Data Source**. Click on the **af_bas.shp** file from the **c:\GeoSFM\workspace** directory and click **OK** to add to the **View**.



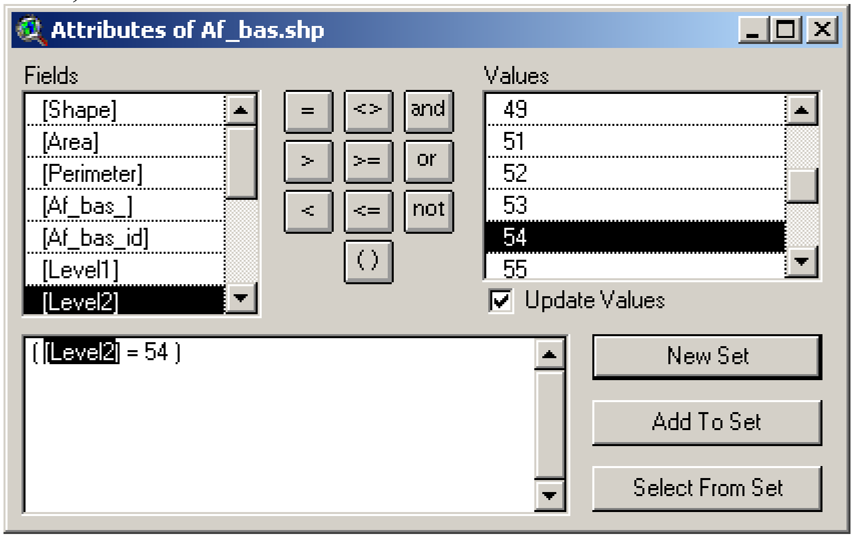
After you have added the shapefile you will select the basin area by the Pfafsteller code in the attribute table. Open the attribute table by clicking on the **Table** icon.



From the **Table** menu select **Query**.

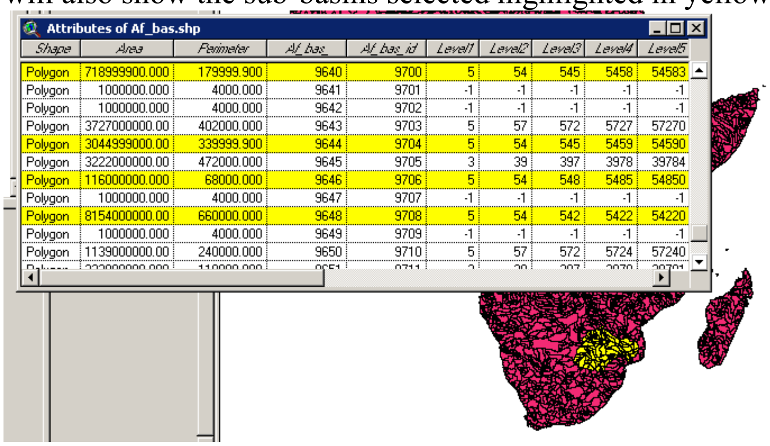
The **Attributes of Af_bas.shp** query box opens.

Double click on **Level 2** under **Fields**. Make sure the **Update Values** box is checked so all **Level 2** values will display under **Values**. Click on the "=" button and then on the value you need for this basin, we will select **54** for this exercise. Click **New Set**.



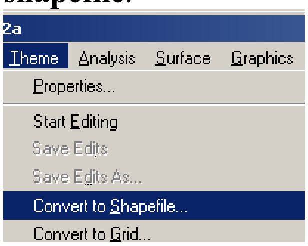
([Level2] = 54)

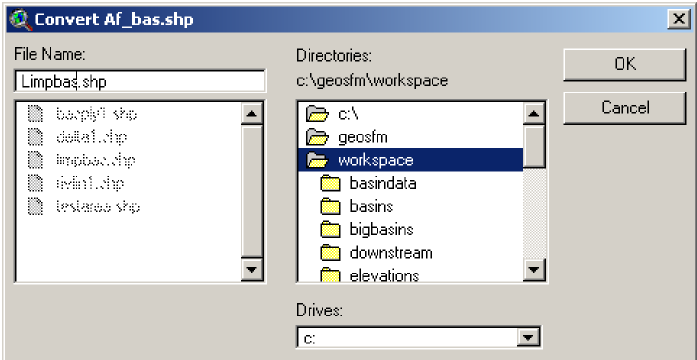
All attributes with a value of **54** in the **Level2** column will highlight yellow. The African shapefile will also show the sub-basins selected highlighted in yellow.



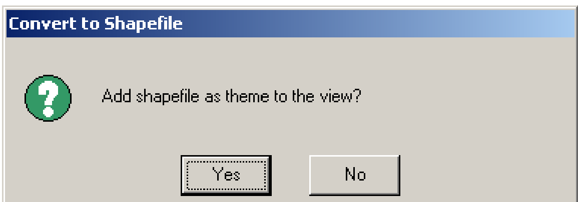
Shape	Area	Perimeter	Af_bas_	Af_bas_id	Level1	Level2	Level3	Level4	Level5
Polygon	718999900.000	179999.900	9640	9700	5	54	545	5458	54583
Polygon	1000000.000	4000.000	9641	9701	-1	-1	-1	-1	-1
Polygon	1000000.000	4000.000	9642	9702	-1	-1	-1	-1	-1
Polygon	3727000000.00	402000.000	9643	9703	5	57	572	5727	57270
Polygon	3044999000.00	339999.900	9644	9704	5	54	545	5459	54590
Polygon	3222000000.00	472000.000	9645	9705	3	39	397	3978	39784
Polygon	116000000.000	68000.000	9646	9706	5	54	548	5485	54850
Polygon	1000000.000	4000.000	9647	9707	-1	-1	-1	-1	-1
Polygon	8154000000.00	660000.000	9648	9708	5	54	542	5422	54220
Polygon	1000000.000	4000.000	9649	9709	-1	-1	-1	-1	-1
Polygon	1139000000.00	240000.000	9650	9710	5	57	572	5724	57240

Now you can convert the selections to a shapefile, from the **Theme** menu select **Convert to shapefile**.



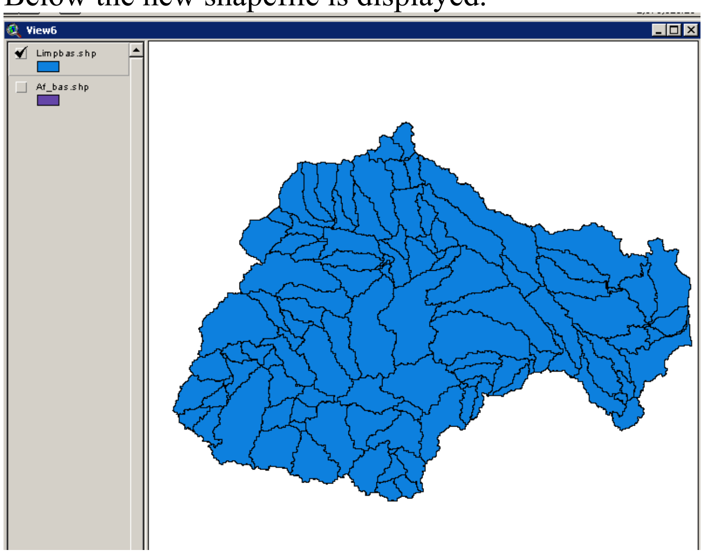


The **Convert Af_bas.shp** dialog box opens. Navigate to the appropriate directory and under **File Name** type in the name of the new shapefile. Click **OK**.



The "**Add shapefile as theme to the view**?" dialog box will display, click **Yes**.

Below the new shapefile is displayed.



The shapefile can be added to the **View** when prompted during the **Processing Elevation Data** process in section 1.3 in the *GeoSFM Training Manual.*

1.2.3 Outputs from Terrain Analysis

Stream/Basin Output Data

Output Grids	**Description**	**Unit**
FlowDir	Flow direction grid consists of numeric values assigned using the eight direction pour point model. Each cell is assigned one of eight compass directions.	Cell
FlowAcc	Flow accumulation grid defines the number of contributing cells draining into each cell. Values range from 0 at topographic highs to large numbers at the mouths of rivers.	Number of cells
FlowLen	Downstream flow length grid defines the distance from the cell to the basin outlet.	meter
Streams	Stream grid defines stream cells. Value 1 = stream, Nodata = land	
StrLinks	Stream link grid assigns a unique value to each stream ID.	
Outlets	Outlet grid defines number of outlets; one outlet per sub-basin, each outlet assigned a unique value.	
Basins	Sub-basin grid assigns a unique ID value to each sub-basin.	
HillLength	Hill length grid defines distance to stream, from cell to nearest stream.	meter
Slope	Hill slope grid describes the maximum change in elevation between each cell and its eight neighbors. Expressed in percentage.	
Downstream	Downstream grid assigns a unique ID number of the sub-basin immediately downstream.	
BigBasins	Basin boundary polygon.	
Basply.shp	Shapefile defining all sub-basins with unique ID and gridcodes.	
Rivline.shp	Shapefile defining streams with unique IDs, gridcodes and from_node and to_node.	

1.3 Generate Basin Characteristics File

1.3.1 Soil Characteristics Processing

The response of a river basin to a rainfall event depends very heavily on the nature and condition of underlying soils. In hydrologic models, soils are characterized through a combination of static parameters (e.g. texture, hydraulic conductivity) and dynamic parameters (soil moisture). In particular, GeoSFM requires a number of parameters including soil water holding capacity in millimeters, hydrological active soil depth in centimeters, texture, and average saturated hydraulic conductivity in meters per hour, Soil Conservation Service (SCS) runoff curve number and percentage of impervious cover. The Digital Soil Map of the World (DSMW) CD-ROM produced by FAO (United Nations Food and Agriculture Organization) and UNESCO (United Nations Educational, Scientific and Cultural Organization) is one data set used in this study because it is the finest resolution soil database with global coverage available. The Digital Soil Map of the World consists of ten map sheets covering Africa, North America, Central America, South America, Europe, Central and Northeast Asia, Far East, Southeast Asia, and Oceania. Each map sheet is available in three different formats including one vector format (ARC/INFO Export) and two raster formats (ERDAS and IDRISI). All the data are in geographic projection and are produced from original map sheets with a scale of 1:5 000 000.

The Zobler data set is also used for calculating soil characteristics. The data sets can be accessed from FTP site –ftp://daac.gsfc.nasa.gov/data/inter_disc/hydrologh/soil/. Soil type and soil texture were constructed from Zobler. When combined with the DSMW data set (Zobler, 1986) there is improved model performance because of an enhanced variability in soil properties.

The NASA Technical Memorandum 4286, *A Global Data Set of Soil Particle Size Properties*, published in 1991, was also used. The authors of this manuscript are Robert S. Webb, Cynthia E. Rosenzweig, and Elissa R. Levine. This data set specifies the top and bottom depths, and the percentage of texture type (sand, silt, and clay) of soil horizons in 106 different soil types cataloged for nine continents. The soil profile depth data set used was constructed by Webb.

Soil Characteristic Input Parameters

Input Grids	Description	Unit
Rcn	SCS runoff curve number grid uses hydraulic soil classes together with the GLCC classes to derive a RCN value.	
Whc	Soil water holding capacity grid is calculated from the DSMW soil class and the total available water median soil moisture value.	mm
Soildepth	Hydrological active soil layer depth grid created from DSMW soil code value and Webb’s soil depth values.	cm
Texture	Texture grid created from Zobler’s seven classes converted to three classes –coarse, medium, and fine.	

Input Grids cont.	Description	Unit
Ks	Saturated soil hydraulic conductivity grid created on Ks values, which are based on Zobler's texture classes.	cm/hr
maxcover	Maximum impervious cover grid based on wetland areas and water bodies found in the GLCC data set and stream cells defined in the flowacc grid.	

Soil Characteristic Data Sources

Soil Depth

Soil depth value source– NASA Technical Memo 4386 - 1991
Titled: *A global Data Set of Soil Particle Size Propeties*
Authored: Robert S. Webb, Cynthia E. Rosenzweig, and Elissa R. Levine
Table 5 - Soil thicknesses for 106 soil types, 9 continents (cm) pg. 21

Soil Code source - Digital Soil Map of the World (DSMW) CD-ROM
FAOSOIL\DATA\AFRIC1.DAT & AFRIC2.DAT

Texture

Texture class source – NASA Technical Memo 87802 – 1986
Titled: *A world soil file for global climate modeling*
Authored: L. Zobler
FTP site: ftp://daac.gsfc.nasa.gov/data/inter_disc/hydrology/soil/
File name: FAO_soil.textur.1nnegl.bin
Converted Zobler's seven texture classes to three for GeoSFM classes

GeoSFM class 1 (coarse) → sandy soils =1, + coarse =2
GeoSFM class 2 (medium) → loamy soils =7, + organic =4, + fine/medium =3
GeoSFM class 3 (fine) → clay soils =5

Table 1.1

GeoSFM Class	Zobler Class	Description
1	1	Sandy soils
	2	Coarse
2	3	Fine/medium
	4	Organic
	7	Loamy soils
3	5	Clay soils

KS – Hydraulic Conductivity

Texture class source – NASA Technical Memo 87802 – 1986
Titled: *A world soil file for global climate modeling*
Authored: L. Zobler
FTP site: ftp://daac.gsfc.nasa.gov/data/inter_disc/hydrology/soil/
File name: FAO_soil.textur.1nnegl.bin

Ks value source – NASA Technical Memo 87802 – 1986
Titled: *A world soil file for global climate modeling*
Authored: L. Zobler
FTP site: ftp://daac.gsfc.nasa.gov/data/inter_disc/hydrology/soil/
See Table 1.2

Hydraulic conductivity values (Ks) are based on seven texture classes defined by the Zobler data set.

Table 1.2

Zobler Class Code	FAOTexture	Porosity	Matric Potential	Ks	Bslope	USDA Soil Texture	Soil Hydraulic Class	Numeric soil Hydraulic Class
1	coarse	0.421	0.0363	**5.076**	4.26	loam sand	a	**88**
2	medium or coarse	0.434	0.1413	**1.882**	4.74	sandy loam	a	**88**
3	medium	0.439	0.3548	**1.217**	5.25	loam	b	**89**
4	fine or medium	0.404	0.1349	**1.602**	6.77	sandy clay or loam	c	**90**
5	fine	0.465	0.2630	**0.882**	8.17	clay or loam	d	**91**
6	ice	0.0	0.0	**0.0**	0.0	ice		
7	organic	0.439	0.3548	**1.217**	5.25	loam	b	**89**

WHC – Soil Water Holding Capacity

Soil Class source – Digital Soil Map of the World (DSMW) CD-ROM
FAOSOIL/DATA/SMAX1.ASC file contains the data elements record number, mapping unit, and the percentage of each mapping unit in one of the following seven classes. (water, A, B, C, D, E, & F)

Soil water holding capacity source – Digital Soil Map of the World (DSMW) CD-ROM
see Table 1.3

The median soil moisture values in the total available water column in Table 1.3 were used for the calculations.

Table 1.3 Table soil water holding capacity by class

Class	**Soil Moisture Range, Easily Available Water**	**Soil Moisture Range, Total Available Water**	**Median Soil Moisture, Easily Available Water**	**Median Soil Moisture, Total Available Water**
Water	0	0	0 mm/m	**0 mm/m**
A	>120 mm/m	>200 mm/m	150 mm/m	**250 mm/m**
B	100-120 mm/m	150-200 mm/m	110 mm/m	**175 mm/m**
C	60-100 mm/m	100-150 mm/m	80 mm/m	**125 mm/m**
D	40-60 mm/m	60-100 mm/m	50 mm/m	**80 mm/m**
E	20-40 mm/m	20-60 mm/m	30 mm/m	**40 mm/m**
F	<20 mm/m	<20 mm/m	10 mm/m	**10 mm/m**

Example calculation:
Assume mapping unit example is –Water=10%, A=0%, B=40%, C=10%, D=0%, E=20%, and F=20%

(Water/100*0) + ("A"/100*250) + ("B"/100*175) + ("C"/100*125) + ("D"/100*80) + ("E"/100*40) + ("F"/100*10)

(10/100*0) + (0/100*250) + (40/100*175) + (10/100*125) + (0/100*80) + (20/100*40) + (20/100*10)

0+0+70+12.5+0+8+2

Total available water = 92.5mm of water

Maxcover

Land cover source – USGS Global Land Cover Characteristics (GLCC) database (Loveland et al., 1999.) The GLCC data were derived from 1-km AVHRR data and are available in the Interrupted Goode Homolosine and Lambert Equal Area Azimuthal projections. The data are available for download over the Internet at http://edcdaac.usgs.gov/glcc/af_int.html. *See section 1.4.1 for instructions on creating landcover grid.*

Flow Accumulation grid source -

- Stream assigned cell values are from the Flow Accumulation (flowacc) grid created during the terrain analysis processing. If flow accumulation is greater than 1000 the cell is considered a stream cell in the Flow Accumulation grid. (This value can be changed depending on the objectives and the scale.)
- Hydro1K data set available from U.S. Geological Survey's Center for Earth Resources Observation Science. The data are available for download over the Internet at http://edcdaac.usgs.gov/gtopo30/hydro/.)

All water bodies, and wetland cells from the GLCC, and all stream cells from the Flow Accumulation grid are combined to form a maxcover grid.

Cell value → 1=water, 0=all other cells

RCN – Runoff Curve Number

Land cover source – USGS Global Land Cover Characteristics (GLCC) database (Loveland et al., 1999.) The GLCC data were derived from 1-km AVHRR data and are available in the Interrupted Goode Homolosine and Lambert Equal Area Azimuthal projections. The data are available for download over the Internet at http://edcdaac.usgs.gov/glcc/af_int.html. *See section 1.4.1 for instructions on creating landcover grid.*

Soil Hydraulic class source –
Titled: *Handbook of Hydrology* – pg.5.25, 1993
Authored: Editor –D.R. Maidment

Soil Hydraulic classes are found in Table 1.2. The Soil Conservation Service (SCS) has classified soils into four hydrologic soil groups according to their infiltration rate.

- Group "A" consists of soils that have low runoff potential and high infiltration rates. The USDA soil textures included in this group are sand, loamy sand, and sandy loam. The transmission rates of these soils are greater than 0.76 cm/h.
- Group "B" consists of soils that have moderate infiltration rates. The USDA soil textures included in this group are silt loam, and loam. The transmission rates of these soils are between 0.38 and 0.76 cm/h.
- Group "C" consists of soils that have low infiltration rates. The USDA soil texture included in this group is sandy clay loam. The transmission rates of these soils are between 0.13 and 0.38 cm/h.
- Group "D" consists of soils that have very low infiltration rates. The USDA soil textures included in this group are clay loam, silty clay loam, sandy clay, silty clay, and clay. The transmission rates of these soils are between 0.0 and 0.13 cm/h.

From these four soil class groups, numeric values were given to ease the grid creation process. The Numeric Soil Hydraulic classes, found in the last column, will be used when creating the RCN grid.

SCS Runoff Curve Number source –
Titled: *Applied Hydrology*, pg. 150, 1988
Authored: V.T. Chow, D.R. Maidment, and L.W. Mays
SCS runoff curve number from Table 1.4 below.

Hyd_a_mean = soil hydraulic class A
Hyd_b-mean = soil hydraulic class B
Hyd_c_mean = soil hydraulic class C
Hyd_d_mean = soil hydraulic class D

Table 1.4

nlucode	Lu_code	Description	Hyd_a_mean	Hyd_b_mean	Hyd_c_mean	Hyd_d_mean
0	0	Unclassified	54.0	70.0	80.0	85.0
1	100	Urban and Built-Up Land	81.0	88.0	91.0	93.0
2	211	Dryland Cropland and Pasture	68.0	79.0	86.0	89.0
3	212	Irrigated Cropland and Pasture	62.0	71.0	78.0	81.0
4	213	Mixed dryland/Irrigated crop land and pasture	65.0	75.0	82.0	85.0
5	280	Cropland/Grassland Mosaic	65.0	75.0	82.0	85.0
6	290	Cropland/Woodland Mosaic	45.0	66.0	77.0	83.0
7	311	Grassland	54.0	70.0	80.0	85.0
8	321	Shrubland	45.0	66.0	77.0	83.0
9	330	Mixed shrumland/grassland	49.5	68.0	78.5	84.0
10	332	Savanna	57.0	73.0	82.0	86.0
11	411	Deciduous Broadleaf Forest	45.0	66.0	77.0	83.0
12	412	Deciduous needleleaf Forest	45.0	66.0	77.0	83.0
13	421	Evergreen Broadleaf Forest	25.0	55.0	70.0	77.0
14	422	Evergreen needleleaf Forest	25.0	55.0	70.0	77.0
15	430	Mixed forest	35.0	60.5	73.5	80.0
16	500	Water Bodies	98.0	98.0	98.0	98.0
17	620	Herbaceous Wetland	30.0	58.0	71.0	78.0
18	610	Wooded Wetland	25.0	55.0	70.0	77.0
19	770	Barren or Sparsely Vegetated	68.0	79.0	86.0	89.0
20	820	Herbaceous Tundra	98.0	98.0	98.0	98.0
21	810	Wooded Tundra	98.0	98.0	98.0	98.0
22	850	Mixed tundra	98.0	98.0	98.0	98.0
23	830	Bare ground tundra	98.0	98.0	98.0	98.0
24	900	Snow or Ice	98.0	98.0	98.0	98.0

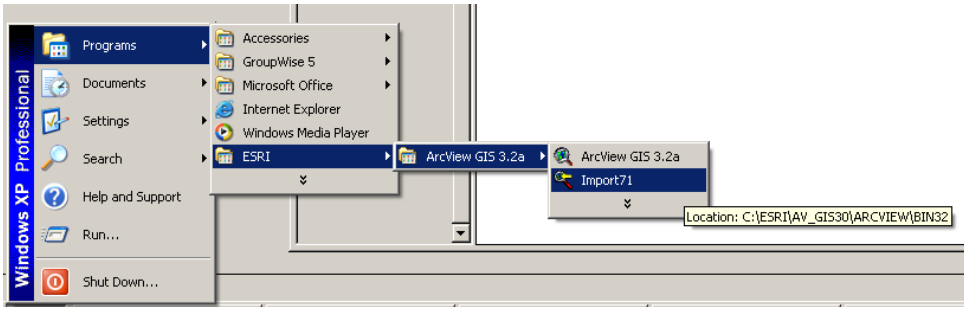
Creating Soil Characteristic Grids

Create a new folder for **DSMW** data to be stored in the GeoSFM folder. Download DSMW data from the CD into **c:\geoSFM\dsmw**. The downloaded files are:

- 1STREAD
- ERDAS
- FAOSOIL
- IDRISI
- RASTEXPN
- VECTOR
- READ1ST.txt

Now, you can begin to import the data into our ArcView project for use in exercise one as outlined in the *GeoSFM Training Manual.*

First, import the vector files by clicking on **Start/Programs/ESRI/ArcView 3.2a/Import71** as seen below.

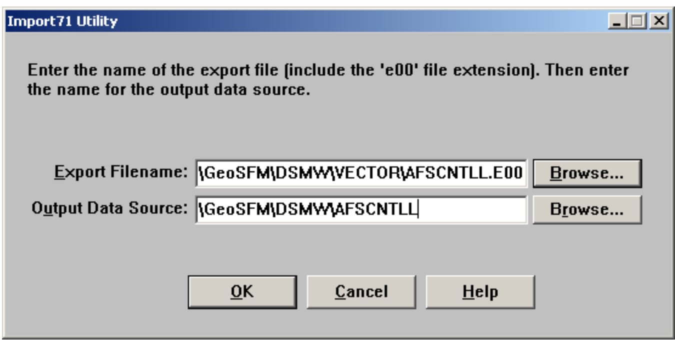


The vector files are found in the Vector folder where they are listed by ten different regions, for exercise one we will chose data for Africa. There are ten files for Africa **AFSNTLL.e00 -.e09**; by selecting **.e00** all files are added.

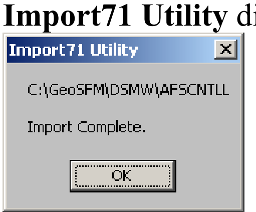
Browse to populate **Export Filename: c:\geoSFM\dsmw\Vector\AFSCNTLL.E00.**

Browse to populate the **Output Data Source.**

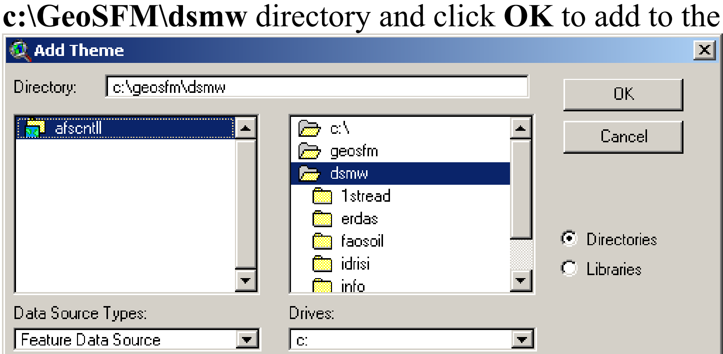
Click **OK.**



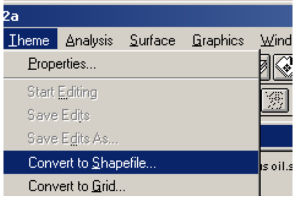
Import71 Utility dialog box displays stating **Import Complete**, click **OK**.



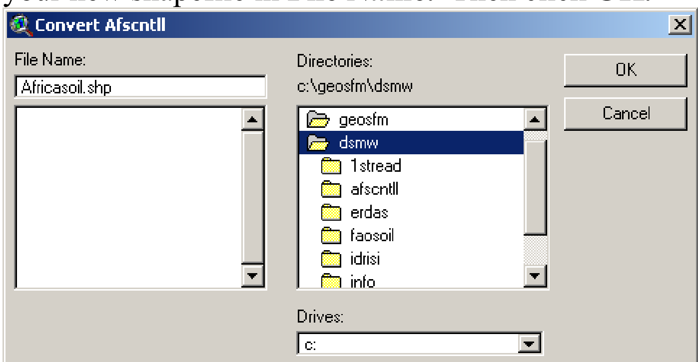
Add the **AFSCNTLL** file to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Feature Data Source**. Click on the **afscntll** file from the **c:\GeoSFM\dsmw** directory and click **OK** to add to the **View**.



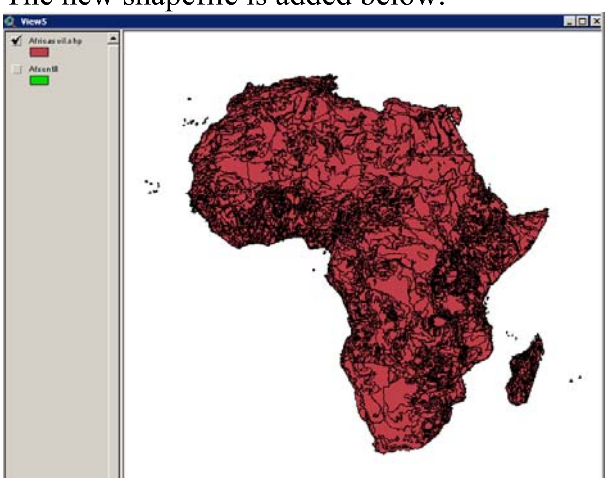
Next, convert **Afscntll** to a shapefile. Select the theme **Afscntll** so that it appears in a raised box. From the **Theme menu** select **Convert to Shapefile…**



The **Convert Afscntll** dialog box appears. Navigate to the **c:\GeoSFM\dwms** directory and name your new shapefile in **File Name.** Then click **OK.**

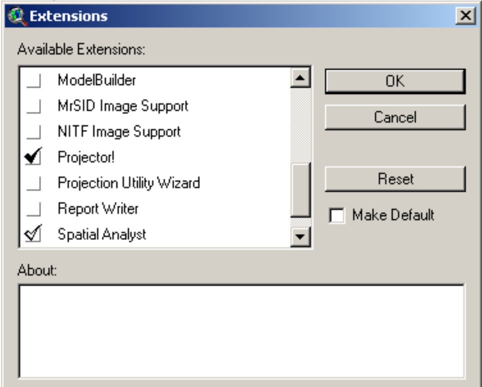


The new shapefile is added below.

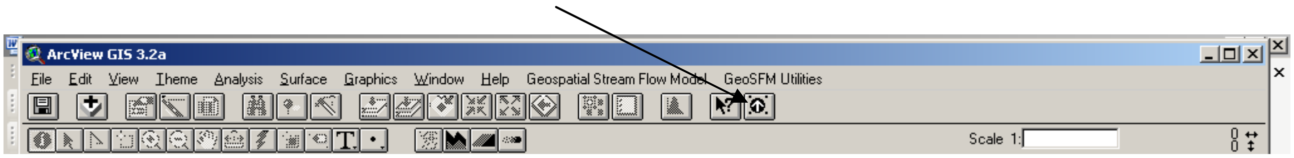


Next, you need to project the shapefile to Lambert Equal-Area Azumuthal.

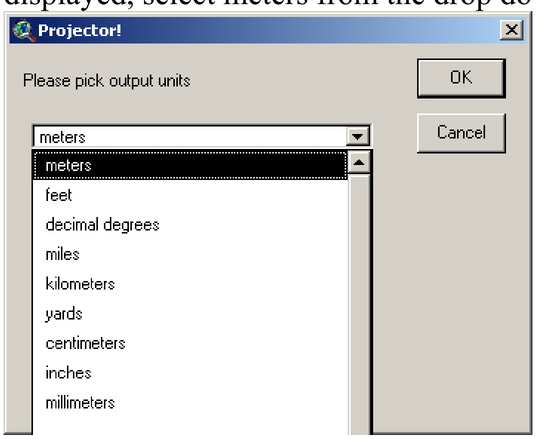
Start by activating the **Projector! Extension,** from the **File** menu select **Extensions**. Scroll down to **Projector!** and click in the box to the left, to select it, click **OK**.



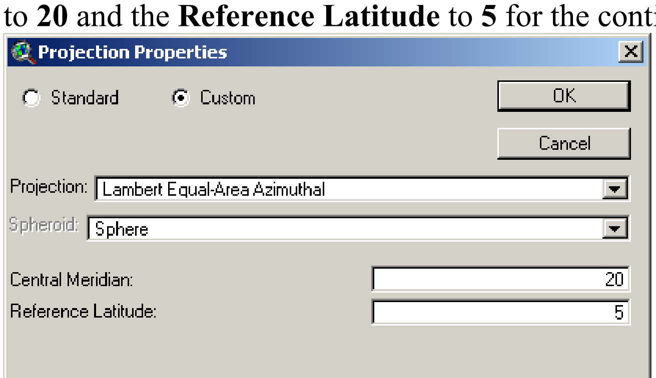
The tool bar is updated to add the **change projection** button.



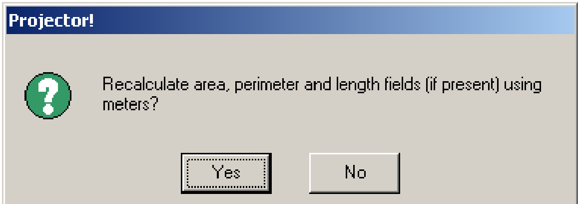
Click on the **change projection** button to start the projection process. The first dialog box is displayed, select meters from the drop down list for the output units. Click **OK**.



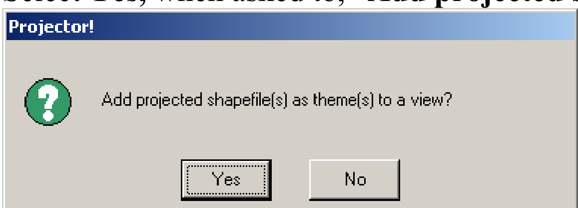
Next, the **Projection Properties** box is displayed. Select the **Custom** radio button. In the **Projection** drop down list select **Lambert Equal-Area Azimuthal**. Change the **Central Meridian** to **20** and the **Reference Latitude** to **5** for the continent of Africa.



Click **Yes** when prompted, "**Recalculate area, perimeter and length fields {if present} using meters?**"

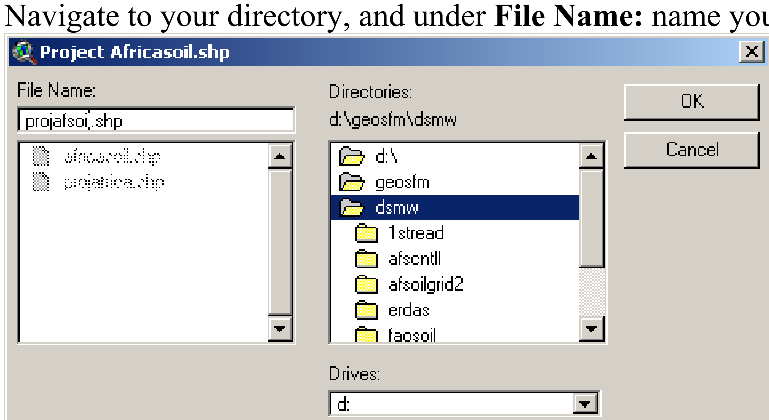


Select **Yes,** when asked to, "**Add projected shapefile as theme to a view?**"

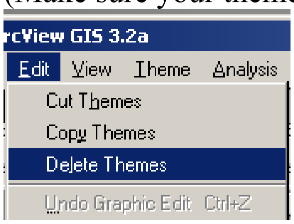


Next, select the view where you want the theme added. Select **View1** and click **OK**.

Navigate to your directory, and under **File Name:** name your new projected shapefile. Click **OK**.

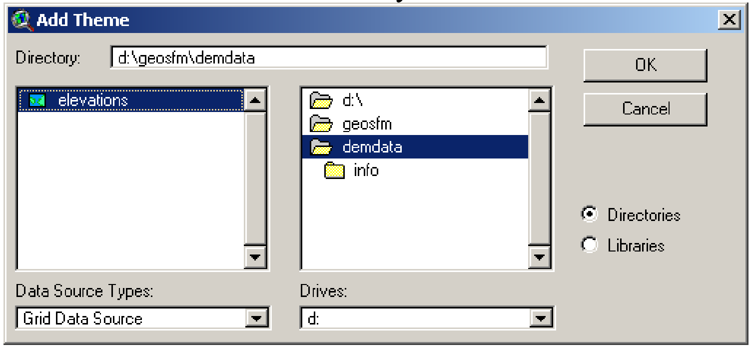


Now, you can delete the original **africasoil.shp**, from **Edit** menu select **Delete Theme** option. (Make sure your theme is in a raised box.)



Before you begin creating the soil depth grid add the **elevations** theme to your view. You will use this theme to define the output grid extent and the cell size.

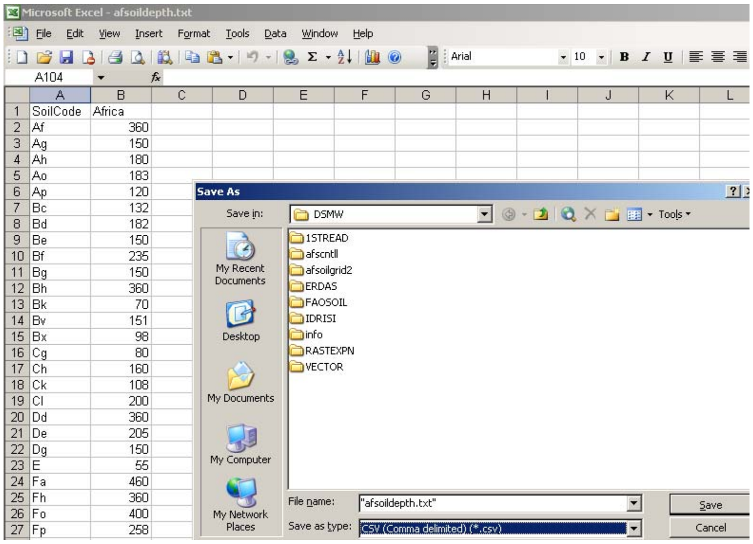
Add the **elevations** file to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Click on the **elevations** file from the **c:\GeoSFM\demdata** directory and click **OK** to add to the **View**.



