

# Delineation and Analysis of a Watershed Cub River

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## Goals

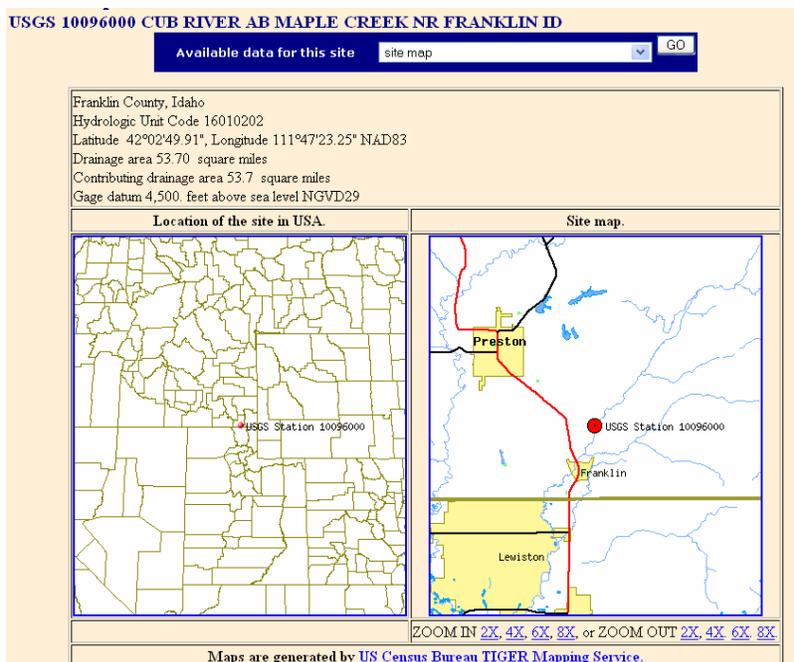
1. Learn the bare essentials of ArcGIS
2. Use Geographic Information System (GIS) tools to delineate a watershed
3. Estimate the mean annual precipitation over a watershed from PRISM data
4. Estimate the mean annual discharge from a nearby USGS gauge
5. Estimate the mean annual discharge from regional regression (e.g. STREAMSTATS) analysis
6. Quantify from the National Land Cover Dataset (NLCD) the land cover classes within a watershed and adjacent to streams.

## Computer and Data Requirements

To complete this exercise, you will need to run ArcGIS 9.1 and use the TauDEM software developed at USU for hydrologic digital elevation model analysis and watershed delineation. This software may be obtained from <http://www.engineering.usu.edu/dtarb/taudem/>, and should be installed on the computer you are using prior to starting this exercise.

## Data

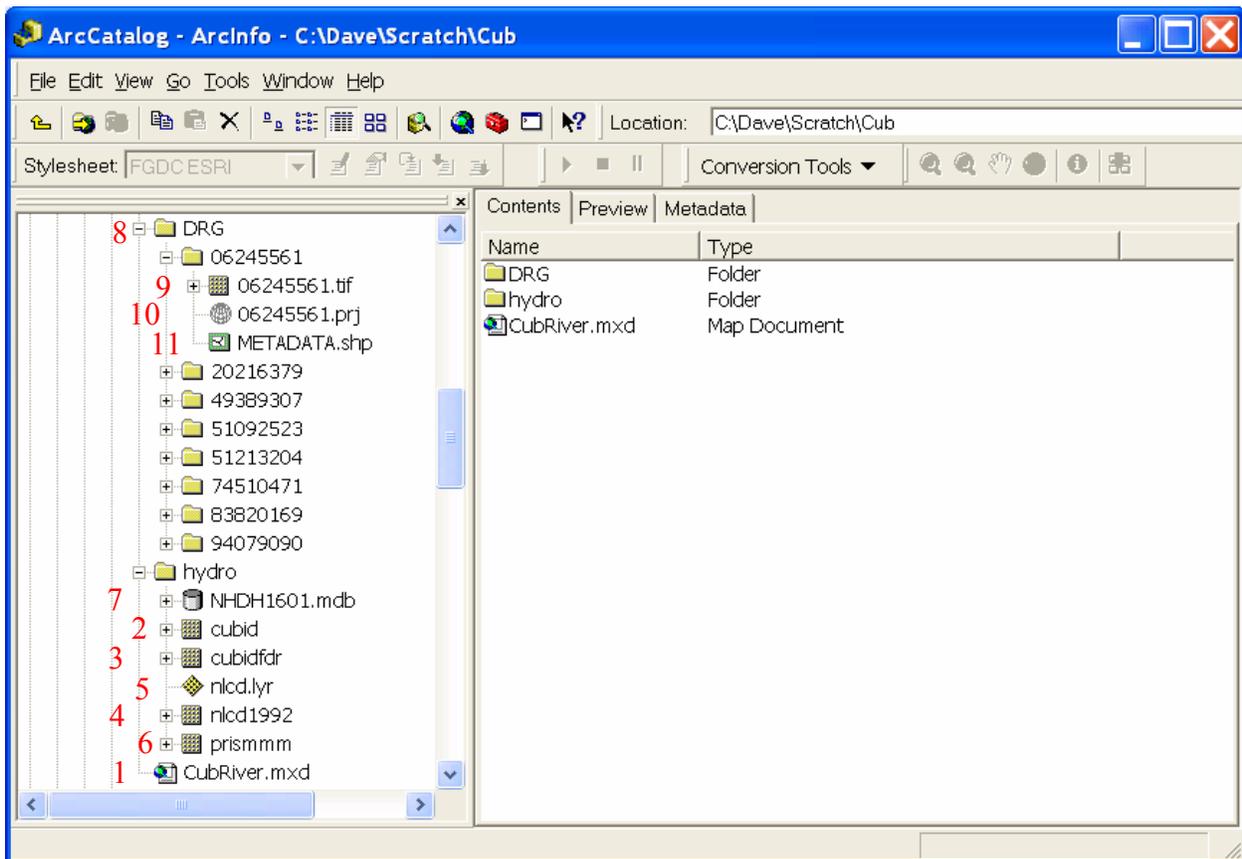
This exercise will use the Cub River watershed as it drains to the location of a discontinued USGS streamflow gauge #100096000 located just north of Preston, Idaho.



The data required is in the file [CubRiver.zip](#) that contains the following

- National Elevation Dataset digital elevation model (DEM)
- National Hydrography Dataset (NHD) stream reach data
- Oregon State University PRISM precipitation data
- NLCD Land Cover Data
- Digital Raster Graph (DRG) topographic map images

To save time, this data has already been downloaded and organized for you. If you would like to know how to download and organize the data see the appendix where details on data preparation for this exercise are given. You could follow this appendix to download and organize the data for a different watershed. The figure below shows the ArcCatalog depiction of the contents of the zip file once unzipped.



ArcCatalog is the ArcGIS software for file management similar to Windows explorer. It should be used for the manipulation of ArcGIS data because ArcGIS data structures are such that a single dataset is often comprised of multiple files on disk and if you use the Windows explorer to move files around and do not move all the right pieces the datasets can become corrupted.

- Item 1 'CubRiver.mxd' is an ArcGIS map document. This is similar to a wordprocessor or spreadsheet document and when opened will facilitate display and analysis of the data. However unlike a wordprocessor or spreadsheet document, the \*.mxd file does not contain the data, rather it contains links to the data that is stored elsewhere.
- Item 2, 'cubid' in the folder 'hydro', is a grid dataset that comprises the Cub River Digital Elevation Model (DEM). This was extracted from the National Elevation Dataset and

projected to UTM coordinates. No data values were inserted at the bottom of internally draining basins within this area. I used the suffix 'id' on the name to remind me of this.

- Item 3, 'cubidfd' is a flow direction raster representing the streams in the Cub River area. This is used to enforce flow directions to follow existing streams to ensure that DEM derived streams are consistent with existing mapped streams.
- Item 4, 'nlcd1992' is the 1992 National Land Cover Dataset data for this region, projected to a 20 m grid on the same UTM projection as the DEM.
- Item 5, 'nlcd.lyr' is a layer file where I saved the table of contents information for the nlcd1992 data, so that the names associated with landuse classes can be added to the symbology in the legend without having to retype them each time.
- Item 6, 'prismmm' is a grid of annual average precipitation data for this region from Oregon State University Spatial Climate Analysis Service for the period 1971-2000. This raster was extracted from a national coverage, converted to mm, and projected on the same UTM projection as the DEM.
- Item 7, 'NHDH1601.mdb' is a geodatabase containing the National Hydrography Dataset (NHD) for this region obtained from the NHD website. The H following NHD indicates that this is high resolution and the 1601 is the 4 digit region code.
- Item 8 is the folder 'DRG'. This contains a number of subfolders.
- Item 9 is a \*.tif file within a numbered folder. This comprises one of the digital raster graph images of standard 1:24000 scale USGS topographic maps. These were downloaded from the USGS seamless data server which packaged the area requested into the eight separate files, each in the eight numbered folders within the folder DRG.
- Items 10 and 11 respectively contain the spatial reference (projection) information and metadata for the digital raster graph images.

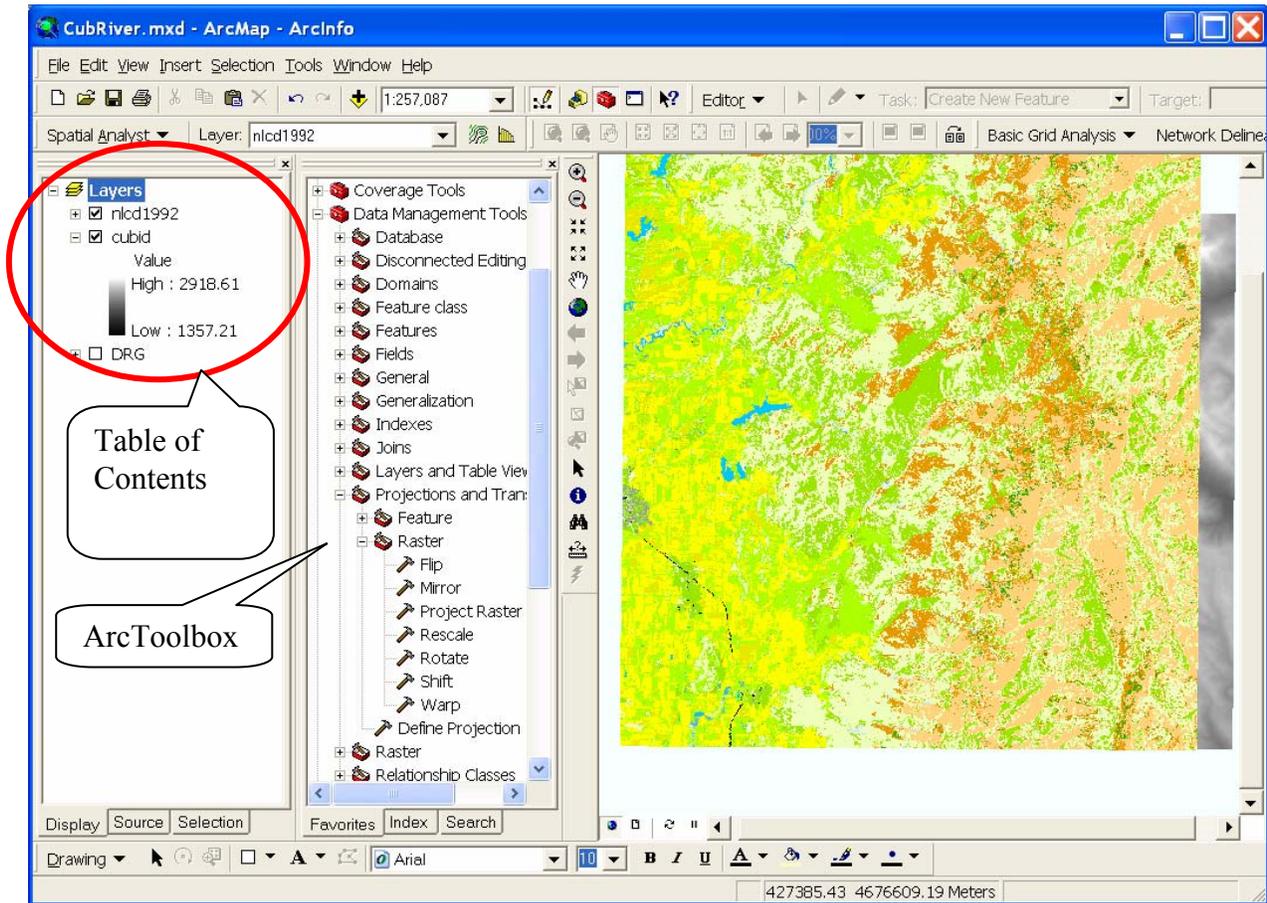
## Step 1. ArcMap Bare Essentials

Extract the contents of the file CubRiver.zip into a working folder. This data once unzipped is 830 Mb. However make sure you have at least 900 Mb of space on this disk to have room for the additional files that will be created during this exercise. If you are short of space you could delete the DRG files. These are the most space consuming files. Without them you will not be able to view the detailed topographic map information.

**It is important that the folder path to which you extract these files should not have spaces in it.** TauDEM uses the ESRI gridio libraries to access grid files from C++ computer programs and these libraries are limited in that, spaces in file names, as well as the file part (not folder) of file names longer than 13 characters do not work. For example you should not try work in "My Documents" because there is a space between My and Documents. However "MyDocuments" without the space will work.

Double click on the file "CubRiver.mxd". This is an ArcGIS map document and ArcMap should open up and display a number of layers that have been prepared for you. You should note that the map document does not contain the data. Rather it contains references to the data, so for everything to display correctly the data needs to be in the place that this document expects it. Therefore if you move the map document somewhere else, but do not move the associated data, then try to open the document it will not display the data correctly. In the case of this document I have set the file name referencing to be relative to the location of the map document so that the

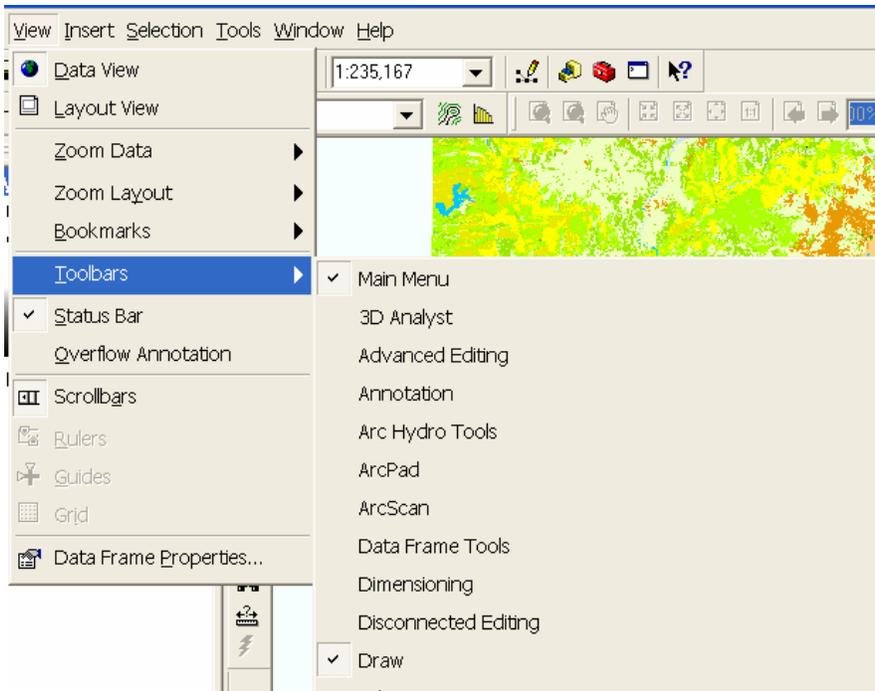
entire folder containing document and data can be moved around. Once ArcMap opens you should get a display as follows.



The panel to the left is referred to as the "Table of Contents". It shows the layers being displayed. Layers may be displayed or hidden by clicking on the check boxes. In the above two layers, the National Land Cover Dataset (nlcd1992) data and Cub River DEM (cubid) are displayed while the DRG layer is hidden. Activate the DRG layer and deactivate the layers above to see the USGS topo quads for this area (provided purely for information and orientation). The next panel over is the "ArcToolbox" that provides access to ArcGIS's geoprocessing tools. To show or hide ArcToolbox toggle the Show/Hide ArcToolbox button on the standard toolbar.



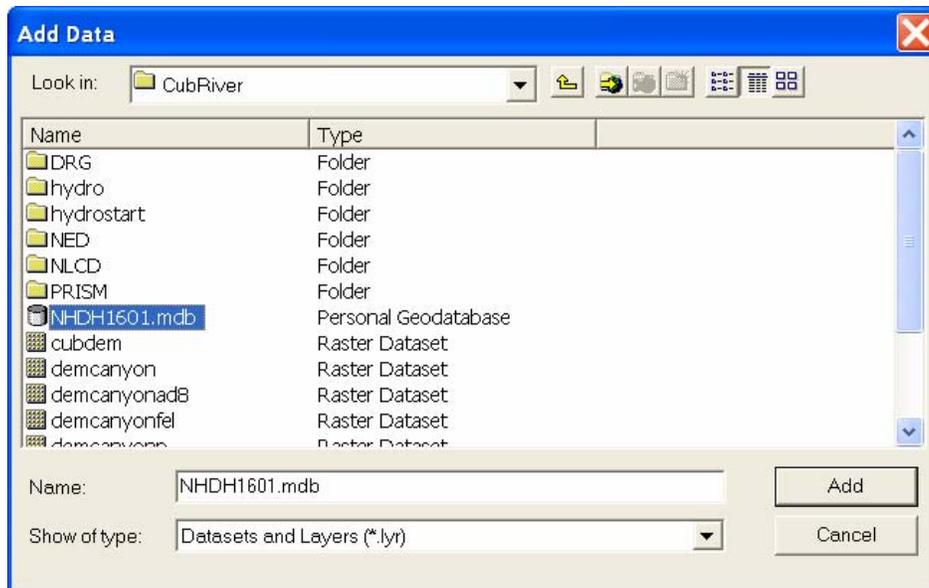
If your display or placement of toolbars looks different it is because toolbars are moveable and dockable similar to other Windows programs. You can control which toolbars are displayed using the View / Toolbars command.