Now, you can begin to create six different soil characteristic grids, these grids will be needed for generating the **Basin Characteristics File**.

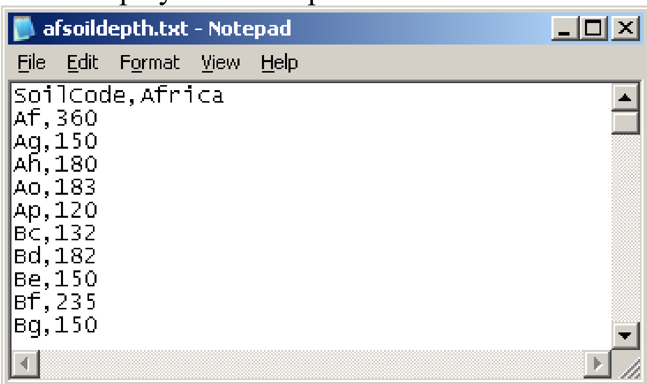
Soil Depth

Soil depth will be the first grid created; it is a hydrological active soil layer depth grid. The source for this data will be a data set found in *NASA Technical Memorandum 4286*. The document is titled *A global Data Set of Soil Particle Size Properties* and was written by Robert Webb, Cynthia E. Roesnzweig, and Elissa R. Levine. On page 21, Table 5, is a data set of soil thickness for 106 soil types for nine continents. You will need to capture the **Soil Code** and the data in the **Africa** column for completing this exercise. Create a text document with two columns of data, example below. (Notice soil code first character is upper case and the second character is lower case.)



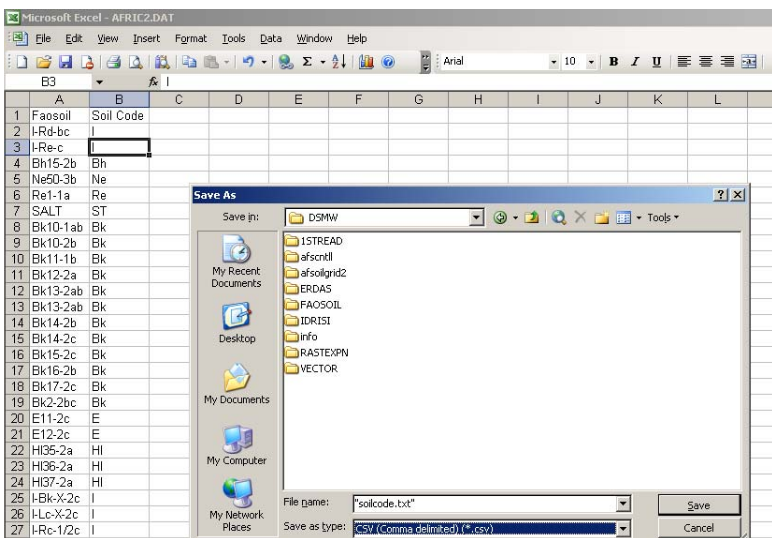
Populate:
File name:
"afsoildepth.txt"
Save as type:
CSV (Comma delimited) (*.csv)

Table displayed in Notepad.



The next text document you will create will capture the **FAOSOIL** code and the **Soil Code** values. The source for this data is found on the DSMW CD in the FAOSOIL\DATA folder. Africa is divided into two files; you will use both **AFRIC1.DAT** and **AFRIC2.DAT**.

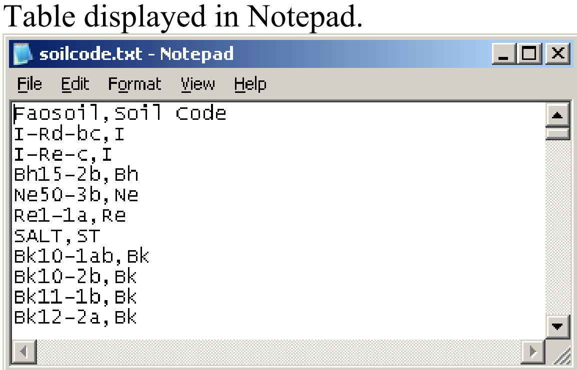
You will need to capture the data in both the **Faosoil** column (4th column) and the **Soil Code** column (8th column.) Create a text document with the two columns of data, example below. Include data from both files (AFRIC1 & AFRIC2.)



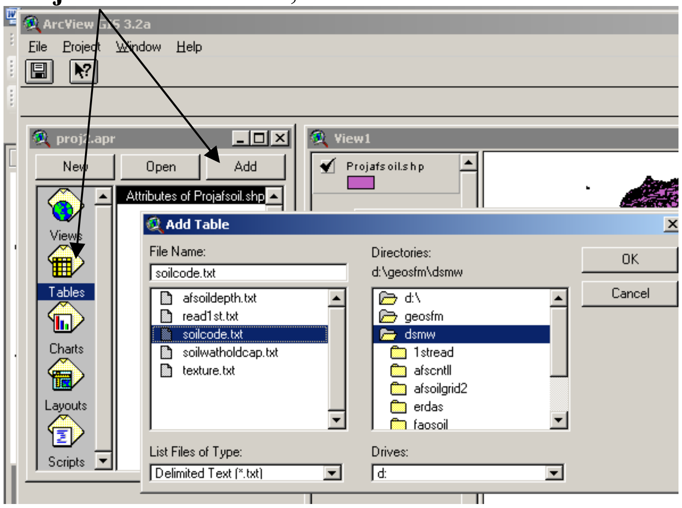
Populate:
File name:
"soilcode.txt"

Save as type:
CSV (Comma delimited) (*.csv)

Table displayed in Notepad.

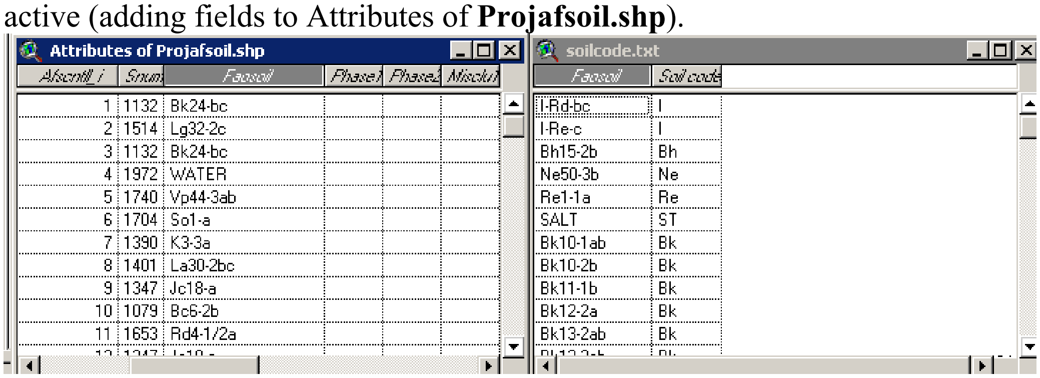


Now, you can add the tables to your view by selecting **Tables** and clicking the **Add** button in the **Project** window. First, select the **soilcode.txt** as seen below. Click **OK**.

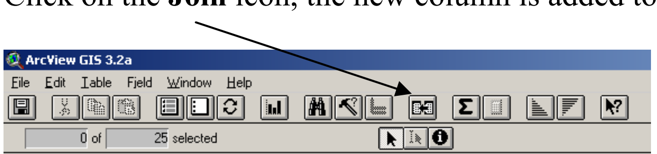


Open the attribute table of **Projafsoil.shp** by selecting the **Projafsoil theme** and clicking on the **Table** icon on the tool bar.

Position the tables as seen below. Click/highlight the common column headers in both tables – **Faosoil** in **Attributes of Projafsoil** and in **Faosoil** in **soilcode.txt**. Make the destination table active (adding fields to Attributes of **Projafsoil.shp**).



Click on the **Join** icon, the new column is added to the **Attributes of Projafsoil** table.

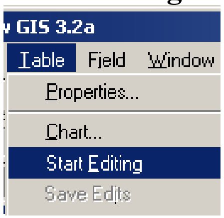


Again, select **Tables** and click the **Add** button in the Project window to add the second table to the view. This time select **afsoildepth.txt**. Click **OK**.

Position the tables side by side. Click/highlight the common column headers in both tables –**Soil code** in **Attributes of Projafsoil** and in **Soilcode** in **afsoildepth.txt**. Make the destination table active (adding fields to Attributes of **Projafsoil.shp**).

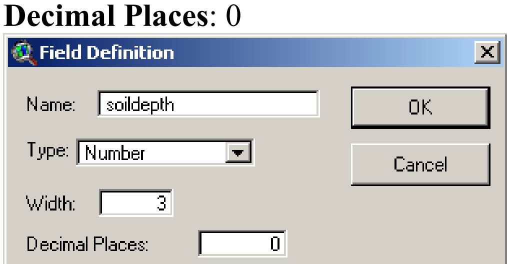
Click on the **Join** icon, the new column is added to the **Attributes of Projafsoil** table.

Now, you will add a new field to the Attributes of Projafsoil.shp. From the **Table** menu select **Start Editing**.

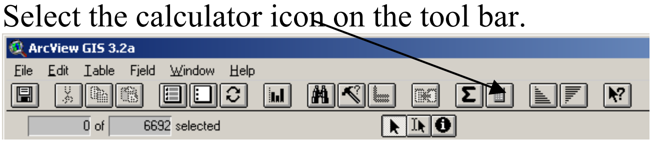


Then from the **Edit** menu select **Add Field**.

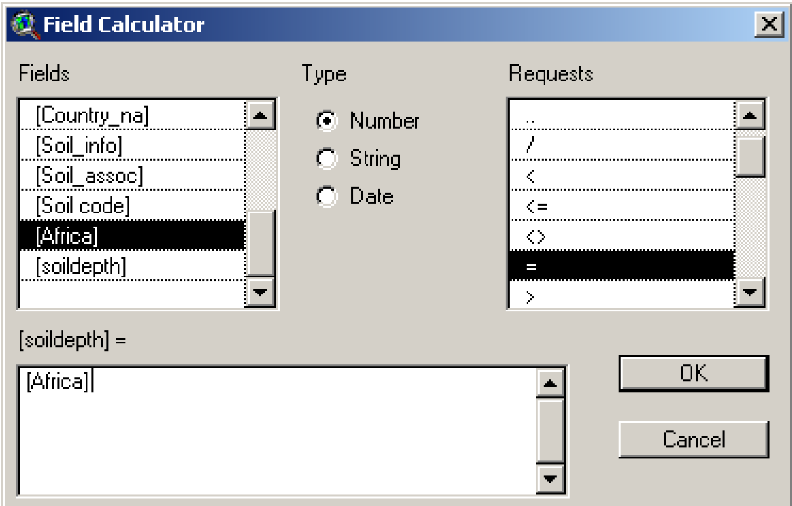
The **Field Definition** dialog box opens.
Populate:
Name: with the name of your new field
Type: number
Width: defaults to 16 –changed to 3
Decimal Places: 0



Select the calculator icon on the tool bar.

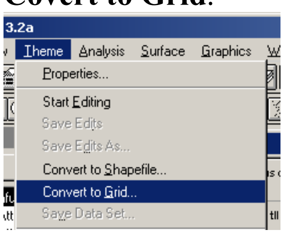


The **Field Calculator** opens enter the following calculation:
[soildepth] = [Africa]
Click **OK**.

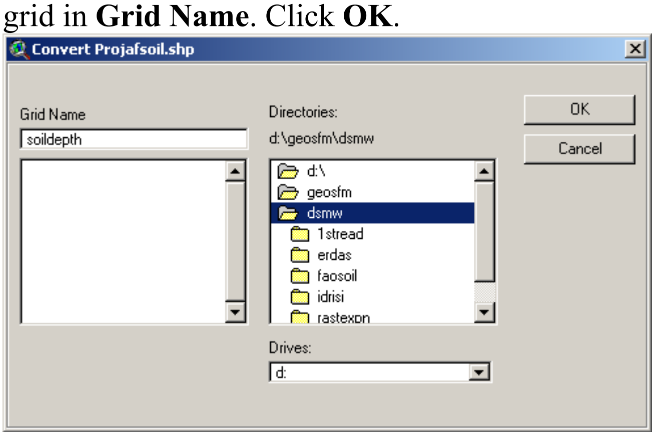


The new soildepth field will be populated with the values from the Africa field.
In the **Table** menu select **Save Edits,** this will save the changes to the attribute table. Then, in the **Tables** menu select **Stop editing**.

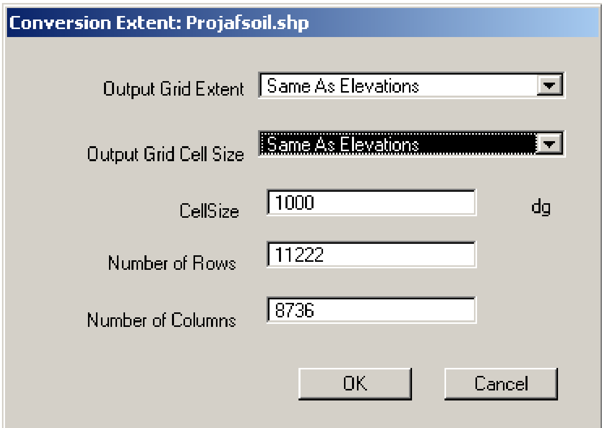
Now you will create a new grid with the data from the soildepth field. From the **Theme** menu select **Covert to Grid**.



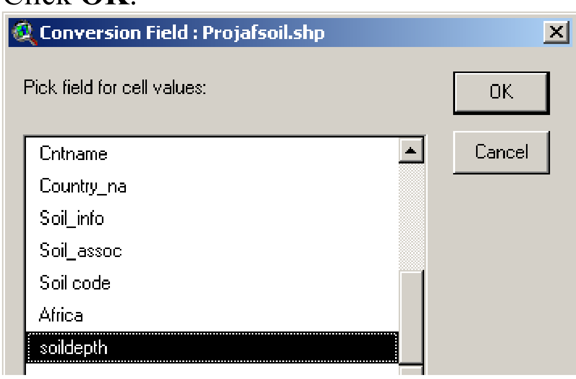
The **Convert Projafsoil.shp** dialog box opens. Select **c:\geosfm\dsmw** directory and name your grid in **Grid Name**. Click **OK**.



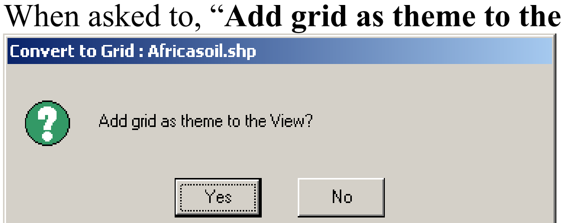
Conversion Extent dialog box opens. **In Output Grid Extent** select **Same as Elevations** from the drop down list. Output grid cell size: **Same as Elevations**. The other values will default. Click **OK**.



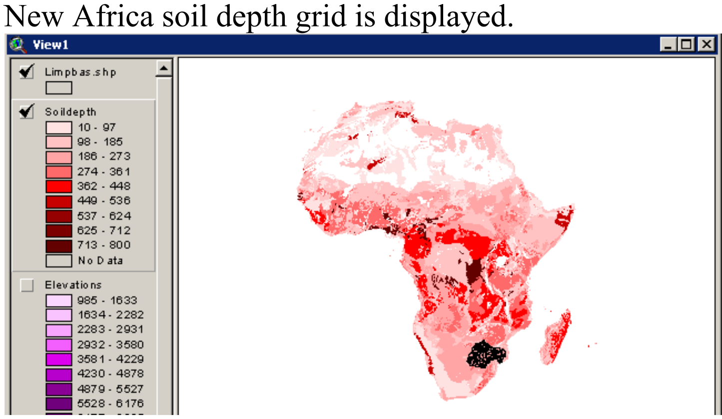
Next, the **Conversion Field** dialog box opens. In **Pick field for cell values:** select **soildepth**. Click **OK**.



When asked to, "**Add grid as theme to the view?"** click **Yes**.



New Africa soil depth grid is displayed.



Texture

The second soil grid you will create is texture. The GeoSFM uses three different texture classes when generating the basin characteristics file. These classes are coarse, medium, and fine.

The texture data set is from Zobler, 1986 and is found at the following FTP site, ftp://daac.gsfc.nasa.gov/data/inter_disc/hydrology/soil/. The file we will be using is FAO_soil.textur.1nnegl.bin.

The following procedure is needed before importing these binary files into ArcView.

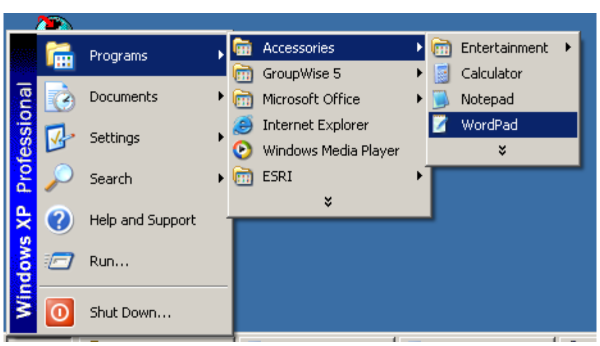
Re-name the **FAO_soil.textur.1nneg1bin** file to filename **texture.bil.**

Next, you will create a header file.
Data fields that are needed for the creation of the header file:

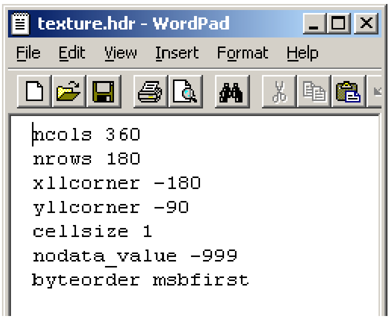
- ncols – the number of columns in the data set
- nrows – the number of rows in the data set
- xllcorner –the x-coordinate of the center or lower-left corner of the lower-left cell
- yllcorner –the y-coordinate of the center or lower-left corner of the lower-left cell
- cell size –cell size of the data set
- nodata_value –value in the file assigned to cells whose value is unknown. This keyword and value is optional. The nodata_value defaults to -9999.
- byteorder – the byte order of the binary cell values. You can choose between two keywords, msbfirst or lsbfirst. Msbfirst is used for cell values written with the most significant bit first. Lsbfirst is used for cell values written with the least significant bit first.

The parameters needed to populate the new header file can be found in the **Readme.fao_soil** documentation.

Now that you have the data you need, you can prepare an ASCII file. To do this, open up WordPad in Start/Programs/Accessories/WordPad.

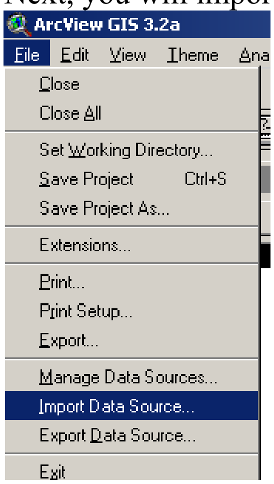


An example of the WordPad document can be seen below.

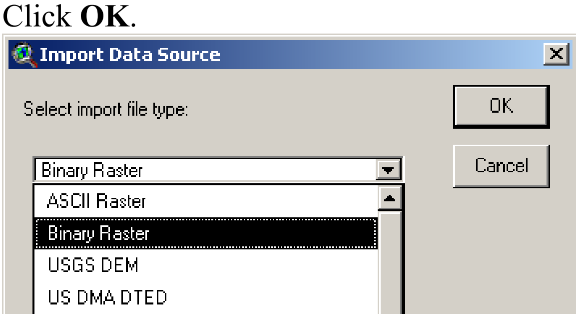


Save the document from the **File** menu select **Save As…**
File Name –**texture.hdr**
Save as Type –**Text Document**
Directory –**c:\GeoSFM\Zobler**

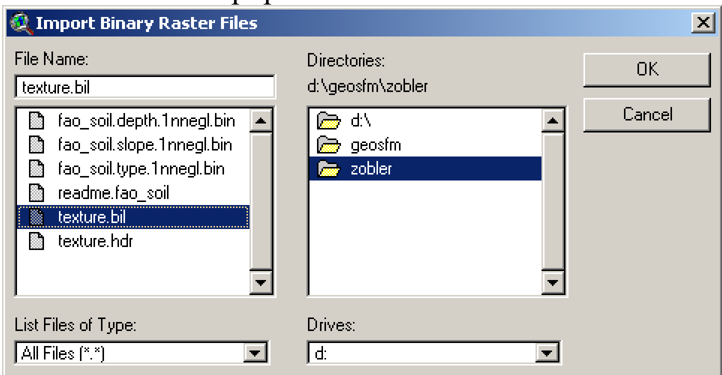
Next, you will import the **texture.bil**; from the **File** menu select **Import Data Source**.



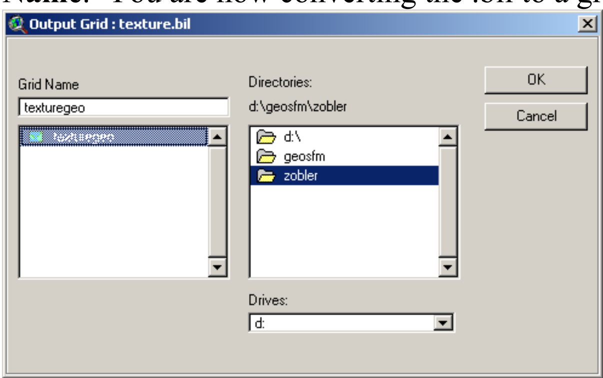
The **Import Data Source** dialog box is displayed; from the drop down list select **Binary Raster**. Click **OK**.



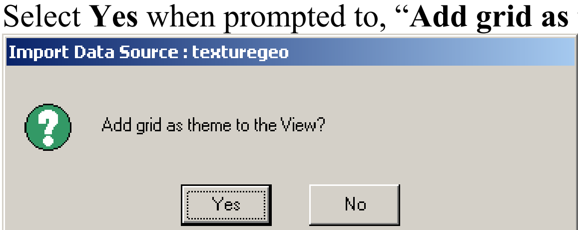
Navigate to your directory, change the **List Files of Type: to All Files (*.*)**. Now you can select the **texture.bil** to populate **the File Name**. Click **OK**.



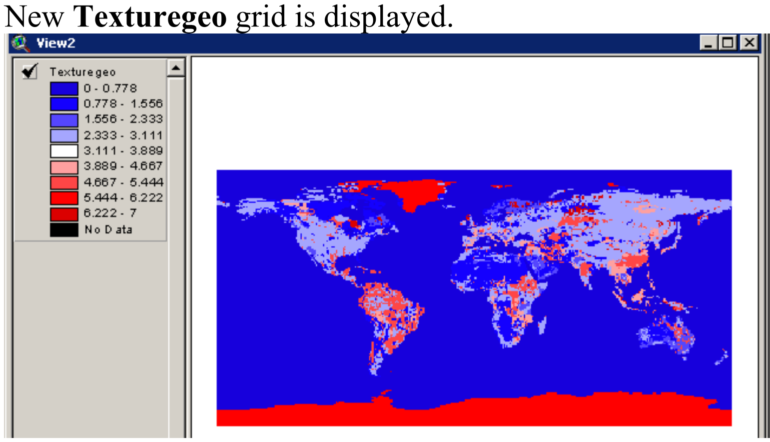
The **Output Grid** dialog box opens, navigate to your directory, name your new grid under **Grid Name**. You are now converting the .bil to a grid. Click **OK**.



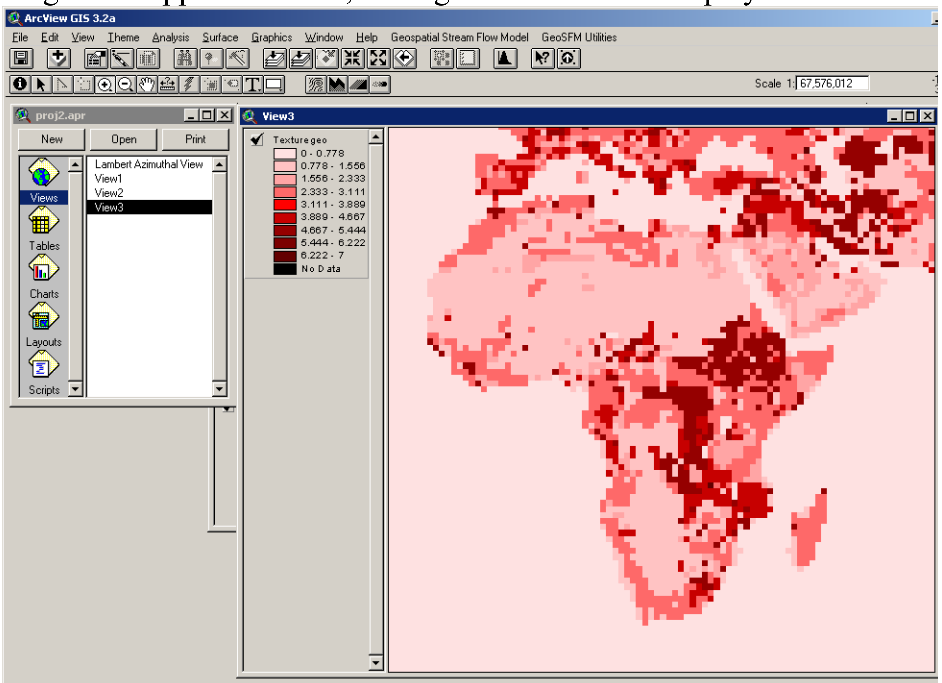
Select **Yes** when prompted to, “**Add grid as theme to the View?**”



New **Texturegeo** grid is displayed.

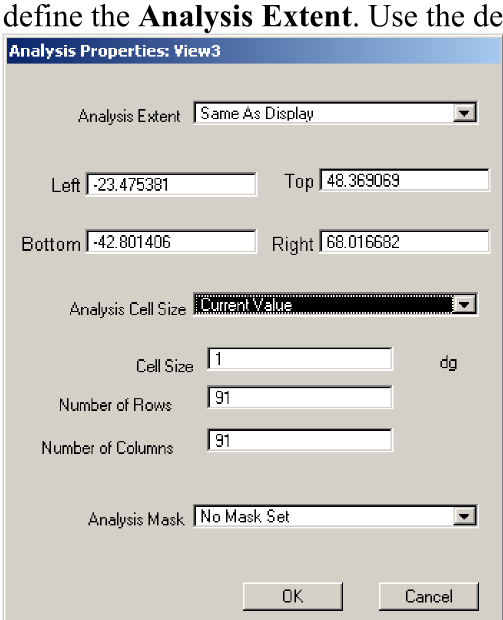


Zoom into the continent of Africa by clicking on the **zoom icon** and putting a box around Africa. To accomplish this, click on one corner of the area you want to capture, hold the mouse button and drag to the opposite corner, boxing in Africa.   See display below.

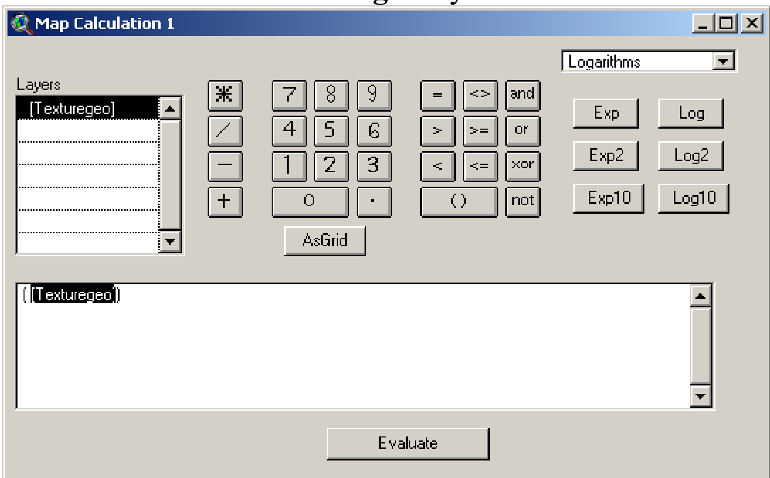


Now, you will set the analysis extent to the display, so you can clip the African continent (what is captured in our display area) from the global data set.

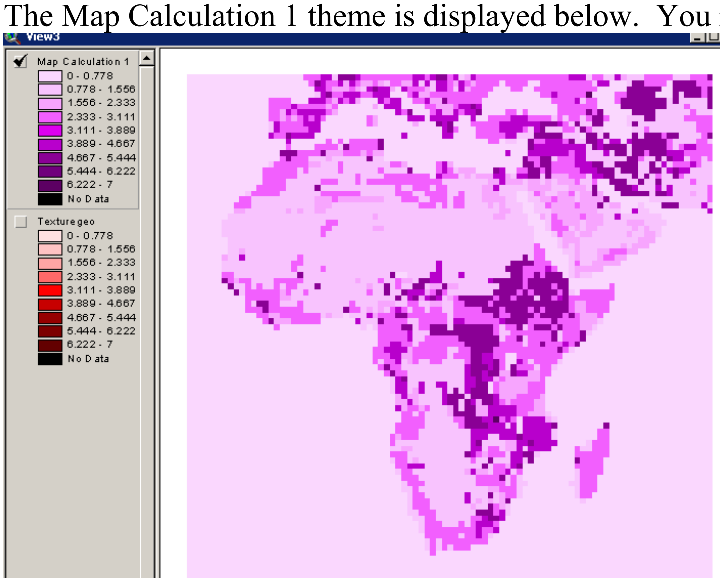
From the **Analysis** menu select **Properties**. Select **Same As Display** from the drop down list to define the **Analysis Extent**. Use the default values for all other fields. Click **OK**.



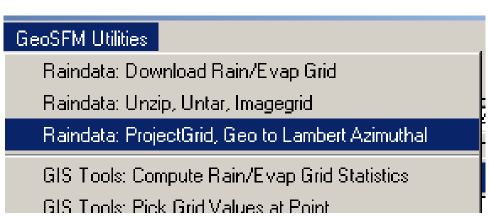
The **Analysis extent** is now defined; using the **Map Calculator** you can clip the extent area from the global data area. To accomplish this, click on the **Analysis** menu and select **Map Calculator**, from here select the **Texturegeo** layer. Click **Evaluate**.



The Map Calculation 1 theme is displayed below. You now have a grid of Africa.

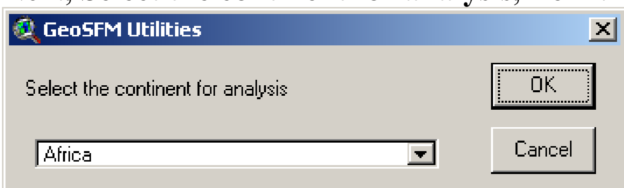


Next, you will project the grid in the Lambert Equal-Area Azimuthal projection to match the other data sets used in the GeoSFM. You will use the GeoSFM Utilities tool to project the grid; from the GeoSFM Utilities menu select Raindata: ProjectGrid, Geo to Lambert Azimuthal. Normally, this function is used for projecting rain and PET data, but you can project any grid except for large global data sets.

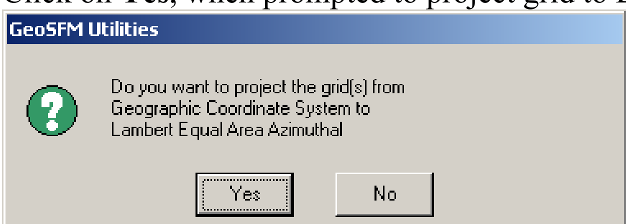


In the first window **Specify your working directory**. Click **OK**.

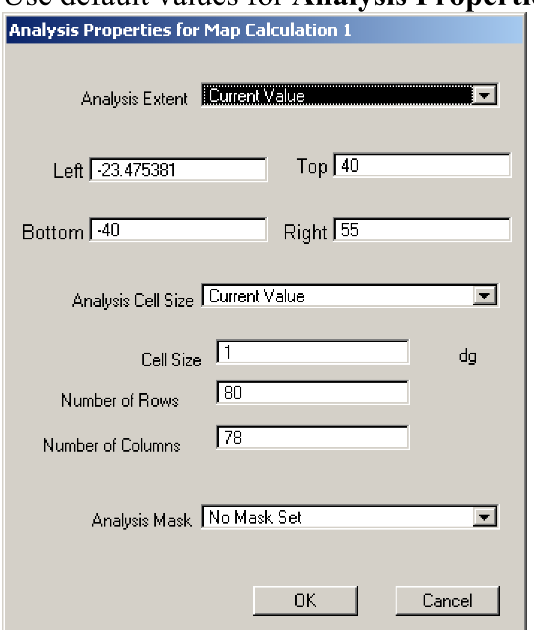
Next, **Select the continent for analysis**, from the drop down list select **Africa**. Click **OK**.



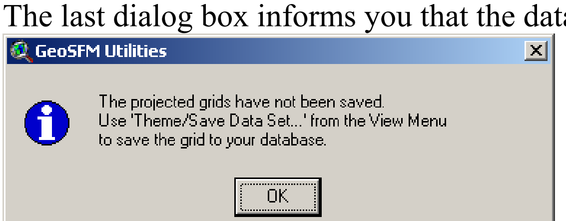
Click on **Yes**, when prompted to project grid to Lambert Equal-Area Azimuthal.



Use default values for **Analysis Properties**. Click **OK**.

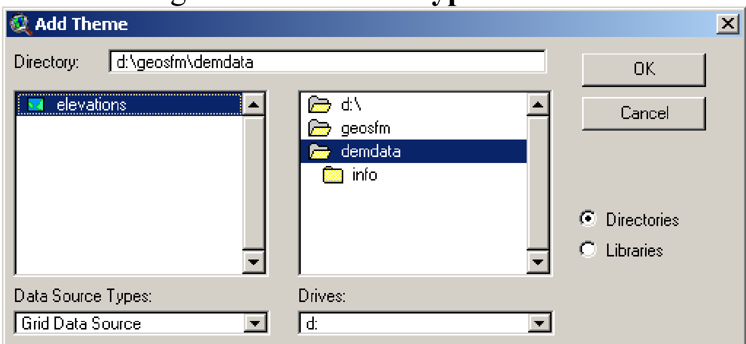


The last dialog box informs you that the data set will need to be saved. Click **OK**.

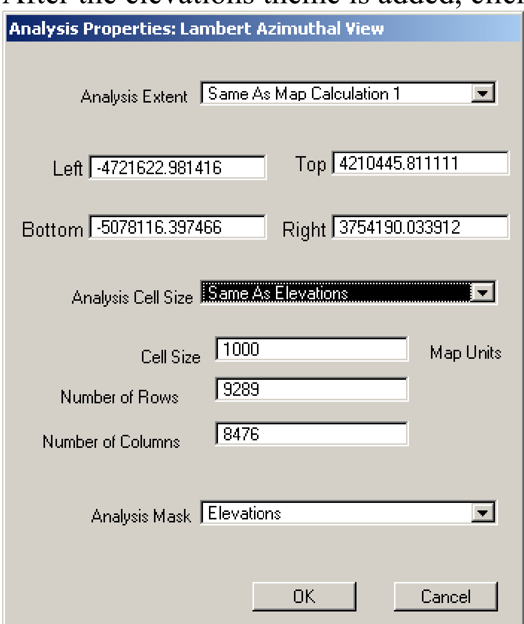


Before you save the data set, you will need to change the cell size to match the cell size of the other data you are using.

First, you need to add the **elevations** grid. Click on the **Add theme** icon. Navigate to the demdata folder. Change the **data source type** to **Grid Data Source**, select **elevations**. Click **OK**.



After the elevations theme is added, click on the **Analysis** menu and select **Properties**.



Populate:
Analysis Extent –
Same As Map Calculation 1

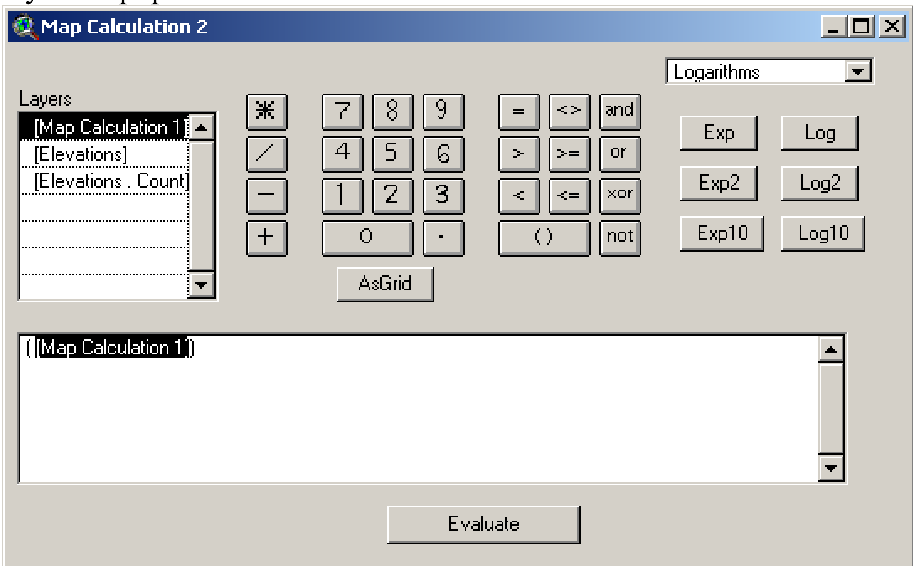
Analysis Cell Size –
Same As Elevations

Analysis Mask –
Elevations

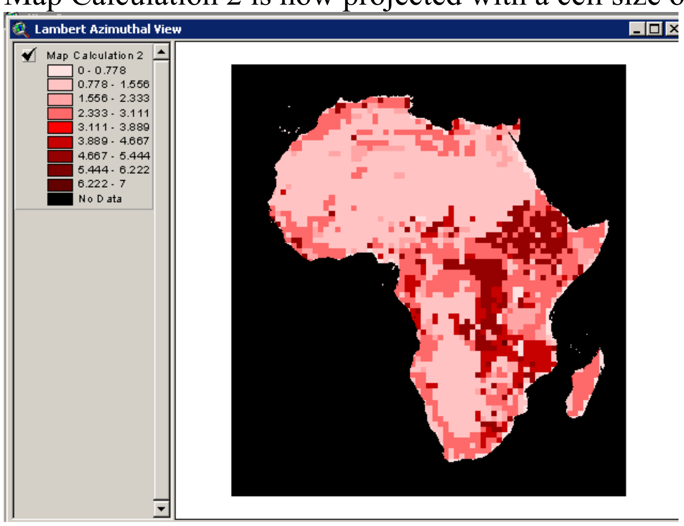
Click **OK**.

Now, you have the cell size defined you need to re-sample the **Map Calculation 1**.

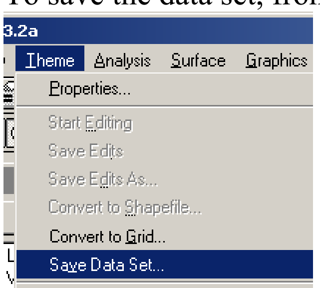
From the **Analysis** menu select **Map Calculator**. Double click on the **Map Calculation 1** under layers to populate evaluate window. Click **Evaluate** button.



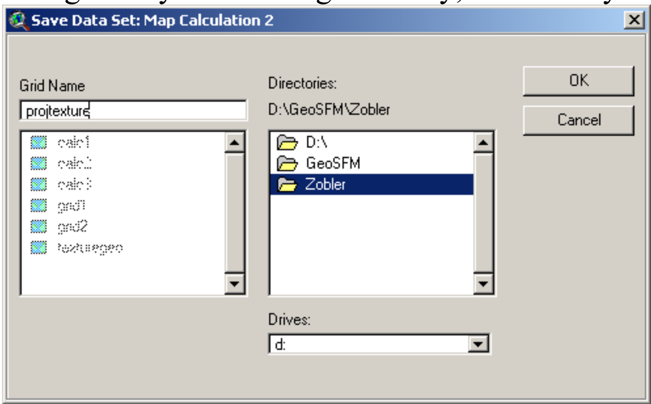
Map Calculation 2 is now projected with a cell size of a 1000.



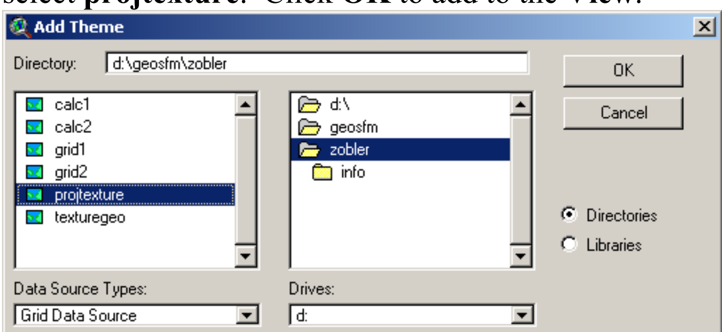
To save the data set, from the **Theme** menu select **Save Data Set**.



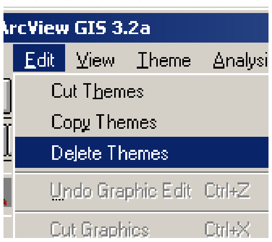
Navigate to your working directory, and name your new grid. Click **OK**.



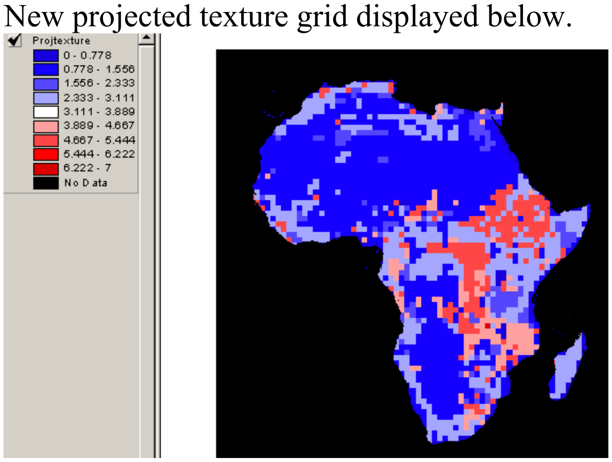
Add the **projtexture** file to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your working directory and select **projtexture**. Click **OK** to add to the **View**.



To delete the **Map Calculation 2**, select the theme in your table of contents. Then from the **Edit** menu select **Delete Themes**.

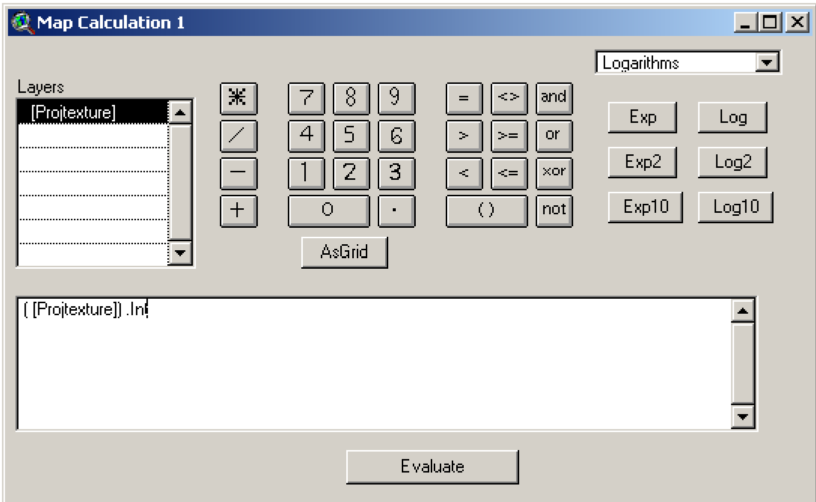


New projected texture grid displayed below.

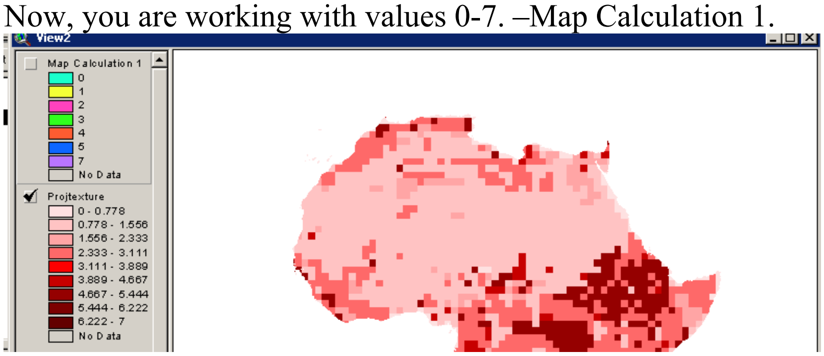


Next, you need to convert the seven different texture classes to GeoSFM’s three classes.

To begin this process you need to work with integers. From the **Analysis** menu select the **Map Calculator**. Double click on **projtexture** to populate the evaluation window, type in the following expression exactly as shown:
([Projtexture]) .Int
Click **Evaluate**.

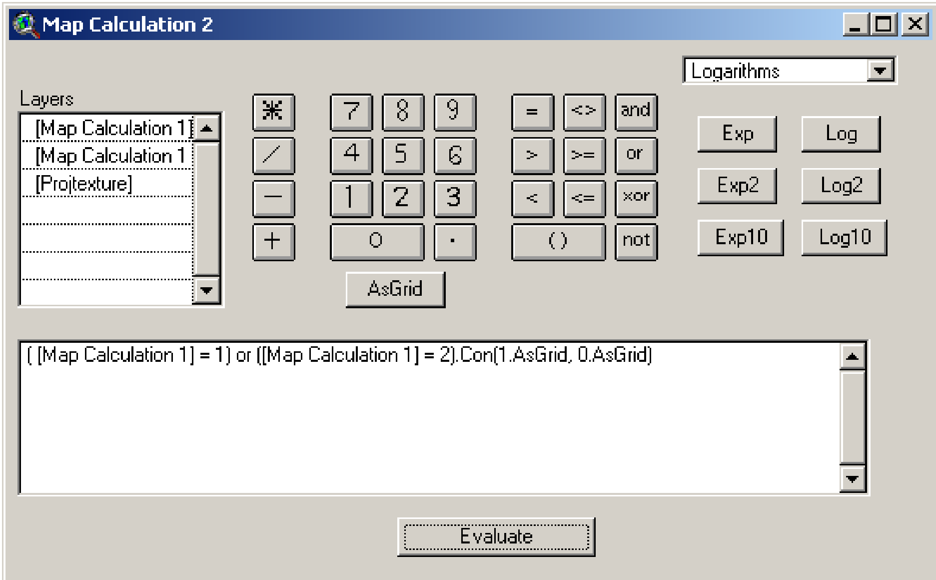


Now, you are working with values 0-7. –Map Calculation 1.

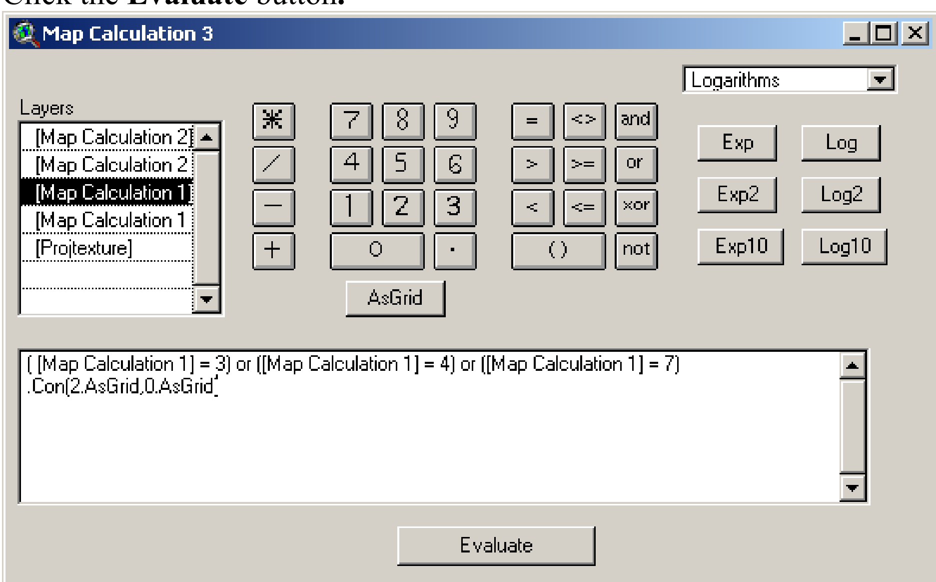


Next, you will define GeoSFM class 1, which will be classes 1 and 2 from the Map Calculation1 theme.

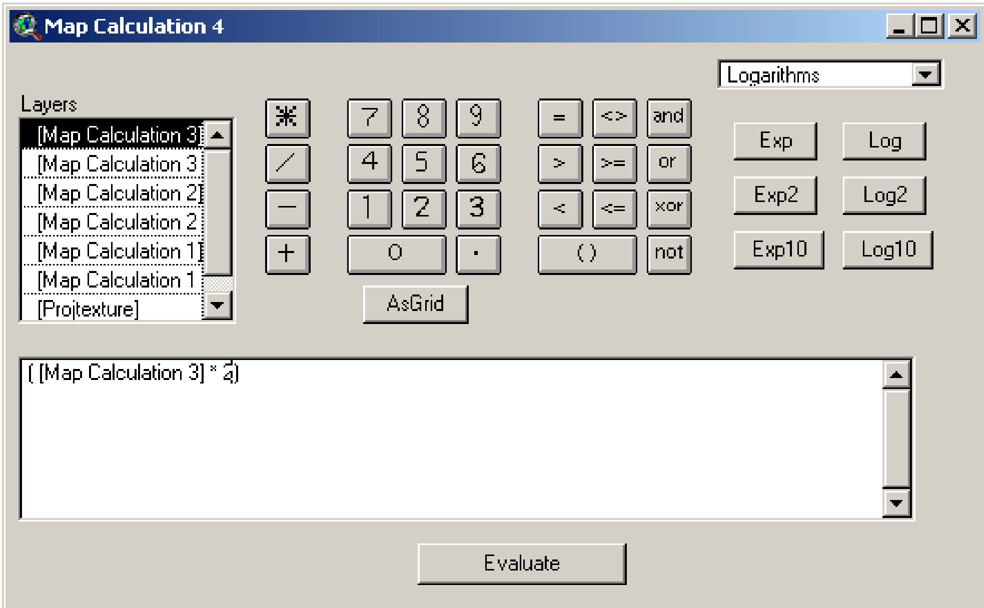
From the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 1] = 1) or ([Map Calculation 1] = 2).Con(1.AsGrid, 0.AsGrid)
Click the **Evaluate** button**.**



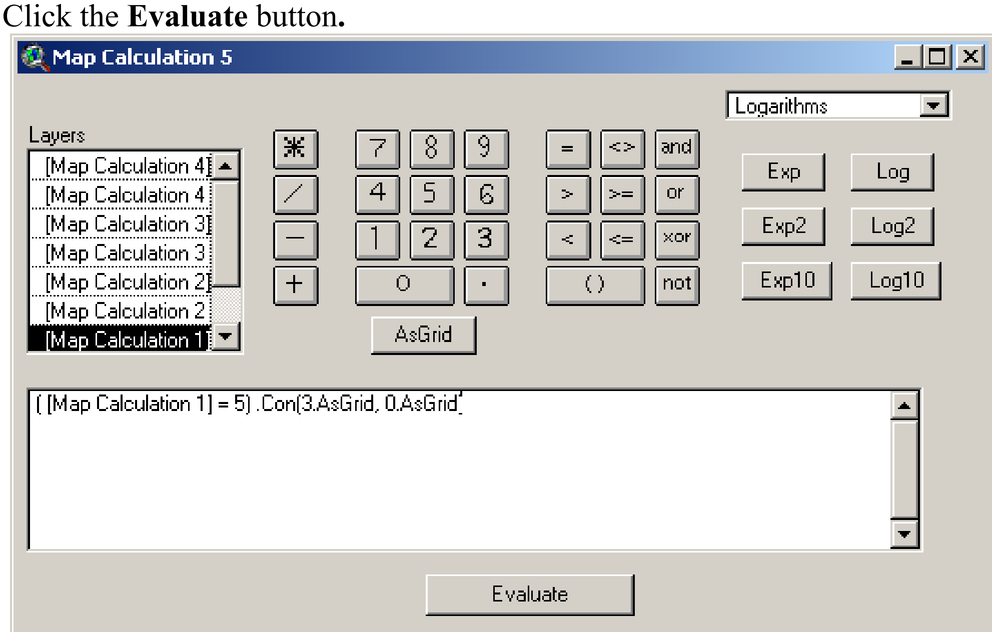
Next, you will define GeoSFM class 2, which are classes 3, 4 and 7 from the Map Calculation1 theme. From the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 1] = 3) or ([Map Calculation 1] = 4) or ([Map Calculation 1] = 7).Con(2.AsGrid, 0.AsGrid)
Click the **Evaluate** button**.**



To change the grid value from l to 2 for our GeoSFM class 2 you need to perform the following calculation. From the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 3] * 2)
Click the **Evaluate** button**.**

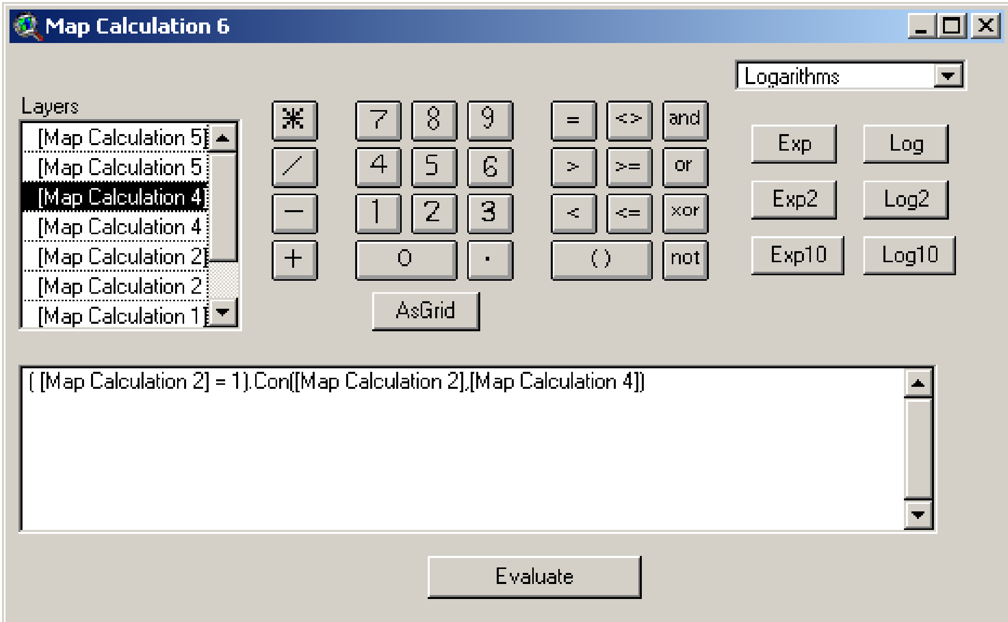


Next, you will define GeoSFM class 3, which is class 5 from the Map Calculation 1 theme. From the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 1] = 5).Con(3.AsGrid, 0.AsGrid)
Click the **Evaluate** button**.**

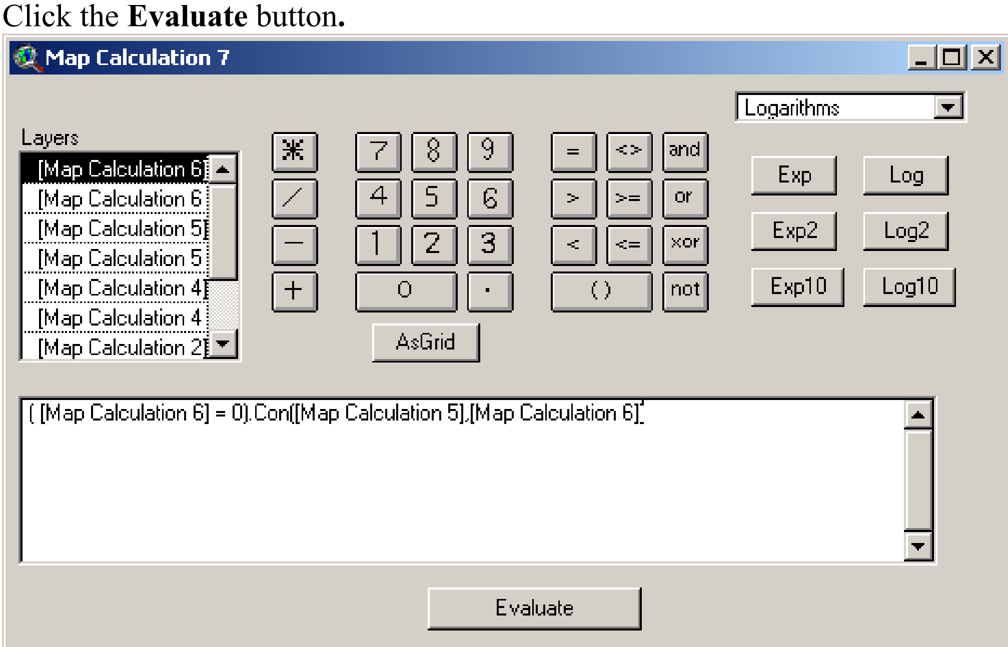


Next, you need to combine the results from Map Calculations 2 and 4 to form a grid that displays 2 classes. Each cell can only carry one value, to prevent an error in cell value by having cell values

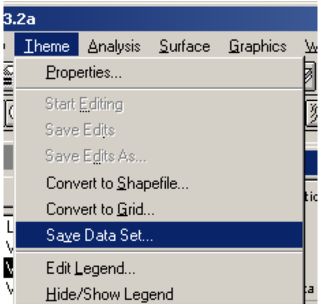
adding together, you will combine the data as follows: from the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 2] = 1).Con([Map Calculation 2],[Map Calculation 4])
Click the **Evaluate** button**.**



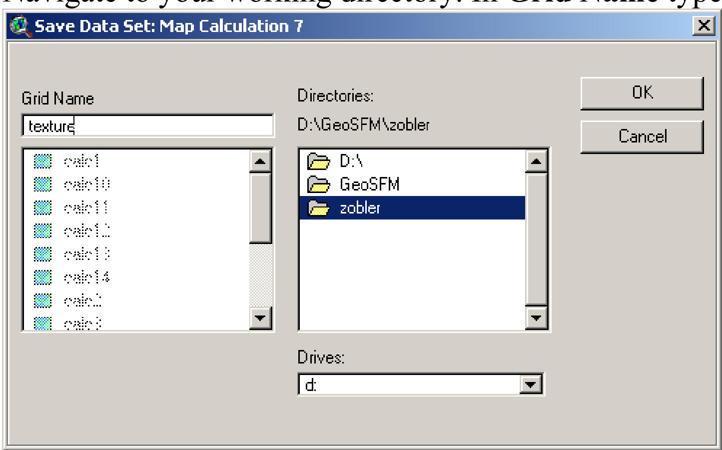
For the final calculation, you will include the third class to create a grid with all three classes. From the **Analysis** menus select **Map Calculator,** type in the following expression exactly as shown:
([Map Calculation 6] = 0).Con([Map Calculation 5],[Map Calculation 6])
Click the **Evaluate** button**.**



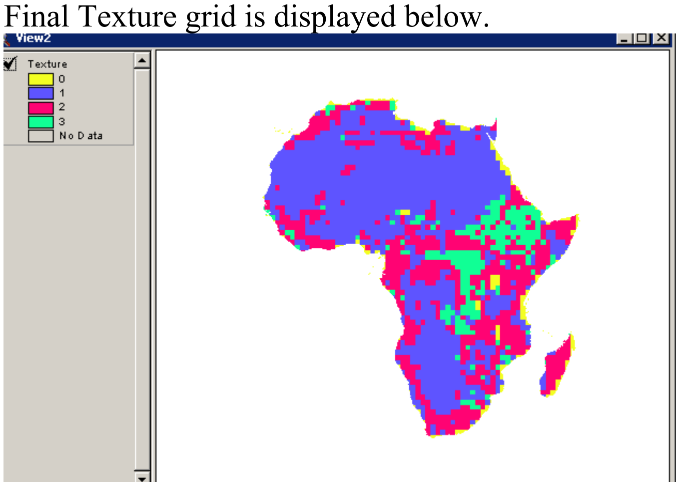
Map Calculation 7 is the final grid with the corrected texture classes. To save this data set, click on Map Calculation 7 to activate the theme in the table of contents, from the **Theme** menu select **Save Data Set**.



Navigate to your working directory. In **Grid Name** type **texture** as your new grid name. Click **OK**.



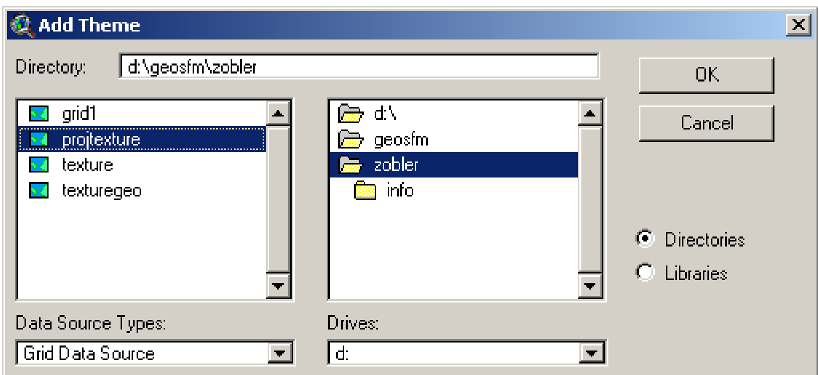
Final Texture grid is displayed below.



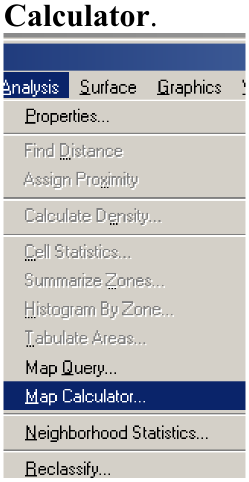
Hydraulic Conductivity

The third soil characteristic grid you will create is Ks. This is the hydraulic conductivity and is based on the seven Zobler texture classes defined in the instructions for creating the texture grid.

First, you will add the **projtexture** grid used in defining the texture classes. Add the **projtexture** file to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your working directory and select **projtexture**. Click **OK** to add to the **View**.



To begin this process you need to work with integers. From the **Analysis** menu select the **Map Calculator**.

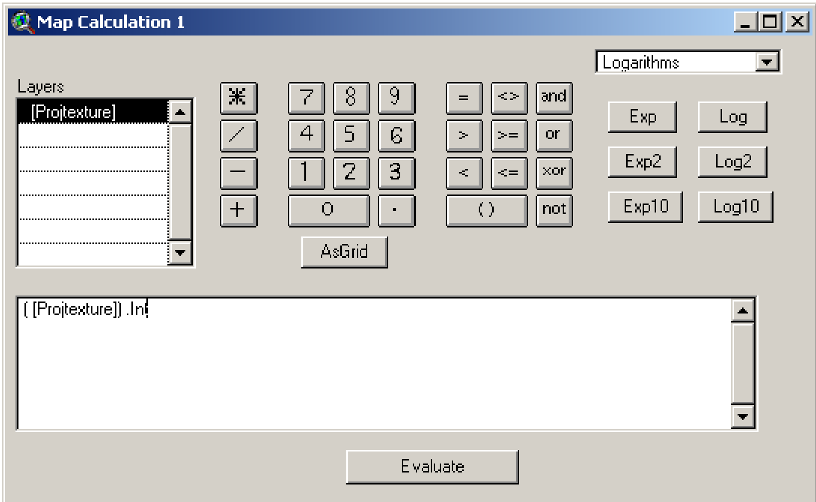


This opens the **Map Calculator** window.

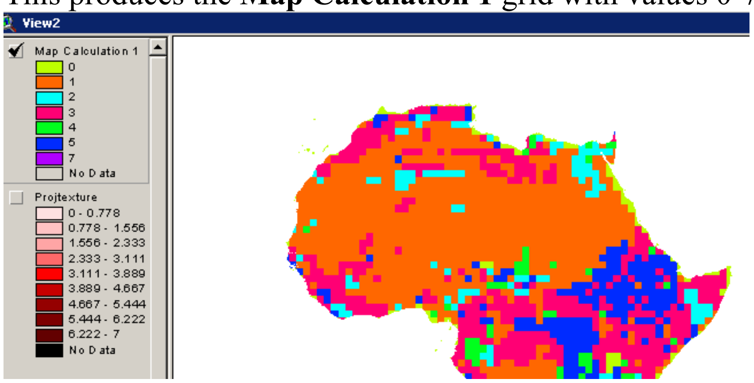
Double click on **projtexture** to populate the evaluation window, type in the following expression exactly as shown:

([Projtexture]) .Int

Click **Evaluate**.



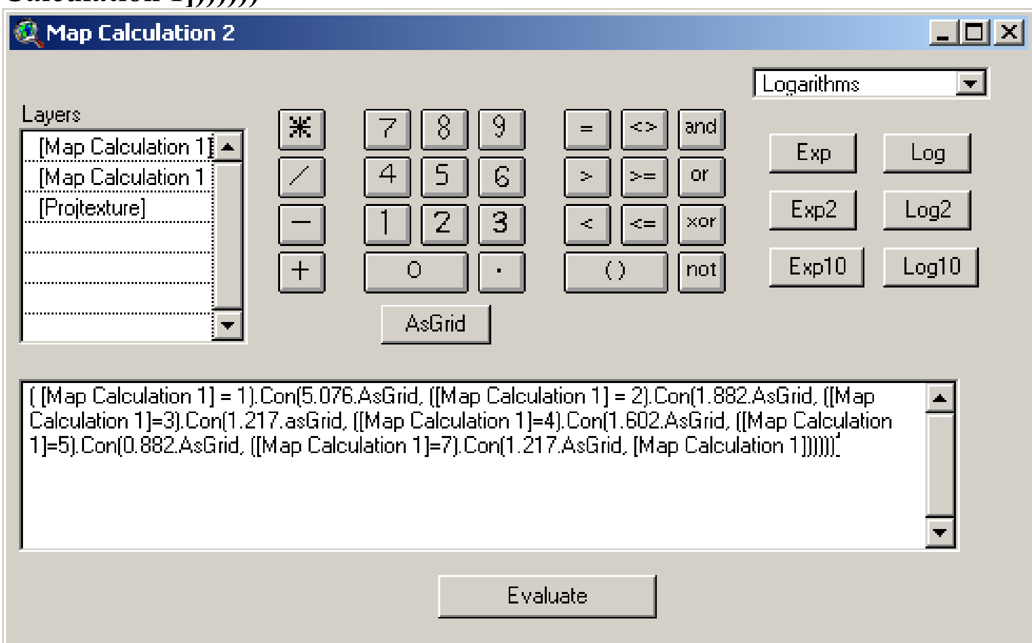
This produces the **Map Calculation 1** grid with values 0-7.



Next, you need to use the Ks values found in **Table 1.2** (*in the Soil Characteristic Data Sources above*.) Notice the relationship of the Ks values to the original seven texture classes. This is why you are using the projtexture grid generated in the texture processing above.

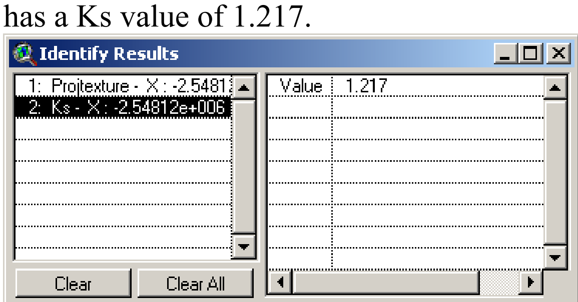
From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:

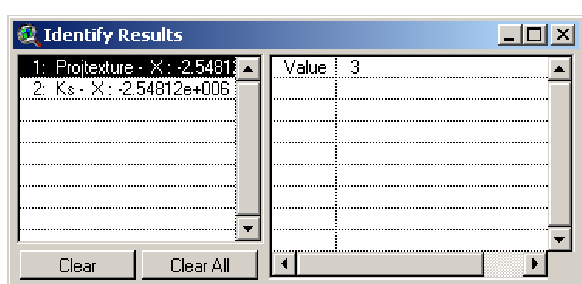
([Map Calculation 1] = 1).Con(5.076.AsGrid, ([Map Calculation 1] = 2).Con(1.882.AsGrid, ([Map Calculation 1]=3).Con(1.217.AsGrid, ([Map Calculation 1]=4).Con(1.602.AsGrid, ([Map Calculation 1]=5).Con(0.882.AsGrid, ([Map Calculation 1]=7).Con(1.217.AsGrid, [Map Calculation 1]))))))



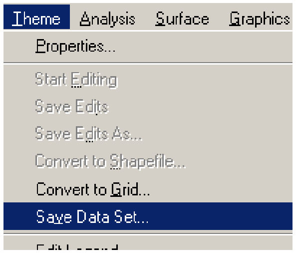
Once the new grid is created you can check your data values by selecting both, your new grid (Ks or Map Calculation 2) and the projtexture or Map Calculation 1 grid. To select more than one **Theme** at a time hold down the shift key while making your selections. Click on the **Identify icon** and then click on a cell in your grid.

The **Identify Results** window will open showing the values. If the Ks grid is highlighted in the table the Ks value will display, **1.217** as shown below. If the projtexture or Map Calculation 1 is highlighted than the value is **3**. This corresponds with our original table, where the texture value 3 has a Ks value of 1.217.