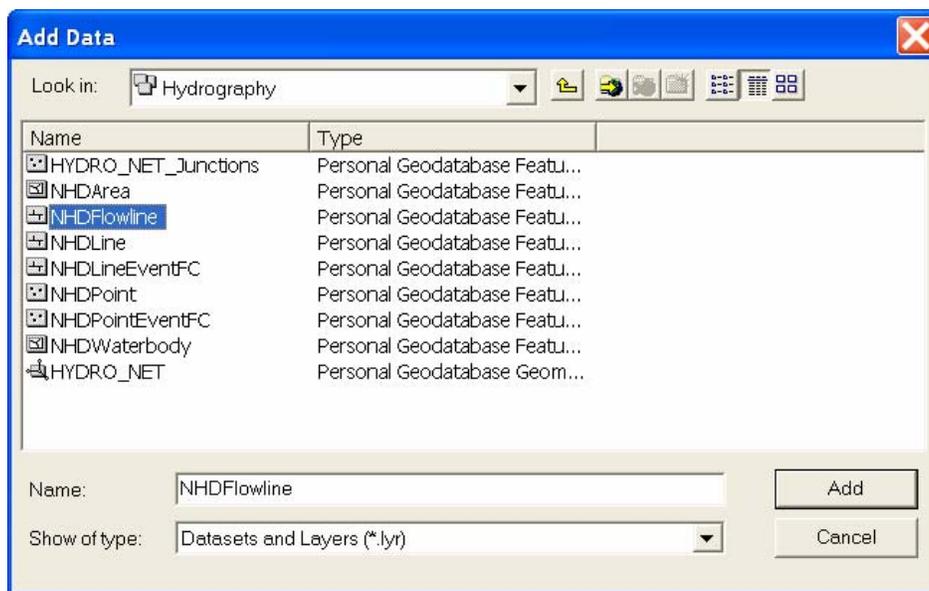
The Tools toolbar is an important toolbar to become familiar with because it contains functions for zooming and panning in the display. Hover over each tool to learn what it does.



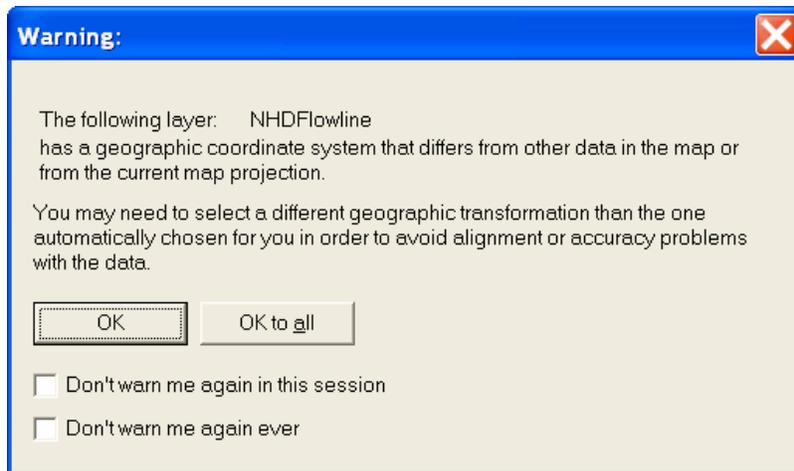
Use the  (Add Data) button on the Standard Toolbar to **Add Data**. Lets add some data from the geodatabase "NHDH1601.mdb" that contains the National Hydrography Dataset data for this region. At the dialog that appears navigate to the personal geodatabase file NHDH1601.mdb then click on it to get inside.



Add the feature class NHDFlowline within the feature dataset Hydrography.

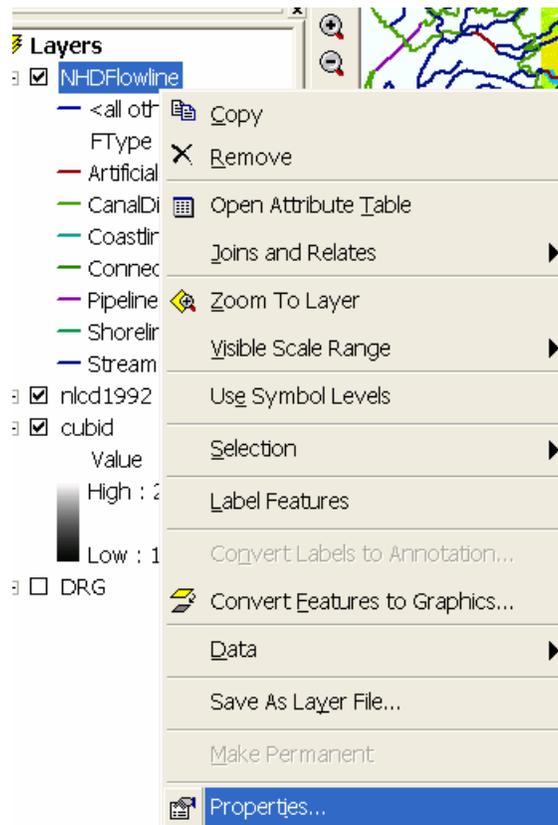


A layer in a geodatabase is referred to as a "feature class" and a "feature dataset" is a collection of feature classes all with the same spatial reference. Click OK to the warning about coordinate systems.

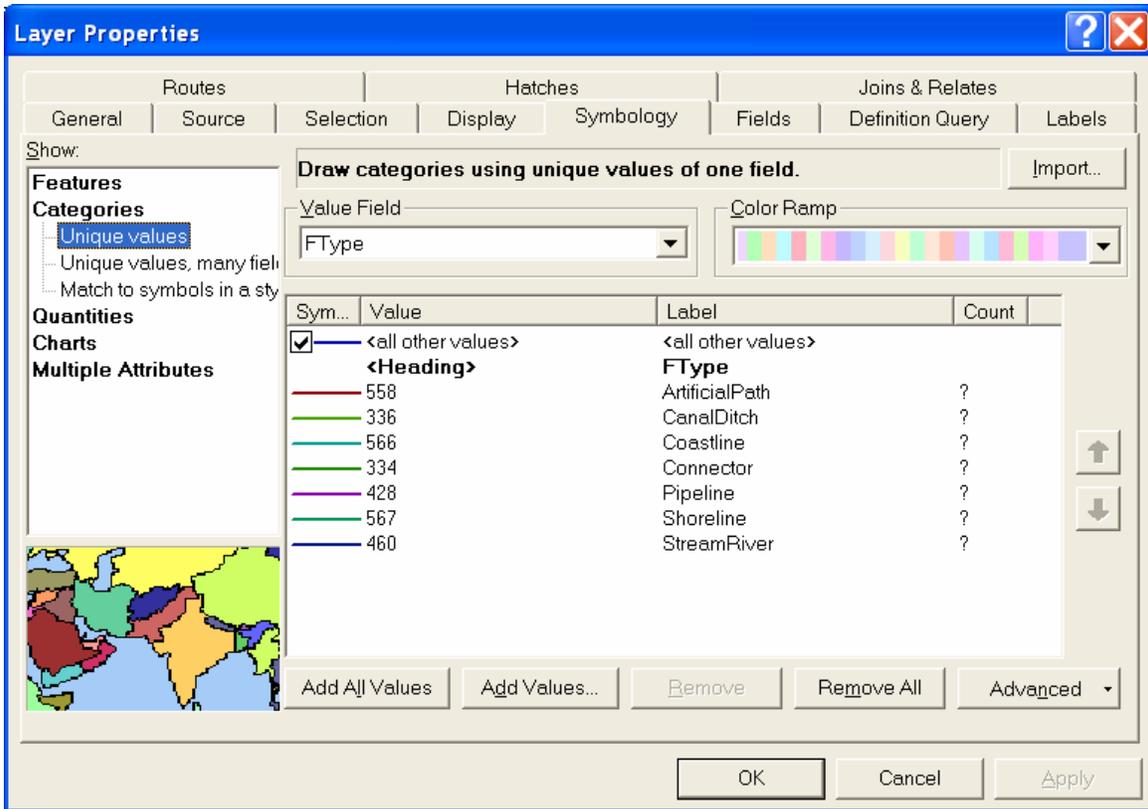


This is a good warning. It means that the system has recognized that the layer being added has a different spatial reference system than the display data frame, so will project the data on the fly and display the data properly. However if you were to do analysis with this data it would be good to project it to a consistent spatial reference. Here these streams are simply for display so this is OK. Your display should now show the NHD streams.

Right click on NHDFlowline in the table of contents and select "Properties" in the menu that appears



Click on the Symbology tab in the Layer Properties dialog that opens

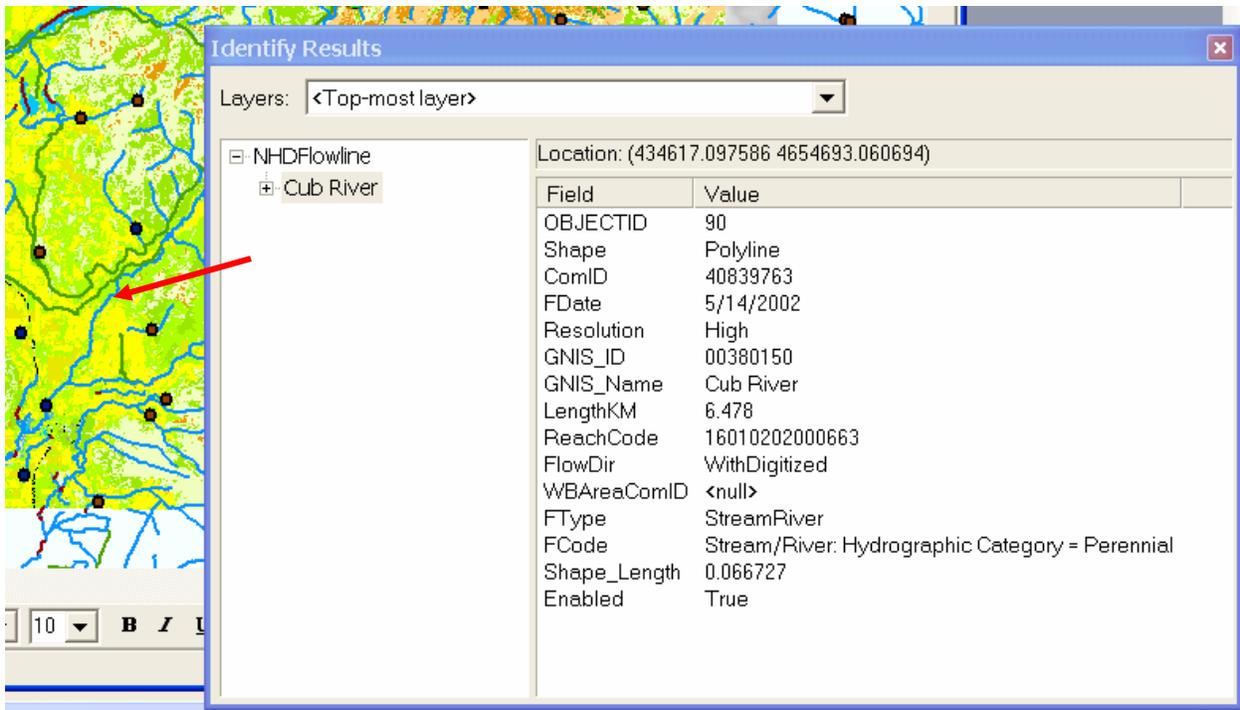


Double click on the lines associated with each flowline type to recolor them to suit your taste and distinguish StreamRivers from other types of path.

Add the NHDPPoint feature class in the Hydrography feature dataset in the NHDH1601.mdb geodatabase. Adjust the symbology to distinguish a stream gauging station from other points.



Click on the Identify button on the Tools toolbar. Then click on a feature of interest to see its properties, for example the properties of the indicated reach of the Cub River.



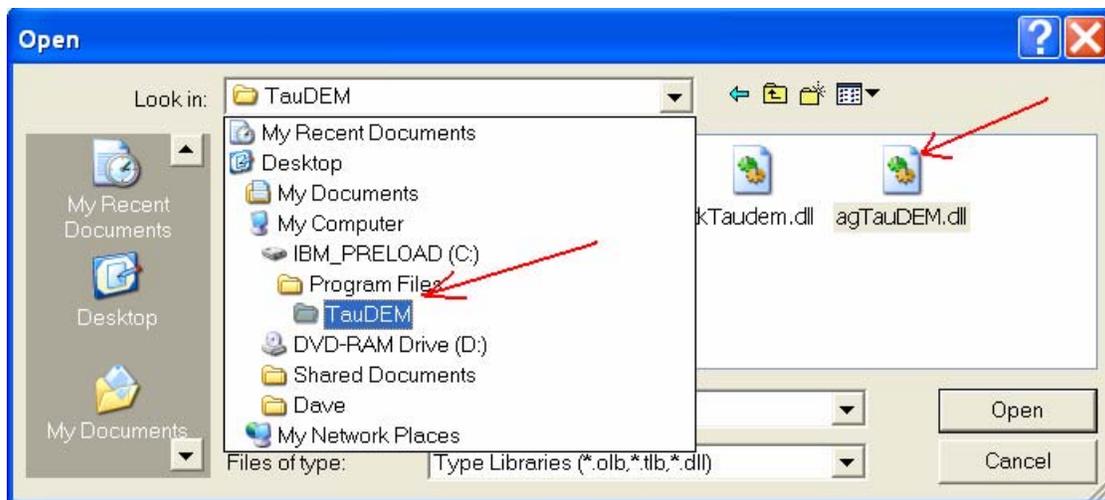
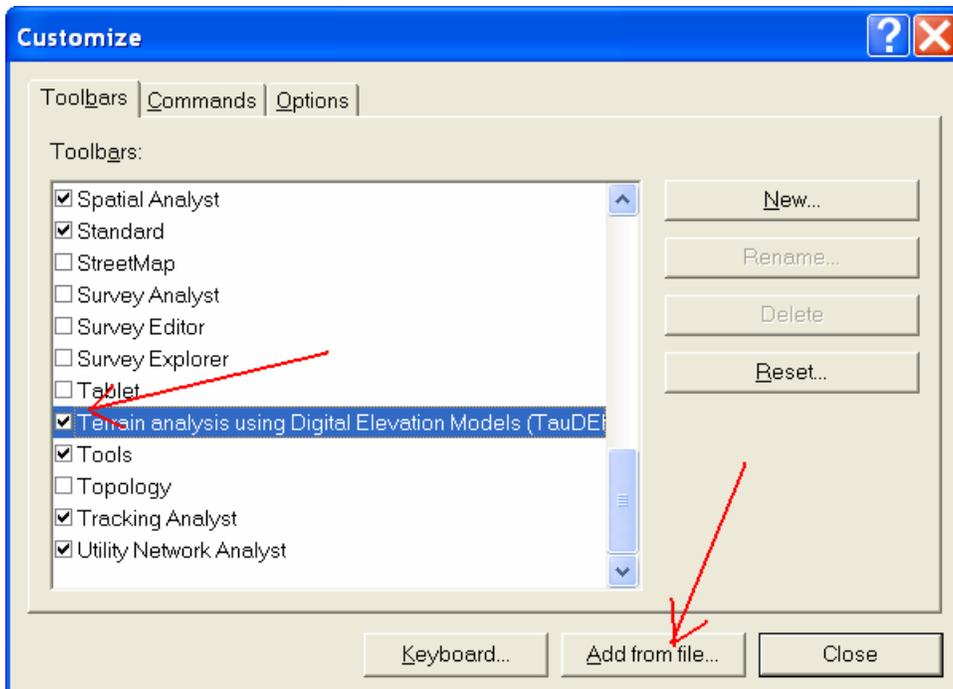
Click on the  Save (Ctrl+S) Save button to save your map document. Do this periodically while

you work in case of a crash or error so you do not lose your work. Click on  Close to close ArcMap.

This is all you get as a bare essentials introduction to ArcGIS and ArcMap. For additional information explore the online help under the help menu or other resources for learning ArcGIS.

## Step 2. Watershed Delineation using TauDEM

Make sure you have the TauDEM software installed from <http://www.engineering.usu.edu/dtarb/taudem/>. In ArcMap click on tools | Customize | Add from file and select the file c:\program files\Taudem\agtaudem.dll

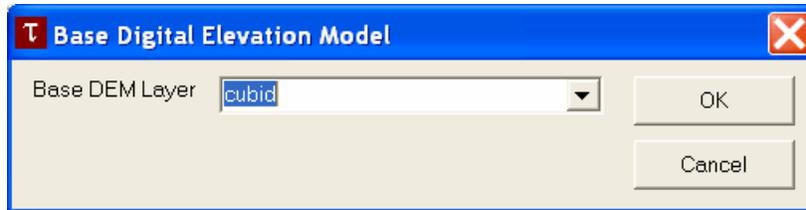


You should get a toolbar that looks like

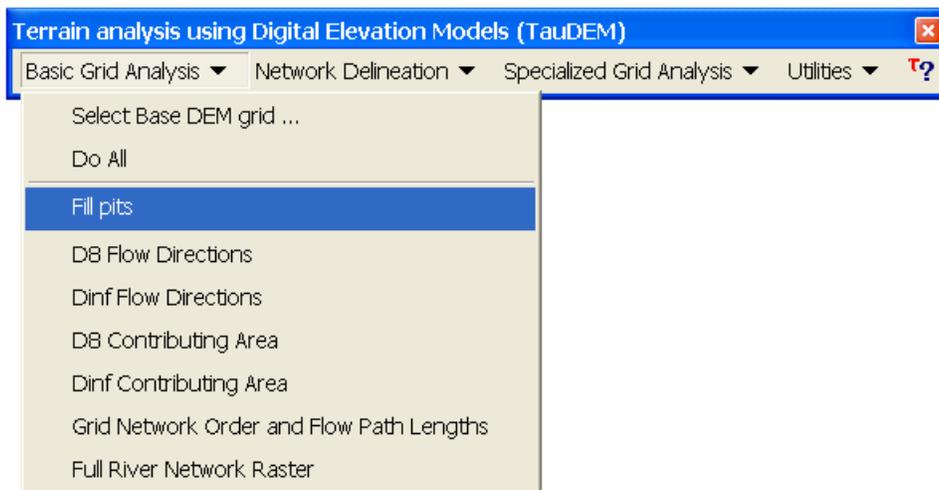


This may be docked in a convenient location.

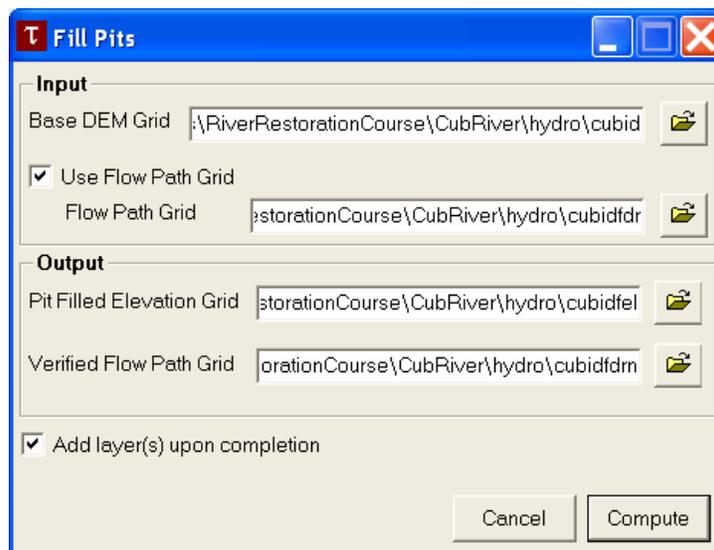
On the TauDEM toolbar from the Grid Analysis menu 'Select Base DEM grid ...'. You should get a dialog like this:



Adjust the Base DEM Layer to be 'cubid' and click OK. This identifies the digital elevation model in the grid layer named cubid to be used for watershed delineation. Recall that this is the Cub River DEM with internal drainage treated by placing no data values that the lowest point of internally draining basins. This prevents the fill pits function from filling known internally draining basins. Next, from the Grid Analysis menu select 'Fill pits'



Check at the dialog that opens that the input grid is 'cubid' and the output pit filled elevation grid is 'cubidfel'. Check the box Use Flow Path Grid. The flow path grid input file cubidfdm has already been prepared for you. This defines a set of flow paths consistent with NHD streams over the watershed to impose (burn in) to the grid. This is done under the assumption that the stream data is higher quality and therefore takes priority over the elevation data. See the data preparation appendix below to learn how to prepare a \*fdm file.