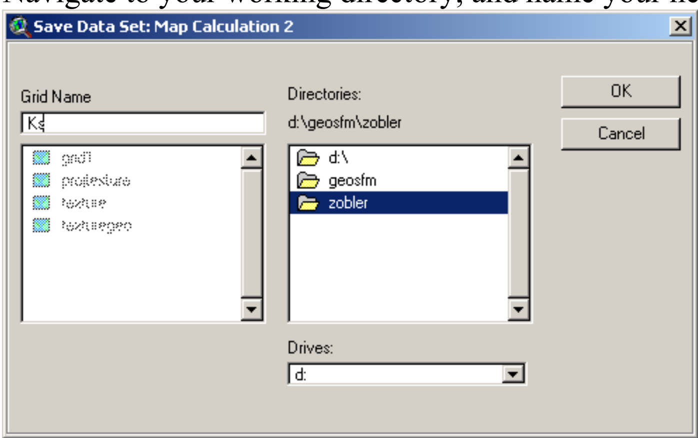




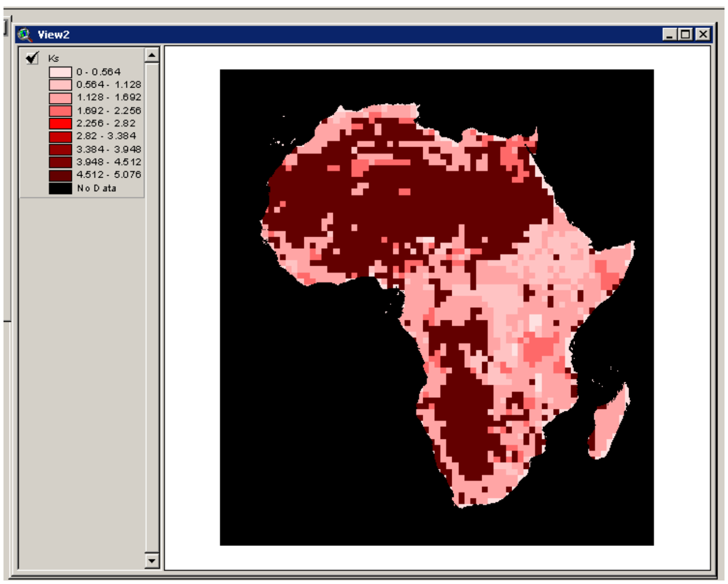
The **Map Calculation 2** grid is the final Ks grid, so we will save this data set. From the **Theme** menu select **Save Data Set**.



Navigate to your working directory, and name your new grid **Ks**. Click **OK**.



Add the **Ks** grid to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your working directory and select **Ks**. Click **OK** to add to the **View.** The other **Themes** can be deleted by selecting the themes and then from the **Edit** menu select **Delete Themes**. Below is the final Ks grid.

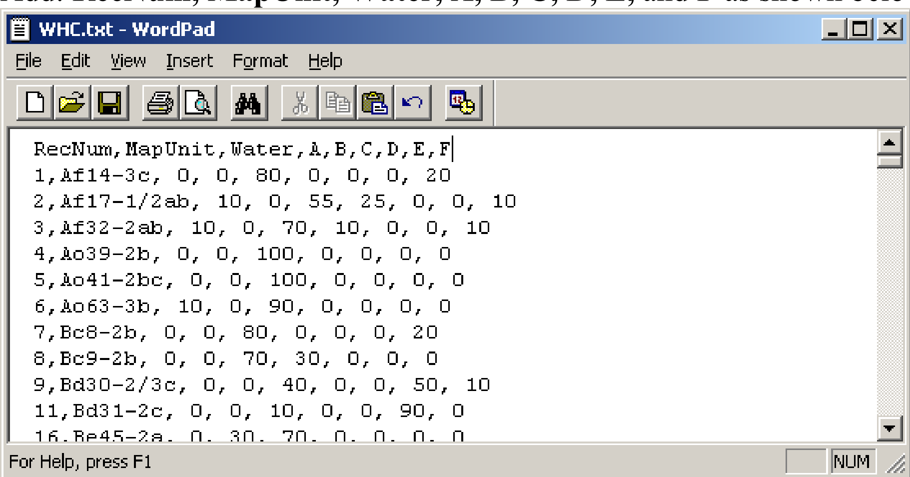


WHC – Soil Water Holding Capacity

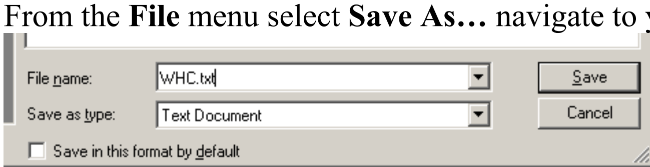
The next soil characteristic grid you will create is the soil water holding capacity grid. The source for this data will be the SMAXl.ASC file found on the FAO Digital Soil Map of the World CD in the FAOSOIL\DATA\folder. You will need to join the data in this file to the **projafrica.shp** file.

Start by opening the **SMAX1.ASC** file in WordPad. Add a line at the top for header information. The file contains a record number, the mapping unit name, and the soil classes of water, A, B, C, D, E, and F.

Add: **RecNum, MapUnit, Water, A, B, C, D, E,** and **F** as shown below.

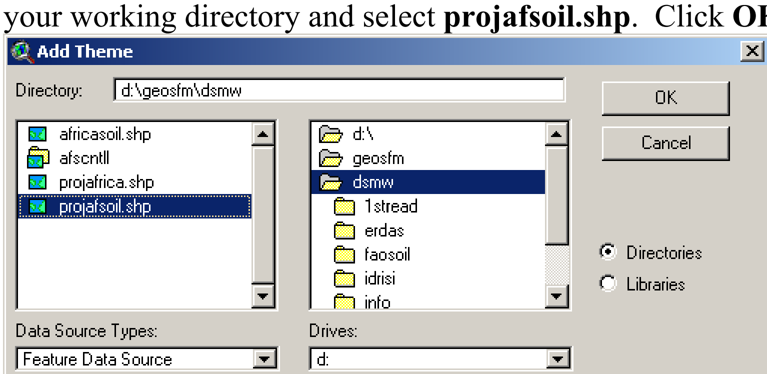


From the **File** menu select **Save As…** navigate to your directory.

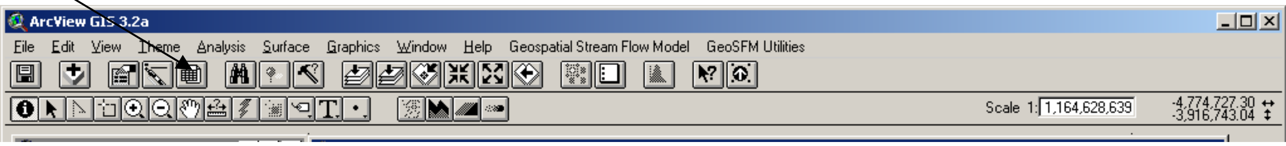


Populate:
File name:
WHC.txt
Save as type:
Text Document

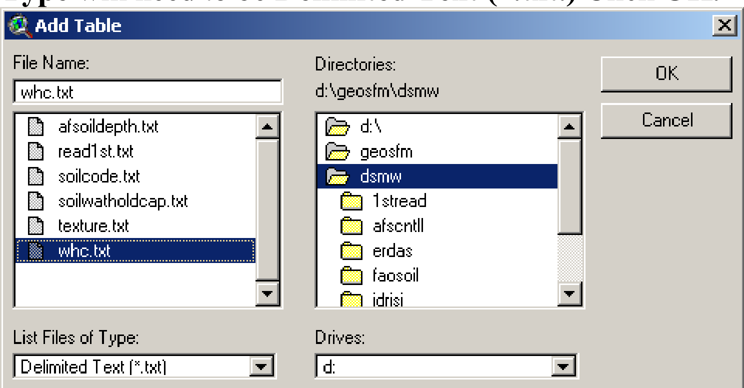
Next, add the projafsoil.shp to the View. Add the shapefile to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Feature Data Source**. Navigate to your working directory and select **projafsoil.shp**. Click **OK** to add to the **View.**



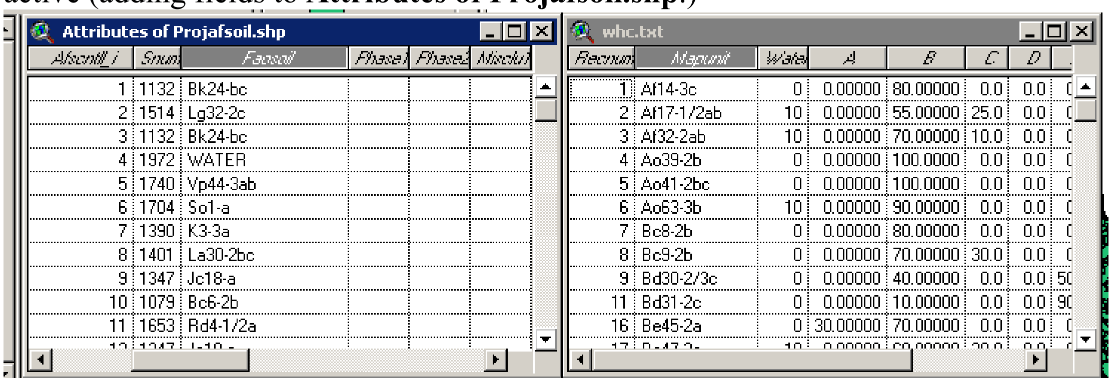
In **View** click on the **projafsoil.shp** so it appears in a raised box, click on the open theme **table** icon.



Next, you need to add the new **whc.txt** to the **View**. From the project window select **Tables** and than click the **Add** button. Navigate to your working directory and select **whc.txt, List Files of Type** will need to be **Delimited Text (*.txt.)** Click **OK.**



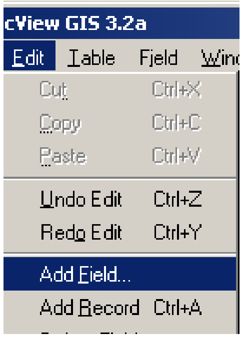
Arrange both tables as seen below. Click/highlight the common column headers in both tables – **Faosoil** in **Attibutes of projafsoil.shp** and **Mapunit** in **whc.txt** file. Make the destination table active (adding fields to **Attributes of Projafsoil.shp**.)



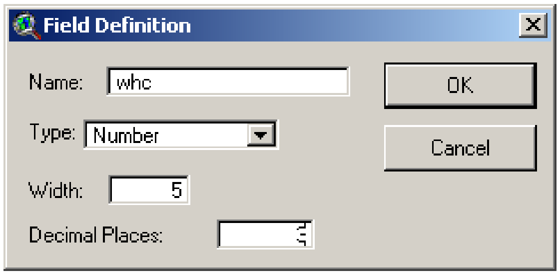
Click on the join icon, the new columns are added to the **Attributes of Projafsoil.shp** table.

Now, you will add a new field to the attribute table. From the **Table** menu select **Start Editing**.

Then from the **Edit** menu select **Add Field**.



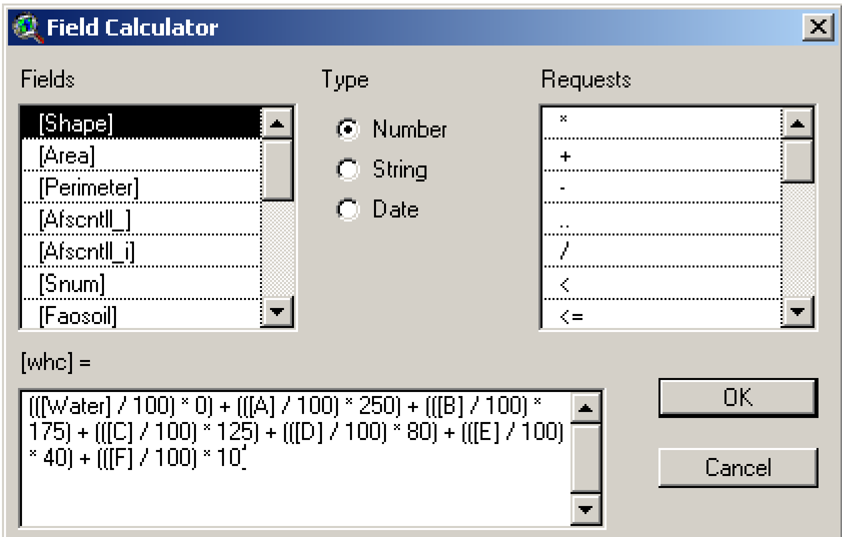
The **Field Definition** box opens.
Populate:
Name: whc
Type: Number
Width: 5
Decimal Places: 3



Click **OK**.

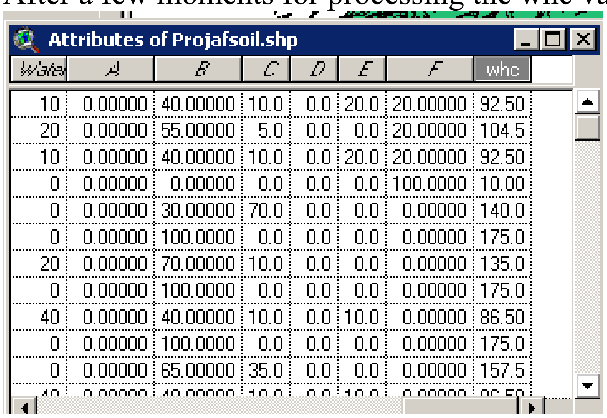
Select the **calculator** icon on the tool bar.

This will display the **Field Calculator,** enter the following expression:
(([Water] / 100) * 0) + (([A] / 100) * 250) + (([B] / 100) * 175) + (([C] / 100) * 125) + (([D] / 100) * 80) + (([E] / 100) * 40) + (([F] / 100) * 10)
Click **OK.**



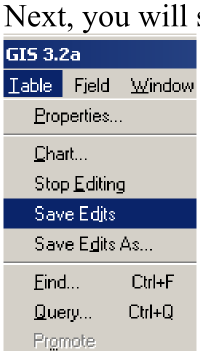
The water, A, B, C, D, E, and F values correspond with the soil class values listed in the attribute table. The values that are multiplied are the median soil moisture, total available water found in Table 1.2.

After a few moments for processing the whc values are populated in the new column.

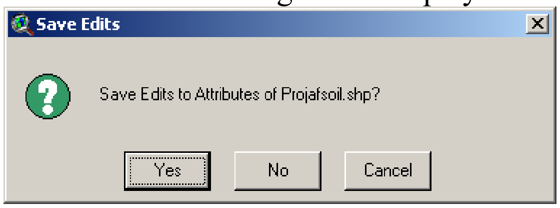


Water	A	B	C	D	E	F	whc
10	0.00000	40.00000	10.0	0.0	20.0	20.00000	92.50
20	0.00000	55.00000	5.0	0.0	0.0	20.00000	104.5
10	0.00000	40.00000	10.0	0.0	20.0	20.00000	92.50
0	0.00000	0.00000	0.0	0.0	0.0	100.0000	10.00
0	0.00000	30.00000	70.0	0.0	0.0	0.00000	140.0
0	0.00000	100.0000	0.0	0.0	0.0	0.00000	175.0
20	0.00000	70.00000	10.0	0.0	0.0	0.00000	135.0
0	0.00000	100.0000	0.0	0.0	0.0	0.00000	175.0
40	0.00000	40.00000	10.0	0.0	10.0	0.00000	86.50
0	0.00000	100.0000	0.0	0.0	0.0	0.00000	175.0
0	0.00000	65.00000	35.0	0.0	0.0	0.00000	157.5

Next, you will save the edits, from the **Table** menu select **Save Edits**.



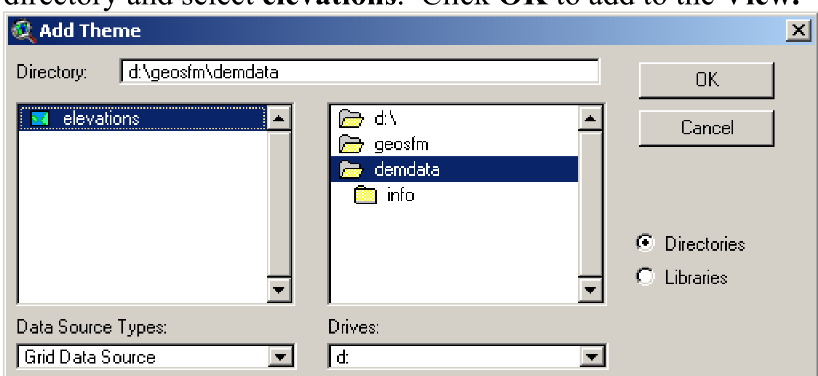
The **Save Edits** dialog box is displayed -click the **Yes** button.



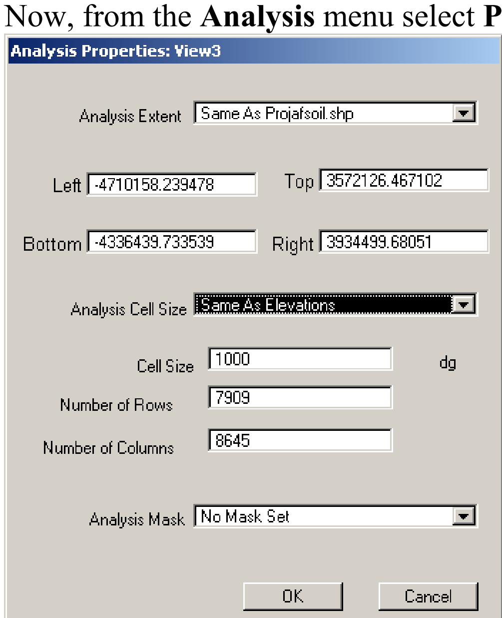
From the Table menu select Stop Editing. This will end the editing secession.

You need to set the **Analysis extent** before you create the new whc grid.

Add the **elevations** grid to the **View**. Add the grid to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your working directory and select **elevations**. Click **OK** to add to the **View.**

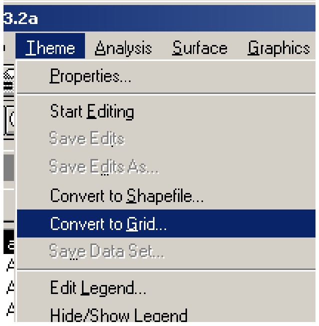


Now, from the **Analysis** menu select **Properties**.   The properties dialog box is displayed.

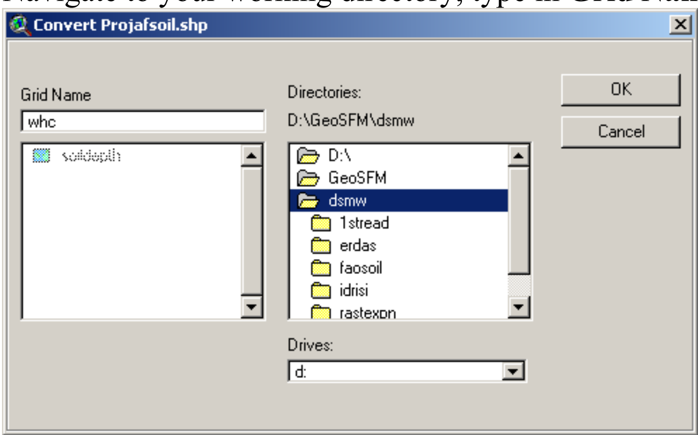


Populate:
Analysis Extent:
Same As Projafsoil.shp
Analysis Cell Size:
Same As Elevations

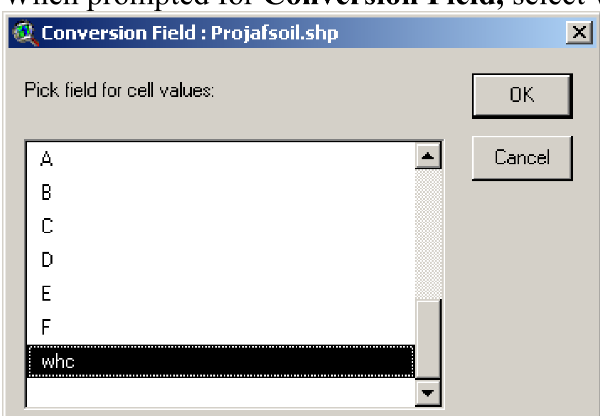
Click **OK**.
From the **Theme** menu select **Convert to Grid**.



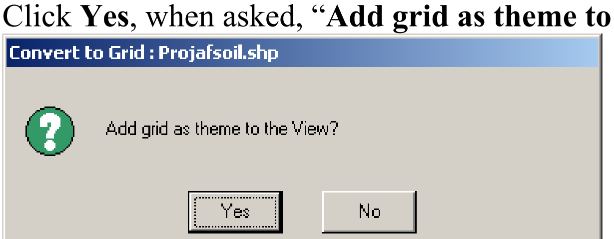
Navigate to your working directory, type in **Grid Name** –whc. Click **OK**.



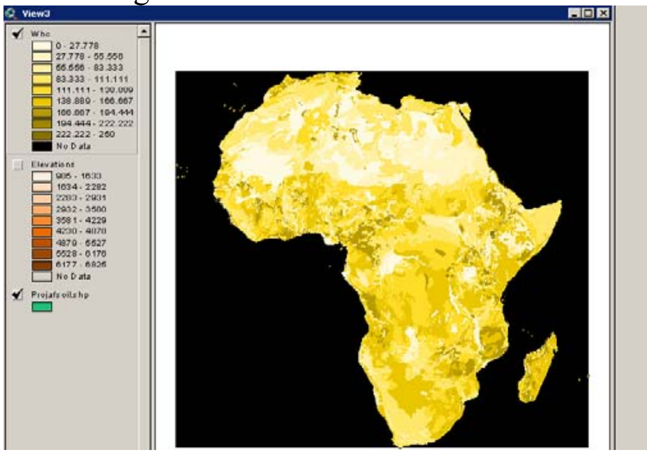
When prompted for **Conversion Field,** select whc from the drop down list. Click **OK**.



Click **Yes**, when asked, "**Add grid as theme to the View?**"



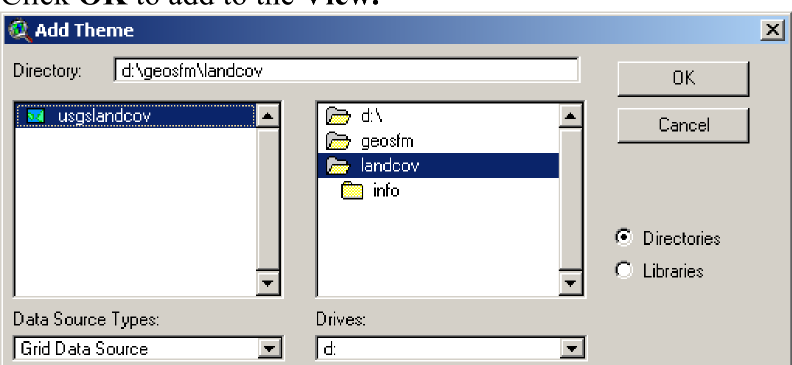
New whc grid is shown below.



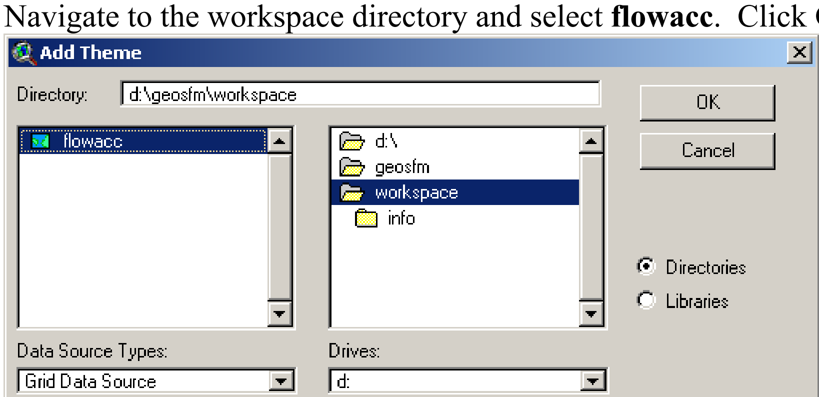
Maxcover

The next soil characteristic grid that you will create is maxcover. It is the area covered by a wetland or water body in the GLCC data or designated as a stream in the flow accumulation grid.

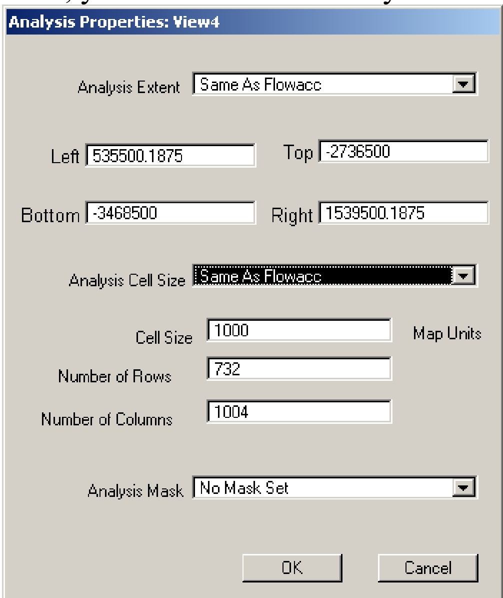
Add the grid to the **View** using **Add Theme button** from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to the land cover directory and select **usgslandcov**. Click **OK** to add to the **View.**



Then add the flow accumulation grid to the **View**. Add the grid to the **View** using **Add Theme button** from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to the workspace directory and select **flowacc**. Click **OK** to add to the **View.**



Next, you will define the analysis extent.

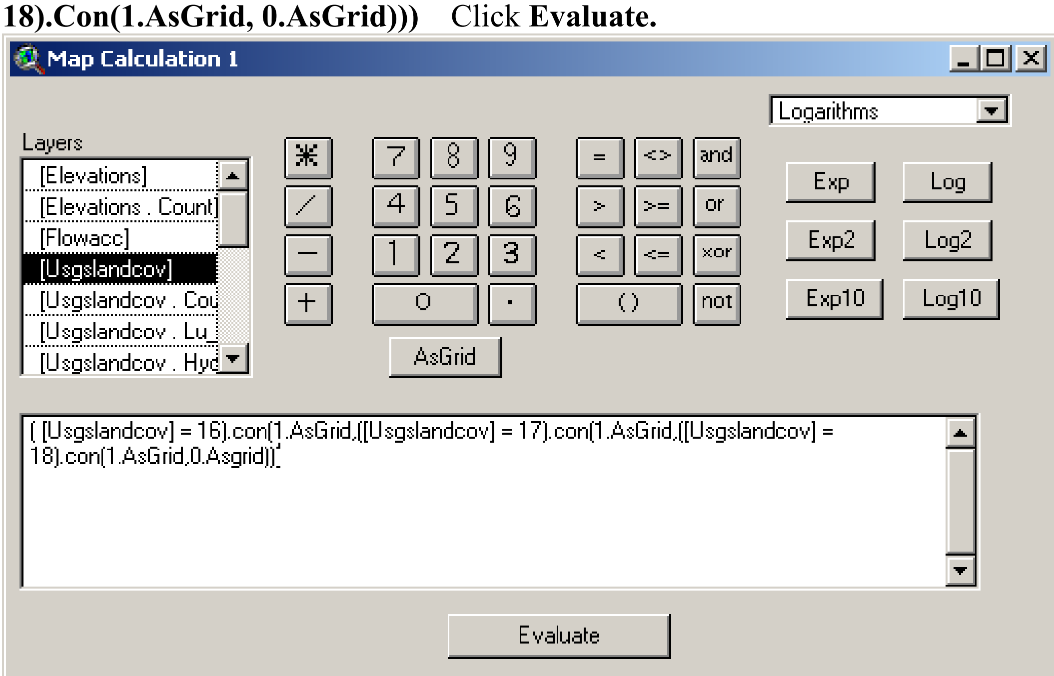


Populate:
Analysis Extent-
Same As Flowacc

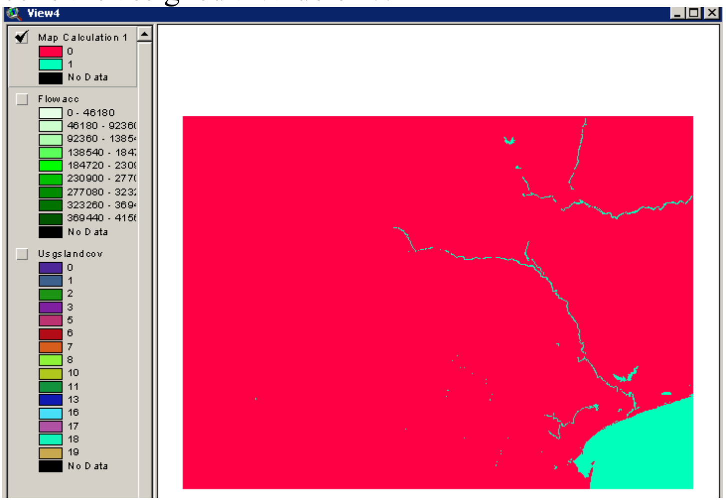
Analysis Cell Size-
Same As Flowacc

Click **OK**.

Next, you will select all water bodies and wetland areas from the landcover grid.
Values: 16 – Water Bodies
17 – Herbaceous Wetland
18 – Wooded Wetland
From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:
([Usgslandcov] = 16).Con(1.AsGrid, ([Usgslandcov] = 17).Con(1.AsGrid, ([Usgslandcov] = 18).Con(1.AsGrid, 0.AsGrid))) Click **Evaluate.**



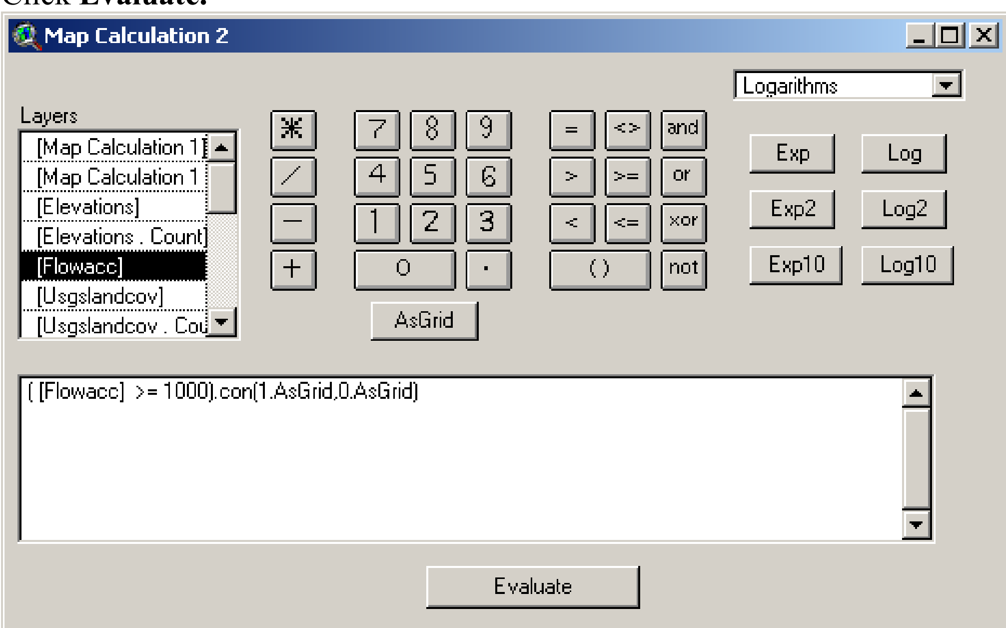
This creates Map Calculation 1 with all water body and wetland cells assigned a value of 1, all other cells are assigned a value of 0.



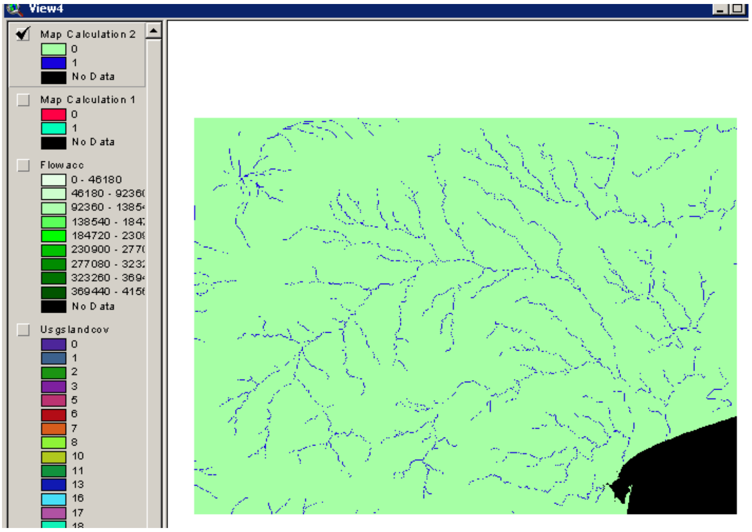
Next, you will select all cells with a value equal to or greater than 1000 in the flow accumulation grid. These cells are defined as streams in the flow accumulation grid. From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:

([Flowacc] >= 1000).Con(1.AsGrid, 0.AsGrid)

Click **Evaluate.**



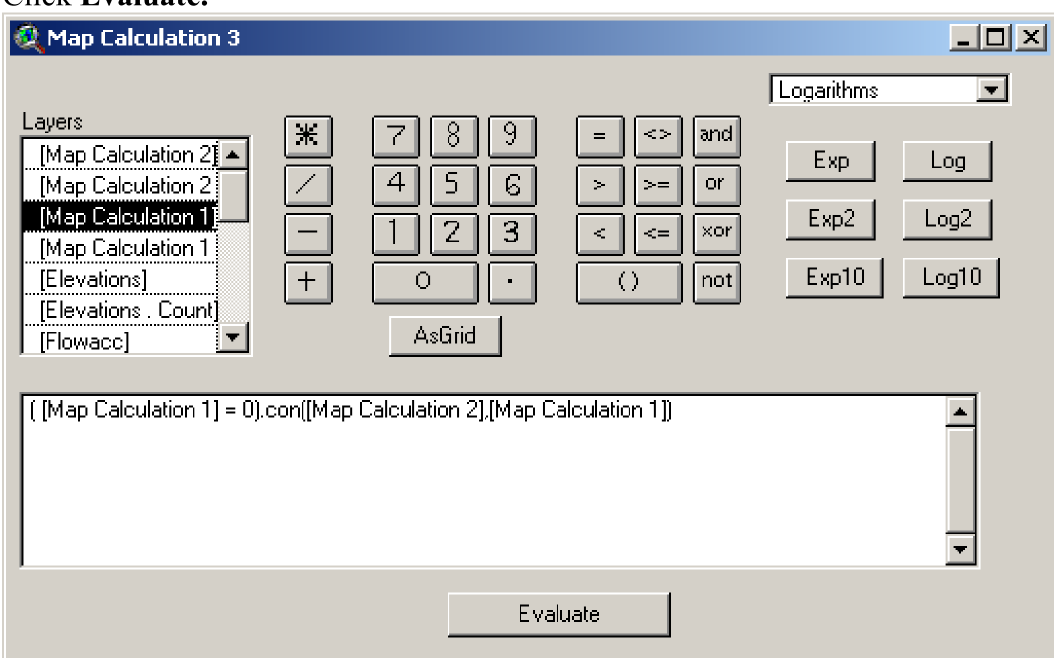
This creates Map Calculation 2 with all stream cells assigned a value of 1, all other cells assigned a value of 0.