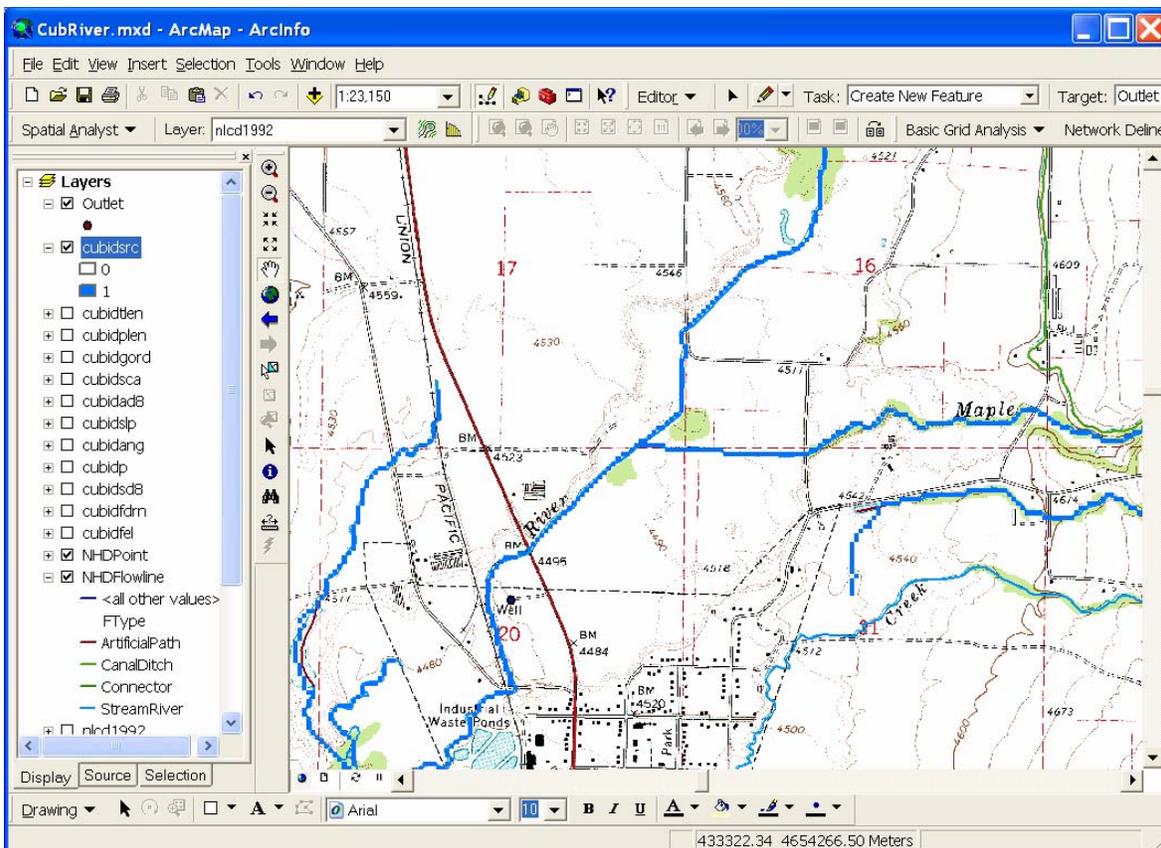


Click on Compute and wait for a few minutes (or more) for the job to complete.

Each of the remaining commands under the grid analysis menu can be run in sequence from top to bottom. The program will provide suggested file names for the outputs that follow the convention described in the documentation at <http://www.engineering.usu.edu/dtarb/taudem/>. Generally you can just click compute at each dialog and have the command execute. [You may learn a bit more about each file by clicking on the file box label in the dialog box associated with each command. You can change the names of input and output grids if you like by editing in the textboxes or using the Browse buttons. If you get an 'Error 1' it means that one of the input grid names specified has a problem. This is commonly caused if commands are run out of sequence.]

Here we will shortcut running each command by selecting the 'Do all preprocessing' command from the 'Grid Processing' menu to have all results generated without any prompts or interruption. Processing of this will take 3 to 5 minutes for the Cub River DEM. You should answer OK to the prompt to overwrite the existing 'cubidfel' file that you created above or else the automatic processing will stop. A number of output layers will be added to the map. The name suffixes designate the contents according to the file naming convention in the documentation. Examine these grid layers to understand their contents.

The next step is to specify the point that defines the watershed outlet. This is done by examining the \*src grid (here cubidsrc) that serves to define a raster of the stream network. Select the properties of the cubidsrc layer and adjust the symbology so that points on the stream network (represented by 1) are symbolized as blue, with points off the stream network (represented by 0) symbolized as no color. Zoom in near the south west corner of the domain and turn off all layers except for cubidsrc, NHDFlowline and DRG. Your zoomed in display should appear as follows.



We are interested in delineating the watershed draining to discontinued USGS stream gage #10096000. The USGS National Water Information System gives the following map for this site.

**USGS Site Map for USGS 10096000 CUB RIVER AB MAPLE CREEK NR FRANKLIN ID - Mozilla Firefox**

File Edit View Go Bookmarks Tools Help

http://nwis.waterdata.usgs.gov/nwis/nwismap/?site\_no=100960008

### Site Map for the Nation

**USGS 10096000 CUB RIVER AB MAPLE CREEK NR FRANKLIN ID**

Available data for this site:

Franklin County, Idaho  
 Hydrologic Unit Code 16010202  
 Latitude 42°02'49.91", Longitude 111°47'23.25" NAD83  
 Drainage area 53.70 square miles  
 Contributing drainage area 53.7 square miles  
 Gage datum 4,500. feet above sea level NGVD29

Location of the site in USA.	Site map.

ZOOM IN [2X](#), [4X](#), [6X](#), [8X](#), or ZOOM OUT [2X](#), [4X](#), [6X](#), [8X](#)

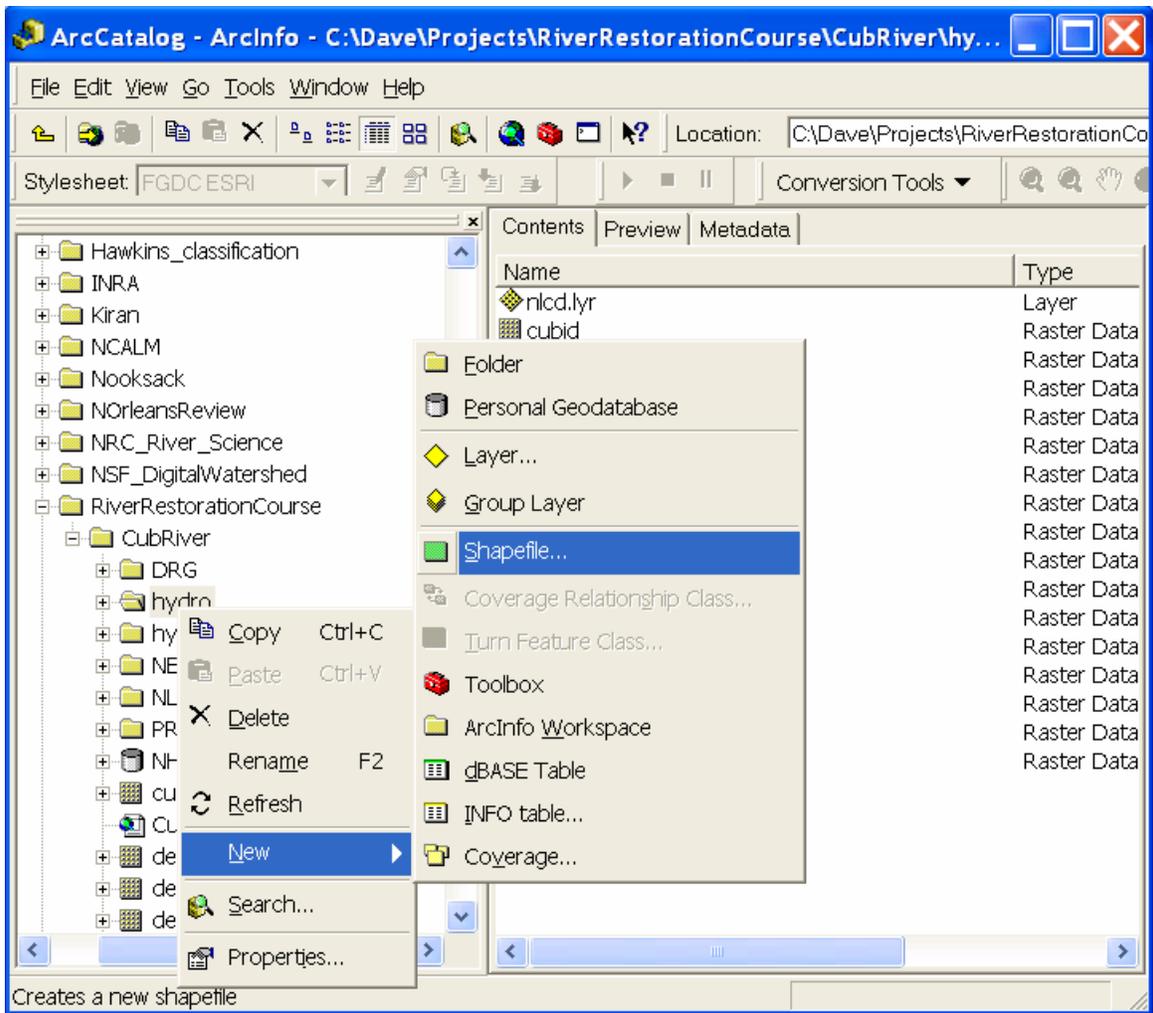
Maps are generated by [US Census Bureau TIGER Mapping Service](#).

Done

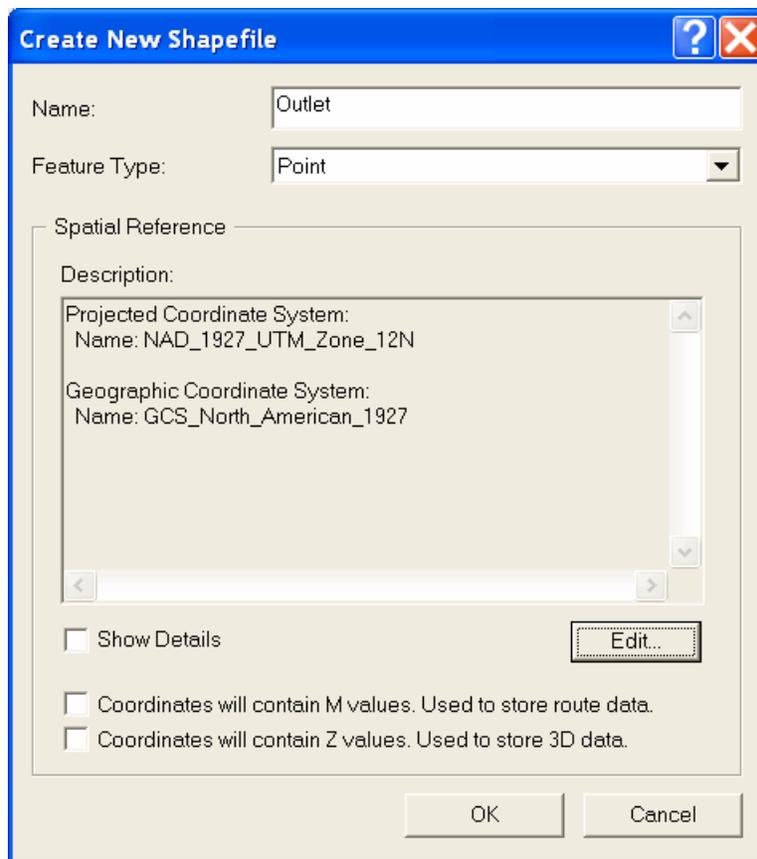
If this had been an active streamgage it should have been in NHDPoints, but since it is not in NHDPoints we need to create a point at this outlet point. Open ArcCatalog by clicking on the



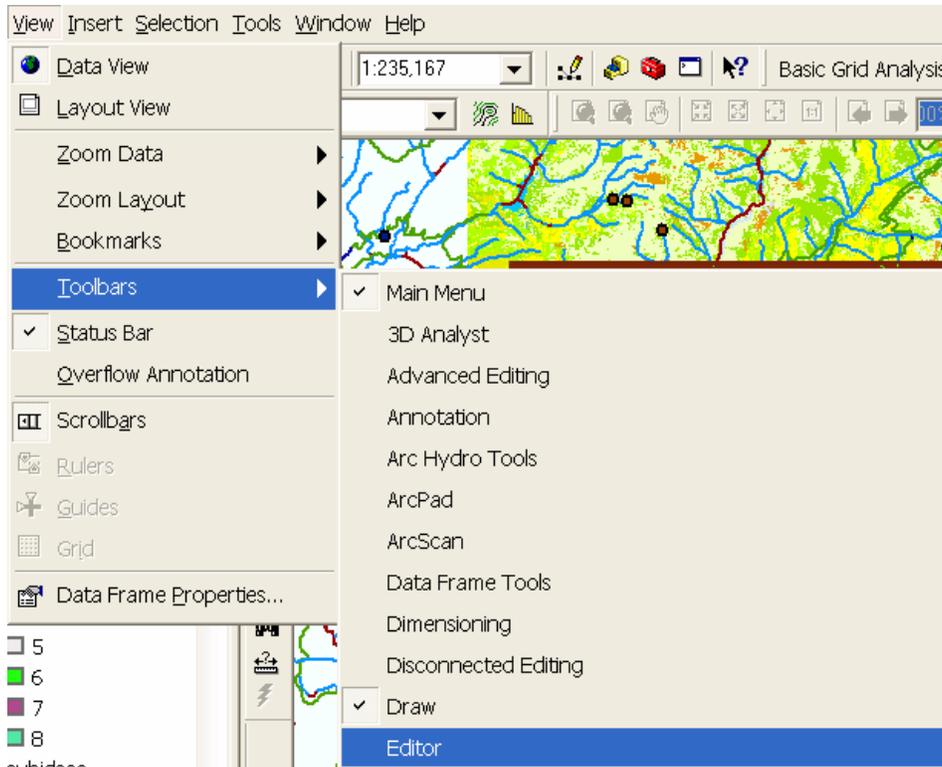
ArcCatalog button  on the standard toolbar. In the ArcCatalog table of contents right click on the '...\hydro' folder in the folder where you are working and select 'New/Shapefile...'



Specify the name as 'outlet' and set the feature class to point. Click 'Edit...' to change the coordinate system then 'Import...' and select the 'cubid' dataset in the '...\hydro' folder so that the coordinate system is inherited from this dataset. Click Add, then OK. The Create New Shapefile dialog should appear as follows



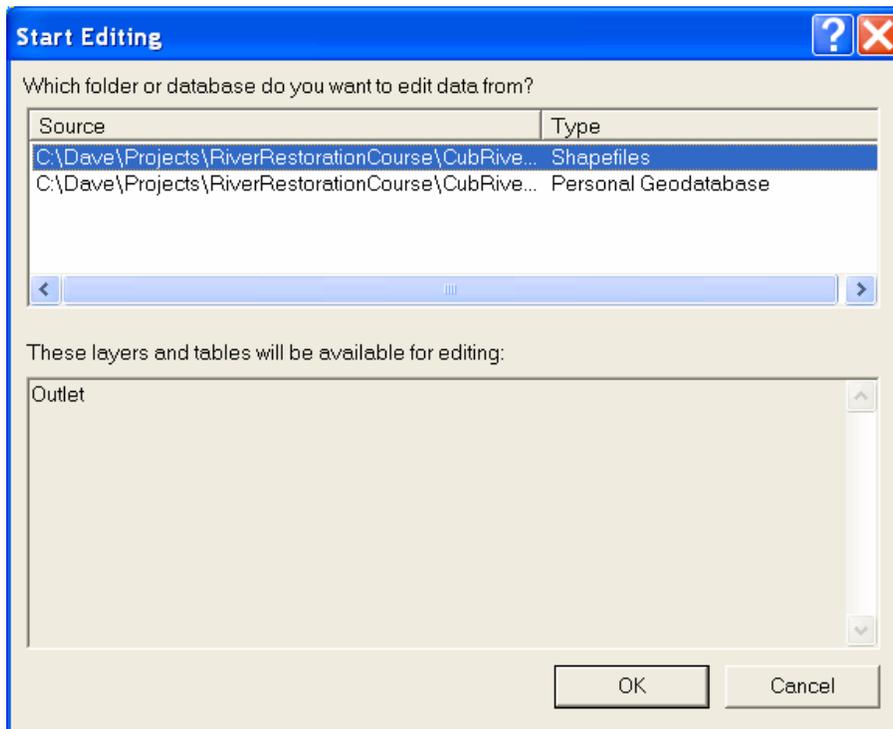
Click OK. With this done you are done with ArcCatalog and may close it. The shapefile just created, named 'outlet' does not have any data in it yet. In ArcMap use the  (Add Data) button on the Standard Toolbar to add the shapefile 'outlet' to ArcMap. Now we are ready to edit this shapefile to add a point to it. In ArcMap display the editor toolbar (View/Toolbars/Editor).



Select Editor/Start Editing.