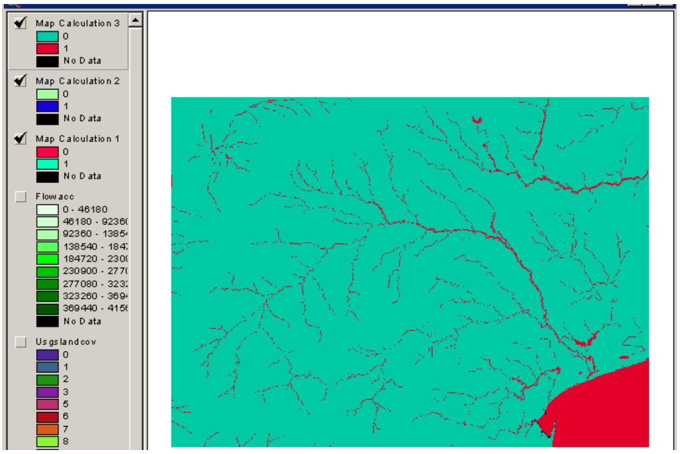
With the next calculation you will combine the water body, wetland, and stream cells in one grid. From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:

([Map Calculation 1] = 0).Con([Map Calculation 2], [Map Calculation 1])

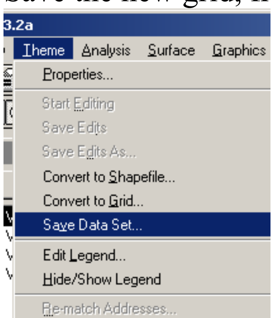
Click **Evaluate.**



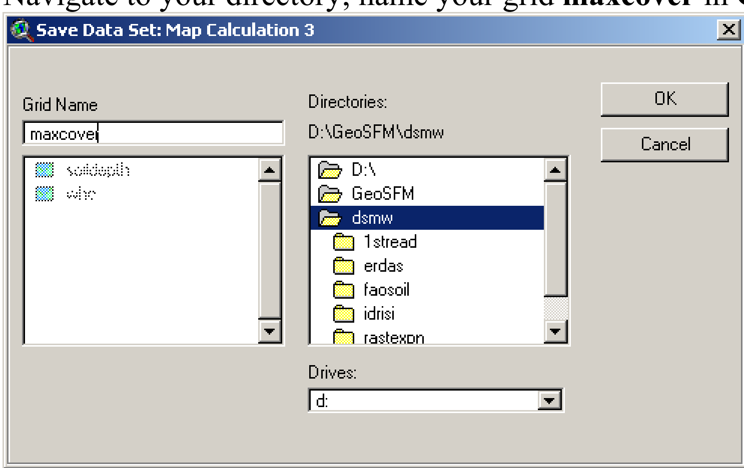
You have created a grid with all water bodies, wetlands, and streams assigned a cell value of one. All other cell values are assigned a value of 0.



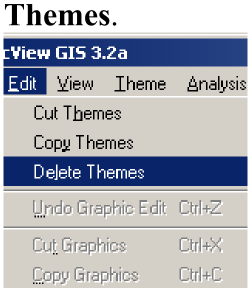
Save the new grid, from the **Theme** menu select **Save Data Set**.



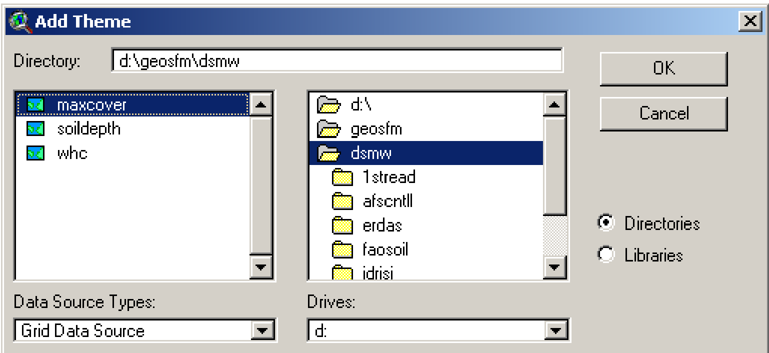
Navigate to your directory; name your grid **maxcover** in **Grid Name**. Click **OK**.



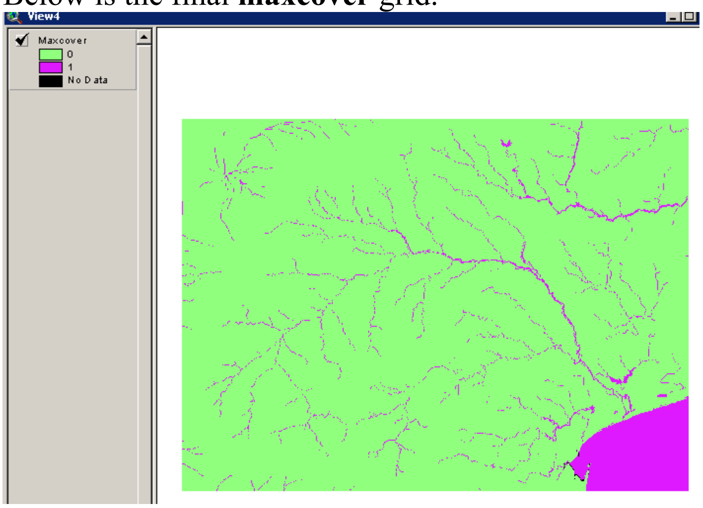
Delete the themes you no longer need from the table of contents. From the **Edit** menu select **Delete Themes**.



Add the new **maxcover** grid to the **View**. Add the grid to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your dsmw directory and select **maxcover**. Click **OK** to add to the **View.**



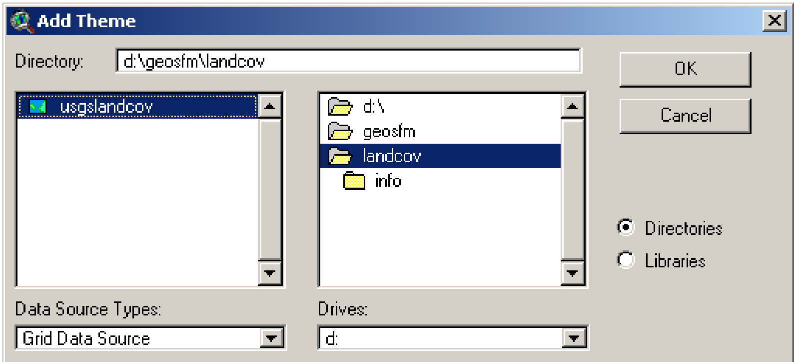
Below is the final **maxcover** grid.



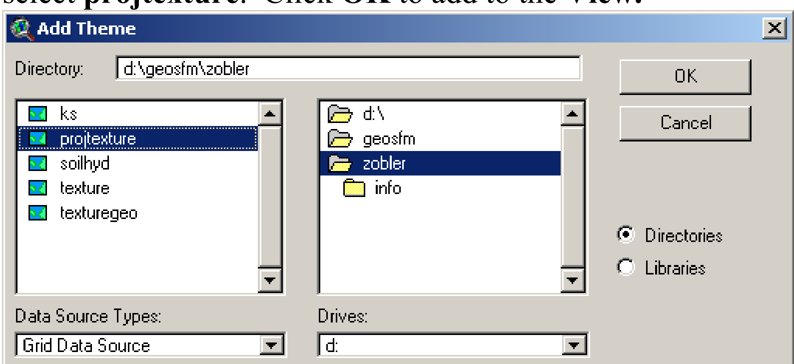
RCN

The last soil characteristic grid you will create is the Soil Conservation Service (SCS) runoff curve number (RCN) grid. The runoff curve numbers are estimated from land cover classes and hydraulic soil groups.

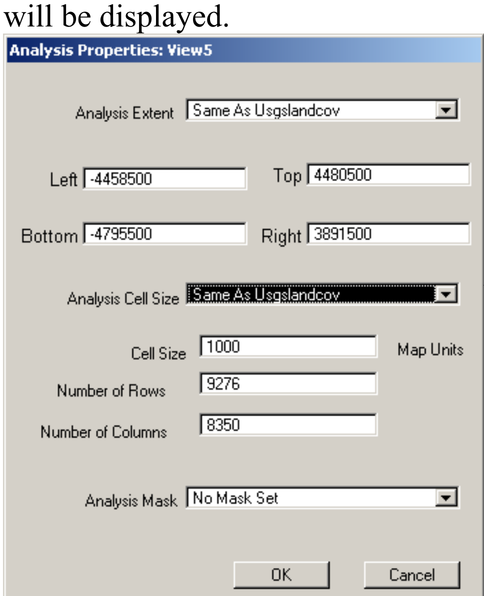
First, you will add the land cover grid. Add the grid to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your land cover directory and select **usgslandcov**. Click **OK** to add to the **View.**



Then add the **protexture** grid. Add the grid to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your directory and select **projtexture**. Click **OK** to add to the **View.**



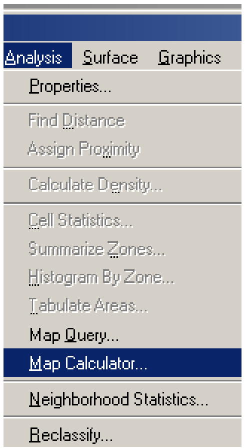
After you have added the landcover and projected texture grids to the view, you will set the **Analysis Extent**. From the **Analysis** menu select **Properties**. The **Analysis Properties** dialog box will be displayed.



Populate:
Analysis Extent-
Same As Usgslandcov

Analysis Cell Size-
Same As Usgslandcov

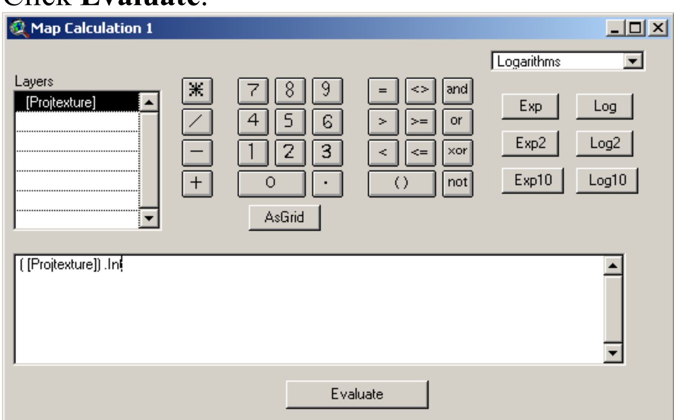
To begin this process you need to work with integers. From the **Analysis** menu select the **Map Calculator**.



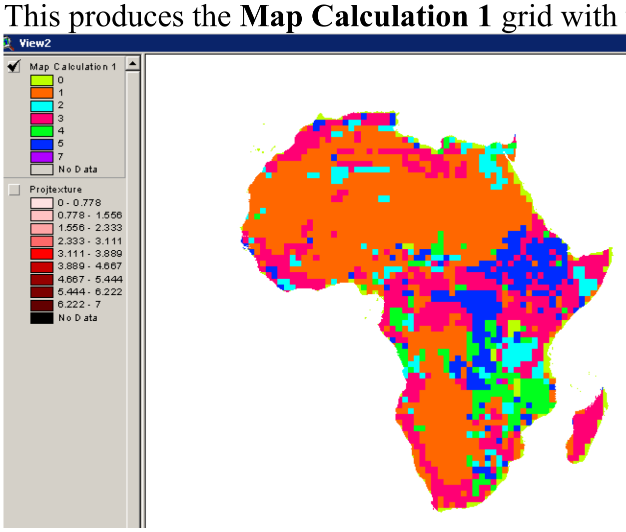
This opens the **Map Calculator** window. Double click on **projtexture** to populate the evaluation window, type in the following expression exactly as shown:

([Projtexture]) .Int

Click **Evaluate**.

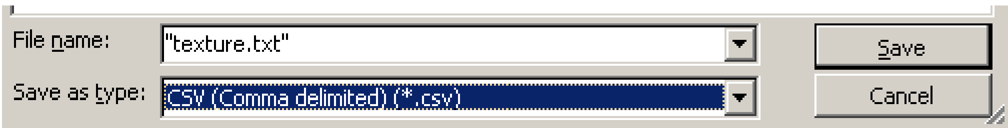


This produces the **Map Calculation 1** grid with values 0-7.



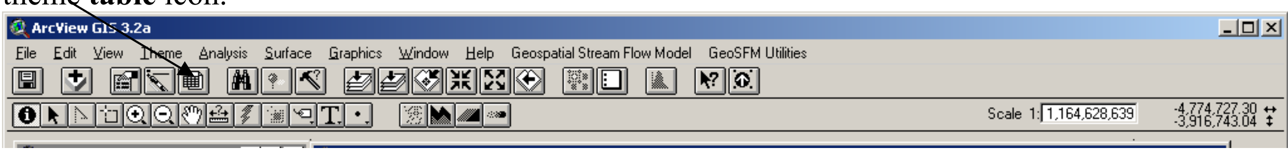
Next, you will create a soil hydraulic class grid. First, you will need to create a text file from **Table 1.2**. (see Soil Characteristic Data Sources) in Excel.

Save as:

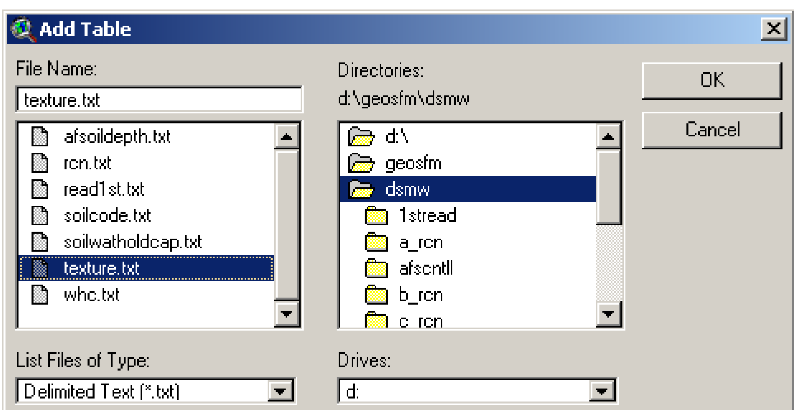


Now you can join the **texture.txt** to the attribute table of **Map Calculation 1**.

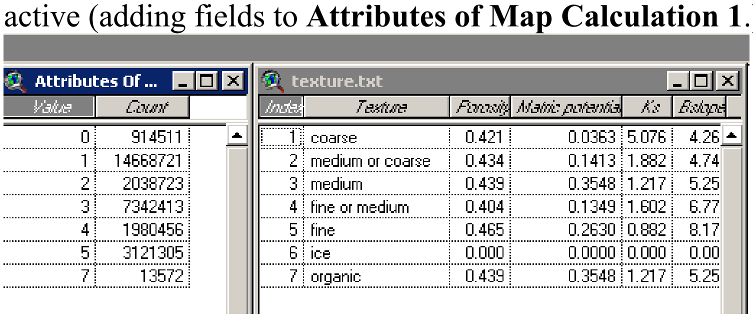
In **View** click on the **Map Calculation 1** theme so it appears in a raised box, click on the open theme **table** icon.



Next, you need to add the new **texture.txt** to the **View**. From the project window select **Tables** and than click the **Add** button. Navigate to your working directory and select **texture.txt, List Files of Type** is set to **Delimited Text (*.txt.)** Click **OK.**



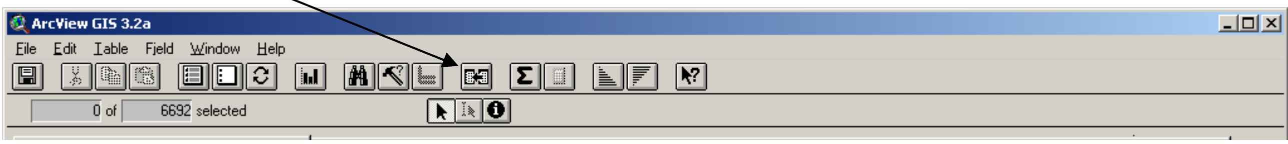
Arrange tables side by side. Click/highlight the common column headers in both tables –**Value** in **Attributes of Map Calculation 1** and **Index** in the **texture.txt** file. Make the destination table active (adding fields to **Attributes of Map Calculation 1**.)



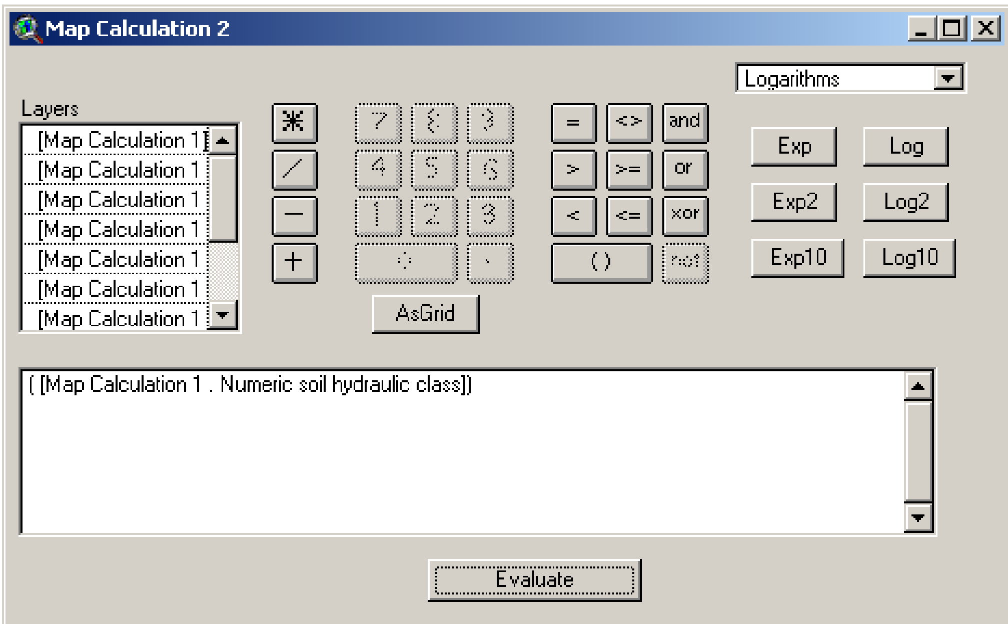
Value	Count
0	914511
1	14668721
2	2038723
3	7342413
4	1980456
5	3121305
7	13572

Index	Texture	Porosity	Matric potential	Ks	Bslope
1	coarse	0.421	0.0363	5.076	4.26
2	medium or coarse	0.434	0.1413	1.882	4.74
3	medium	0.439	0.3548	1.217	5.25
4	fine or medium	0.404	0.1349	1.602	6.77
5	fine	0.465	0.2630	0.882	8.17
6	ice	0.000	0.0000	0.000	0.00
7	organic	0.439	0.3548	1.217	5.25

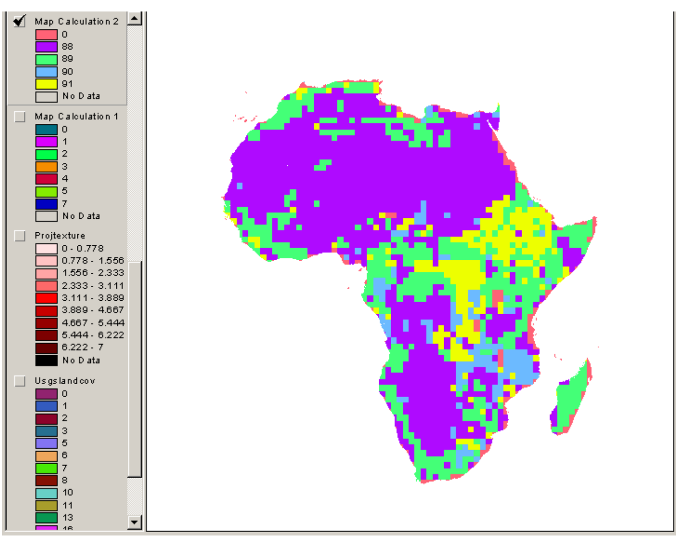
Click on the join icon, the new columns are added to the **Attributes of Map Calculation 1** table.



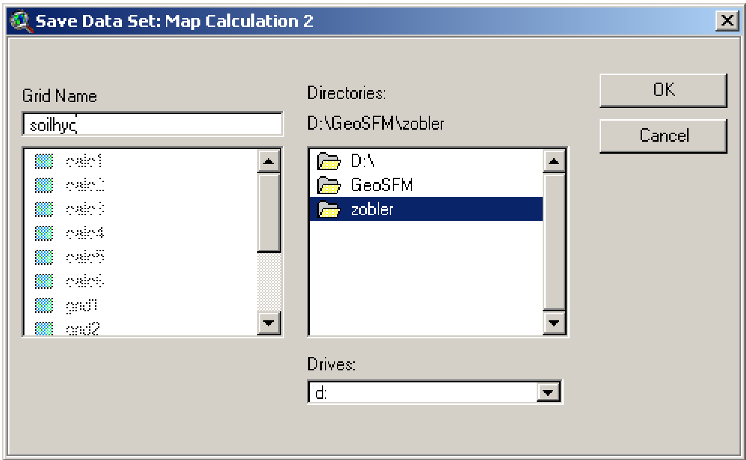
Now you can create a grid of the **Numeric soil hydraulic classes**. From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:
([Map Calculation 1 . Numeric soil hydraulic class])
Click **Evaluate.**



Below the created grid is displayed - with values of 0, 88, 89, 90, and 91.



Save this data set, from the **Theme** menu select **Save Data Set**. Navigate to your directory and name your new grid –**soilhyd**. Click **OK**.

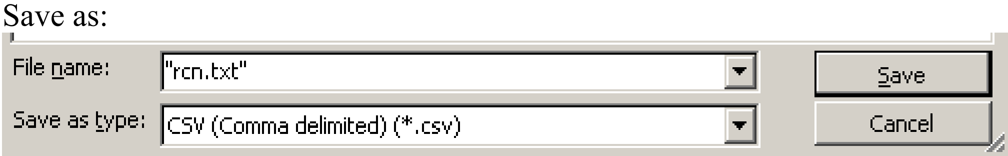


Now, you can delete all themes, except for the usgslandcover grid; from the **Edit** menu select **Delete Themes**. Make sure the themes you want deleted are selected in a raised box. Now add your new **soilhyd** grid to your view. You will use this grid later in the process.

Create four grids for each Soil Hydraulic class (A, B, C & D) each with the RCN values for the landcover classes. The **Hyd_a_mean** field in the **usgslandcov** attributes table, indicates the RCN values for soil hydraulic class "**A**", **Hyd_b_mean** for soil hydraulic class "**B**", **Hyd_c_mean** for soil hydraulic class "**C**", and **Hyd_d_mean** for soil hydraulic class "**D**". If your attribute table does not contain these **Hyd_a-d_mean** values you will need to add them to the table.

If you need to add values to the land cover attribute table create **Table 1.4** (see Soil Characteristic Data Sources) in Excel.

Save as:



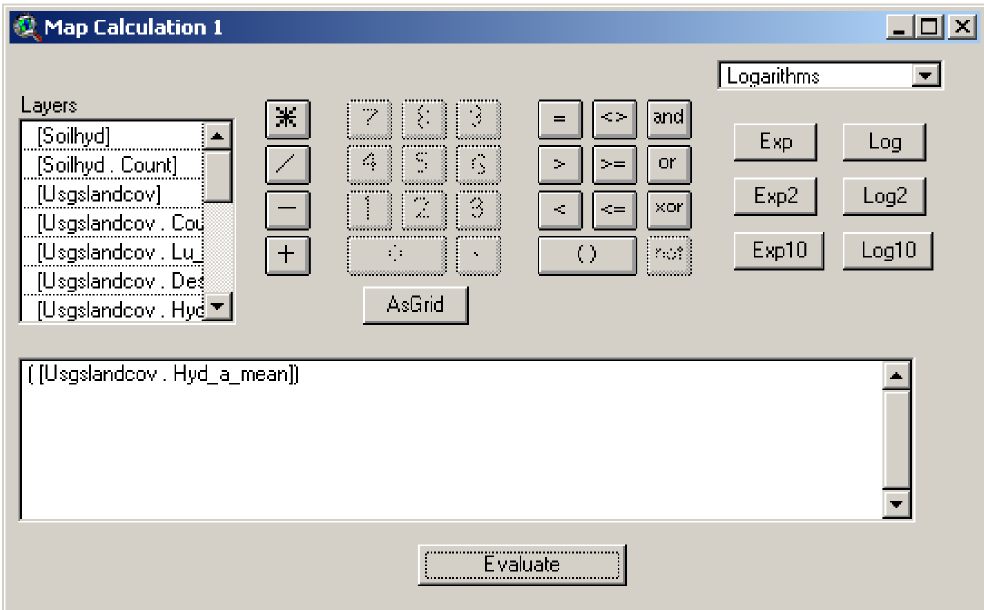
Next, you need to add the new **rcn.txt** to the **View**. From the project window select **Tables** and than click the **Add** button. Navigate to your working directory and select **rcn.txt, List Files of Type** is set to **Delimited Text (*.txt.)** Click **OK.**

Arrange tables side by side. Click/highlight the common column headers in both tables –**Value** in **Attibutes of Usgslandcov** and **nlucode** in the **rcn.txt** file. Make the destination table active (adding fields to **Attributes of Usgslandcov**.)

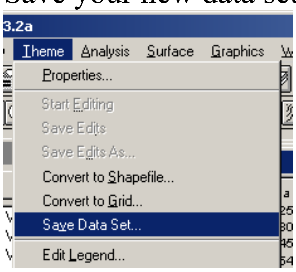
Click on the join icon, the new columns are added to the **Attributes of Usgslandcov** table.

Next, you will create the four grids; the first grid will capture all the **Hyd_a_mean** values.

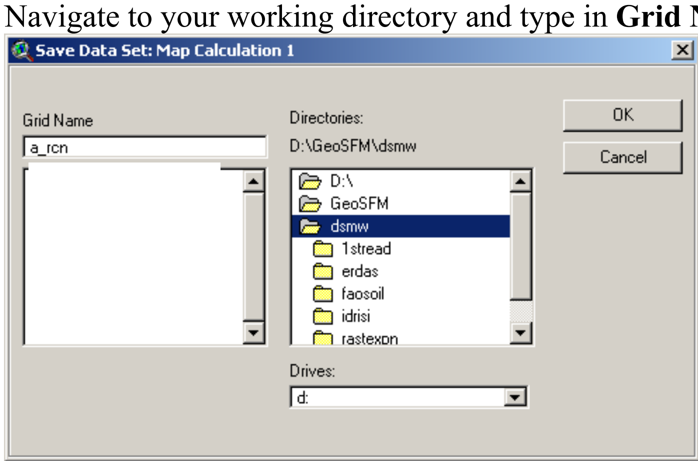
From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:
([Usgslandcov.Hyd_a_mean]) You can double click on the field under **Layers** to populate the evaluation area. Click on **Evaluate.**



Save your new data set, from the **Theme** menu select **Save Data Set**.



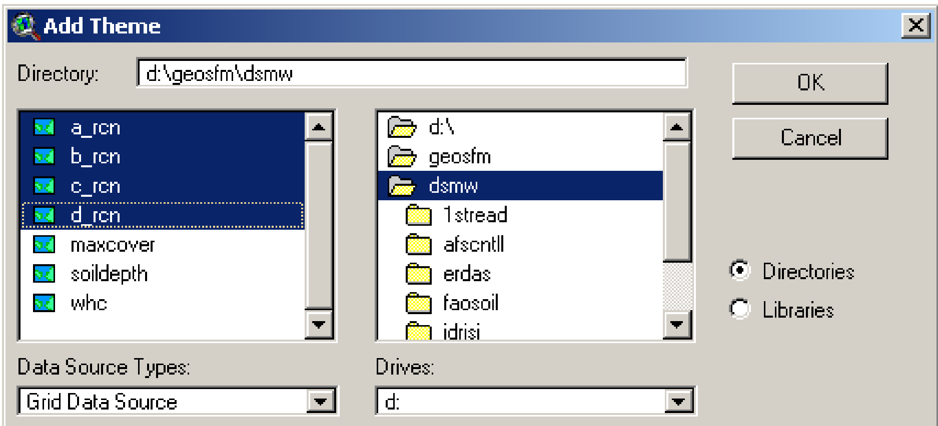
Navigate to your working directory and type in **Grid Name** – **a_rcn**. Click **OK**.



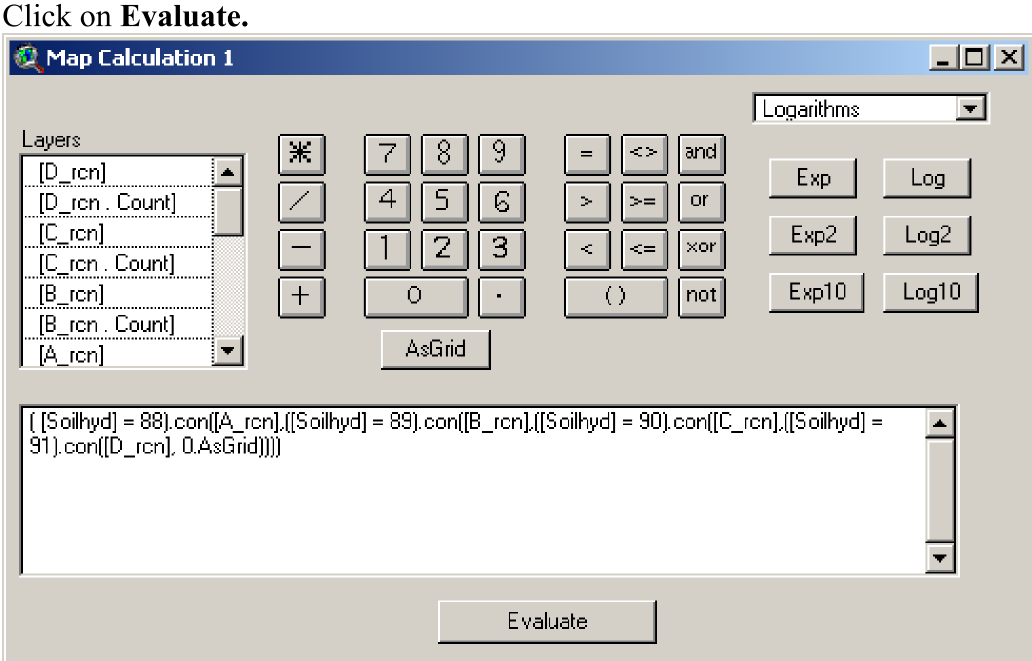
Repeat this process for the remaining three grids. The second grid will capture the **Hyd_b_mean** values and saved as **b_rcn**. The third grid will capture the **Hyd_c_mean** values and saved as **c_rcn**. The last grid will capture the **Hyde_d_mean** values and saved as **d_rcn**.

Delete all the Map Calculation 1-4 grids, and add the newly created **a_rcn**, **b_rcn**, **c_rcn** and **d_rcn** grids. You can select more than one grid by holding down the shift key while selecting.

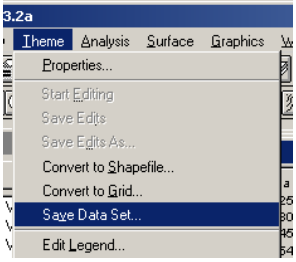
Add the grids to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Grid Data Source**. Navigate to your directory and select the four grids. Click **OK** to add to the **View.**



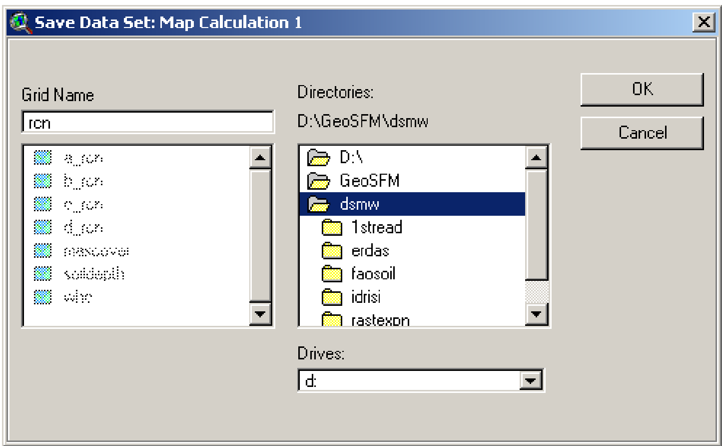
The next step is to combine the grids into one final rcn grid. From the **Analysis** menu select the **Map Calculator**. Type in the following expression exactly as shown:
([Soilhyd]=88).con([A_rcn],([Soilhyd]=89).con([B_rcn],([Soilhyd]=90).con([C_rcn],([Soilhyd]=91).con([D_rcn], 0.AsGrid))))
Click on **Evaluate.**



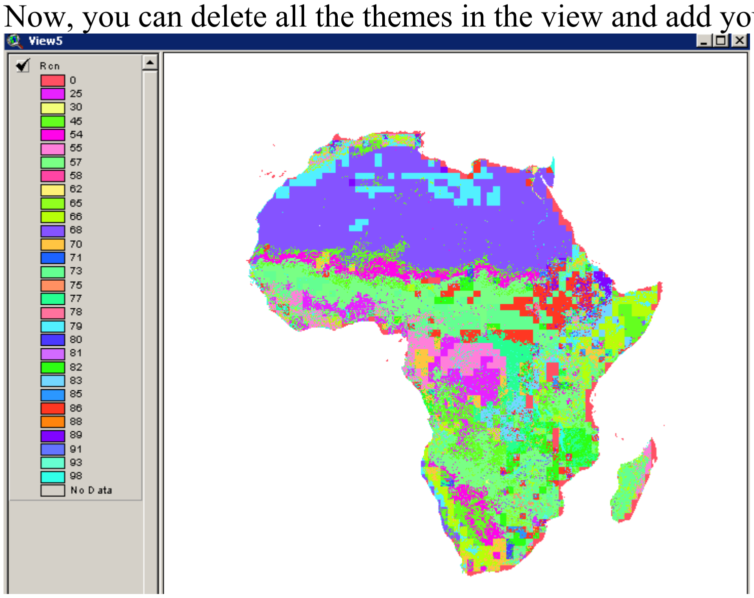
Save your new data set, from the **Theme** menu select **Save Data Set**.



Navigate to your working directory and type in **Grid Name – rcn**. Click **OK**.



Now, you can delete all the themes in the view and add your new rcn grid –seen below.



All of the soil characteristic grids have been created. Now the soil grids can be added to the **View** when prompted during the **Creating Basin Characteristics** process in section 1.5 in the *GeoSFM Training Manual.*

1.3.2 Basin Characteristics Output Files

Basin and River Characteristics Output

Output Files	**Description**
basin.txt *see .txt file detail below*	File containing each sub-basin characteristics. This file is rewritten during the calibration process for each model run.
basin_original.txt	Copy of basin.txt. Retains original basin characteristic data.
order.txt *see .txt file detail below*	Computational order – used in subsequent program operations
river.txt *see .txt file detail below*	File containing river characteristics. This file is rewritten during the calibration process for each model run.
river_original.txt	Copy of river.txt. Retains original river characteristic data.
describe.txt *see .txt file detail below*	File descriptions for twelve different files generated in modeling process

basin.txt Parameters	**Description**	**Units**	**Range of Values**
BasinID	Sub-basin identification number		1-366
SoilWHC	Soil water holding capacity calculated from the DSMW soil class and the total available water median soil moisture value.	mm	76-175
SoilDepth	Hydrological active soil laver depth created from DSMW soil code value and Webb's soil depth values.	cm	100-360
Texture	Texure value created from Zobler's seven classes and converted to three classes –coarse, medium, and fine.		1-5
Ks	Saturated soil hydraulic conductivity value created based on Zobler's Ks and texture values.	cm/hr	0.882 – 5.076
Area	Drainage area of the sub-basin	km^2	4-10166
Interflowlag	Residence time for the interflow reservoir	days	30
Hslope	Average sub-basin slope		0.001-1.6815
Baseflowlag	Residence time for the baseflow reservoir	days	365
RCNumber	SCS runoff curve number uses hydraulic soil classes together with GLCC classes to derive a RCN value.		56.3-84.3
MaxCover	Maximum impervious cover value based on wetland area and water bodies found in the GLCC data set a long with the stream cells defined in the flow accumulation data.		0-0.002

BasinLoss	Fraction of the soil water infiltrating to ground water		0.4-0.8
Pancoeff	Pan coefficient for correcting PET readings		0.85
Topsoil	Fraction of soil layer classified as hydrologically active top soil layer		0.1
Aridity	Aridity index range (1=arid, 2=wet)		1-2

order.txt Parameters	**Description**	**Range of Values**
BasinID	Most downstream sub-basin Number	1-366
	2^{nd} most downstream sub-basin Number	
	3^{rd} most downstream sub-basin Number	
	↓	
	Most upstream sub-basin Number	

river.txt Parameters	**Description**	**Units**	**Range of Values**
RiverID	Identification number of the river reach		1-366
Area	Local drainage area of the river reach	km^2	4-10166
UpArea	Total area upstream of the river reach	km^2	1003-415620
RivSlope	Average slope of the river reach/basin mainstream channel mean slope		0.001-1.1557
RivLength	Length of the river reach	m	1000-313816.2
DownID	Identification number of the downstream river reach		-9999-365
RivManning	Value of Mannings n for the river reach		0.035
RiverLoss	Fraction of river water lost to infiltration		1
RiverPloss	Fraction of the river water lost to evaporation		1
HasDam	Indicates whether the river reach contains a dam (0=no, 1=yes)		0-1
HasRating	Indicates whether the reach has a rating curve (0=no, 1=yes)		0-1
HasFlowData	Indicates whether the river reach has observed flow data (0=no, 1=yes)		0-1
Celerity	Velocity of the flood wave through the river reach	m/s	0.3-1.6
Diffusion	Flow attenuation (or dispersion) coefficient of the reach	m^2/s	45-42695.2
RivWidth	Average channel width	m	67-545.9
FlowRef	Reference flow for the section	m^3/s	1.3701-283.279

RunType	Indicates if simulation should proceed from a existing or a new run (0=new, 1=existing)		0-1

describe.txt	Description
Basin Characteristics	List and description of the twelve different characteristics generated in the basin.txt
River Characteristics	List and description of the seventeen different characteristics generated in the river.txt
Response Characteristics	Explanation of the time step runoff data generated in the response.txt
Computation Order	Explanation of the sub-basin downstream/upstream flow in the order.txt
Rainfall Characteristics	Explanation of the time step rainfall data generated in the rain.txt
Evapotranspiration Characteristics	Explanation of the time step PET data generated in the evap.txt
Balance Parameters	List and description of the nine different characteristics generated in the balparam.txt
Balance File Listing	List and description of the seventeen different input/output files in the balfiles.txt
Route Parameters	List and description of the nine different characteristics generated in the routparam.txt
Route File Listing	List and description of the thirteen different input/output files in the routfiles.txt
Total Runoff from each Sub-basin	Explanation of the time step total runoff data generated in the basinrunoffyield.txt
Total Stream flow from each Sub-basin	Explanation of the time step total discharge generated in the streamflow.txt

1.4 Generate Basin Response File

GeoSFM is a semi-distributed hydrologic model. This implies that a single value of precipitation and other forcing data are computed for each catchment. The distribution of water within the catchment is not modeled explicitly during each time step. Instead, a unit hydrograph is developed to simulate the typical response of the catchment to a uniformly distributed water input event. The unit hydrograph is developed for each catchment during the model preprocessing phase. GeoSFM contains automated GIS based algorithms for generating these responses. The default procedure begins by estimating a uniform overland velocity for each catchment based on the mean slope of the catchment and dominant land cover type present. The algorithm also supports the use of non-uniform velocity grids as well as predetermined uniform velocity values, but these have to be supplied by the user. The distance along the flow path from each grid cell in the catchment to the catchment outlet is also computed. The travel time from each grid cell to the catchment outlet is also computed as shown in equation 1 below.

$$t_i = \frac{l_i}{v_i}$$ **Equation 1**

Where:

t_i is the travel time from a given grid cell to the catchment outlet
l_i is the flow length from a given grid cell to the catchment outlet
v_i is the average overland velocity for the catchment

The distribution of discharge at the catchment outlet is given by the probability density function (PDF) of travel times in the catchment. The PDF is in essence analogous to the geomorphologic instantaneous unit hydrograph (GIUH) of Rodriguez-Iturbe and Valdes (1979). The unit hydrograph or probability mass function of flow travel times is obtained by discretizing the PDF over the routing interval. Note that the resulting unit hydrograph is only applicable for the particular routing interval for which it was defined. Hence a change from a daily routing interval to say a six hourly interval would require the definition of a new unit hydrograph response. The unit hydrograph response is computed for each catchment during preprocessing and is stored in an ASCII file for subsequent use.

Method of Over Land Flow Velocity Computation

Option 1 –**Non –Uniform from USGS Land Cover Grid**

Input Grids/File	**Description**	**Unit**
Basins	Sub-basin grid assigns a unique ID value to each sub-basin.	
Flowdir	Flow direction grid consists of numeric values assigned using the eight direction pour point model. Each cell is assigned one of eight compass directions.	
Flowlen	Downstream flow length grid defines the distance from the cell to the basin outlet.	
Outlets	Outlet grid defines number of outlets, one outlet per sub-basin, each assigned a unique value.	
Usgslandcov	USGS Land Cover grid	
Elevations	Elevation grid	meter
Flowacc	Flow accumulation grid defines the number of contributing cells draining into each cell. Values range from 0 at topographic highs to large numbers at the mouths of rivers.	
Order.txt *see .txt file detail -1.3*	Computational order file	

Land cover input data used to determine velocity output.

Option 2 –**Non –Uniform from User Supplied Velocity Grid**

Input Grids/File	**Description**	**Unit**
Basins	Sub-basin grid assigns a unique ID value to each sub-basin.	
Flowdir	Flow direction grid consists of numeric values assigned using the eight direction pour point model. Each cell is assigned one of eight compass directions.	
Flowlen	Downstream flow length grid defines the distance from the cell to the basin outlet.	
Outlets	Outlet grid defines number of outlets, one outlet per sub-basin, each assigned a unique value.	
Velocity	Overland flow user defined velocity grid.	m/s
Order.txt *see .txt file detail -1.3*	Computational order file	

The user supplies velocity input grid values.

Option 3 – **Uniform from User Supplied Velocity Value**

Input Grids/File	**Description**	**Unit**
Basins	Sub-basin grid assigns a unique ID value to each sub-basin.	
Flowdir	Flow direction grid consists of numeric values assigned using the eight direction pour point model. Each cell is assigned one of eight compass directions.	
Flowlen	Downstream flow length grid defines the distance from the cell to the basin outlet.	
Outlets	Outlet grid defines number of outlets, one outlet per sub-basin, each assigned a unique value.	
Velocity	Overland flow velocity value.	m/s
Order.txt *see .txt file detail -1.3*	Computational order file	

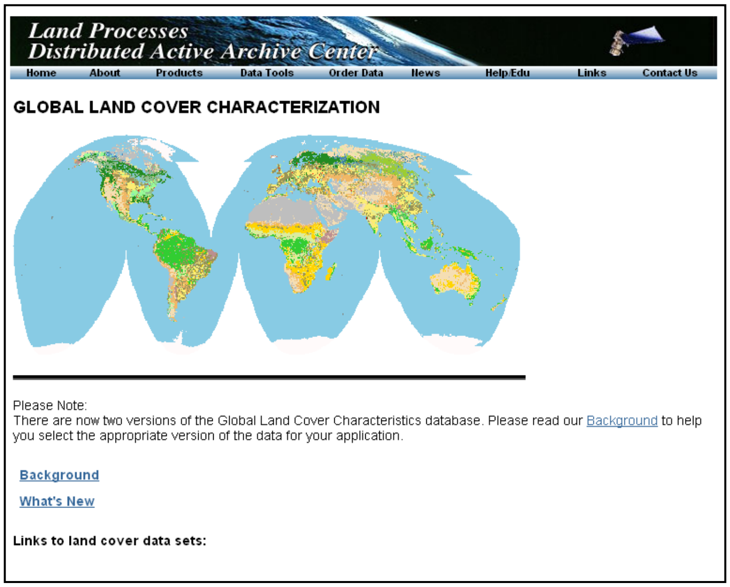
The user supplies velocity inputs –default values for the velocity of 0.3 m/s for each cell.

1.4.1 Landcover Processing (option 1)

The nature of vegetation on the land surface influences runoff generation and overland flow processes. The USGS Global Land Cover Characteristics (GLCC) database (Loveland et al., 1999) is used in GeoSFM because of it global coverage. The GLCC data were derived from 1-km AVHRR data and are available in the Interrupted Goode Homolosine and Lambert Equal Area Azimuthal projections. The data are available for download over the Internet at http://edcdaac.usgs.gov/glcc/af_int.html. Land cover data are used along with soils data in the determination of SCS runoff curve numbers in GeoSFM. The curve numbers determine the amount of incident precipitation that becomes surface runoff. Vegetation also influences the velocity at which this surface runoff is transported over the land surface to the river network. GeoSFM contains routines for making a first estimate of overland velocity from the GLCC data and the topography.

Downloading USGS Landcover

Download the data from the Internet at http://edcdaac.usgs.gov/glcc/af_int.html.



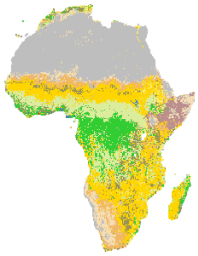
This website will bring you to the *Land Processes Distributed Active Archive Center –Global Land Cover Characterization* page, from this page scroll down to the **Links to land cover data sets**: there are two different versions available; select **Version 2**.

Select appropriate area for download from table shown below.

GLCC – Version 2		
Global	North America	Eurasia
Africa	South America	Australia Pacific

To complete exercise one outlined in the *GeoSFM Training Manual*, **Africa** will be selected. This exercise was developed for the Limpopo Basin in southern Africa. Create a new folder in the GeoSFM folder called **glcc** for all of the land cover data. Selecting Africa will display the *Africa Land Cover Characteristics Data Base Version 2.0* page.

Africa Land Cover Characteristics Data Base Version 2.0



- Africa Readme
- Africa Land Cover Database Table
- Data in Interrupted Goode Homolosine Projection
- Data in Lambert Azimuthal Equal Area Projection

From the Africa Land Cover page, select **Data in Lambert Azimuthal Equal Area Projection**. This will link to a page that contains links to all the documentation files and the image files, either compressed or uncompressed.

Scroll down the page to the **image files**, select

• **USGS Land Use/Land Cover Scheme**

compressed **3.3 Mb**

Image Files (Download binary ftp files)
Note: When downloading compressed files, add the .gz extension to the file name.

USGS Land Use/Land Cover Scheme	**compressed** **3.3 Mb**	**uncompressed** **77.4 Mb**

Click on – **Compressed/3.3 Mb** and save the file, **c:\GeoSFM\glcc**. Use WinZip to select and extract all files to your workspace. From the **afusgs2_0l.img.gz.file** extract the **afusgs2_0l.img.** If you do not already have WinZip installed you can download a free trial version from http://www.winzip.com/winzip/download.htm.

Or select

• **USGS Land Use/Land Cover Scheme**

uncompressed **77.4 Mb**

Click on –**UnCompressed/77.4 Mb**
and save the file to your directory, **c:\GeoSFM\glcc**.

The downloaded land cover data is provided in a generic image array format (flat, headerless, binary raster data) this is to maximize the flexibility for importing the data into a variety of software systems. The following procedure is needed before importing these raster image files into ArcView.

Re-name the image file to filename **afusgs2_0l.bsq.** (.bsq –image file– band sequential)

Next, a header file will need to be created.
Data fields that are needed for the creation of the header file:

- nrows – the number of rows in the image
- ncols – the number of columns in the image
- nbands – the number of spectral bands in the image –default is 1
- nbits –the number of bits per pixel per band –default is 8
- layout –the organization of the bands in the image file –acceptable values bil, bip & bsq
- skpbytes –the number of bytes of data in the image file to skip to reach start of image data (bypass header information) –default is 0
- ulxmap –the x-axis map coordinate of the center of the upper-left pixel
- ulymap –the y-axis map coordinate of the center of the upper-left pixel
- xdim –the x dimension of a pixel in map units
- ydim –the y dimension of a pixel in map units

The image parameters needed to populate the new header file can be found in the documentation for each of the continental data bases.

Lambert Azimuthal Equal Area Projection File Listing

Documentation Files (View ascii ftp files)

- **Africa Documentation**
- **Seasonal Land Cover Region Legend**
- **Global Ecosystem Legend**
- **International Geosphere Biosphere Programme Legend**
- **Biosphere Atmosphere Transfer Scheme Legend**
- **Simple Biosphere Model Legend**
- **Simple Biosphere 2 Model Legend**
- **USGS Land Use and Land Cover Classification Legend**
- **Vegetation Lifeforms Legend**

Click on **Africa Documentation** and scroll down to section **2.2 Lambert Azimuthal Equal Area Projection Parameters.**

Items in **bold** are needed for header file.

The data dimensions of the Lambert Azimuthal Equal Area projection for the Africa land cover characteristics data set are **9,276 lines (rows)** and **8,350 samples (columns)** resulting in a data set size of approximately 77 megabytes for **8-bit** (byte) images. The following is a summary of the map projection parameters used for this projection:

Projection Type: Lambert Azimuthal Equal Area

Units of Measure: meters

Pixel Size: **1000** meters

Radius of sphere: 6370997 m

Longitude of origin: 20 00 00 E

Latitude of origin: 5 00 00 N

False easting: 0.0

False northing: 0.0

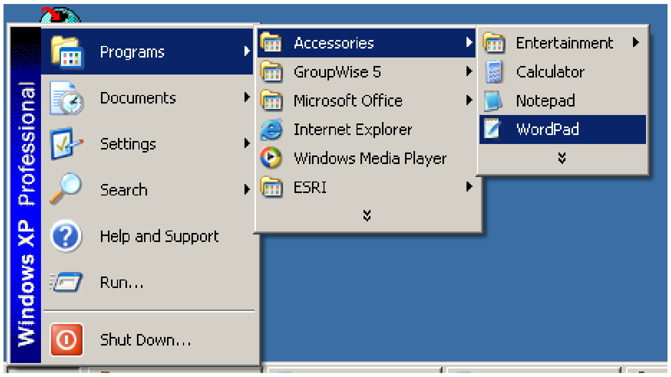
XY corner coordinates (center of pixel) in projection units (meters):
Lower left: (-4458000, -4795000)

Upper left: (**-4458000, 4480000**)

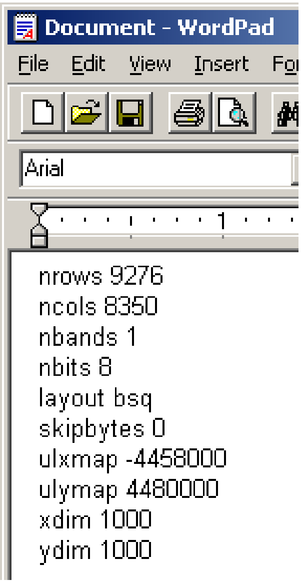
Upper right: (3891000, 4480000)

Lower right: (3891000, -4795000)

Now that you have the data you need, you can prepare an ASCII file. To do this, open up WordPad in Start/Programs/Accessories/WordPad.

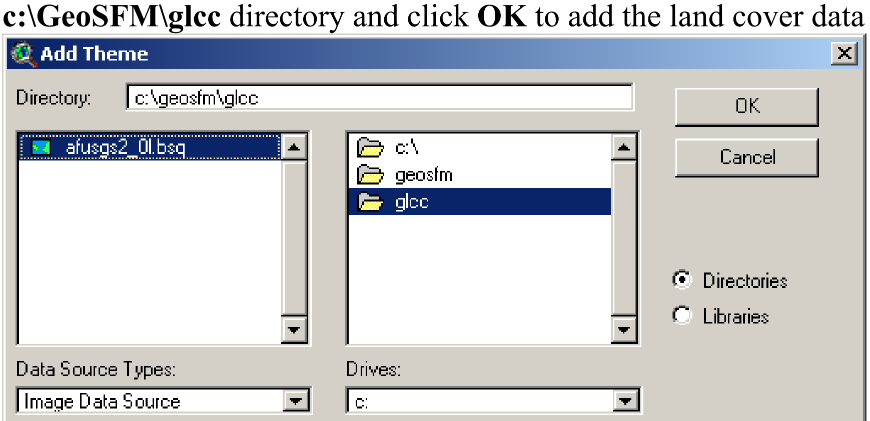


An example of the WordPad document can be seen below. Remove the commas from the nrows and ncols values.



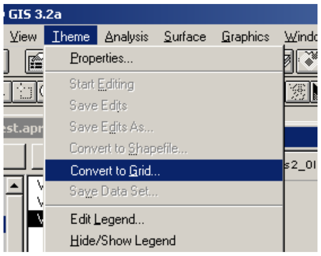
Save the document from the **File** menu select **Save As…**
File Name –afusgs2_0l.**hdr**
Save as Type –Text Document
Directory **–c:\GeoSFM\glcc**
Next, you need to add the land cover data to the ArcView project and convert into a grid for use in exercise one as outlined in the *GeoSFM Training Model*.

Add the **afusgs2_0l.bsq** to the **View** using **Add Theme button**  from the **View** menu. Change the **Data Source Types** to **Image Data Source**. Click on the **afasgs2_0l.bsq** file from the **c:\GeoSFM\glcc** directory and click **OK** to add the land cover data to the **View**.

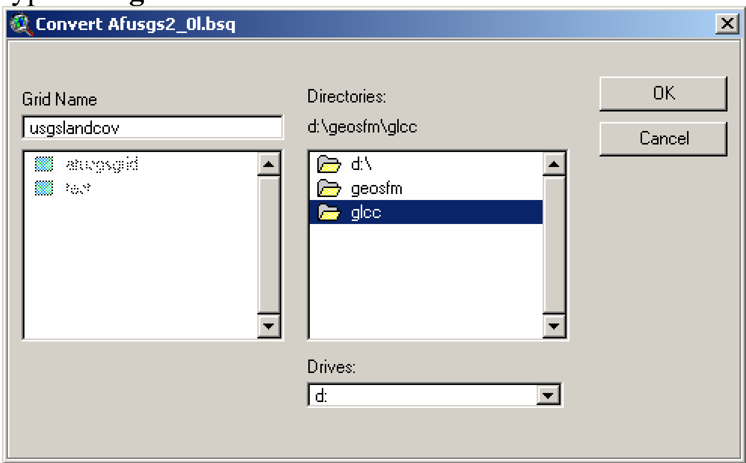


The land cover data will not display until it has been converted to a grid.

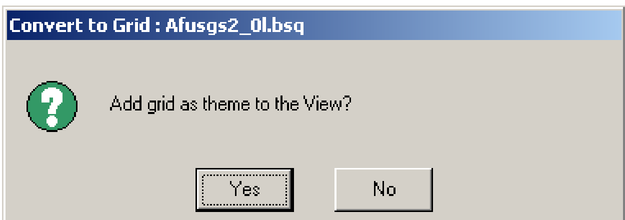
To convert the land cover data to a grid, select the theme **afusgs2_0l.bsq** so that it appears in a raised box. From the **Theme menu** select **Convert to Grid…**



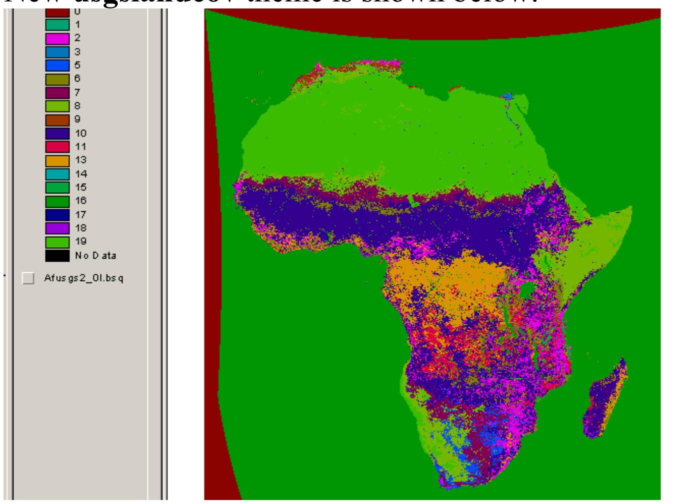
The **Convert Afusgs2_0l.bsq** dialog box appears. Navigate to the **c:\GeoSFM\glcc** directory and type in **usgslandcov** in **Grid Name.** Then click **OK.**



A dialog box appears asking if you would like to **Add grid as theme to View.** Click **Yes**.

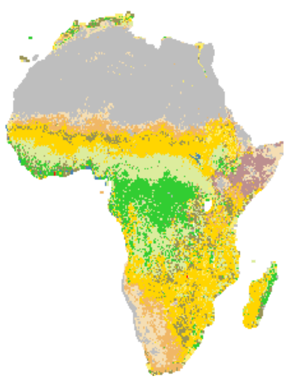


New **usgslandcov** theme is shown below.



Next, you need to add the **Lu_code** and **description** fields to the attribute table. The values needed for these new fields are found in **AfricaReadme** section **4.4.**

Africa Land Cover Characteristics Data Base Version 2.0



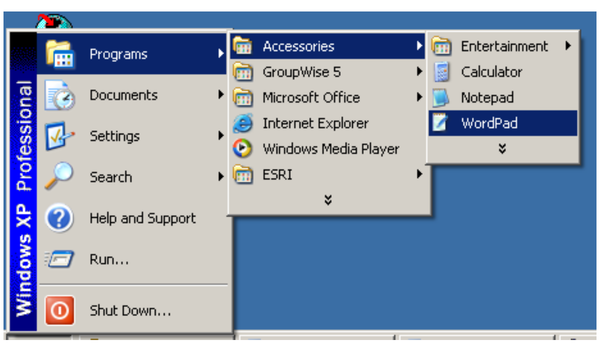
- Africa Readme
- Africa Land Cover Database Table
- Data in Interrupted Goode Homolosine Projection
- Data in Lambert Azimuthal Equal Area Projection

4.4 USGS Land Use/Land Cover System Legend (Modified Level 2)

Value	Code	Description
1	100	Urban and Built-Up Land
2	211	Dryland Cropland and Pasture
3	212	Irrigated Cropland and Pasture
4	213	Mixed Dryland/Irrigated Cropland and Pasture
5	280	Cropland/Grassland Mosaic
6	290	Cropland/Woodland Mosaic
7	311	Grassland
8	321	Shrubland
9	330	Mixed Shrubland/Grassland
10	332	Savanna
11	411	Deciduous Broadleaf Forest
12	412	Deciduous Needleleaf Forest
13	421	Evergreen Broadleaf Forest
14	422	Evergreen Needleleaf Forest
15	430	Mixed Forest
16	500	Water Bodies
17	620	Herbaceous Wetland
18	610	Wooded Wetland
19	770	Barren or Sparsely Vegetated
20	820	Herbaceous Tundra
21	810	Wooded Tundra
22	850	Mixed Tundra
23	830	Bare Ground Tundra
24	900	Snow or Ice

Value 330 not recognized in model need to add

Now that you have the data you need, you can prepare an ASCII file. To do this, open up WordPad in Start/Programs/Accessories/WordPad. Cut and paste data into WordPad.



Commas need to be added to separate column values and each line needs to be on a separate row. The header and the first line of data also need to be added.

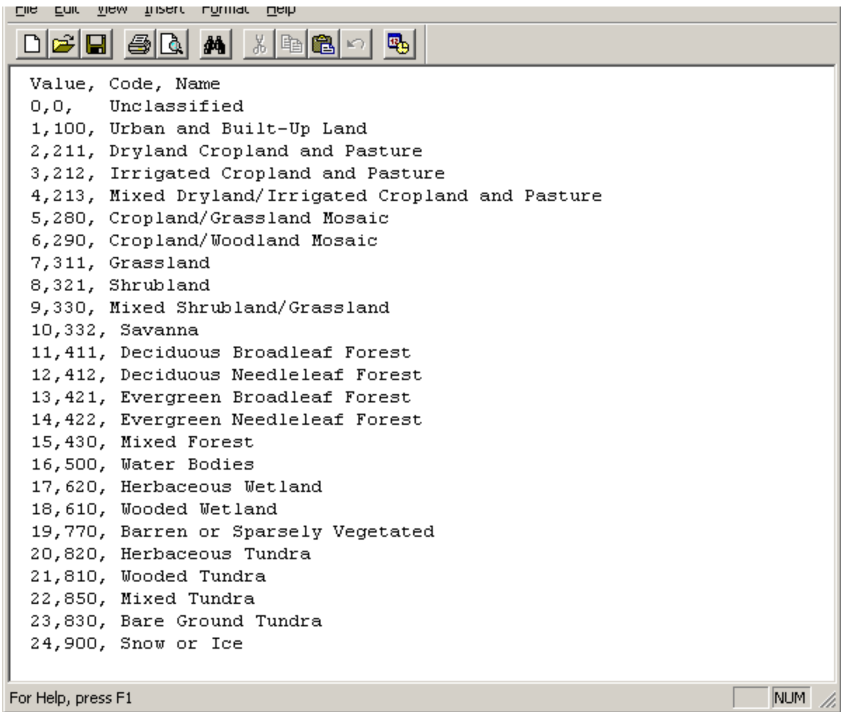
The header names added:

Value, Code, Name

Second line was also added:

0, 0, Unclassified –notice the commas separating field values

An example of the WordPad document can be seen below.



```
Value, Code, Name
0,0,   Unclassified
1,100, Urban and Built-Up Land
2,211, Dryland Cropland and Pasture
3,212, Irrigated Cropland and Pasture
4,213, Mixed Dryland/Irrigated Cropland and Pasture
5,280, Cropland/Grassland Mosaic
6,290, Cropland/Woodland Mosaic
7,311, Grassland
8,321, Shrubland
9,330, Mixed Shrubland/Grassland
10,332, Savanna
11,411, Deciduous Broadleaf Forest
12,412, Deciduous Needleleaf Forest
13,421, Evergreen Broadleaf Forest
14,422, Evergreen Needleleaf Forest
15,430, Mixed Forest
16,500, Water Bodies
17,620, Herbaceous Wetland
18,610, Wooded Wetland
19,770, Barren or Sparsely Vegetated
20,820, Herbaceous Tundra
21,810, Wooded Tundra
22,850, Mixed Tundra
23,830, Bare Ground Tundra
24,900, Snow or Ice
```

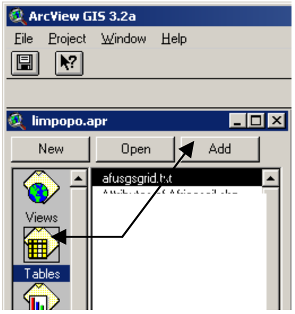

Save the document, from the **File** menu select **Save As…**

File Name –**usgslandcov.txt**
Save as Type –**Text Document**
Directory –**c:\GeoSFM\glcc**

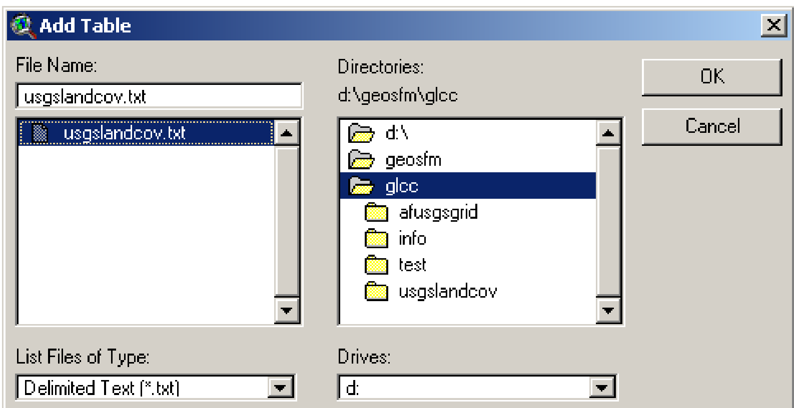
Click on new grid theme so it appears in a raised box. Click on table icon to open attribute table. The table should contain **Value** and **Count** fields.

Next, you need to add the new **usgslandcov.txt** file that was created.

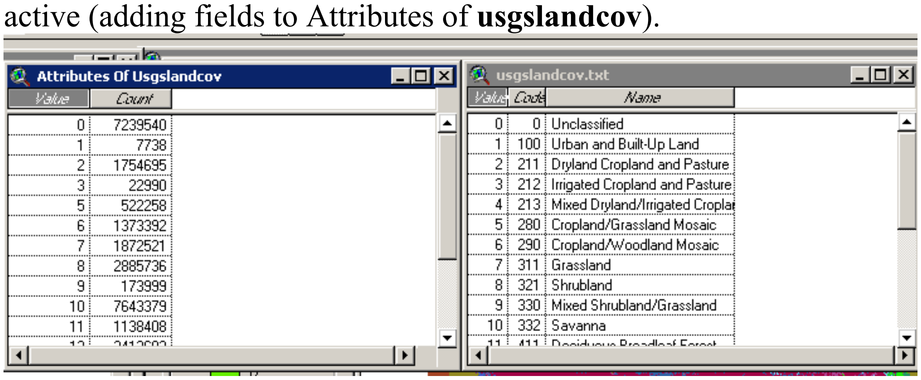
Click on **Tables**, **Add** in the project window.



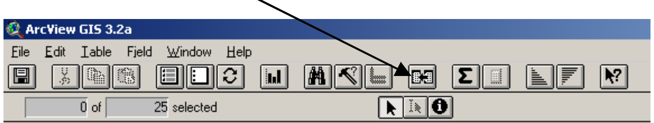
The **Add Table** dialog box will open. In **c:\geosfm\glcc** select **usgslandcov.txt**. **List of Files of Type:** Delimited Text (.txt) should be displayed. Click **OK**.



Arrange both tables as seen below. Click/highlight the common column headers in both tables – **Value** in **Attributes of usgslandcov** and in **Value** in **usgslandcov.txt**. Make the destination table active (adding fields to Attributes of **usgslandcov**).

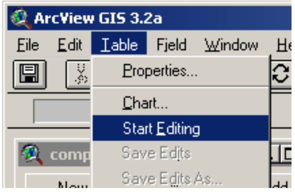


Click on the **Join** icon, the new columns are added to the **Attributes of usglandcov** table.

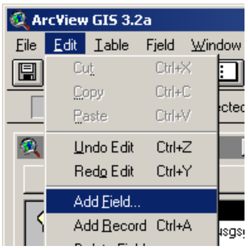


Once the new fields are added to the attribute table you need to make the added data permanent.

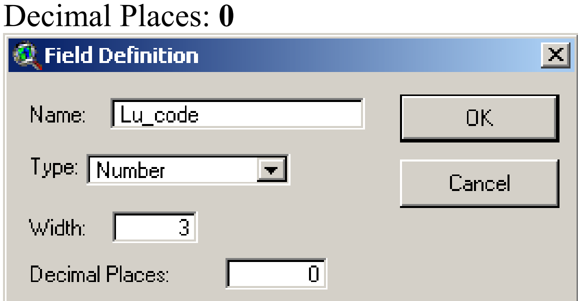
From the **Table** menu select **Start Editing**.



Then from the **Edit** menu select **Add field**.

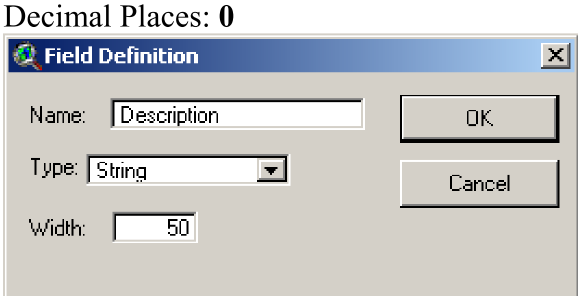


Two fields will be added.
Field One:
Name**: Lu_ Code**
Type: **Number**
Width: **3**
Decimal Places: **0**



After **Field Definition** is populated click **OK**.

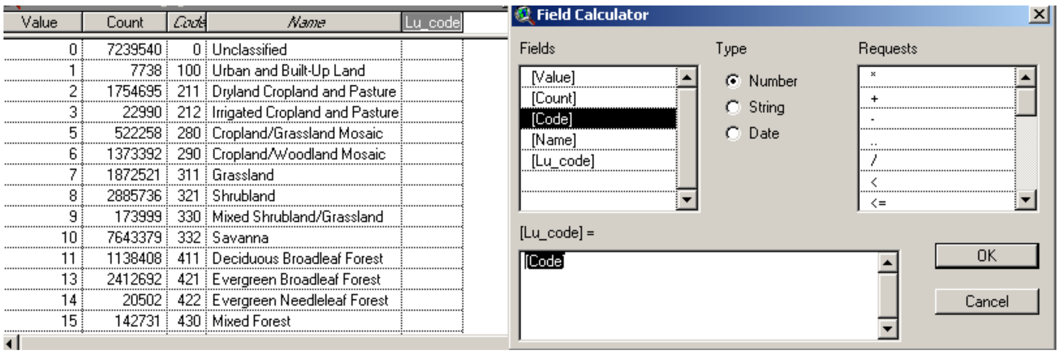
Field Two:
Name: **Description**
Type: **String**
Width: **50**
Decimal Places: **0**



After **Field Definition** is populated click **OK**.

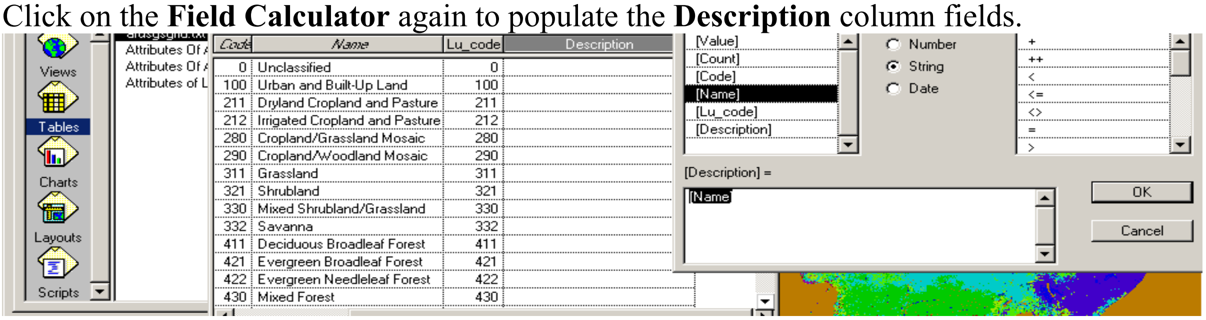
Next, you will populate the column values for the new fields by using the **Field Calculator** icon on the tool bar.   Click on the **Field Calculator** icon.

The **Field Calculator** dialog box opens – double click **[Code]** under **Fields.**
Calculation reads → **[Lu_code] = [Code]**, as seen below. Click **OK**.



The new **Lu_code fields** are populated with the same values as the **Code fields**.

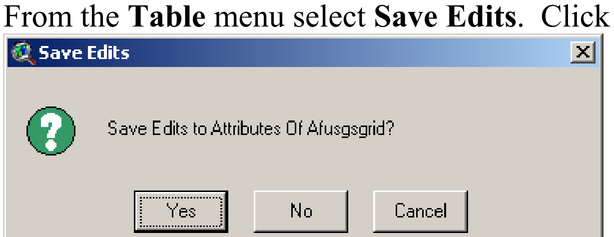
Click on the **Field Calculator** again to populate the **Description** column fields.



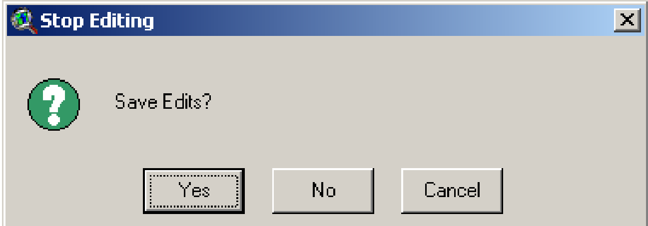
The **Field Calculator** dialog box opens – double click **[Name]** under **Fields.**
Calculation reads → **[Description] = [Name]**. Click **OK**.
The new **Description** fields are populated with the same values as the **Name** fields.

Next, you will remove the join leaving **Value, Count, Lu_code**, and **Description** fields.
From the **Table** menu select **Remove All Joins**.