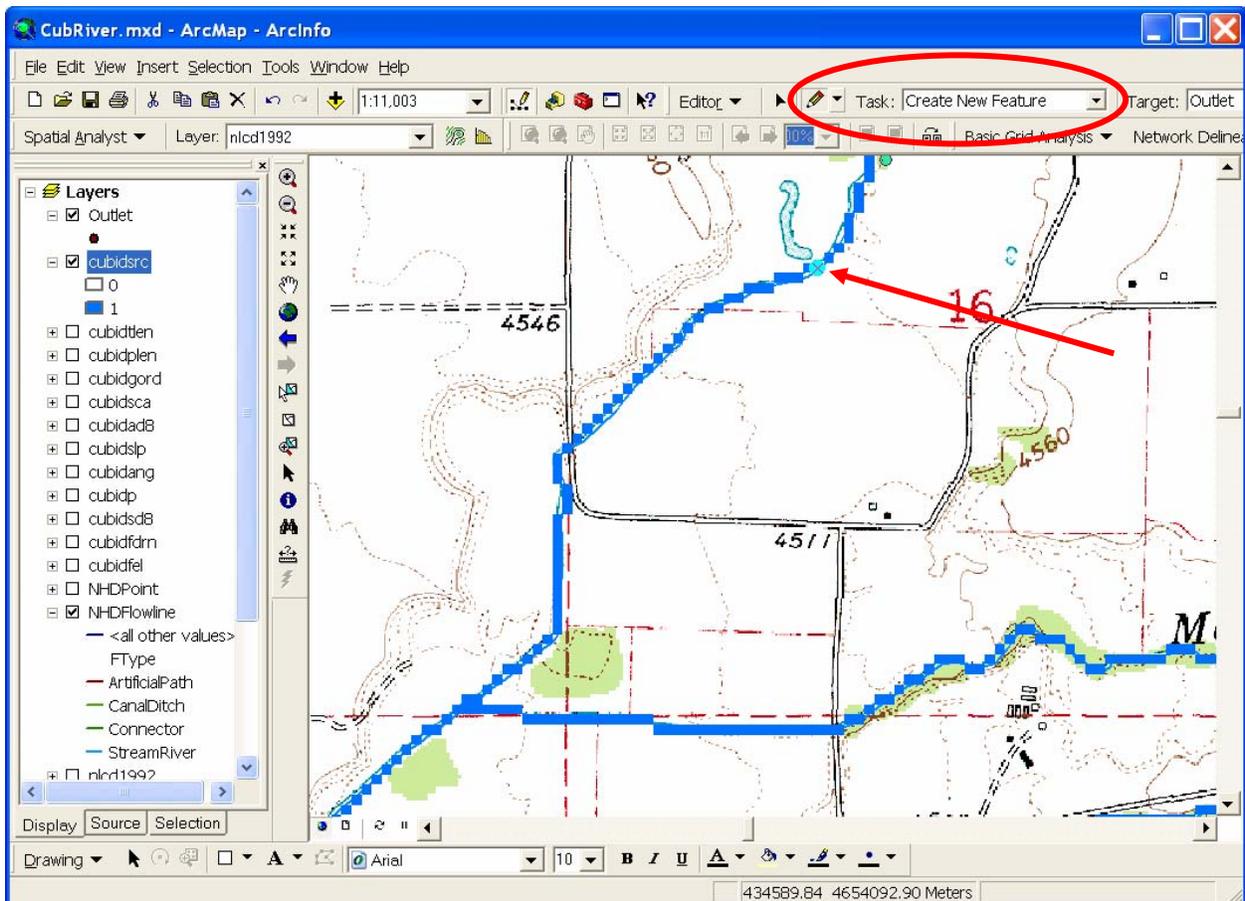


Select the folder that contains the shapefile 'outlet.shp', and set this as the target layer.



Click OK.

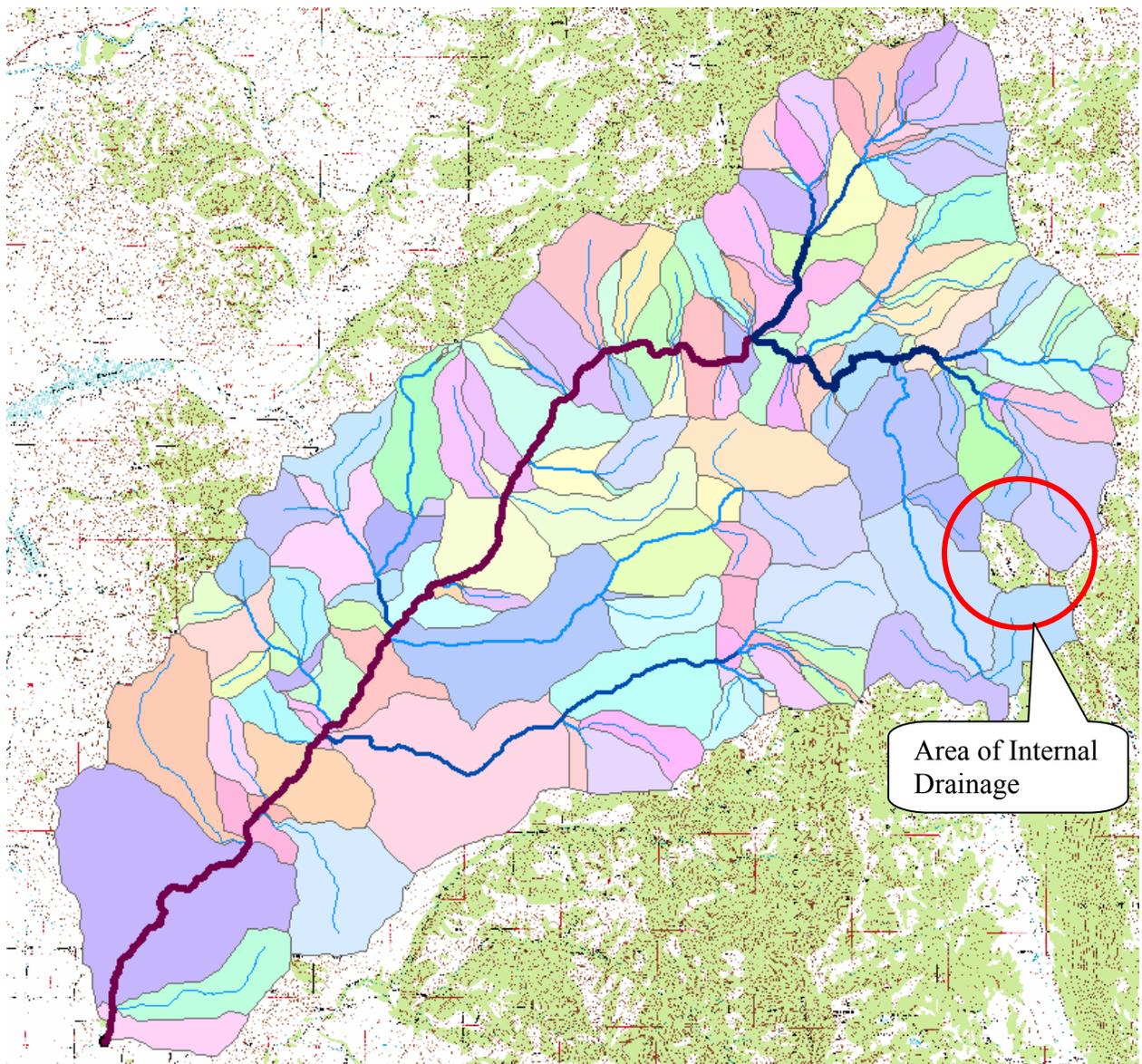
Set the Editor task to 'create new feature' and use the create new feature button  to carefully locate a point at the outlet of Cub River near the SW corner of the domain. Use the \*src layer as a backdrop to ensure that you are locating a point on a valid stream path. It is not too critical exactly where this point is, but this point **must be on** the \*src stream network. Even in cases where the NHD flow line is offset from \*src streams (sometimes it happens), the user should still create the outlet on the \*src stream and not the NHD flow line..



Select Editor/Stop Editing and Save edits. This is now a one point shapefile. More points for multiple channel networks can be added if desired.

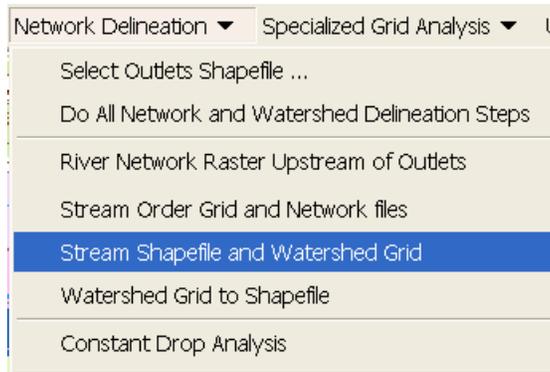
Now select TauDEM/Network Delineation/Select Outlets Shapefile ... Browse to select the shapefile and click Open and OK. Now select TauDEM/Network Delineation/Do All Network and Watershed Delineation steps. Click OK to delete existing dataset \*src. The same file is being reused for writing the grid raster only for the network draining to the outlet. A channel network and watersheds are delineated. Since at the beginning a flow direction raster (\*fdr) file was used to enforce flow directions from existing streams, TauDEM will have used the "Use existing streams" setting to delineate watersheds. TauDEM has a number of other settings for stream delineation that you may explore if interested. The channel network shapefile 'cubidnet.shp' has an attribute table that includes among other fields the field 'order' that contains the Strahler stream order. This can be used in symbology to indicate stream order by different

colors or line thickness. You can also symbolize the different watersheds with different colors to make a map similar to the following that shows the subwatersheds draining to each stream segment.



The chunk out of the watershed is an area of internal drainage. In the preparation of this data I edited the DEM to include no data cells at the bottom of these internal drainage basins so that they are excluded from the watershed.

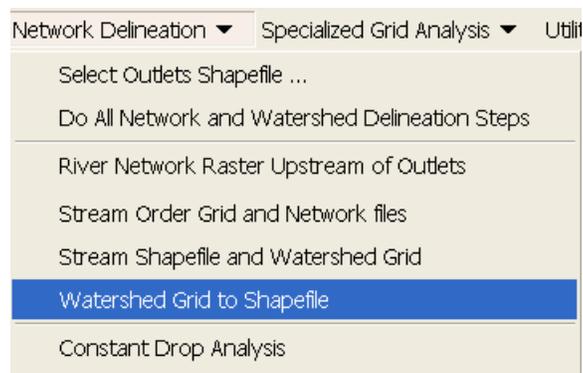
For this exercise, we are primarily interested in the single watershed that drains to the outlet that we designated. To delineate this rerun the TauDEM stream shapefile and watershed grid function.



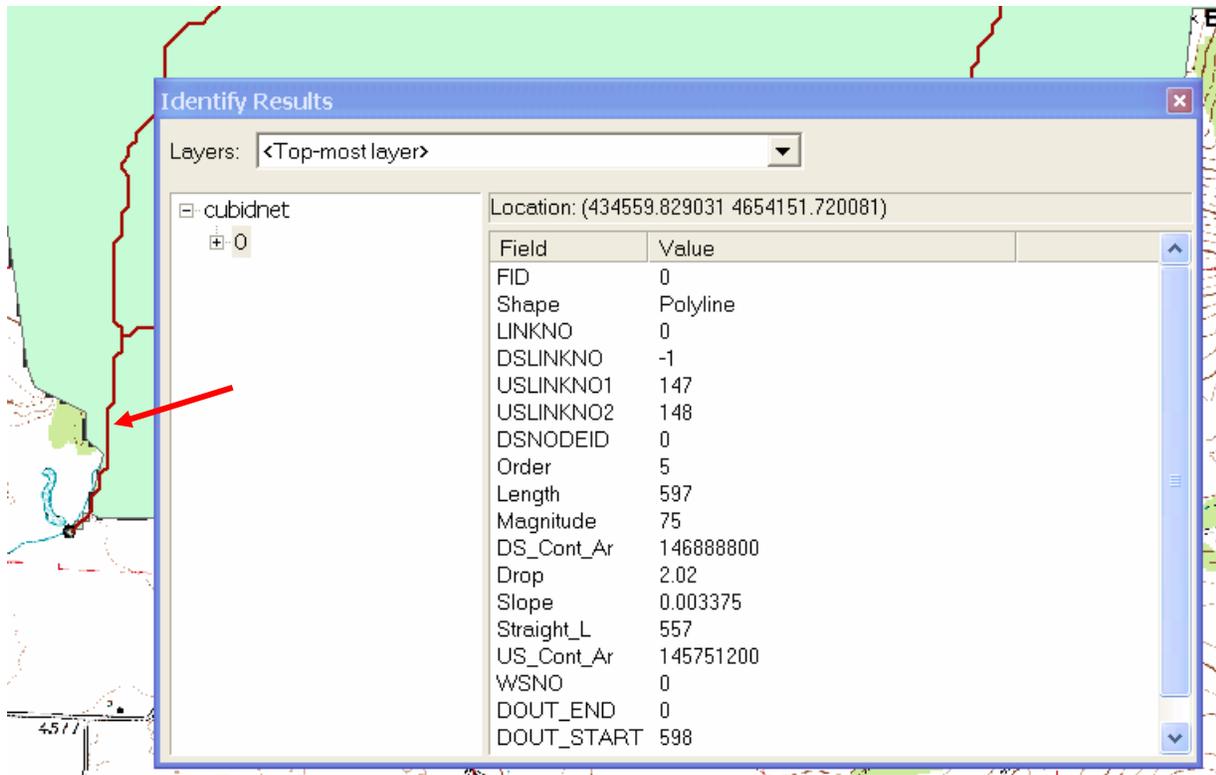
Select the Delineate single watershed check box



The Watershed Grid that is output is a single watershed for the entire Cub River upstream of the outlet point. Use the Watershed Grid to Shapefile function to create a Shapefile of this watershed.



The area of this watershed may be found by zooming in on the stream reach at the outlet and using the identify tool  to identify reach properties.

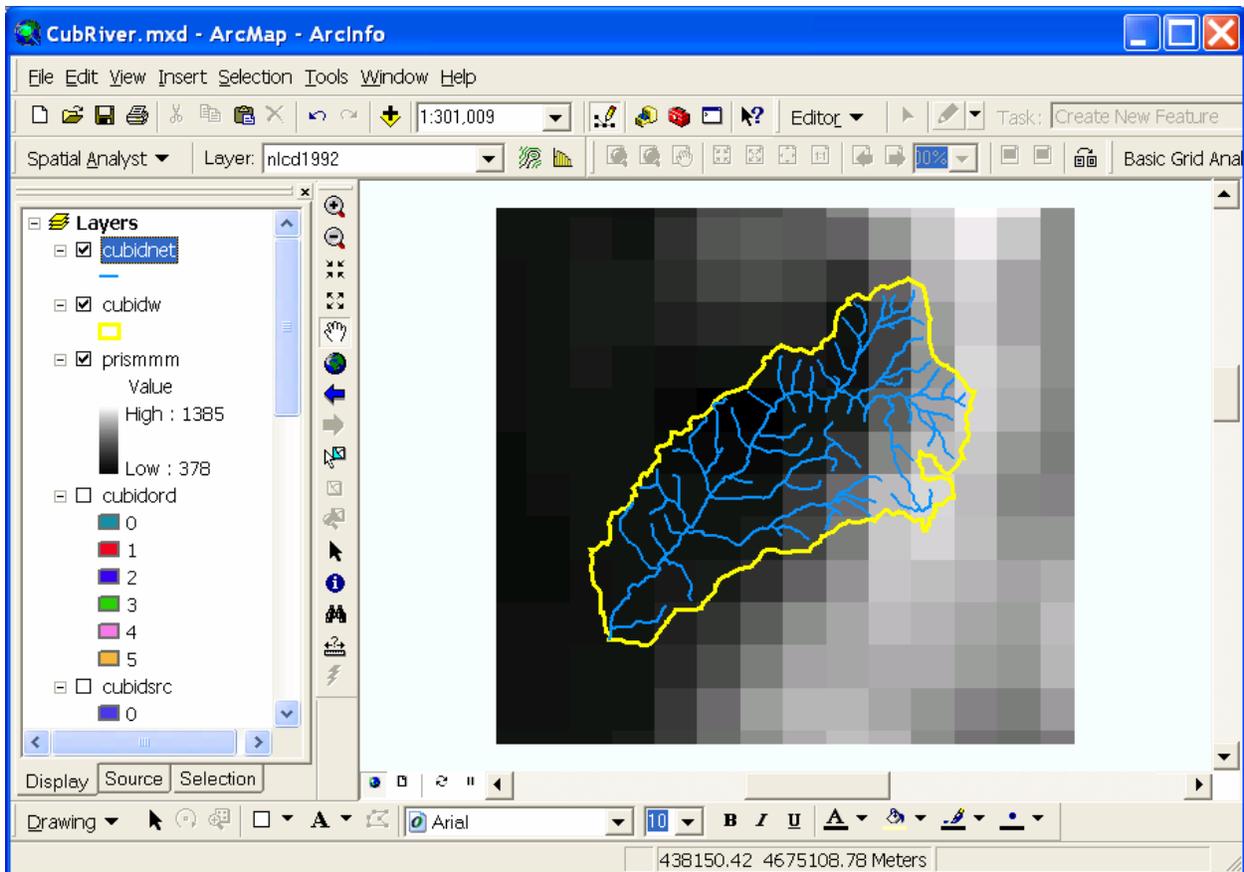


In the example shown the downstream contributing area is  $146.9 \times 10^6 \text{ m}^2$ . This converts to  $57.4 \text{ mi}^2$ .

### Step 3. Mean Annual Precipitation

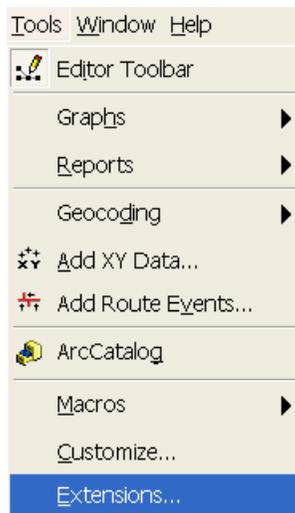
The Spatial Climate Analysis Service at Oregon State University (<http://www.ocs.orst.edu/prism/>) distributes climate data interpolated from point gauges using a regression methodology that accounts for slope, aspect and elevation known as PRISM. The 30 year (1971-2000) annual precipitation 'normals' were downloaded from this website, projected and clipped to the domain of interest to obtain the file prismmm that represents mean annual rainfall in mm. See the appendix for how to do this.

Use the  (Add Data) button on the Standard Toolbar to add the grid 'prismmm' to your map.

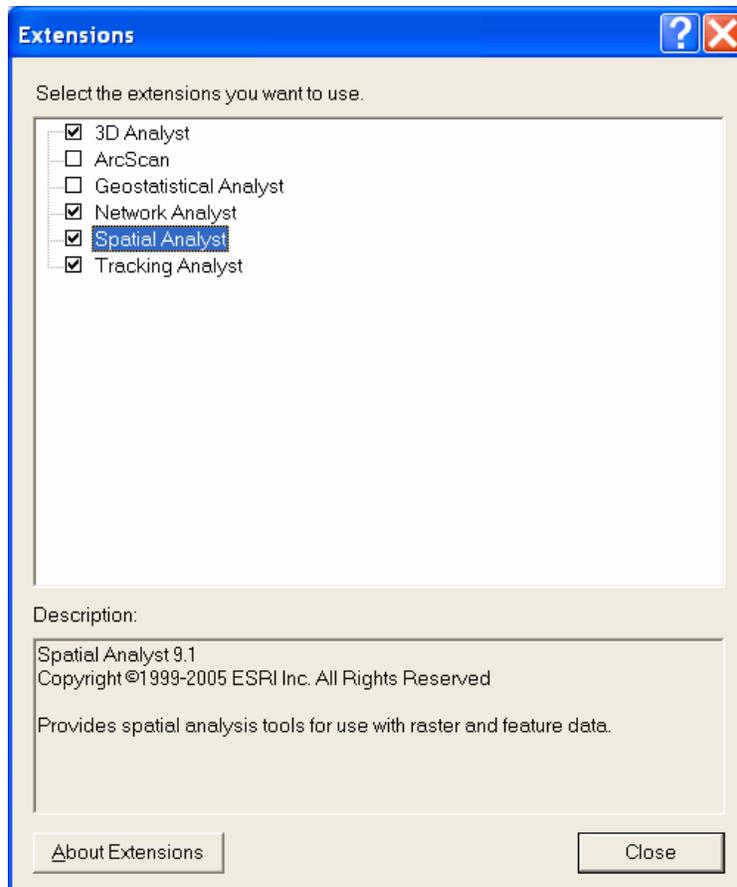


The PRISM data has a blocky appearance to it because its native resolution is about 4 km.

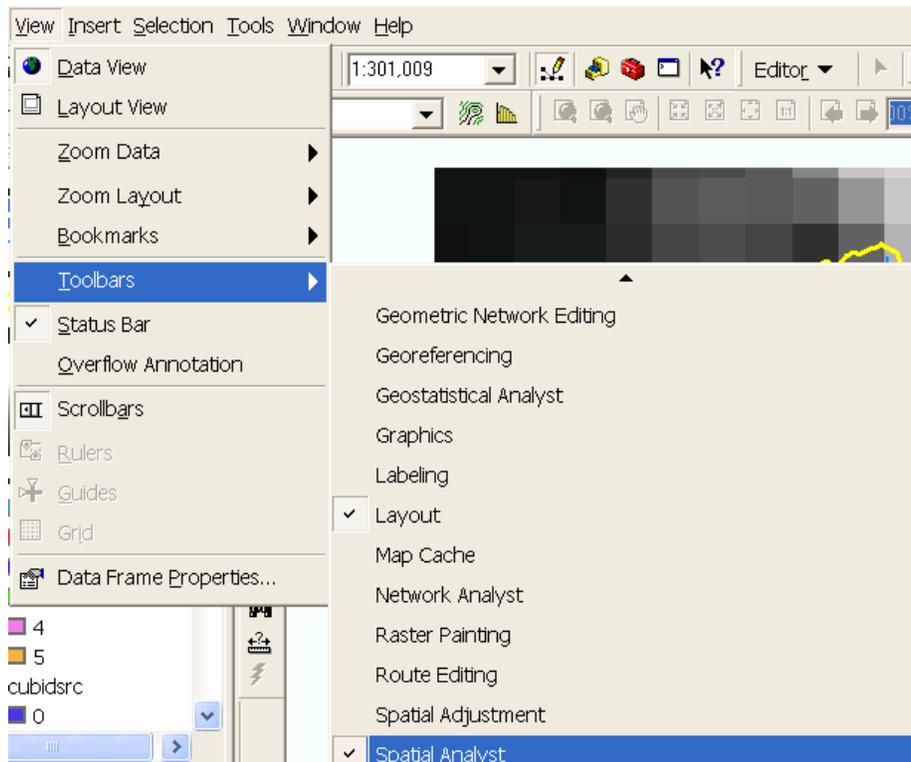
We will use ArcGIS's spatial analyst tools to average the PRISM precipitation over our watershed. Select Tools/Extensions



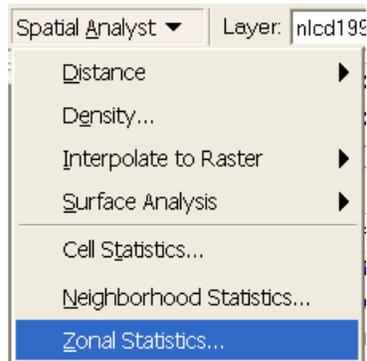
In the dialog that appears make sure that Spatial Analyst is checked, then click Close.



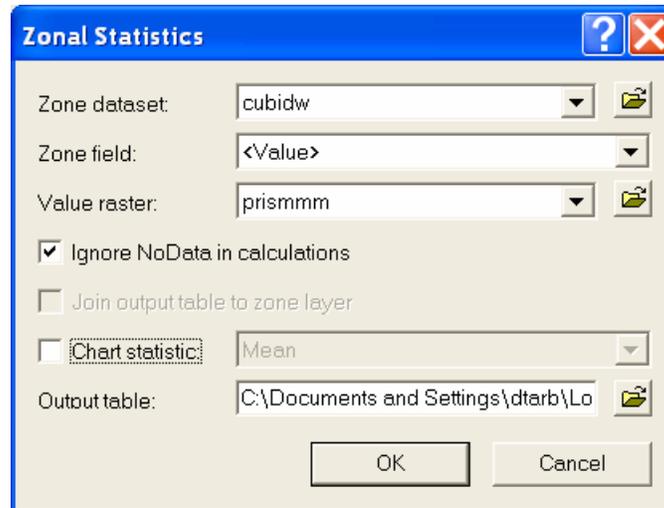
Select View/Toolbars/Spatial Analyst to make the Spatial Analyst toolbar visible.



On the Spatial Analyst toolbar select Zonal Statistics



On the Zonal Statistics dialog set the Zone dataset to 'cubidw' – the single watershed that we delineated. The Zone field can be left to <Value>. Set the Value raster to 'prismmm'. We do not need a chart, so uncheck Chart statistic and click OK.



The zonal statistics table should appear

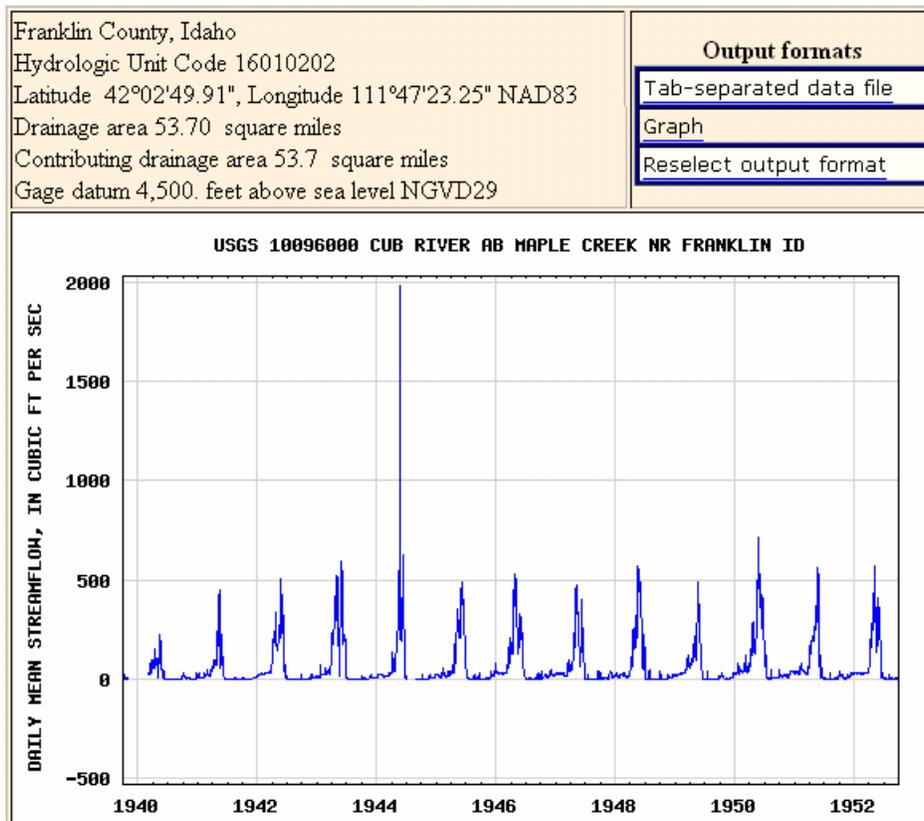
Stats of "prismmm" Within Zones of "cubidw"							
OID	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN
0	0	367223	1.46889E+08	378	1254	876	650.345

Record: 1 Show: All Selected Records (0 out of 1 Selected.) Options

This shows statistics of the prismmm grid within the watershed we delineated. This function could have been used to calculate the statistics over a number of zones, e.g. subwatersheds. Here we have a single zone that is the entire watershed. The mean precipitation is 650 mm which is equivalent to 25.6 inches. The statistics table is saved in a \*.dbf file which can be imported to Excel or any other statistical software for further analysis. This is useful when looking at statistics of more than one watershed.

#### Step 4. Mean Annual Discharge from nearby USGS Gauge.

Go to NWISWeb (<http://waterdata.usgs.gov/nwis>). Find the daily streamflow data for station 10096000 and plot the data.



Note the drainage area and mean annual discharge. How well does the drainage area compare to the GIS derived drainage area? Convert the mean annual discharge to an annual depth that can be compared with mean annual precipitation. What is the annual runoff ratio?

### Step 5. Mean Annual Discharge from Regional Regression (StreamStats)

The USGS has put considerable effort into developing equations for the estimation of streamflow properties based on watershed attributes. StreamStats is a Web-based tool that allows users to obtain streamflow statistics, drainage-basin characteristics, and other information for user-selected sites on streams. StreamStats users can choose locations of interest from an interactive map and obtain information for these locations. StreamStats implements regional regressions for the estimation of streamflow statistics.

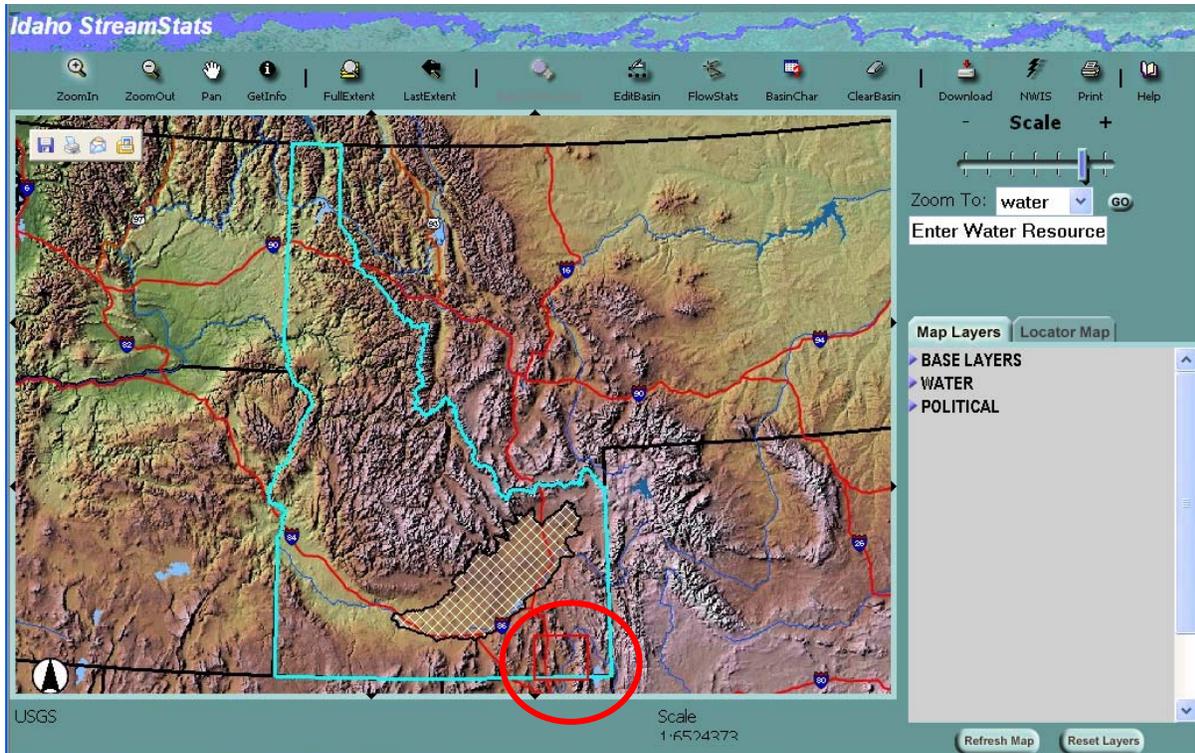
Go to the StreamStats website: <http://water.usgs.gov/osw/streamstats/index.html>. Click on State Applications, then Idaho (<http://water.usgs.gov/osw/streamstats/idaho.html>). Review the USGS reports that describe the regional regressions. The report: Hortness, J. E., and Berenbrock, C, 2001, [Estimating Monthly and Annual Streamflow Statistics at Ungaged Sites in Idaho](#): U.S. Geological Survey Water Resources-Investigations Report 01-4093, 36 p. gives on page 22 the following equation for estimating mean annual streamflow for region 8 within Idaho.

**Table 10.** Results of regional regression analysis based on data from 31 gaging stations for region 8  
 [Q.xx, daily mean discharge exceeded xx percent of the time during the specified month, in cubic feet per second; A, drainage area, in square miles; F\*, forested area, in percent of drainage area plus 1 percent; P, mean annual precipitation, in inches; E\*, mean basin elevation, in thousands of feet above sea level; BS, basin slope, in percent; S30\*, slopes greater than 30 percent, in percent of drainage area plus 1 percent; Qa, mean annual discharge, in cubic feet per second]

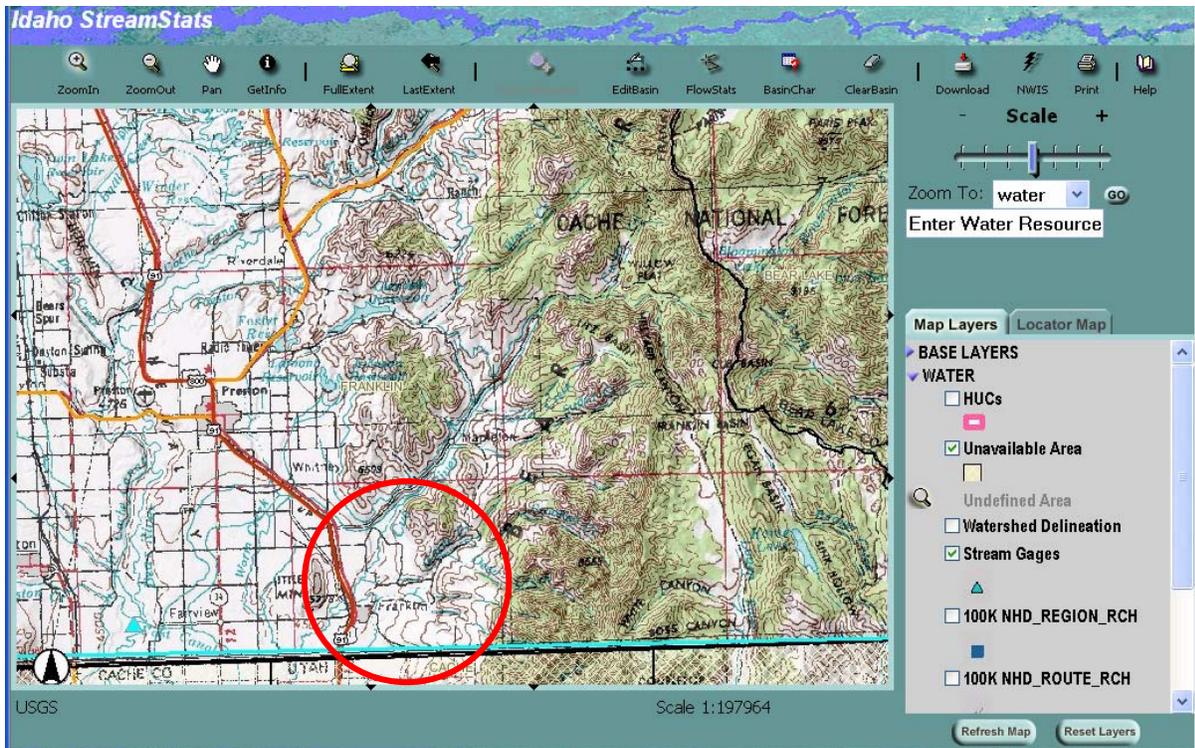
$$Qa = 2.72E-02 A^{1.03} E^{*-2.36} BS^{0.522} F^{*-0.659} P^{2.70}$$

The Cub River that we are working with is in region 8 according to Figure 2 on page 7 of Hortness and Berenbrock.

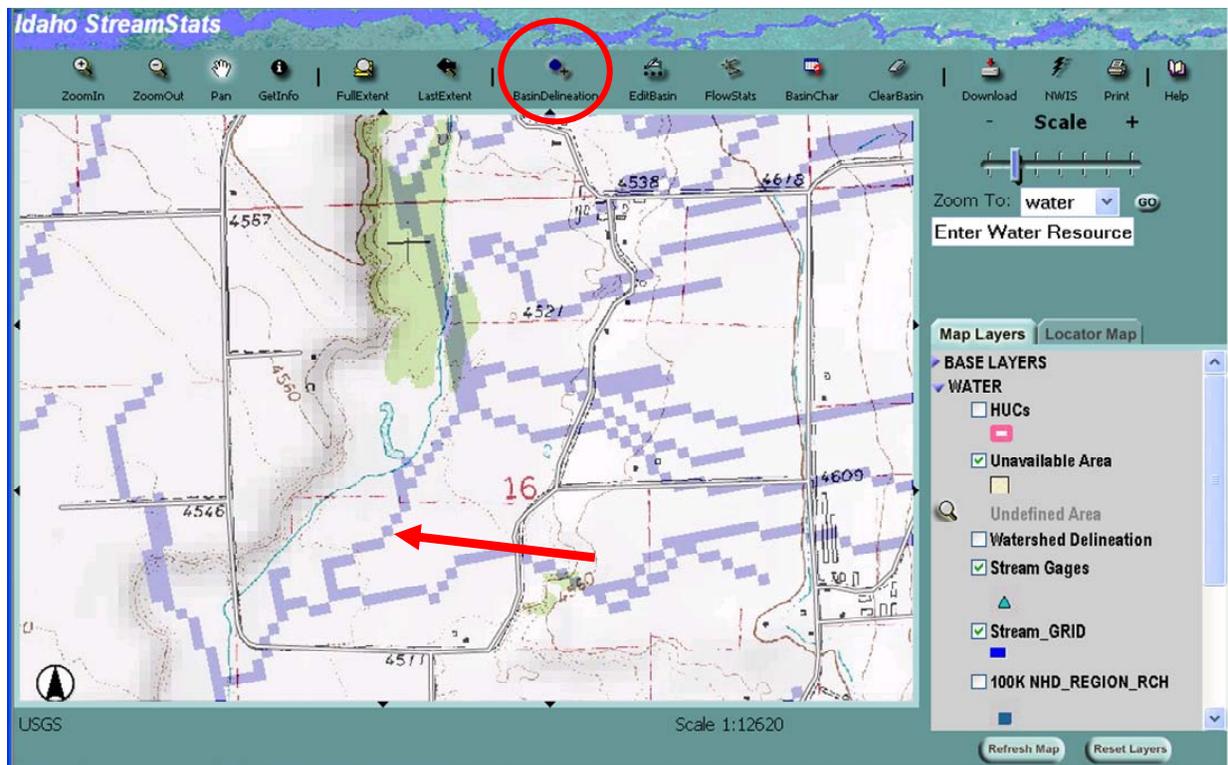
Click on the Interactive Map link. The display should appear as follows



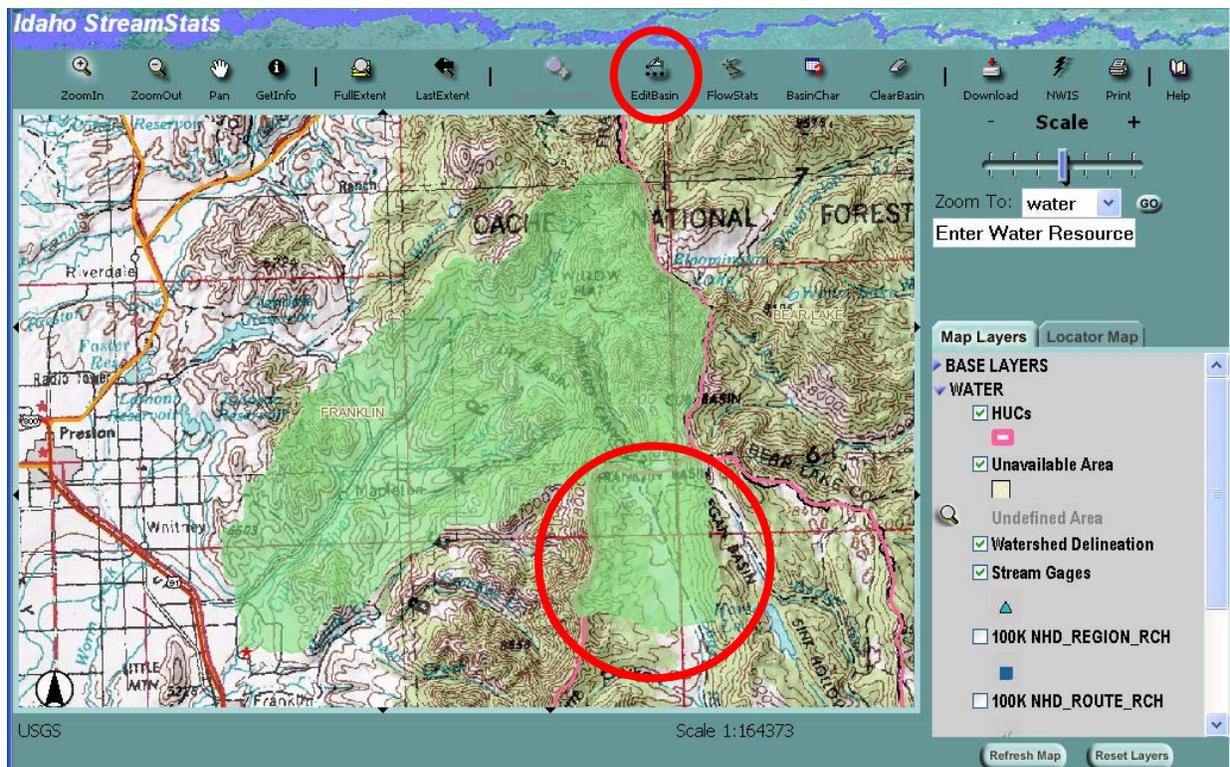
Zoom in on the area in south eastern Idaho where the Cub River is located.