From the **Table** menu select **Save Edits**. Click **Yes**.



From the **Table** menu select **Stop Editing**. Click **Yes**.



The USGS Land Cover grid can be added to the **View** when prompted during the **Method of OverLand Flow Velocity Computation** process in section 1.6 in the *GeoSFM Training Manual*.

1.4.2 Basin Response Outputs

Output Grids/File	**Description**
Traveltime	Travel time from each grid cell to the catchment outlet based on slope, watershed size, flow resistance (Manning's roughness coefficient), and water input.
Velocity	Option 1-Estimated uniform overland velocity for each catchment based on the mean slope of the catchment and dominant land cover. Option 2-Velocity values for each catchment defined by user. Option 3-Velocity default value for each catchment defined by user.
response.txt *see .txt file detail below*	File containing fraction of excess runoff arriving at sub-basin outlet in each subsequent time step, similar to a unit hydrograph for each sub-basin.

response.txt Parameters	**Description**	**Units**	**Range of Values**
BasinID	BasinID of sub-basin beginning with the most downstream		1-366
	↓		
	Most upstream sub-basin		
Day 0	Fraction of excess runoff arriving at sub-basin outlet in each subsequent time step		0.0-1.0
Day 1	↓		
Day 2			
↓			
Day 20			

2.0 Performing Stream Flow Analysis

2.1 Generate Rainfall and Evapotranspiration Files

NOAA Satellite Rainfall Estimates (RFE)
Precipitation data is the most essential input to any hydrologic model, and in the case of the GeoSFM, it was the driving factor in the design of the model and the wide monitoring system. In order to accurately simulate stream flow conditions on the ground, the most precise source of precipitation data with near global coverage had to be used. Ground based gauges are widely considered to provide the most accurate measure of precipitation at any location. However, the spatial coverage of ground based gauges is very poor in many regions of the world and is therefore inadequate to support hydrologic modeling needs. While global climate models can be run operationally to generate precipitation globally, the accuracy of the resulting precipitation fields is insufficient to support hydrologic modeling efforts. The Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration (NOAA) uses satellite images in conjunction with ground based gauges to process rainfall estimates on a daily basis. These satellite derived rainfall estimate, commonly known by the abbreviation RFE, can be generated for most parts of the world since weather satellites have global coverage. The inclusion of ground observations in these rainfall estimates provides a means of ground-truthing satellite observations on a daily basis thus minimizing inaccuracies in the estimate.

The theoretical basis for satellite rainfall estimation derives from the fact that rainfall forms when moisture in the atmosphere is cooled to condensation. In the absence of condensation nuclei, moisture condenses at temperatures of 235 Kelvin and below. By monitoring the temperature of cloud tops from infrared imagery from geostationary satellites such as Meteosat 7, scientists are able to determine areas where moisture condensation and consequently rainfall is occurring. Infrared satellite imagery gives a good indication of the spatial distribution of convective rainfall. Microwave imagery from sensors such as the Special Sensor Microwave/Imager (SSM/I) of Defense Meteorological Satellite Program and the Advanced Microwave Sounding Unit (AMSU) from NOAA are also incorporated to identify other types of non-convective rainfall. However, satellite imagery do not give a good indication of the rainfall rate, and consequently, other sources of rainfall rate information must be incorporated in order to calculate a daily rainfall accumulation.

The World Meteorological Organization (WMO) collects and archives weather information (including rainfall accumulations) from around the world on a daily basis. National meteorological agencies throughout the world obtain readings of weather conditions for the previous 24 hours through their network of ground-based synoptic weather stations. These data are transmitted daily through WMO's Global Telecommunications System (GTS) to a central archive, and a consolidated archive documenting global weather conditions is redistributed via the same system to the member countries. Barring any transmission errors, these data provide an accurate assessment of the quantity of rainfall at selected points throughout the world. However, there are not enough stations in the

GTS system to support hydrologic modeling in most parts of the world. By combining observed rainfall from the GTS system with satellite rainfall estimates, scientists at NOAA have produced an RFE product which captures both the spatial and quantitative distribution of rainfall. The resulting RFE product has a spatial resolution of 8-kilometers and can be produced for virtually any part of the world.

USGS Potential Evapotranspiration (PET) Data

Evapotranspiration is one of the important processes by which water is extracted from the soil column. While the rate of evapotranspiration depends on the amount of water present in the soil column, the maximum extraction rate (also called potential evapotranspiration, PET) depends on prevailing weather conditions including temperature, fluxes of long and short wave radiation, atmospheric pressure, relative humidity and wind speed. There are several equations for computing PET, the most comprehensive of which is the Penman-Monteith equation. Data from the Global Data Assimilation System (GDAS) is used to solve the Penman-Monteith equation to generate grids of PET at a daily time step. GeoSFM contains procedures for ingesting the resulting PET grids and computing actual daily evapotranspiration based on antecedent soil moisture conditions.

Input Grid/File	**Description**	**Unit**
Basins	Basin Grid	
order.txt *see .txt file detail - 1.3*	Computational order file	

Rain and Evap Input Parameters

Input Parameters	**Description**	**Unit**
raindata	Rain data from directory	mm
evapdata	Evap data from directory	tenths of mm
Start Year	Start year of data	
End Year	End year of data	
Start Day Number	Start day of data –defaults 1– Julian Date	
End Day Number	End day of data –number of days included for data estimate –defaults -240- entered **10** (for shorter processing time) – Julian Date	

2.1.1 Rain and Evapotranspiration Output Files

Rain and Evap Output Data for Each Sub-Basin

Output Files	**Description**
rain.txt *see .txt file detail*	File containing time step rainfall (mm) for each sub-basin (per day)

below	
evap.txt *see .txt file detail below*	File containing time step PET (tenths of mm) for each sub-basin (per day)

rain.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd		1999001-1999010
	↓		
	Date 1999010		
BasinID of sub-basin beginning with the most downstream	time step rainfall for each sub-basin	mm	0.0 – 54.6
↓			
Most upstream sub-basin			

evap.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd		1999001 – 1999010
	↓		
	Date 1999010		
BasinID of sub-basin beginning with the most downstream	time step PET for each sub-basin	Tenths of mm	26-72
↓			
Most upstream sub-basin			

2.2 Compute Soil Water Balance

As a continuous simulation model, GeoSFM contains routines for computing soil moisture conditions on a daily basis. The soil parameters required by the model are extracted for each catchment from the FAO Soil Map described in section 1.3. Two Soil Moisture Accounting routines, using single and double soil layers respectively, have been coded in a mixed programming environment and compiled into dynamic link libraries (DLL). Avenue code has been rewritten to call up and execute the DLL routines from within ArcView. The user is consequently able to perform SMA runs from within the GIS environment. The features of the respective single and double layer models are described below.

The single layer soil model is a simple bucket model with partial contributing area for Hortonian surface runoff generation. In essence, the soil column is modeled as a single control volume with rainfall as the only input and evapotranspiration, subsurface runoff and deep ground water percolation as the only outputs. A fraction of incident rainfall becomes surface runoff before entering the control volume. The magnitude of this fraction is directly proportional to the fraction of the control volume that is filled with water. A simple soil moisture accounting method is used to track the moisture in the control volume during each simulation time step. The only parameters that need to be estimated are water holding capacity of the control volume, the response times for interflow and base flow extraction and the rate of percolation to deep ground water. The relatively simplicity of this model lends itself to implementation in data scarce wide-area applications. A significant limitation of this approach is that the type and condition of land cover within a catchment is not taken into account.

The two layer soil model provides a more complete representation of subsurface processes by creating separate soil layers within which interflow and base flow processes occur. Soil Conservation Service (SCS) runoff curve number method (which takes vegetation and soil type into account) is used for separating runoff into surface and interflow components while the Green-Ampt equation is used for extracting water from the interflow soil layer to feed the base flow soil layer. In addition to the parameters from the single layer model, parameters describing the fraction of the soil column that is attributable to the respective interflow and base flow layers, SCS curve numbers and Green-Ampt parameters are required for the two layer model. The superior representation of land surface and soil moisture processes makes the two layer model better suited for application in areas where finer resolution data is available to support its parameterization.

Irrespective of the choice of soil moisture accounting model, GeoSFM generates a series of ASCII files containing the fluxes from the respective surface, interflow, base flow and deep percolation phases of flow as well as the soil moisture storage. The output files are formatted for ingestion by the channel routing routines in GeoSFM.

Rain, Evap, Basin and Response Input Data

Input Files	**Description**
rain.txt *see .txt file detail -2.1*	File containing time step rainfall (mm) for each sub-basin
evap.txt *see .txt file detail -2.1*	File containing time step PET (tenths of mm) for each sub-basin
basin.txt *see .txt file detail -1.3*	File containing each sub-basin characteristics

response.txt *see .txt file detail -1.4*	File containing time step excess runoff arriving at sub-basin outlet

Input Data – Selection of Single or Double Layer Soil Model

Input Parameters	Description	Unit
Computation Start Year	Year entered into field	
Computation Start Day	Day --- default 001- Julian Date	
Number of Rain/Evap Days	Days --- default 10	
Number of Response Days	Days --- default 21 (how long the hydrograph is stretched)	
Number of Sub-basins	Number --- default 365	
Initial Soil Moisture	Assume soil is dry containing only 10% of its storage capacity ---- default 0.1 (decimal)	
Data Format (l for Daily Data)	1 = Day ---- default 1.0 0 = Hourly	
New Run or Continue Previous Run	0 = New run – default 0 – 1 = Continue previous run	
Basin Polygon Theme	Polygon of analysis area – selected **basply.shp** for exercise	
Key Field e.g. Grid Code	Selected **gridcode** for exercise–number ID	
Mode	0=Simulation, 1=Calibration -defaults-0	
Soil Model	Option of Single Layer Soil Model or Double Layer Soil Model ---selected **Single Layer** for exercise	

2.2.1 Soil Water Balance Outputs

Output parameters

Output Files	Description
balparam.txt *see .txt file detail below*	File containing: Number of ordinates of unit hydrograph response, number of simulation time steps, simulation start year/day, number of catchments, simulation interval in hours, data format, model initialization code, and initial soil fraction.
balfiles.txt *see .txt file detail below*	File listing input and output .txt files

Soil Moisture Output Data

Output Files	Description
basinrunoffyield.txt *see .txt file detail below*	Basin runoff yield –runoff for each sub-basin
soilwater.txt *see .txt file detail below*	Output soil moisture storage
actualevap.txt *see*	Actual evapotranspiration (mm)

.txt file detail below	
gwloss.txt *see .txt file detail*	Output file water lost to the regional groundwater flow
cswater.txt *see .txt file detail below*	Output file containing last model time step simulated soil water content (mm)
excessflow.txt *see .txt file detail below*	Output file excess runoff fluxes (mm)
interflow.txt *see .txt file detail below*	Output file interflow or fast base flow fluxes (mm)
baseflow.txt *see .txt file detail below*	Output file base flow fluxes (mm)
logfilesoil.txt *see .txt file detail below*	Process/Error Log File
massbalance.txt *see .txt file detail below*	Output file of sum of water cycle components for the total simulation period (mm) –only for **Double Layer Soil Model**
initial.txt *see .txt file detail below*	Input/output file that contains initial conditions for model state variables –only if **Double Layer Soil Model** is selected
default.txt *see .txt file detail below*	Soil model and routing configuration selected for model run.

balparam.txt Parameters	**Description**	**Units**	**Range of Values**
No headers	Number of ordinates of unit hydrograph response		13
	Number of simulation time steps		10
	Simulation start year		1999
	Simulation start day		001
	Number of catchments		355
	Simulation interval in hours		24
	Data format indicator (1/0) –defaults 1		0-1
	Model initialization mode (1/0) –defaults 0		0-1
	Initial soil fraction		0.1

balfiles.txt Parameters	**Description**
No header	Input rainfall file (rain.txt)
	Input potential evapotranspiration file (evap.txt)
	Input basin characteristics file (basin.txt)
	Input unit hydrograph response file (response.txt)

	Output balance parameter file (balparam.txt)
	Output runoff yield file (basinrunoffyield.txt)
	Output soil moisture storage file (soilwater.txt)
	Output actual evapotranspiration file (actualevap.txt)
	Output ground water loss file (gwloss.txt)
	Output final soil water storage file (cswater.txt)
	Output surface precipitation excess file (gwloss.txt)
	Output interflow file (interflow.txt)
	Output baseflow file (baseflow.txt)
	Output mass balance file (massbalance.txt)
	Output log file (logfilesoil.txt)
	Output initialization file (initial.txt)
	Output workdirectory (<full directory pathname>)

basinrunoffyield.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd		1999001 – 1999110
	↓		
	Date 1999110		
BasinID of sub-basin beginning with the most downstream	Time step runoff for each sub-basin.	mm	0.01-3.05
↓			
Most upstream sub-basin			

soilwater.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin	Time step soil moisture storage for		0.8-69.9

beginning with the most downstream	each sub-basin		
↓			
Most upstream sub-basin			

actualevap.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin beginning with the most downstream	Time step for actual evapotranspiration for each sub-basin	mm	0.001-5.1
↓			
Most upstream sub-basin			

gwloss.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin beginning with the most downstream	Time step water lost to the regional groundwater flow for each sub-basin		0-33.1
↓			
Most upstream sub-basin			

cswater.txt Parameters	**Description**	**Units**	**Range of Values**
Basin ID	ID of sub-basin beginning with the most downstream		
	↓		
	Most upstream sub-basin		
CurrentSW	Contains last model time step	mm	2.9-102.1

	simulated soil water content		

excessflow txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin beginning with the most downstream	Time step of excess runoff fluxes	mm	0-3.8
↓			
Most upstream sub-basin			

interflow.txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin beginning with the most downstream	Time step of interflow or fast base flow fluxes	mm	0-1.9
↓			
Most upstream sub-basin			

baseflow.txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd (first column)		1999001 – 1999110
	↓		
	Date 1999110		
ID of sub-basin	Time step base flow fluxes	mm	0.001-0.23

beginning with the most downstream			
↓			
Most upstream sub-basin			

logfilesoil.txt Parameters	**Description**	**Units**	**Range of Values**
	Process/Error Log File		

default.txt	**Description**	**Units**	**Range of Values**
No header	Soil configuration selected for model run. **Soil1** – Single layer soil model **Soil2** –Double layer soil model		
	Routing method selected for model run. **Rout1** –Simple Lag Routing Method **Rout2** –Diffusion Analog Routing Method **Rout3** –Mushingum Cunge Routing Method		

Additional Output for Double Layer Soil Model

massbalance.txt Parameters	**Description**	**Units**	**Range of Values**
basinId	ID of sub-basin beginning with the most downstream		1-366
	↓		
	Most upstream sub-basin		
precipitation	Sum of water cycle precipitation for the total simulation period.	mm	7-122
surfaceRunoff	Sum of water cycle surface runoff for the total simulation period.	mm	0-5
interflow	Sum of water cycle fast base flow flux for the total simulation period.	mm	0
baseflow	Sum of water cycle base flow flux for the total simulation period.	mm	0
evaportation	Sum of water cycle evaporation for the total simulation period.	mm	0-18
moisture_change	Difference of the water cycle value from start of model to end of model for the total simulation period.	mm	14-174

residual	Difference of water cycle (rain in, evaporation/runoff out) for the total simulation period.	mm	0-14

Additional Output for Double Layer Soil Model

initial.txt Parameters	**Description**	**Units**	**Range of Values**
Basin ID	ID of sub-basin beginning with the most downstream		1-366
	↓		
	Most upstream sub-basin		
upperSoilWater	Upper soil water values for each sub-basin.		
lowerSoilWater	Lower soil water values for each sub-basin.		
fastBaseflow	Fast base flow values for each sub-basin.		
slowBaseflow	Slow base flow values for each sub-basin.		
interflowWater	Interflow reservoir water values for each sub-basin.		
upperSoilExcessWater	Upper soil excess water values for each sub-basin.		
lowerSoilExcessWater	Lower soil excess water values for each sub-basin.		
surfaceWaterAtTime0	Surface water value at first time step of hydrograph for each sub-basin.		
surfaceWaterAtTime1	Surface water value at next time step of hydrograph for each sub-basin.		
surfaceWaterAtTime2	Surface water value at next time step of hydrograph for each sub-basin.		
↓	↓		
surfaceWaterAtTime19	Surface water value at next time step of hydrograph for each sub-basin		

2.3 Compute Stream Flow

When runoff generated within a given catchment arrives at the catchment outlet, it enters the river network and works its way downstream to the basin outlet. There are a variety of linear and non-linear routing methods for simulating the in-channel phase of flow. GeoSFM supports two linear methods namely pure translation and the diffusion analog, and one non-linear method, the Muskingum Cunge.

The pure translation approach is the simplest of the routing approaches. It accounts for the advection of flow but does not include any attenuation or deformation of the input. Consequently, the input flow remains unaltered in magnitude at the discharge point, and a single flow parameter namely travel time between the input and discharge locations is required for the computation. Mathematically, pure translation routing can be expressed as follows:

Equation 2

$$Q(t) = I(t - t')$$

where Q(t) is the discharge at time, t

t' is the travel time between input and discharge locations and

I(t-t') is the input at time (t-t')

The diffusion analog method is a linear routing method which accounts for both flow advection and attenuation. It includes one parameter for flow translation (flow time or celerity) and another for the attenuation or spreading out of flow (dispersion coefficient). The diffusion analog equation is fact the linear solution of the Advection-dispersion equation (also known as the Navier-Stokes equation for a plane rectangular source). Mathematically, the diffusion analog equation can be expressed as follows:

Equation 3

$$Q(x,t) = I(0,0)\left(\frac{x}{\sqrt{4\Pi D t^3}}\right)\exp\left[-\left(\frac{(Vt - x)^2}{4Dt}\right)\right]$$

where

D is the dispersion coefficient in m2/s

V is the flow celerity in m/s

x is the distance from the origin in m

t is the time elapsed since the input in seconds

π is the numerical constant Pi and has a value of 3.14159

Q(x,t) is the discharge at time t at a distance x from the origin

I(0,0) is the input at time zero at the origin

The Muskingum Cunge is a non-linear, variable parameter routing method. Like the linear Muskingum routing method, it involves the use of the continuity equation and an empirical storage equation. It relies on the Muskingum K coefficient (analogous to flow time) to control the rate of advection and the Muskingum x coefficient to control the rate of attenuation or spreading out. Cunge proposed to amend the method by allowing the Muskingum x coefficient to vary during each time step based on the condition of flow at the previous time step. In effect, the rate of attenuation of flow is dependent on the condition of flow. Mathematically, Muskingum Cunge routing can be expressed as follows:

Equation 4

$$\frac{dS}{dt} = I - Q$$

Equation 5

$$S = K\left[XI + (1 - X)Q\right]$$

where

Equation 6

$$K = \frac{\Delta x}{\bar{c}}$$ and

Equation 6

$$X = \frac{1}{2} - \left(\frac{\overline{Q}}{2\bar{c}\overline{B}S_e\Delta x} \right)$$

where

K is the Muskingum K coefficient in seconds
X is the dimensionless Muskingum X coefficient
c is the average flood wave celerity in m/s
B is the average channel width in m
Se is the dimensionless friction slope
x is the length of the channel
S is the storage in the channel at time t in m/s
I is the inflow in m/s
Q is the discharge in m/s

All catchments within the analysis area are parameterized for the three routing methods during preprocessing such that the user can opt for any of the three methods just prior to execution without additional preprocessing.

Stream Flow Input Data

Input Files	Description
basinrunoffyield.txt *see .txt file detail -2.2*	Basin Runoff Yield File
response.txt *see .txt file detail -1.4*	File containing time step excess runoff arriving at sub-basin outlet
river.txt *see .txt file detail -1.3*	File containing river characteristics
reservoir.txt *see .txt file detail below*	Reservoir Characteristic File
rating.txt *see .txt file detail below*	Stream gauge input containing BasinID, type, parameters and maximum river depth.

Input Data –Selection of Routing Method

Input Parameters	Description	Units
Basin Polygon Theme	Polygon of analysis area – selected **basply.shp** for exercise	
Key Field eg Grid Code	Selected **gridcode** for exercise	
Number of Days of Forecast Required	Default - 3	
Mode	0=Simulation, 1=Calibration -default 0-	
Routing Method	Needed for the computation –three options Simple Lag Routing Method, Diffusion Analog Routing Method, or Muskingum Cunge Routing Method – selected **Simple Lag Routing Method** for exercise	

Input Data for Stream Flow Routing if dams exist

reservoir.txt Parameters	Description	Units	Range of Values
DamID	Basin Id where dam is located.		
Storage	Storage in 1000m3		
Residence Time	Defaults **30**		
Operated	0 –No user defined file 1 –User defined file used		0, 1
OpFilName	Path and file name if user defined file is used. Defaults -**None**		

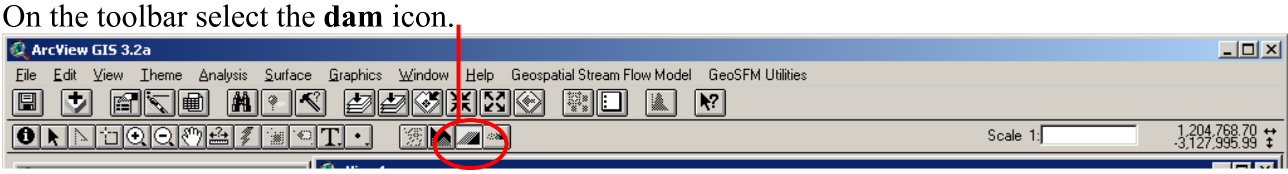
Input only when stream gauges are used in streams

rating.txt	Description	Units	Range of Values
BasinID	BasinID of sub-basin beginning with		

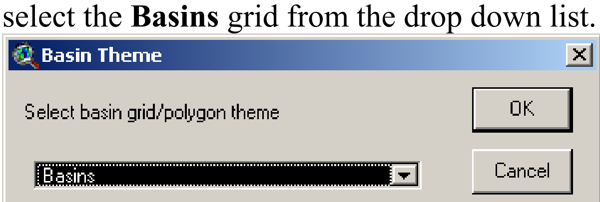
	the most downstream		
	↓		
	Most upstream sub-basin		
Type	Two different types based on the following equations: Type1 – Q = A(H+B)^C Type 2 –Q = (A*H^2)+ BH + C where: A= Par1 B= Par2 C= Par3	Q =m^3/sec (flow) H = m (height)	1, 2
Par1	Equation Parameter for "A"		
Par2	Equation Parameter for "B"		
Par3	Equation Parameter for "C"		
hmax	Maximum height where equation is valid.		

Creating a Reservoir Characteristic File – reservoir.txt

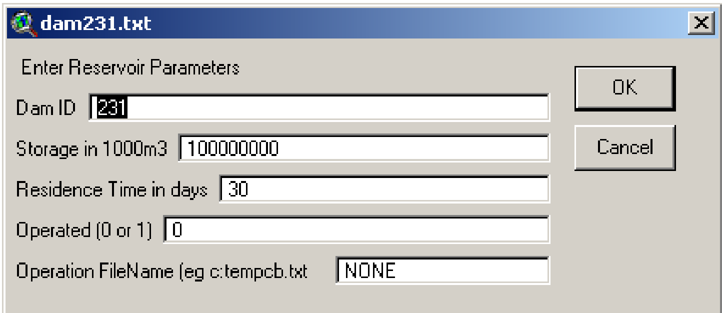
If there are any dams on a river or stream within the basin you will need to create a reservoir file. On the toolbar select the **dam** icon.



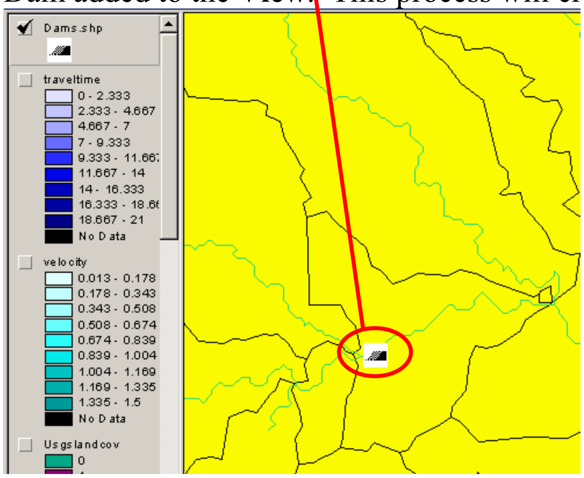
The curser will change symbols, position your mouse on the stream containing the dam. Left click your mouse and a **Dams** shapefile will be added to your project. In the first dialog box displayed, select the **Basins** grid from the drop down list. Click **OK**.



Next, you will enter the reservoir parameters. The **Dam ID** will populate with the **Basin Id** of the selected point on the stream. The **Storage** value is needed along with the **Residence Time in days**. The **Operated** field is populated with either a 0 or 1 depending on a user defined file. (0 if no file, 1 if there is a file.) If the file is needed the file path and name will be populated in the **Operation FileName** field. Click **OK**.



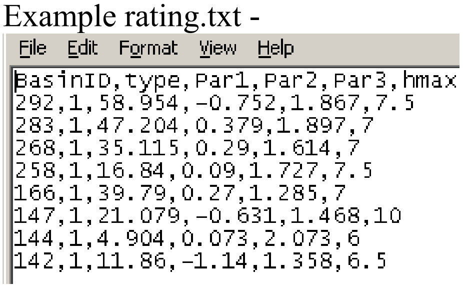
Dam added to the **View**. This process will create a **reservoir.txt** file.



Creating a Stream Gauge File – rating.txt

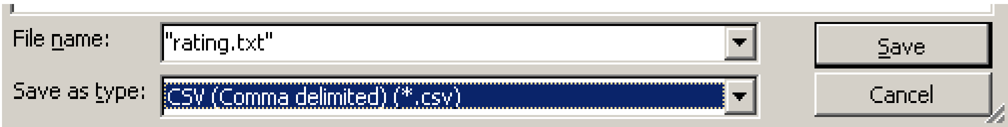
If you need to input stream flow data from stream gauges the data will need to be in a format as the file below. The first column header is **BasinID**, starting with the most downstream basin. The next column header is **Type** here you will populate with either a 1 or 2 depending on which equation you will be using. The next three column headers are the three different equation parameters –**Par1**, **Par2**, and **Par3**. The last column is **hmax** which is populated with the maximum flow height where the equation is valid. Create your file using Excel.

Example rating.txt -


File Edit Format View Help

```
BasinID,type,Par1,Par2,Par3,hmax
292,1,58.954,-0.752,1.867,7.5
283,1,47.204,0.379,1.897,7
268,1,35.115,0.29,1.614,7
258,1,16.84,0.09,1.727,7.5
166,1,39.79,0.27,1.285,7
147,1,21.079,-0.631,1.468,10
144,1,4.904,0.073,2.073,6
142,1,11.86,-1.14,1.358,6.5
```

To save the file select **File** and **Save As…**
File name: "rating.txt"
Save as type: CSV (Comma delimited) (*.csv)



2.3.1 Stream Flow Routing Outputs

Output from Routing Method

Output Files	**Description**
routparam.txt *see .txt file detail below*	File containing: number of simulation time steps, simulation start year/day, number of catchments, simulation interval in hours, model type, number of forecast days, model initialization mode, number of reservoirs
routfiles.txt *see .txt file detail below*	File listing input and output .txt files

Stream Flow Routing Output files

Output Files	**Description**
inflow.txt *see .txt file detail below*	Flow values coming from upstream for each sub-basin.
streamflow.txt *see .txt file detail below*	Stream flow file contains a time series of velocity values in cubic meters per second for each sub-basin.
localflow.txt *see .txt file detail below*	Flow value generated in each sub-basin.
riverdepth.txt *see .txt file detail below*	River depth file populates when **Muskingum Cunge Routing Method** is selected.
diffresponse.txt *see .txt file detail below*	Output file …….–only if **Diffusion Analog Routing Method** is selected
damstatus.txt *see .txt file detail below*	Reservoir status file –only if there are dams in sub-basin
damlink.txt *see .txt file detail below*	Dam link file –only if there are dams in sub-basins
forecast.txt *see .txt file detail below*	
obsflow.txt *see .txt file*	

detail below	
times.txt *see .txt file detail below*	Start/end time and date of computing stream flow process.
logfileflow.txt *see .txt file detail below*	Process/Error log file.

routparam.txt Parameters	**Description**	**Range of Values**
No Header	Number of simulation time steps	10
	Simulation start year	1999
	Simulation start day	001
	Number of catchments	365
	Simulation interval in hours	24
	Model type (0=Musk-Cunge, 1=Linear Reservoir)	0,1
	Number of forecast day	3
	Model initialization mode (1/0)	1
	Number of reservoirs	0

routfiles.txt Parameters	**Description**
No Header	Route parameter file (routparam.txt)
	Input river characteristics file (river.txt)
	Input river initialization file (initial.txt)
	Input runoff yield file (basinrunoffyield.txt)
	Input reservoir-river link file (damlink.txt)
	Input observed flow file (obsflow.txt)
	Input rating curve flow file (rating.txt)
	Output streamflow file (streamflow.txt)
	Output sub-basin flow contribution file (localflow.txt)
	Output average river depth file (riverdepth.txt)
	Output sub-basin upstream flow contribution (inflow.txt)
	Output flow routing log file (logfileflow.txt)
	Output work directory (<full directory pathname>)

inflow.txt Parameters	**Description**	**Units**	**Range of Values**
Time	Date – example 1999001 – format yyyyddd		1999001 – 1999013
	↓		
	Date 1999013		
BasinID of sub-	Upstream flow values for each sub-		0-1470

basin beginning with the most downstream	basin.		
↓			
Most upstream sub-basin			

streamflow.txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd		1999001 – 1999013
	↓		
	Date 1999013		
BasinID of sub-basin beginning with the most downstream	Time step total discharge for each sub-basin	m3/s	0.279-1471.28
↓			
Most upstream sub-basin			

localflow.txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd		1999001 – 1999013
	↓		
	Date 1999013		
BasinID of sub-basin beginning with the most downstream	Flow value generated in each sub-basin.		.001-148.293
↓			
Most upstream sub-basin			

forecast.txt	Description	Units	Range of Values
Time			
BasinID of sub-basin beginning with the most downstream			
↓			
Most upstream sub-basin			

obsflow.txt	Description	Units	Range of Values

times.txt	Description
No header	Starting time: Day of the week, month/day, hour/minute/second, year. Ending time: Day of the week, month/day, hour/minute/second, year. Example – Fri Oct 28 16:49:59 2005

logfileflow.txt	Description
No header	File history.
	CREATED LOGFILEFLOW.TXT FILE ****READ ROUTFILES.TXT **** ***OPENED ROUTPARAM.TXT FILE*** ****READ ROUTPARAM.TXT **** ***OPENED RIVER.TXT FILE*** ***OPENED BASINRUNOFFYIELD.TXT FILE*** ***CREATED INFLOW.TXT FILE*** ***CREATED STREAMFLOW.TXT FILE*** ***OPENED DAMLINK.TXT FILE*** ***CREATED LOCALFLOW.TXT FILE*** ****READ BASIN FILE HEADER**** ****READ RUNOFF FILE HEADER**** ****READ BASIN FILE**** ****READ BASIN RUNOFF YIELD FILE**** ****INITIATING ROUTING**** ***WRITING OUTPUT FILES*** ***CLOSING TIME SERIES FILES*** ***RETURNING TO ARCVIEW***

Additional Output for Muskingum Cunge Routing Method

riverdepth.txt Parameters	Description	Units	Range of Values
Time	Date – example 1999001 – format yyyyddd (first column)		

	↓		
	Date 1999013		
BasinID of sub-basin beginning with the most downstream	Time step river depth for each sub-basin.	m	0.01 – 16.55
↓			
Most upstream sub-basin			

Additional Output for Diffusion Analog Routing Method

diffresponse.txt	**Description**	**Units**	**Range of Values**
	14 columns of data		
Could not re-create 8/11			

Output only if dams are present in sub-basins

damstatus.txt Parameters	**Description**	**Units**	**Range of Values**

Output only if dams are present in sub-basins

damlink.txt	**Description**	**Units**	**Range of Values**

3.0 Calibration

3.1 Perform Sensitivity Analysis

Sensitivity analysis (SA) serves a dual purpose of testing which sensitive parameters should be used for calibration as well as analyzing feasible parameter ranges. The goal of SA is to see if there is a change in model results when the parameter values are changed. The program SArun.exe tests twenty input parameters over user specified ranges. It takes a total of 400 model runs to complete the SA test. The SA result can be used to tests the model structure, if parameters assumed to have a strong impact on model results do not show any sensitivity, the model structure should be reassessed. The SA can give a clear understanding of the feasible parameter space. If the SA results show a parameter to be too sensitive or not sensitive at all, it may be that the parameter range must be refined. Getting the minimum and maximum parameter space refined as much as possible using realistic values for the specific watershed one is modeling is imperative for realistic calibration results.

Input Parameters	**Description**
River Reach	Drop down list of river reach –selected 140 for exercise 4
Model Configuration	Drop down list of all possible model configurations – soil/routing. Selected one soil layer, lag routing for exercise 4.

Multiplier Range for Sensitivity Parameters --populates range.txt

Name	**Description**	**Unit**	**Default Value Min/Max**
soilwhc	Soil water holding capacity	mm	1,600
depth	Total soil depth	cm	1,800
texture	Soil texture: 1=sand, 2=loam, 3=clay, 5=water		1,5
Ks	Saturated hydraulic conductivity	cm/hr	0.001,150
Interflow	Interflow storage residence time	days	1,365
Hslope	Average sub-basin slope		0.001,10
Baseflow	Baseflow reservoir residence time	days	1,365
Curvenum	SCS runoff curve number		25,98
Maxcover	Permanently impervious cover fraction		0.01,1
Basinloss	Fraction of soil water infiltrating to ground water		0.01,0.5
PanCoeff	Pan coefficient for correcting PET readings		0.6,0.95
Topsoil	Fraction of soil layer that is hydrologically active		0.05,1
raincalc	Excess rainfall mode 1=Philip, 2=SCS, 3=BucketModel		3
rivrough	River Channel Roughness Coefficient (Manning n)		07
rivslope	Average slope of the river		0.001,10
rivwidth	Average channel width	m	1,1000
rivloss	Fraction of flow lost within the river channel		0.01,0.5
rivfploss	Fraction of the river flow lost in floodplain		0.01,0.5
Celerity	Flood wave celerity	m/s	0.1,5

diffusion	Flow attenuation coefficient	m^2/s	100,10000

Input Files	**Description**
range.txt *see above table*	Provides minimum and maximum values of a feasible parameter range for testing model sensitivity.
balparam.txt *see section 2.2*	File containing: Number of ordinates of unit hydrograph response, number of simulation time steps, simulation start year/day, and number of catchments, simulation interval in hours, data format, model initialization code, and initial soil fraction.
basin_original.txt *see section 1.3*	Original basin characteristics.
basin.txt *see section 1.3*	File containing each sub-basin characteristics. This file is rewritten during the sensitivity analysis process.
river_original.txt *see section 1.3*	Original river characteristics.
river.txt *see section 1.3*	File containing river characteristics. This file is rewritten during the sensitivity analysis process.
moscem_param.txt *see .txt file detail below*	Gives location of outlet in model output file.
whichmodel.txt *see .txt file detail below*	Sets choice of water balance and routing model configurations.