When you zoom close enough a stream raster layer defined using a DEM becomes visible. Notice how I zoomed in to the same location as was used to delineate the watershed in the GIS work above. Click on Basin Delineation and select a point for the basin outlet as indicated.

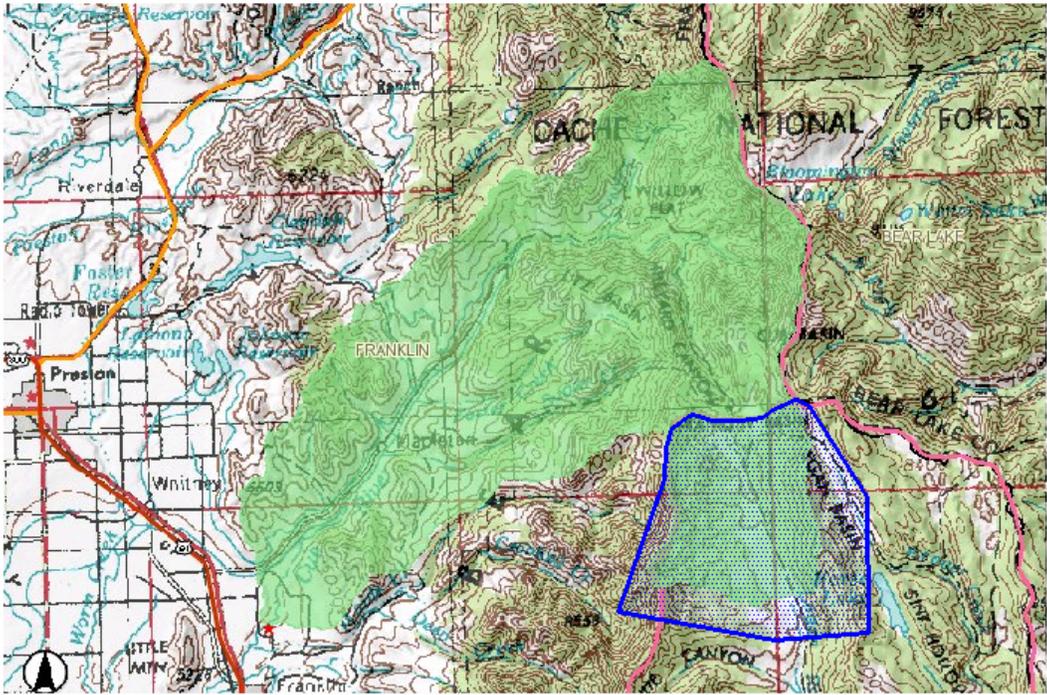


The following map showing the basin that was delineated appears.



This map has extra area at the upper end where the contributing area has "leaked in" due to the automated DEM analysis procedure being used not accounting for internally draining areas. Click on the Edit Basin button and remove the problem area.

Blue ▾ for Outline ▾  Add  Remove  Measure



The result is

The screenshot shows the 'Idaho StreamStats' web application interface. The 'FlowStats' tool icon is circled in red. The interface includes a toolbar with various tools like ZoomIn, ZoomOut, Pan, GetInfo, FullExtent, LastExtent, EditBasin, FlowStats, BasinChar, ClearBasin, Download, NWIS, Print, and Help. A scale bar and a 'Zoom To' dropdown menu are also visible. The map area shows the same watershed as the previous image. On the right side, there is a 'Map Layers' panel with the following settings:

- BASE LAYERS
  - WATER
    - HUCs
    - Unavailable Area
    - Undefined Area
    - Watershed Delineation
    - Stream Gages
    - 100K NHD\_REGION\_RCH
    - 100K NHD\_ROUTE\_RCH

Buttons for 'Refresh Map' and 'Reset Layers' are at the bottom of the panel. The map shows a scale of 1:164373 and is labeled 'USGS'.

Click on FlowStats to obtain the statistics and regional streamflow estimates for this watershed. Compare the results to the quantities estimated above. How consistent is the drainage area, with the DEM derived drainage area? How consistent is the precipitation with the GIS derived

precipitation? How consistent is the Mean Annual Flow with what was recorded at the gauge from 1940 to 1952?

http://streamstats.usgs.gov - Streamstats Report - Microsoft Internet Explorer

File Edit View Favorites Tools Help



## Streamflow Statistics Report

**Date:** Sun May 28 2006 12:33:09  
**Site Location:** Idaho  
**Latitude:** 45.2248  
**Longitude:** -114.1406  
**Drainage Area:** 57.3 mi<sup>2</sup>

### Peak Flow Basin Characteristics

100% Peak Flow Region 8 (57.3 mi<sup>2</sup>)

Parameter	Value	Min	Max
Drainage Area (square miles)	57.3	2.5	874.8
Mean Basin Slope from 30m DEM (percent)	30.3	5.1	53.6
Slopes Greater Than 30 Percent (percent)	45.2	1.2	88.7

### Low Flow Basin Characteristics

100% Low Flow Region 8 (57.3 mi<sup>2</sup>)

Parameter	Value	Min	Max
Drainage Area (square miles)	57.3	16.3	874.8
Percent Forest (percent)	32	2.3	93.9
Mean Annual Precipitation (inches)	22.2	14.2	56
Mean Basin Elevation (feet)	6140	5691.9	8951
Mean Basin Slope from 30m DEM (percent)	30.3	6.1	49.7
Slopes Greater Than 30 Percent (percent)	45.2	1.2	86.6

Done Internet

http://streamstats.usgs.gov - Streamstats Report - Microsoft Internet Explorer

File Edit View Favorites Tools Help

### Streamflow Statistics

Statistic	Flow (ft <sup>3</sup> /s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
<b>Peak-Flow Statistics</b>					
Q1.5	340	74		113	1020
Q2	394	69		139	1120
Q2.33	429	68		154	1190
Q5	532	64		200	1420
Q10	613	63		234	1610
Q25	705	63		269	1850
Q50	764	64		289	2020
Q100	855	64		320	2280
Q200	916	65		339	2470
Q500	965	67		351	2660

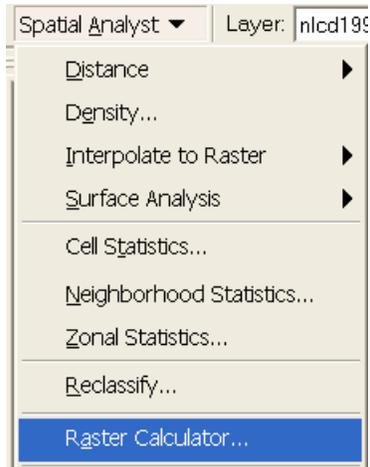
### Streamflow Statistics

Statistic	Flow (ft <sup>3</sup> /s)	Standard Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
<b>Mean Annual Flow Statistics</b>					
Qa	62.1	50			
<b>January Flow-Duration Statistics</b>					
Jan_Q20	23.6	67			
Jan_Q50	18	75			
Jan_Q80	12.7	86			
<b>February Flow-Duration Statistics</b>					
Feb_Q20	24.4	67			
Feb_Q50	17.8	74			
Feb_Q80	12.5	83			

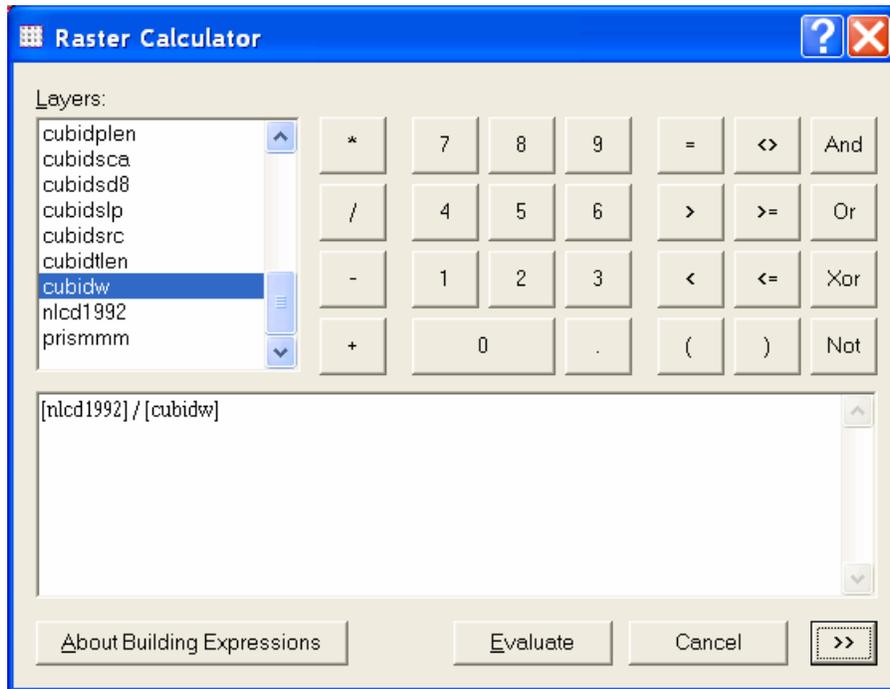
Done Internet

## Step 6. Land Cover Classes within a watershed and adjacent to streams

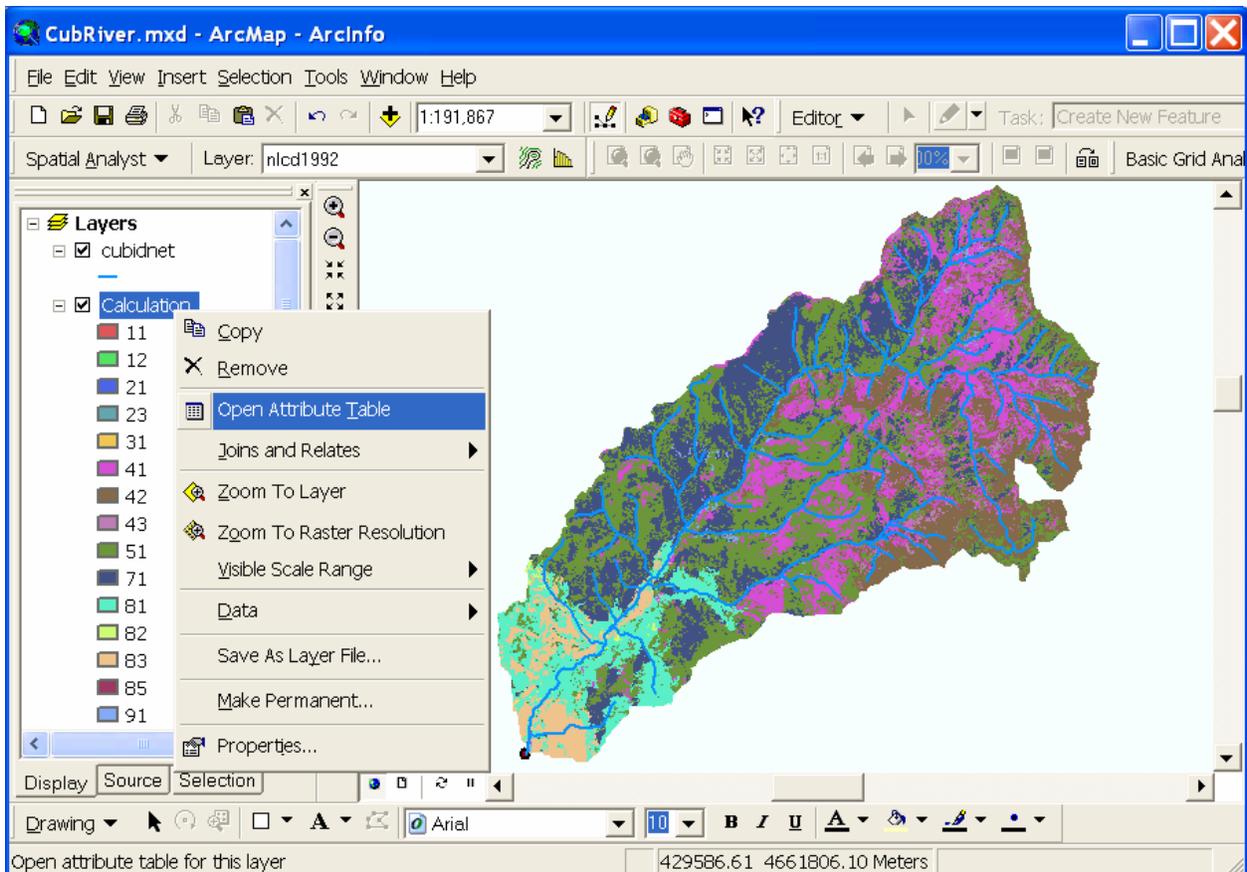
The grid 'nlcd1992' contains data from the National Land Cover dataset surveyed in 1992 as obtained from the USGS seamless data server. See the appendix for the procedures for extracting and preparing this data. It is useful in watershed modeling to know the fraction of the watershed under different land cover classes. For example the regional regression above used the percent of forest cover. Land cover percentages can be calculated by clipping the nlcd1992 data to only cover the watershed delineated. An easy way to do this is with the Spatial Analyst Raster Calculator. On the Spatial Analyst toolbar select Raster Calculator



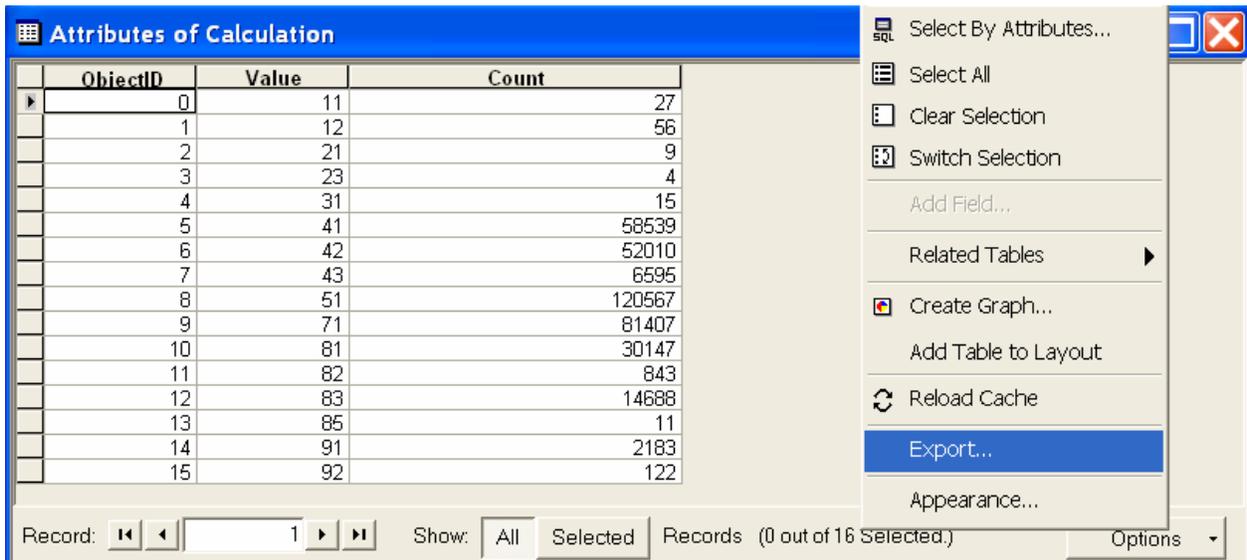
Build the expression  $[nlcd1992] / [cubidw]$ . The cubidw grid is a mask of the watershed that has the value 1 within the watershed and 0 outside it. Dividing by 1 inside the watershed does not alter the data, but dividing by 0, outside of the watershed gives a no-data result, effectively clipping the nlcd1992 grid to the watershed.



Evaluate this expression. The result is saved in a grid named Calculation that presents land cover data only over the watershed.



Right click on Calculation and Open Attribute table to display the attributes which in this case are the count of the number of grid cells of each land cover class in the watershed.



Note that land cover class 51 (shrubland) has the highest count of grid cells. To determine fractions it is easiest to export this data to Excel. Click on Options/Export and save the table as a DBF file. Open the DBF file using Excel to calculate percentages. The data analyzed in Excel is as follows:

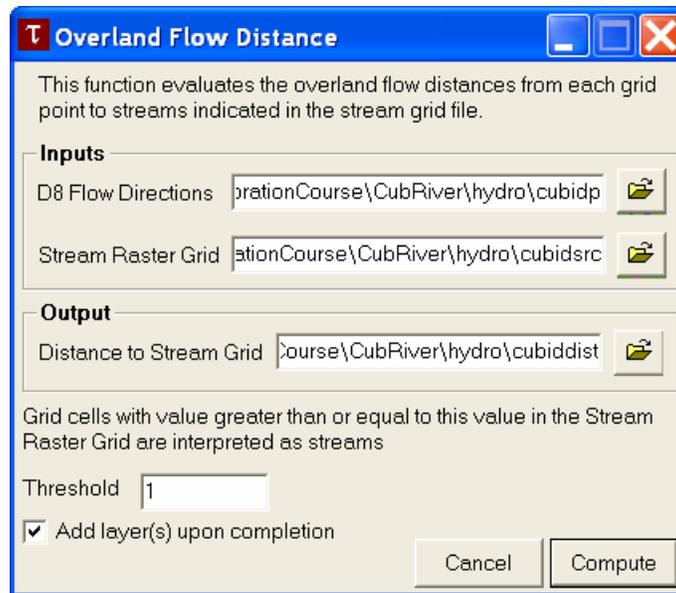
Value	Count	Percentage	Name
11	27	0.01%	Open Water
12	56	0.02%	Perennial Ice/Snow
21	9	0.00%	Low Intensity Residential
23	4	0.00%	Commercial/Industrial/Transportation
31	15	0.00%	Bare Rock/Sand/Clay
41	58539	15.94%	Deciduous Forest
42	52010	14.16%	Evergreen Forest
43	6595	1.80%	Mixed Forest
51	120567	32.83%	Shrubland
71	81407	22.17%	Grasslands/Herbaceous
81	30147	8.21%	Pasture/Hay
82	843	0.23%	Row Crops
83	14688	4.00%	Small Grains
85	11	0.00%	Urban/Recreational Grasses
91	2183	0.59%	Woody Wetlands
92	122	0.03%	Emergent Herbaceous Wetlands
Total	367223		

Note that forest (deciduous and evergreen) together comprise about 30% of the watershed, consistent with the StreamStats information.

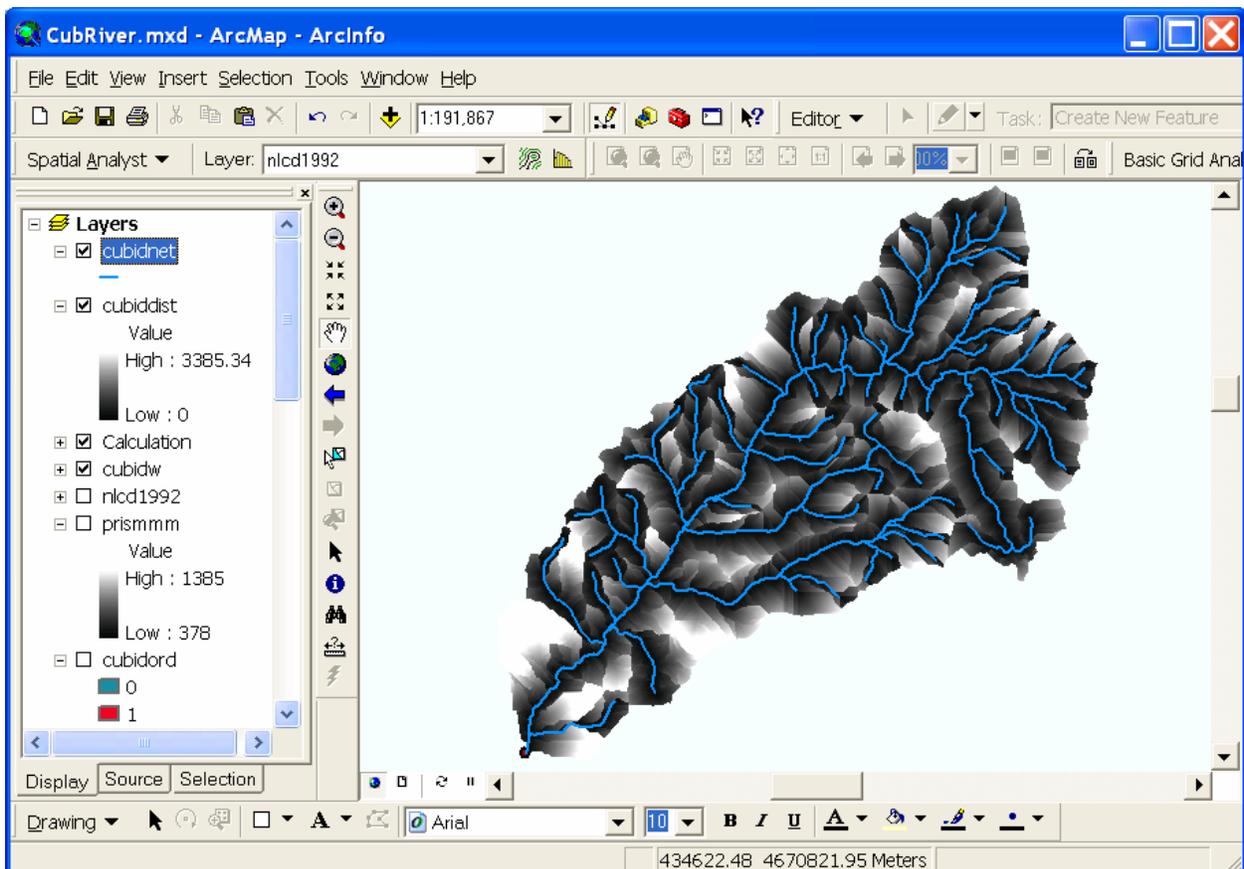
Sometime we may be interested in examining information adjacent to or in the vicinity of the streams. For example we may be interested in looking at the land cover distribution within a 200m buffer along the stream. The following steps show the derivation of land cover distribution in the vicinity of the stream.

The TauDEM function Flow Distance to Streams under Specialized Grid Analysis calculates the overland flow distance to streams. This estimates the distance along the flow path from any point in the watershed to the stream.

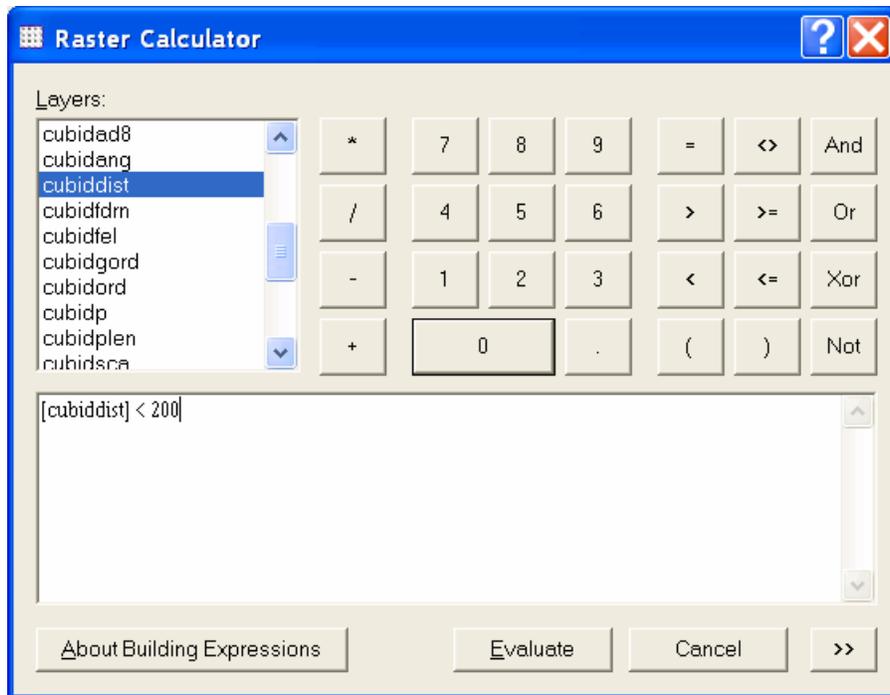




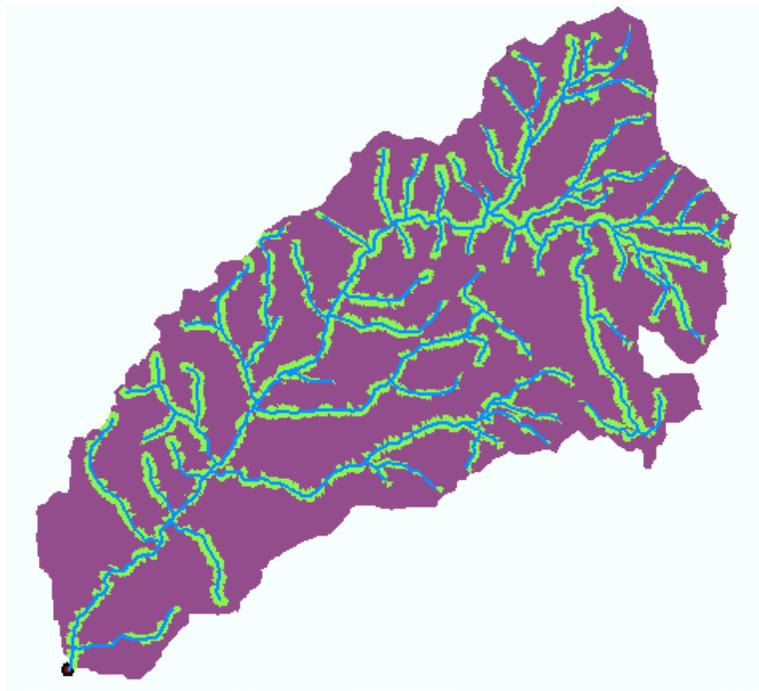
Click Compute. The results are stored in a grid file with suffix \*dist, i.e. 'cubiddist'.



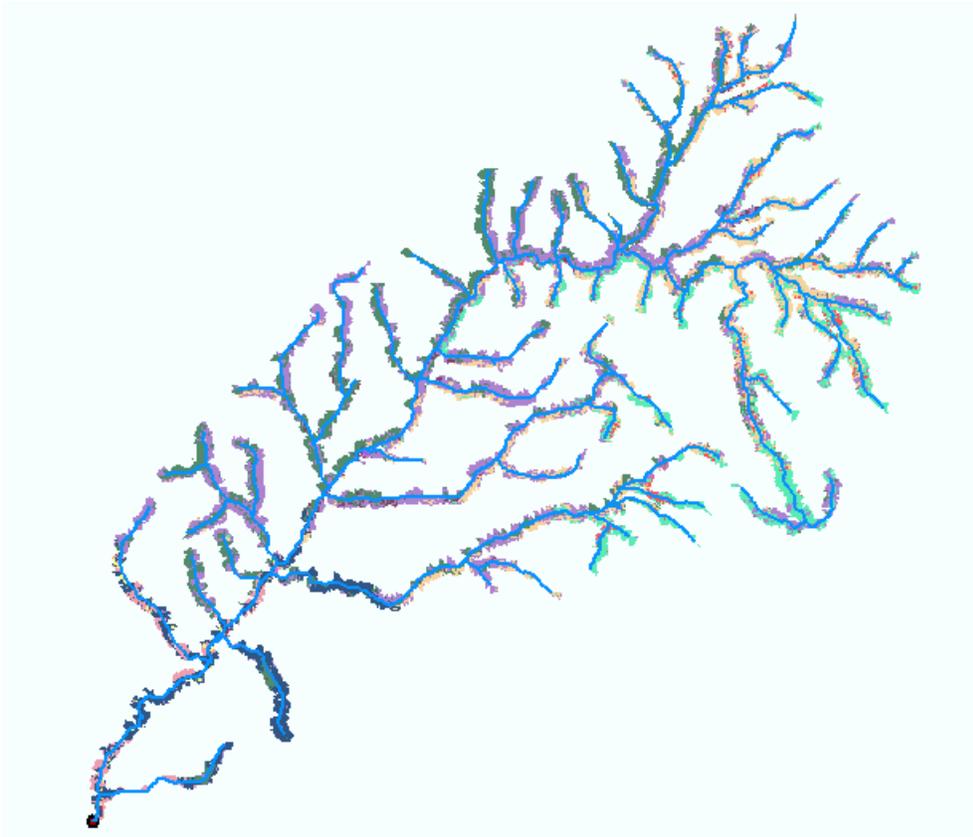
A stream buffer may be defined using Raster Calculator selecting only grid cells where the flow distance is less than a threshold (e.g. distance < 200 m)



The result is as shown below.



The Raster Calculation:  $[nlcd1992] / [Calculation2]$  where Calculation2 is the buffer above results in a selection of only the nlcd1992 data within the buffer.



The attribute table from this calculation gives the count of land cover types within this 200 m buffer.

ObjectID	Value	Count
0	11	9
1	12	8
2	21	9
3	23	3
4	31	5
5	41	15112
6	42	10296
7	43	1475
8	51	28193
9	71	21667
10	81	6791
11	82	259
12	83	2270
13	85	10
14	91	1227
15	92	56

This data may too be exported to Excel and percentages calculated.

Value	Count	Percentage	Name
11	9	0.01%	Open Water
12	8	0.01%	Perennial Ice/Snow
21	9	0.01%	Low Intensity Residential
23	3	0.00%	Commercial/Industrial/Transportation
31	5	0.01%	Bare Rock/Sand/Clay
41	15112	17.29%	Deciduous Forest
42	10296	11.78%	Evergreen Forest
43	1475	1.69%	Mixed Forest
51	28193	32.26%	Shrubland
71	21667	24.79%	Grasslands/Herbaceous
81	6791	7.77%	Pasture/Hay
82	259	0.30%	Row Crops
83	2270	2.60%	Small Grains
85	10	0.01%	Urban/Recreational Grasses
91	1227	1.40%	Woody Wetlands
92	56	0.06%	Emergent Herbaceous Wetlands
Total	87390		

For this watershed the land use fractions in a 200 m buffer adjacent to streams are quite similar to the entire watershed.

The end!

## Appendix: Data downloading and organization

### USGS Seamless data server

The USGS Seamless data server was used to obtain National Elevation Dataset, National Land Cover Dataset and Digital Raster Graph topographic map images.

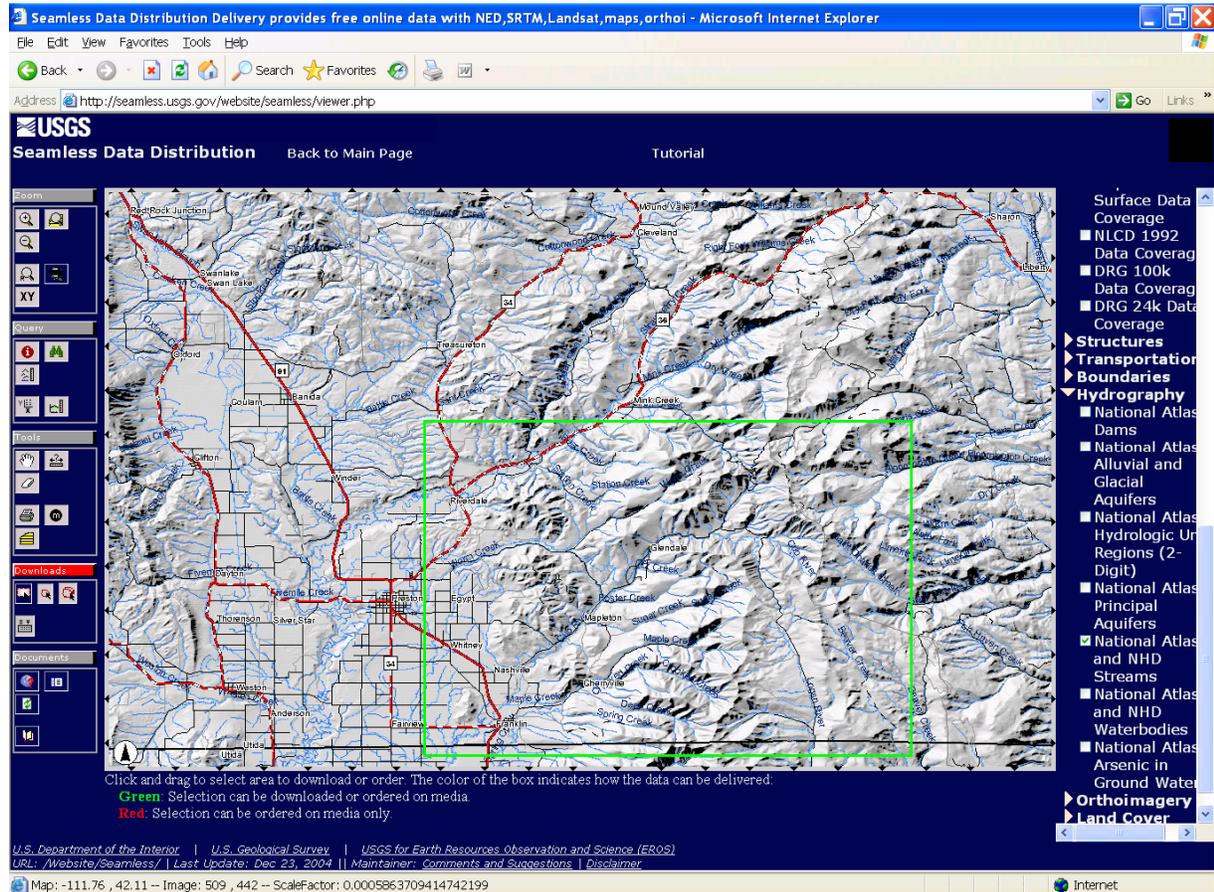
The steps followed were

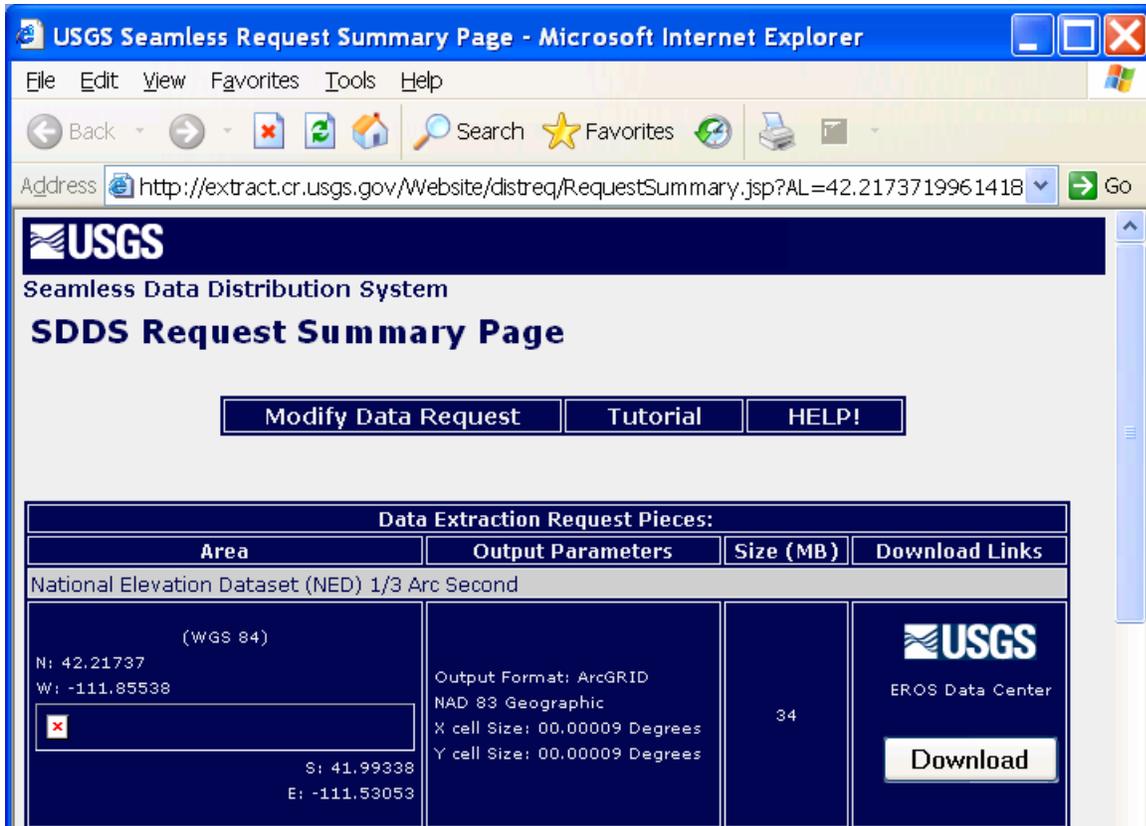
1. Access USGS Seamless data server <http://seamless.usgs.gov/>
2. Click view and download United States Data
3. Zoom to the area of interest. Activate layers on the right to help identify your area of interest.
4. Define a download region that covers your area of interest.
5. Modify the data request to comprise the data sets (parameters) that you want to obtain
6. Download the data.