Moscem_param.txt parameters	**Parameter**	**Description**	**Range of Values**
No header	Nflux	Number of output variables (fluxes).	1
	Ntstep1	Number of time steps of input variables.	10
	Nstep2	Number of time steps of output variables.	10
	Obj_func	Statistical test: 1 = “RMSE” root mean square error function 2 = “STD” standard deviation 3 = “HMLE” maximum likelihood error function 4 = “NSE” Nash-Sutcliffe efficiency 5 = “NSC” Number of sign changes 6 = “BIAS”	1
	Missing Value	Value of missing data in observed_streamflow.txt.	-9999
	Nflux_obs	Column in observed_streamflow.txt to test.	1
	Nflux_model	Column in streamflow.txt to extract modeled data	10

whichModel.txt parameters	**Description**	**Range of Values**
Model Index	Models: Water balance model Routing model	1-3
Index Description	Water balance model – 1=1D balance, 2=2Dbalance	
	Routing model –1=diffusion, 2=Muskingham-Cunge, 3=lag	

Output Files	**Description**
oat.txt *see .txt file detail below*	One-at-a-Time parameter index and multiplier values used in sensitivity analysis.
SensAnalysis.txt *see .txt file detail below*	Results of sensitivity analysis for each model run, includes parameter index, multiplier value, mean, maximum, and standard deviation of modeled streamflow results.
SArunOutput.txt *see .txt file detail below*	Gives the mean absolute difference of test results over the parameter range for each parameter. The greater the differences, the more sensitive the parameter.

oat.txt parameters	**Description**	
Whichparam	List of 1	1-20
	↓	
	through 20 For all 20 runs, total of 400 lines.	
OAT Parameter Value	Multiplier values used in sensitivity analysis.	0.0011 – 495.0495

SensAnalysis.txt parameters	**Description**	**Range of Values**
whichParam	List of 1	1-20
	↓	
	through 20 For all 20 runs, total of 400 lines.	
OAT Parameter Value	Multiplier values used in sensitivity analysis.	0.0011 – 495.0495
Max_mod	Maximum of modeled streamflow results.	0 – 3989.274
Mean_mod	Mean of modeled streamflow results.	0 – 2933.24
stddev	Standard deviation of modeled streamflow results.	0 – 1149.123

SArunOutput.txt Parameters	Description	Range of Values
whichparm	List of 1	1 - 20
	↓	
	through 20	
max_mod	The maximum difference of test results over the parameter range for each parameter.	0 – 9.256
mean_mod	The mean difference of test results over the parameter range for each parameter	0 – 6.834
stddev	The standard deviation of test results over the parameter range for each parameter.	0 – 2.705

3.2 Perform Model Calibration

The purpose of calibration is to adjust the model parameters so that the model closely matches the real system. Although many GeoSFM model parameters are derived from spatially distributed observed data, uncertainties in parameter adjustment to differences in scale, uncertainty in deriving the parameter values from observed data, and uncertainties in the structure of the model require that parameters be adjusted to overcome what we do not know, and can not measure about the watershed. These issues apply to all hydrologic models.

The calibration process begins with the model setup. The terrain analysis extracts model parameters and creates basin.txt and river.txt watershed attributes. Next, the user must make an assessment of the un-calibrated model. The best calibration results can only be achieved with realistic parameter inputs and an appropriate model structure for the watershed that is being modeled. The un-calibrated model results should be analyzed before beginning the calibration. The program dllcaller.exe will call the GeoSFM and run the model one time using the basin.txt and river.txt inputs. The program UncalibStats.exe will report basic model performance statistics using the model output and observed streamflow.

For calibration, a subset of the 20 parameters tested in the SA should be selected. For the parameters not selected for calibration, the default 'uncalibrated' values in the watershed attribute files are used. The program RunMOSCEM.exe is the main calibration program. Although there are many calibration algorithms that have been developed for hydrologic modeling over the years, the MOSCEM algorithm has been chosen for its ability to consistently find optimum parameter sets with the least amount of model runs. The range of model runs will generally be on the order of 5000 -10000 model runs necessary to converge to a global minimum. The parameter values that created the best model results are retained. The program MOSCEMpostprc.exe is used to post-process the calibration results, or rerun the model using the best parameter values so that the streamflow results can be plotted and analyzed.

Input Parameters	Description
Observed Streamflow Stations	The streamflow station Id displayed in a drop down list. Selected **1** for exercise 4.
Basin ID for Streamflow Station	Drop down list of basin Ids, select Id that corresponds with the streamflow station selected. In exercise 4 selected **140**.
Number of Runs	Drop down list of choices. Selected **54** for exercise 4. (Selected for faster processing time.) The number of model runs depends on the length of streamflow record, number of parameters being tested, and the complexity of the parameter dependent model response for the watershed being modeled. The range will generally be on the order of 5000 -10,000 model runs necessary to converge to a global minimum.
Objective Function Type	Convergence can be measured: Root Mean Square Error (RMSE) Standard Deviation (STD) Maximum Likelihood Error (MLE) Nash-Sutcliffe Efficiency (NSE) Number of Sign Changes (NSC) BIAS Selected **RMSE** for exercise 4.

Parameters to be Calibrated

Parameter	Description
SoilWhc	Soil water holding capacity
Depth	Total soil depth
Texture	Soil texture: 1=sand, 2=loam, 3=clay, 5=water
Ks	Saturated hydraulic conductivity
Interflow	Interflow storage residence time
HSlope	Average sub-basin slope
Baseflow	Baseflow reservoir residence time
CurveNum	SCS runoff curve number
MaxCover	Permanently impervious cover fraction
BasinLoss	Fraction of soil water infiltrating to ground water
PanCoeff	Pan coefficient for correcting PET readings
TopSoil	Fraction of soil layer that is hydrologically active
RainCalc	Excess rainfall mode 1=Philip, 2=SCS, 3=BucketModel
RivRough	River Channel Roughness Coefficient (Manning n)
RivSlope	Average slope of the river
RivWidth	Average channel width
RivLoss	Fraction of flow lost within the river channel
RivFPLoss	Fraction of the river flow lost in floodplain
Celerity	Flood wave celerity
Diffusion	Flow attenuation coefficient

Input Files	Description
balparam.txt *see section 2.2*	File containing: Number of ordinates of unit hydrograph response, number of simulation time steps, simulation start year/day, and number of catchments, simulation interval in hours, data format, model initialization code, and initial soil fraction.
basin_original.txt *see section 1.3*	Original basin characteristics.
basin.txt *see section 1.3*	File containing each sub-basin characteristics. This file is rewritten during the sensitivity analysis process.
river_original.txt *see section 1.3*	Original river characteristics.
river.txt *see section 1.3*	File containing river characteristics. This file is rewritten during the sensitivity analysis process.
streamflow.txt *see .txt detail in section 3.2*	Streamflow file contains a time series of velocity values in cubic meters per second for each sub-basin.
parameter.in *see file detail below*	Range of multiplier values used to define parameter search space: $Min_{parameter.in} = Min_{range.txt}$ / (basin ave param) $Max_{parameter.in} = Max_{range.txt}$ / (basin ave param)
moscem.in *see file detail below*	Main calibration algorithm control file.
MOSCEMx.txt *see .txt file detail below*	File listing which parameters to calibrate.
moscem_param.txt *see .txt detail in section 4.1*	Calibration control file.
ObjOptFlag.in *see file detail below*	Flag for number of fluxes to "multi"-calibrate.
whichModel.txt *see .txt detail in section 4.1*	Sets choice of water balance and routing models.
observed_streamflow.txt *see .txt file detail below*	Observations from which to compare model results.

parameter.in	Description	Unit	Range of Values
No	Index		1 - 20

Name	Parameter name *see "Parameters to be Calibrated"*		
Default	Dummy variable		1
Lower	Minimum multiplier value		0.001 – 2.222
Upper	Maximum multiplier value		0.234 – 495.049
OptIdx	Optimization flag: 0 = do not optimize, 1 = optimize		0,1
Description	Description of parameter *see "Parameters to be Calibrated"*		

moscem.in	**Parameter**	**Description**	**Values**
No Header	nOptPar	Number of parameters used for optimization.	6
	nOptObj	Number of fluxes used for optimization.	1
	nSamples	Number of random samples from nOptPar dimensioned parameter space per shuffle.	54
	nComplex	Number of complexes.	3
	nMaxDraw	Maximum number of function evaluations/model runs.	54
	ParamMult file	Name of the parameter file including path	D:\GeoSFM\workspace\parameter.in
	whichFlux file	Name of the file specifying which fluxes to be calibrated, including path.	D:\GeoSFM\workspace\objoptflag.in
	Observed streamflow file	Name of the file providing evaluation data, including path.	D:\GeoSFM\workspace\observed_streamflow.txt
	ObjectiveResults output	Name of file storing the parameter values of the final points, including path.	D:\GeoSFM\workspace\objectives.out
	Parameter values output	Name of file storing the objective function values of the final points, including path.	D:\GeoSFM\workspace\parameter_values.out
	Parameter convergence output	Name of the file keeping track of the convergences of each of the parameters, including path.	D:\GeoSFM\workspace\par_convergence.out

MOSCEMx.txt	**Description**	**Value**
Parameter Index	One line for each parameter to be calibrated.	1 - 20
	↓	

	Last line setting to denote end of life.	-999

ObjOptFlag.in

Example of two fluxes –multi-objective

No Header	Description	Value
	Runoff_1	1
	Runoff_2	1

Example of one flux –single-objective

No Header	Description	Value
	Runoff_1	1
	Runoff_2	0

See section 4.2.1 for instructions on creating an observed_streamflow.txt file.

observed_streamflow.txt	Description	Value
Time	Date – example 1999001 – format yyyyddd	
	↓	
	Date 1999365	
Streamflow Stations	Streamflow values	0.542 – 353.646
↓		
Last station		

Output Files	Description
Par_convergence.out *see file detail below*	Parameter convergence for best nSamples.
Objectives.out *see file detail below*	Parameter_values for best nSamples.
Parameter_values.out *see file detail below*	Objective function results for best nSamples.

Par_convergence.out		
No data written to file		

Objectives.out	Description	Value
nSampleIndex	Sample number starting with 1	1 - 60
	↓	
	Last sample 60	

Objective values for each flux	Parameter_values for best nSamples	1058.466 – 4453.49
Fitness/Probability for each sample		0

Parameter_values.out		
No data written to file		

Post-processing

Input Files	**Description**
balparam.txt *see section 2.2*	File containing: Number of ordinates of unit hydrograph response, number of simulation time steps, simulation start year/day, and number of catchments, simulation interval in hours, data format, model initialization code, and initial soil fraction.
basin_original.txt *see section 1.3*	Original basin characteristics.
basin.txt *see section 1.3*	File containing each sub-basin characteristics. This file is rewritten during the sensitivity analysis process.
river_original.txt *see section 1.3*	Original river characteristics.
river.txt *see section 1.3*	File containing river characteristics. This file is rewritten during the sensitivity analysis process.
postproc.in *see file detail below*	File containing nSamples, observed streamflow values, Parameter_values.out, Objectives.out, Timeseries.out, ObjectStats.out and Trdoff_bounds.out.

postproc.in	**Parameter**	**Description**	**Default**
No Header	nSamples	Same nSamples from moscem.in, equivalent to number of parameter sets saved in parameter_values.out	
		Observed values	Observed_streamflow.txt
		Parameter value output file from calibration	Parameter_values.out
		Objective function results output file from calibration	Objectives.out
		Timestep, Observed Streamflow, Single timeseries of "best" calibration run	Timeseries.out
		Objective Statistics for all six objective functions for the streamflow runs presented in timeseries.out	ObjectStats.out
		Timestep, Lower boundary, upper boundary, and average streamflow over the nSample model runs	Trdoff_bounds.out

Post-Processing

Output Files	**Description**
timeseries.out *see file detail below*	Objective function results output file from calibration.
objectiveStats.out *see file detail below*	All statistic tests from "best" calibration run in timeseries.out.
Trdoff_bounds.out *see file detail below*	Timestep, lower boundary, upper boundary, and average streamflow over the nSample model runs.

timeseries.out	**Description**	
Timestep	Date 1	1 - 365
	↓	
	Date 365	
Observed Station 1	Observed Streamflow values.	38.23 – 963.21
Calibrated Station 1	Single time series of "best" calibration run.	22.65 – 10109.30

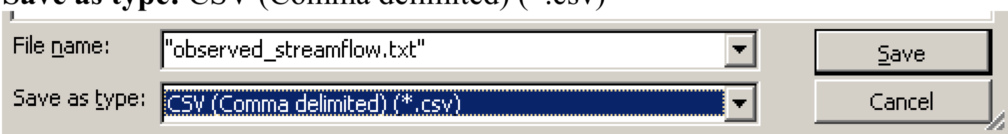
objectiveStats.out	**Description**	
No data written to file		

trdoff_bounds.out	**Description**	
Timestep	Date 1	1 - 365
	↓	
	Date 365	
LowerBound Station1	Lower boundary streamflow values for station 1.	12.06 – 2906.70
UppBound Station1	Upper boundary streamflow values for station 1.	61.05 – 41697.60
Average Station1	Average streamflow values for station 1.	25.13 – 9196.44

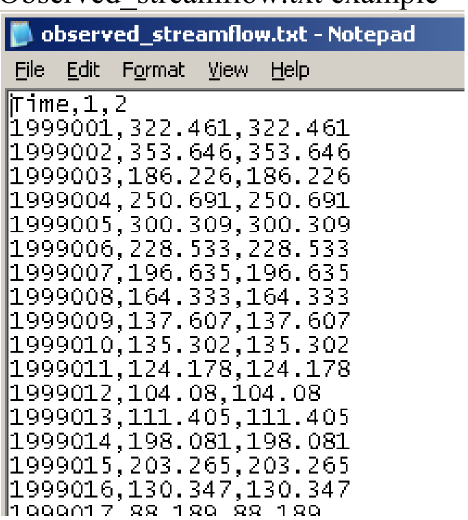
3.2.1 Creating Observed Streamflow File

To complete the calibration process you will need observed streamflow data in a format the same as the file below. The first column header is Time, with a time series of days formatted yyyyddd populating column "A". The rest of the header information is the streamflow gauge IDs. In your example two different streamflow gauges are used labeled 1 and 2. These columns are populated with the observed stream flow values. Create your file using Excel. Copy and paste your streamflow data into the Excel file.

To save the file select **File** and **Save As…**
File name: "observed_streamflow.txt"
Save as type: CSV (Comma delimited) (*.csv)



Observed_streamflow.txt example




```
Time,1,2
1999001,322.461,322.461
1999002,353.646,353.646
1999003,186.226,186.226
1999004,250.691,250.691
1999005,300.309,300.309
1999006,228.533,228.533
1999007,196.635,196.635
1999008,164.333,164.333
1999009,137.607,137.607
1999010,135.302,135.302
1999011,124.178,124.178
1999012,104.08,104.08
1999013,111.405,111.405
1999014,198.081,198.081
1999015,203.265,203.265
1999016,130.347,130.347
```

You now have a file that will be used in the **Calibration** process.

4.0 Post-Processing

4.1 Update Bankfull and Flow Statistics

At the end of a simulation run, the user often wants to compute a summary of the results. GeoSFM includes a tool for computing a variety of flow statistics including the maximum, minimum, mean, standard deviation, median, 25^{th}, 33^{rd}, 66^{th}, and 75^{th} percentile flows for each catchment. The results of the flow statistics computations are stored in the form of tables which are linked to the catchment data layer. The user can access the values for each catchment by clicking on the catchment in the visual interface or by modifying the legend of the associated data layer in the visual interface to display the computed values.

Input Files	**Description**
streamflow.txt *see .txt detail section 2.3*	Stream flow file contains a time series of velocity values in cubic meters per second for each sub-basin.

4.1.1 Flow Statistics Outputs

Output Files	**Description**
monthlyflow.txt *see .txt detail below*	Stream flow file contains a monthly time series of velocity values in cubic meters per second for each sub-basin.
annualflow.txt *see .txt detail below*	Stream flow file contains an annual time series of velocity values in cubic meters per second for each sub-basin.
riverstats.txt *see .txt detail below*	List of stream flow statistic types and corresponding values.
statsparam.txt *see .txt detail below*	
logfilestats.txt *see .txt detail below*	
Table 1 *see table detail below*	

monthlyflow.txt	**Description**	**Units**	**Range of Values**
Time	Date – example 199901 – format yyyymm (year, month)		
BasinID of sub-basin beginning with the most downstream	Stream flow file contains a monthly total time series of velocity values in cubic meters per second for each sub-basin.	m^3/s	8.266 – 1471.28
↓			
Most upstream sub-basin			

annualflow.txt	**Description**	**Units**	**Range of Values**
Time	Date – example 1999 –year		
BasinID of sub-basin beginning with the most downstream	Stream flow file contains an annual total time series of velocity values in cubic meters per second for each sub-basin.	m^3/s	8.266 – 1471.28
↓			
Most upstream sub-basin			

riverstats.txt	**Description**	**Units**	**Range of Values**
Id	File record number		1 - 415
Gridcode	Sub-basin ID number		1- 366
Soilwater	Soil water value for sub-basin		8.3 – 84.7
Currentsw	Current soil water value (same as Soilwater) for sub-basin		8.3 – 84.7
Sum			0
Count	Number of days		13
Mean	Stream flow mean value for sub-basin		1 – 983.6
Maximum	Stream flow maximum value for sub-basin		4.4 – 1471.3
Minimum	Stream flow minimum value for sub-basin		0.1 – 396.2
Range	Stream flow range value for sub-basin		4.3 – 1141.6
Variance	Stream flow variance value for sub-basin		1.6 – 174152.3
Stddev	Stream flow standard variation value for sub-basin		1.3 – 417.3
Median	Stream flow median value for sub-basin		0.1 – 1034.4
Quart25			0.1 – 728.4
Quart75			0.4 – 1226.4
Quart33			0.1 – 794.8
Quart66			0.1 – 1034.4
Highflow	Stream flow high flow value for sub-basin		2.1 - 1203
Lowflow	Stream flow low flow value for sub-basin		1 – 31.4
Medflow	Stream flow medium flow value for		1 – 983.6

	sub-basin		

statsparam.txt	Description
No header	1999
	1
	1
	1999
	13
	365
	Max
	C:\GeoSFM\workspace\streamflow.txt
	C:\GeoSFM\workspace\monthlyflow.txt
	C:\GeoSFM\workspace\annualflow.txt

logfilestats.txt	**Description**	**Units**
	Start Year=1999	
	Start Day=1	
	Number of Records=13	
	Number of Fields=365	
	Operation (0-MEAN, 1-MEDIAN, 2-MAX) = 2	
	Input filename C:\GeoSFM\workspace\streamflow.txt	
	Monthly Output filename C:\GeoSFM\workspace\monthlyflow.txt	
	Annual Output filename C:\GeoSFM\workspace\annualflow.txt	
	Calculating monthly max for month 1	
	Writing annual values	

4.2 Display Flow Percentile Map

Visual maps are considerably easier to interpret than tabular time series data particularly when dealing with large river basins. GeoSFM contains a tool for displaying the results of simulations for any given date in a visual map. The stream flow values on a user-selected date are presented in the form of indices which present the values in the context of predefined criteria. The default criterion for differentiating between low and normal flow is the 33rd percentile flow for the analysis period, while the 66th percentile flow is the minimum threshold separating normal flow and high flows. However, the user can define other criteria such as return period flow or predetermined drought and flood warning levels for the classification of flows. Each catchment is assigned a flow status index of 1, 2 or 3 to signify the respective low, normal and high flow conditions. A color-coded map is then produced showing the flow status of each catchment for the select day.

Input File	**Description**
streamflow.txt *see .txt detail in section 3.2*	Stream flow file contains a time series of velocity values in cubic meters per second for each sub-basin.

Additional Input Parameters

Input Parameter	**Description**	**Units**
Date	Selected from drop-down list of dates for flow percentile map --yyyyddd –Julian day	

4.2.1 Flow Condition Output

Output	**Description**
Map	Map showing daily variation of stream flow values displayed as low, normal and high conditions

4.3 Display Flow Hydrographs

GeoSFM contains a graphing tool for plotting hydrographs at the completion of a simulation run. The tool can be activated from either a program menu or the tool menu bar. The user can then visually select the catchment for which a hydrograph is required by clicking on the catchment in the visual interface. The program automatically matches the spatial information with the time series and produces a hydrograph. The flexibility of this tool is limited by ArcView's rather limited charting capabilities. The user is consequently encouraged to import the ACSII files resulting to flow simulations into spreadsheet programs such as Microsoft's Excel for more sophisticated time series plotting capabilities.

Input Parameters	**Description**
Basin Theme	Drop down list of choices – **basply.shp** selected
Sub-basin ID	Drop down list of choices –**Gridcode** selected

4.3.1 Hydrograph Outputs

Output	Description
Hydrograph	Graph showing daily variation of stream flow at the outlet of the selected sub-basin

GeoSFM Utilities

5.0 GeoSFM Utilities –Raindata

The GeoSFM Utilities Raindata section consists of three steps for processing rain/evap data. The first step is to download the rain/evap data from the FTP site. The second step is to prepare the data for analysis by unzipping, untarring and converting image files to grids. The last step in preparing the rain/evap data is to change the projection from geographic to Lambert Azimuthal.

5.1 Downloading Rain/Evap Grid

Input Parameters	Description
FTP Site Information	FTP Site Location default-**edcftp.cr.usgs.gov**
	Site User Name default -**anonymous**
	Site Password default –**anonymous@edc**
Specify Type of Data to Download	Options: **Get Rainfall Grids**, Get Foredast Rainfall Grids, **Get Global Pet Grids**, and Get Global TRMM Rainfall Grids – selections made for exercise six are in bold
Region of Analysis	Options: Global, **Africa**, SE Asia, Afghanistan, Australia, NAmerica, CAmerica, SAmerica, and Europe –selected Africa for exercise six -data is not available for all regions
Select Grids to downloaded	A list of sixteen days of data is presented –ten days were selected to complete exercise six –**rain_yyyyddd.tar.gz** or **evap_yyyyddd.tar.gz**

5.1.1 Available Data

Sixteen days of data are available for downloading from the FTP site.

The best data currently available by region for rain data:

Global – TRMM (Tropical Rainfall Measuring Mission)
File naming convention –TRMMYYMMDD*g –TRMM, YY (year), MM (month), DD (day)
*g at the end of the file name if the data is in geographic projection
Afghanistan – no data
South East Asia –RFE (rainfall estimates)
File naming convention -Rain_YYYYDDD*g –Rain_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection
Australia – TRMM (Tropical Rainfall Measuring Mission)
File naming convention –TRMMYYMMDD*g –TRMM, YY (year), MM (month), DD (day)
*g at the end of the file name if the data is in geographic projection
North America –TRMM (Tropical Rainfall Measuring Mission)
File naming convention –TRMMYYMMDD*g –TRMM, YY (year), MM (month), DD (day)
*g at the end of the file name if the data is in geographic projection
South America –TRMM (Tropical Rainfall Measuring Mission)
File naming convention –TRMMYYMMDD*g –TRMM, YY (year), MM (month), DD (day)
*g at the end of the file name if the data is in geographic projection
Europe – TRMM (Tropical Rainfall Measuring Mission)
File naming convention –TRMMYYMMDD*g –TRMM, YY (year), MM (month), DD (day)
*g at the end of the file name if the data is in geographic projection
Africa – RFE (rainfall estimates)
File naming convention -Rain_YYYYDDD*g –Rain_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection
Central America –no data

The best data currently available by region for PET (Potential Evapotranspiration) data:

Global –PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection
Afghanistan – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection
South East Asia – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection
Australia – PET (global)

File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

North America – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

South America – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

Europe – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

Africa – PET
File naming convention -Evap_yyyyddd*g (African continent) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

Central America – PET (global)
File naming convention -Evap_yyyyddd*g (global) –Evap_YYYY (year), DDD (Julian Day)
*g at the end of the file name if the data is in geographic projection

5.1.2 Rain/Evap Zip File Outputs

Rain/Evap Output Data

Zip File	Description	Unit
rain_yyyyddd.tar.gz	Zip rainfall data downloaded to local working directory –one file per day	mm
evap_yyyyddd.tar.gz	Zip evap data downloaded to local working directory –one file per day	tenths of mm

5.2 Unzip, Untar, Imagegrid

Rainfall/Evap Input Grids

Input Grid	Description
rain_yyyyddd.tar.gz	Zip rainfall data downloaded to local working directory –one file per day
evap_yyyyddd.tar.gz	Zip evap data downloaded to local working directory –one file per

	day

Unzipped Output Grids

.bil grids	Description
	Unzipped rainfall image files processes in local working directory
evap_yyyyddd.bil	Unzipped evap image files processes in local working directory

Image Files converted to Grids

Output Grid	Description
rain_yyyydddg	Grid containing rainfall data for each day –geographic projection, added to ArcView table of contents
evap_yyyydddg	Grid containing evap data for each day –geographic projection added to ArcView table of contents

5.3 ProjectGrid Geo to Lambert Azimuthal

Rainfall/Evap Input Grids

Input Grid	Description
rain_yyyydddg	Grid containing rainfall data for each day –geographic projection, added to ArcView table of contents
evap_yyyydddg	Grid containing evap data for each day –geographic projection added to ArcView table of contents

Input Parameters	Description	Unit
Select Continent for Analysis	Options: Global, **Africa**, SE Asia, Afghanistan, Australia, NAmerica, CAmerica, SAmerica, and Europe –selected **Africa** for exercise six	
Analysis Properties	AnalysisExtent: **Current Value** Analysis Cell Size: **Current Value** Use all default values	
Projection	Lambert Equal-Area Azimuthal	

5.3.1 Projected Outputs

Rainfall/Evap Output Grids

Output Grid	Description	Unit
rain_yyyyddd	Grid containing rainfall data for each day –Lambert	mm

	Azimuthal projection added to ArcView table of contents	
Evap_yyyyddd	Grid containing evap data for each day –Lambert Azimuthal projection added to ArcView table of contents	tenths of mm

6.0 GeoSFM Utilities –GIS Tools

6.1 Compute Rain/Evap Grid Statistics

Because input precipitation data are spatial distributed, it is often difficult to fully discern the evolution of rainfall events over time. Precipitation and evapotranspiration data may also be required for longer accumulation periods such as dekadal and monthly totals. GeoSFM includes for vertically integrating grid layers to perform pixel level accumulations and other temporal statistics such as maxima, minima, standard deviations, medians, modes, variety, range and non-zero values for each pixel. The results of these analyses are presented as grids. While not directly related to the computation of stream flow, the spatial statistic routines are very useful for running verification checks on input data and for studying sources anomalously with high stream flow or soil water levels in simulation results.

Rain/Evap Input Data

Input Parameters	**Description**	**Unit**
raindata	Rain data from directory	mm
evapdata	Evap data from directory	mm*10
Start Year	Start year of data --1999	
End Year	End year of data --1999	
Start Day Number	Start day of data –defaults 1-Julian Day	
End Day Number	End day of data –number of days included for calculation of statistics –defaults 365-entered **10** (shorter processing time) –Julian Day	

Type of Statistics to be Computed

Input Parameter	**Description**	**Unit**
GRID_STATYPE_SUM	Sum of values for date range	
GRID_STATYPE_MAX	Maximum value for date range	
GRID_STATYPE_MEAN	Average of values for date range	
GRID_STATYPE_STD	Standard Deviation value for date range	
GRID_STATYPE_MEDIAN	Median value for date range	
GRID_STATYPE_RANGE	Range of values for date range	

GRID_STATYPE_MIN	Minimum value for date range	
GRID_STATYPE_MAJORITY	Majority value for date range	
GRID_STATYPE_MINORITY	Minority value for date range	
GRID_STATYPE_VARIETY	Number of different values for date range	
GRID_NONZERO_VALUES	Non-zero values for date range	

6.1.1 Rain/Evap Statistical Output Grids

Output Grid	**Description**	**Unit**
R10SUM1-*grid name depends on type and number of days selected*	R=rain, 10=number of days, SUM=statistical type, 1=each calculation is incremented	
E10SUM1-*grid name depends on type and number of days selected*	E=evap, 10=number of days, SUM=statistical type, 1=each calculation is incremented	

6.2 Pick Grid Values at Point

One function within the GeoSFM utility tool is to pick grid values at points. These points could be rain gauge stations within a basin. In some areas these rain gauge data are not available but, if available, ground data can be converted from polygon data to point data. Through the use of this functionality, we can compare the rainfall/evap values gathered using satellite products, with observed data gathered from rain gauge stations.

Input Station Gauge Data

Point theme	**Description**	**Unit**
gauges2.shp	Site IDs, latitude and longitude coordinates in decimal degrees	

Rain/Evap Input Data

Input Parameters	**Description**	**Unit**
raindata	Rain data from directory	mm
evapdata	Evap data from directory	mm*10
Start Year	Start year of data --1999	
End Year	End year of data --1999	
Start Day Number	Start day of data –defaults 1-Julian Day	
End Day Number	End day of data –number of days included for	

	calculation of statistics –defaults 365-entered **10** (shorter processing time) –Julian Day	

6.2.1 Rain/Evap Point Outputs

Output File	**Description**
rainpoint.txt *see .txt detail below*	File containing time step rainfall (mm) for each station ID (per day)
evappoint.txt *see .txt detail below*	File containing time step PET (tenths of mm) for each station ID (per day)File

rainpoint.txt	**Description**	**Unit**	**Range of Values**
Time	Date – example 1999001 -- format yyyyddd		
	↓		
	Date 1999010		
Station ID number starting with the smallest number	Time step rain for each point (rain gauge station)	mm	0-16
↓			
Largest number			

evappoint.txt	**Description**	**Unit**	**Range of Values**
Time	Date – example 1999001 -- format yyyyddd		
	↓		
	Date 1999010		
Station ID number starting with the smallest number	Time step PET for each point (evap gauge station)	Tenths of mm	33-64
↓			
Largest number			

6.3 Interpolate Station Data to Grid

For areas over which spatially distributed precipitation data is not available, data interpolation routines are provided for converting station readings into a continuous surface. The routines include inverse distance weighting, spline and kriging interpolation methods.

Input Shapefile	**Description**
gauges2.shp	Site IDs, latitude and longitude coordinates in decimal degrees
Limpbas.shp	Shapefile defining modeled basin region

Point Data

Input Files	**Description**
rainstations.txt *see .txt detail below*	File containing time step rainfall (mm) for each station ID
evapstations.txt *see .txt detail below*	File containing time step PET (tenths of mm) for each station ID

Parameters

Input Parameters	**Description**	**Unit**
Date	Data start date formatted m/d/yyyy	
Interpolate Surface Method	Two interpolation methods are displayed in the drop down list: **Inverse Distance Weighted** (IDW) interpolator assumes each input has a local influence that diminishes with distance; the points closer to the processing cell are given a greater weight. **Spline** interpolator is a general purpose method that fits a minimum-curvature surface through the input points.	
Inverse Distance Weighted (IDW) parameters	This is the default interpolation method.	
Z Value Field	The field containing the values to be used in the interpolation. –**Stations_i**	
	For IDW specify either **Nearest Neighbors** or a **Fixed Radius** in the interpolation. –defaults **Nearest Neighbors.**	
Number of Neighbors / Fixed Radius	**Number of Neighbors** or input points –defaults **12**. For **Fixed Radius** enter the radius to search for points.	
Power	Controls the significance of the surrounding points on the interpolated value – the lower the number the more influence from distance points. Defaults **2**	

	For exercise six changed to **1**.	
Barriers	A break that limits the search for input points. Defaults **No Barriers**.	
Spline Parameters		
Z Value Field	The field containing the values to be used in the interpolation. –**Stations_i**	
Weight	Weight factor	
No: of Points	Specifies the number of points to use per region.	
Type	Select from drop down list: **Regularized** – a smooth surface **Tension** – tunes the stiffness of the surface according to the character of the modeled phenomenon.	

6.3.1. Rain/Evap Sub-basin Outputs

Output Grids	**Description**	**Unit**
Rain_1999001	Grid showing rainfall values interpolated across sub-basins originating from ground station data for one day	mm
↓		
Rain_1999010	(ten day example)	
Evap_1999001	Grid showing PET values interpolated across sub-basins originating from ground station data for one day	tenths of mm
↓		
Evap_1999010	(ten day example)	

7.0 GeoSFM Utilities –DEM Tools

7.1 Fill Sinks in DEM

The direction and rate of the movement of water over the land surface is influenced very heavily on underlying topography. A hydrologically corrected DEM, which is a DEM that is devoid of spurious pits that interrupt hydraulic connectivity over the land surface, must be used when running the **Geospatial Stream Flow Model**. These pits are the result of the interpolation procedure used in the creation of the DEM. Once they are removed there will be no breaks within the flow network.

If the DEM you are working with has not been corrected than this process will fill the sinks, then water will properly transport across the surface.

Input DEM

Input Grid	Description
DEM	Elevation data requiring fill sink process

7.1.1 Fill Output

Output DEM

Output Grid	Description
fill1	Elevation data after fill sink process

8.0 GeoSFM Utilities –Time Series

8.1 Convert Daily to Monthly and Annual

Computing Flow Statistics
At the end of a simulation run, the user often wants to compute a summary of the results. GeoSFM includes a tool for computing a variety of flow statistics including the maximum, minimum, mean, standard deviation, median, 25^{th}, 33^{rd}, 66^{th}, and 75^{th} percentile flows for each catchment. The results of the flow statistics computations are stored in the form of tables which are linked to the catchment data layer. The user can access the values for each catchment by clicking on the catchment in the visual interface or by modifying the legend of the associated data layer in the visual interface to display the computed values.

Input Files	Description
streamflow.txt *see .txt detail section 3.2*	Stream flow file contains a time series of velocity values in cubic meters per second for each sub-basin.

Parameter

Input Parameter	Description
Statistic to be computed	List includes max and mean -max chosen for exercise

8.1.1 Stream Flow Statistics Outputs

Output Stream Flow Statistics

Output Files	**Description**
monthlyflow.txt *see .txt file detail below*	Stream flow file that contains a monthly time series of velocity values for each sub-basin.
annualflow.txt *see .txt file detail below*	
statsparam.txt *see .txt file detail below*	

monthlyflow.txt	**Description**	**Units**	**Range of Values**
Time	Date – example 199901 – format yyyymm (year, month)		
BasinID of sub-basin beginning with the most downstream	Stream flow file contains a monthly total time series of velocity values in cubic meters per second for each sub-basin.	m3/s	8.266 – 1471.28
↓			
Most upstream sub-basin			

annualflow.txt	**Description**	**Units**	**Range of Values**
Time	Date – example 1999 –year		
BasinID of sub-basin beginning with the most downstream	Stream flow file contains an annual total time series of velocity values in cubic meters per second for each sub-basin.	m3/s	8.266 – 1471.28
↓			
Most upstream sub-basin			

statsparam.txt	**Description**
No Header	1999

	1
	1
	1999
	13
	365
	Max
	C:\GeoSFM\workspace\streamflow.txt
	C:\GeoSFM\workspace\monthlyflow.txt
	C:\GeoSFM\workspace\annualflow.txt

8.2 Compute Daily Characteristic Flows –under development

8.3 Compute Frequency Distribution

Need to add some text……

Input File	**Description**
streamflow.txt *see .txt detail section 3.2*	Stream flow file contains a time series of velocity values in cubic meters per second for each sub-basin.

Input Parameters

Input Parameters	**Description**
Basin coverage/grid theme	Selected **basply.shp** for exercise
Select statistics to be computed	Selected **Total Flow, Mean Flow, Maximum Flow**, and **Minimum Flow** for exercise -multiple choices from a drop down list
Select field to display	Selected **Mean** for exercise –multiple choices from a drop down list

8.3.1 Distribution Outputs

Output	**Description**
Map	Map showing daily variation of stream flow values displayed as selected statistic –for the exercise **Mean** was

	selected --multiple choices are presented in drop down list

Output flow.avl ???

References

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