I selected the following:

- 1/3 arc second National elevation dataset DEM ( $\approx 10$  m grid)
- National Land Cover Dataset 1992
- 24k-DRG – UTM zone 12 (This came in 8 pieces)

Screen Image of the area that I selected





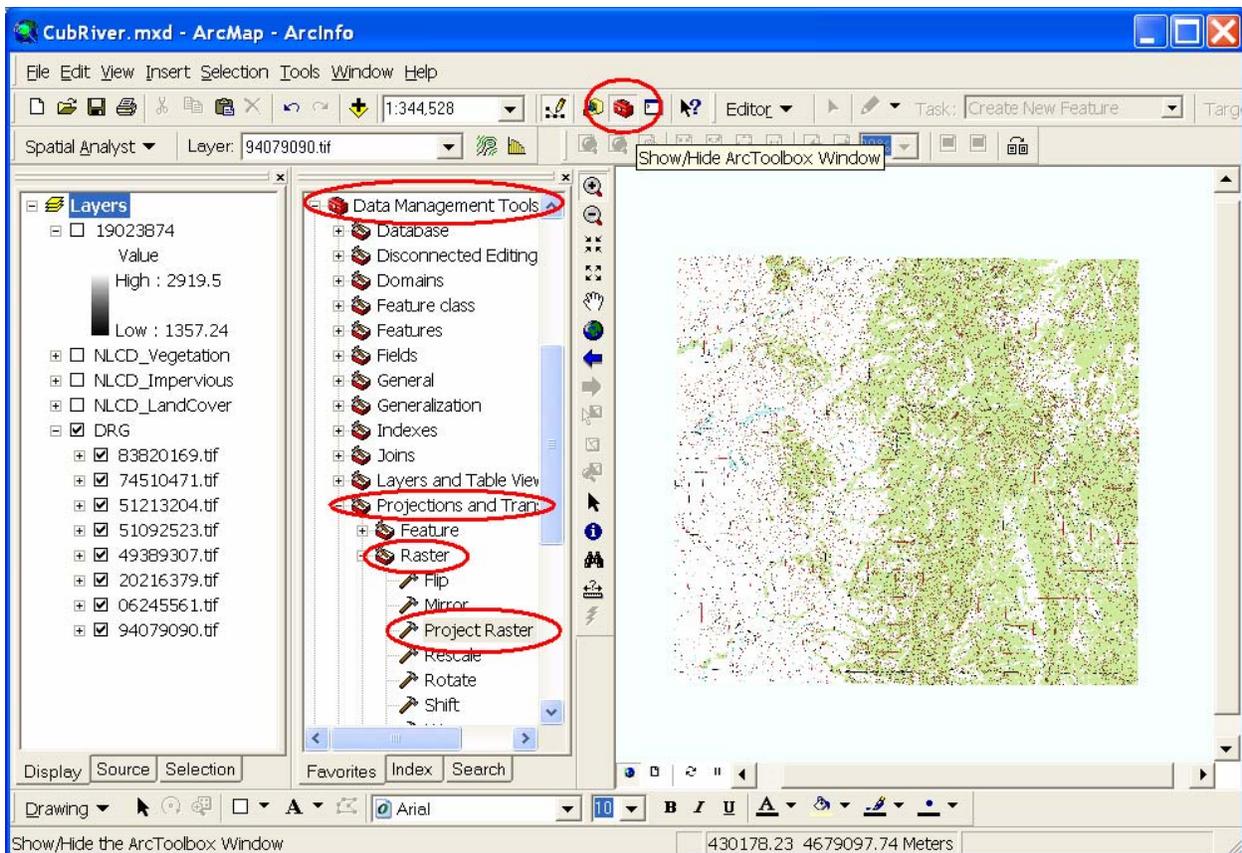
Screen Image of a Data Download Request

### DRG data

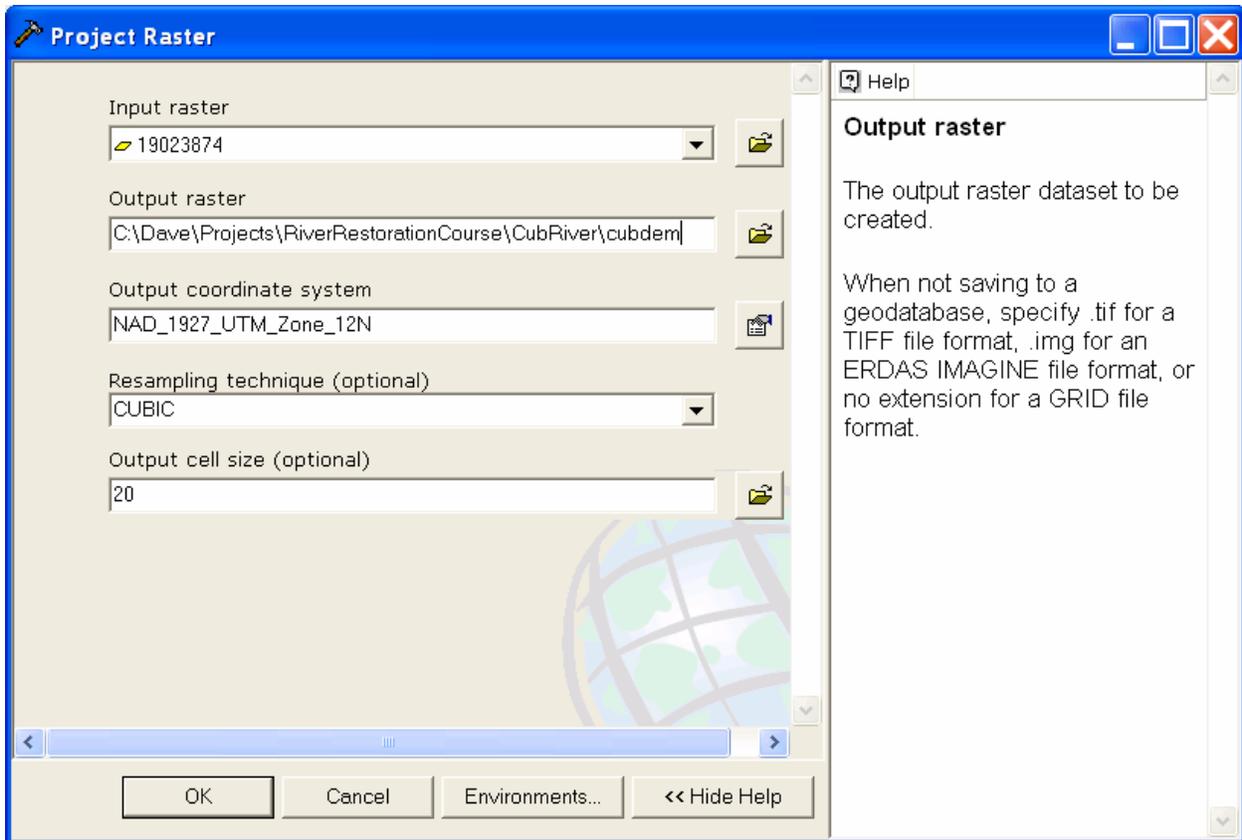
The eight Digital Raster Graph files were extracted into a folder named DRG and added to a new ArcMap document. The data frame inherited the spatial reference properties of this data (NAD\_1927\_UTM\_Zone\_12). This was therefore chosen as a standard spatial reference coordinate system for this example.

### Projecting the Digital Elevation Model data

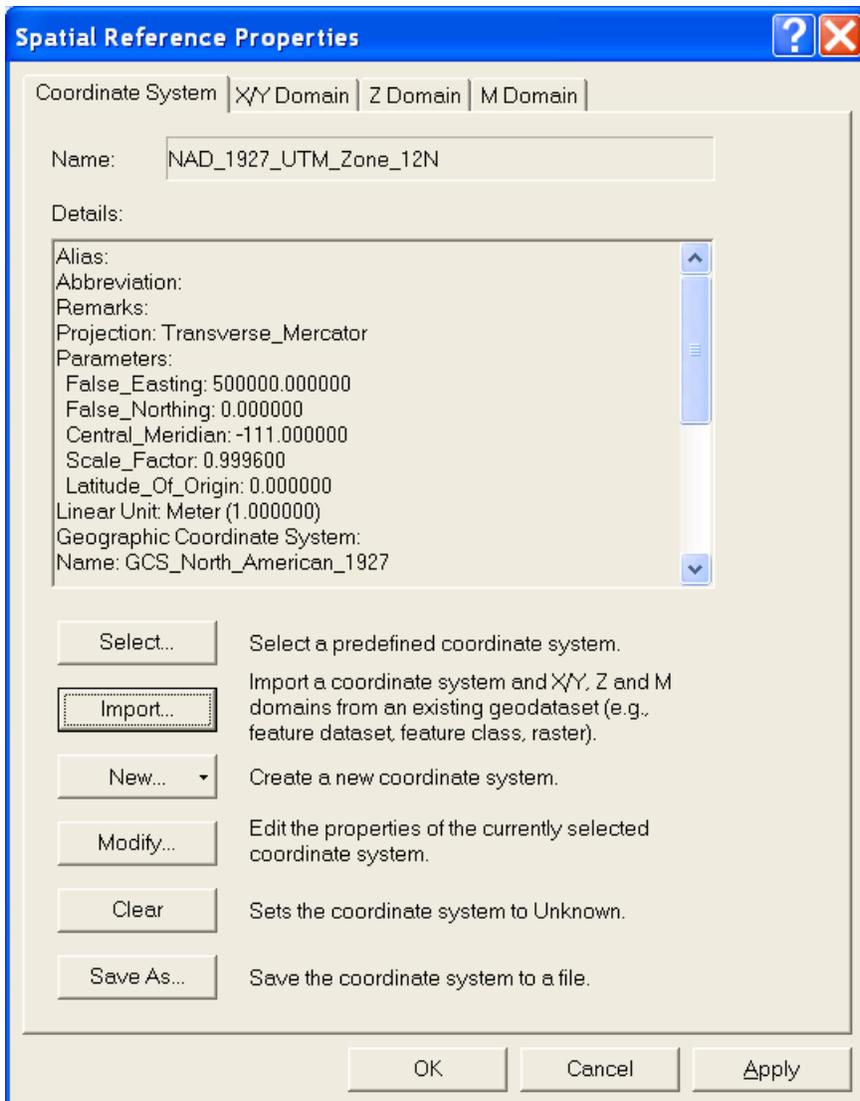
The Digital Elevation Model grid from the Seamless Data Server is in Geographic Coordinates. This was added to ArcMap. Then the ArcToolBox Project Raster tool was used to project this data to the same coordinate system as the DRG files. The ProjectRaster Tool is found within Data Management Tools / Projections and Transformations / Raster.



In the Project Raster dialog that opens specify the input raster as the National Elevation Dataset DEM that was unzipped from the download. Name the output raster something convenient. Here I used "cubdem". Click on the button next to Output coordinate system to open the Spatial Reference Properties dialog.



At this Spatial Reference Properties dialog click "Import" and navigate to one of the DRG tiff files to import the same spatial reference properties as these files (NAD\_1927\_UTM\_Zone\_12N) being used as the standard spatial reference system for this exercise. Click OK.



Back at the Project Raster dialog set the resampling technique to CUBIC (I have found by experience that this works best for DEMs) and set the output cell size to 20 m. The raw data in this case is at 1/3 arc second which is roughly 10 m. 20 m cell size is undersampling this a bit, but is perfectly adequate for what we are doing and is better than oversampling. Click OK. A processing dialog box should appear and after a few seconds indicate completion of the projection of the DEM. The DEM data has now been projected. The result is named 'cubdem'

### NLCD data

The same procedure as used to project the DEM data was used to project the NLCD data to the NAD\_1927\_UTM\_Zone\_12N spatial reference. However instead of CUBIC resampling, I used nearest neighbor resampling because this is discrete data. A 20 m cell size was used for consistency with the DEM.

The NLCD 1992 dataset used the following codes to represent land cover classes (<http://www.epa.gov/mrlc/definitions.html#1992>)

- Water
  - 11 Open Water
  - 12 Perennial Ice/Snow
- Developed
  - 21 Low Intensity Residential
  - 22 High Intensity Residential
  - 23 Commercial/Industrial/Transportation
- Barren
  - 31 Bare Rock/Sand/Clay
  - 32 Quarries/Strip Mines/Gravel Pits
  - 33 Transitional
- Vegetated; Natural Forested Upland
  - 41 Deciduous Forest
  - 42 Evergreen Forest
  - 43 Mixed Forest
- Shrubland
  - 51 Shrubland
- Non-natural Woody
  - 61 Orchards/Vineyards/Other
- Herbaceous Upland
  - 71 Grasslands/Herbaceous
- Herbaceous Planted/Cultivated
  - 81 Pasture/Hay
  - 82 Row Crops
  - 83 Small Grains
  - 84 Fallow
  - 85 Urban/Recreational Grasses
- Wetlands
  - 91 Woody Wetlands
  - 92 Emergent Herbaceous Wetlands

## **National Hydrography Dataset (NHD)**

The NHD website is: <http://nhd.usgs.gov/>. I clicked on data then Go to NHD Viewer. I zoomed in on the area of interest and discovered that the first 4 digits of the region containing the Cub River are 1601. I then clicked on Staged SubRegions and downloaded the high resolution NHD file (NHDH1601.zip) for this region from <ftp://nhdftp.usgs.gov/SubRegions/High/>. This zip file contains the geodatabase file NHDH1601.mdb.

## **PRISM Data**

The PRISM website is: <http://www.ocs.orst.edu/prism/>. I clicked on 1971-2000 Normals, then Gridded data, then Ann 1971-2000. At the following screen I examined the FGDC metadata to establish that the horizontal datum for the data is WGS\_1972 and that the data is in 1/100 of mm on a roughly 4 km grid.



spatial climate analysis service

PRISM PRODUCT VIEWER



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 [View Map Graphic](#)
 [Browse FTP](#)

## Precipitation (Normals)

<p><b>Description:</b> Total Precipitation (30-yr average)</p> <p><b>Time period:</b> Annual 1971-2000</p> <p><b>Spatial format:</b> grid</p> <p><b>Spatial Resolution:</b> 2.5 arc-minute (~4 km)</p> <p style="padding-left: 20px;"><b>Units:</b> Millimeters</p> <p><b>Scale Factor:</b> 100</p>	<p><b>Date Created:</b> February 4,2004</p> <p><b>Time interval:</b> Annual</p> <p><b>Projection:</b> Geographic</p> <p><b>Spatial Extent:</b> Conterminous United States</p> <p><b>Spatial Format:</b> <a href="#">Arc/Info ASCII GRID</a></p> <p><b>Metadata:</b> <a href="#">FGDC metadata</a></p>
---	---

**Data Status: Final**

IMPORTANT! These data may not cost you anything but that doesn't mean it's FREE. Please read the [terms of use](#) before using.

The following is the header portion of the data. To view entire file click the Printer icon, or click the download icon to save file to disk.

```
ncols 1465
nrows 623
xllcorner -126.020833
yllcorner 24.062500
cellsize 0.041667
NODATA_value -9999
```

Copyright ©2006. Spatial Climate Analysis Service, Oregon State University.

I clicked download gridded data to download the file `us_ppt_1971_2000.14.gz`. This file was unzipped and the output file renamed `usppt.asc`. The ArcToolBox ASCII to raster function was used to convert this file into ArcGIS grid format. The ArcToolBox DefineProjection was used to define the spatial reference for this file as `GCS_WGS_1972`. The ArcToolBox function Project Raster was used to project this data to a `NAD_1927_UTM_Zone_12N` projection being used for the Cub River example. Cubic interpolation was used. Spatial Analyst Raster Calculator was then used to resample this grid to an extent, and cell size the same as the Cub River DEM, and to divide by 100 to obtain the grid `prismmm` that contains PRISM mean annual precipitation in mm.

### Internal Drainage Preprocessing

1. Fill Pits was run on 'cubdem'. The result is 'cubdemfel'
2. The Raster calculation `cubdemfel - cubdem` was examined and found visually to identify the bottom of internally draining regions when its value is greater than 30.9. The result is named Calculation.
3. A raster calculation `(cubdem / (Calculation < 30.9))` sets these grid cells to no data values. The result was named cubid.

## **Imposed Flow Direction Raster (\*.fdr) file**

The following steps were used to derive the imposed flow direction file.

1. In ArcMap features with Ftype=460 that correspond to StreamRiver were selected from the NHDFlowline feature class in Hydrography in NHDH1601.mdb. These were then exported as a shape file retaining the spatial reference properties of the data frame to achieve the conversion to NAD\_1927\_UTM\_Zone\_12N.
  2. Spatial Analyst options were set to have the same extent and cell size as the Cub River DEM, cubdem. Spatial Analyst Convert features to Raster was then used to convert the stream shape file from step 1 to a stream raster grid 'strgrd'. The resulting stream raster grid has the same cell size and extent as the DEM.
  3. The no data values in strgrd were reclassified to 0
  4. The raster calculation cubid - 100 \* strgrd was used to create a grid with streams burned in to it. The result was named 'cubcanyon'.
  5. "Fill pits" and "D8 flow directions" functions were run.
  6. "D8 contributing area" was run using strgrd as a weight input grid.
  7. The raster calculation cubcanyonp/[cubcanyonad8 > 3] was performed and the result named cubidfdr.
-