Exercise 4. Watershed and Stream Network Delineation

GIS in Water Resources, Fall 2014

Prepared by David G Tarboton and David R. Maidment

Purpose

The purpose of this exercise is to illustrate watershed and stream network delineation based on digital elevation models using the Hydrology tools in ArcGIS and online services for Hydrology and Hydrologic data. In this exercise, you will select a stream gage location and use online tools to delineate the watershed draining to the gage. National Hydrography and Digital Elevation Model data will be retrieved for this area (Logan River Basin) from online services. You will then perform drainage analysis on a terrain model for this area. The Hydrology tools are used to derive several data sets that collectively describe the drainage patterns of the basin. Geoprocessing analysis is performed to fill sinks and generate data on flow direction, flow accumulation, streams, stream segments, and watersheds. These data are then used to develop a vector representation of catchments and drainage lines from selected points that can then be used in network analysis. This exercise shows how detailed information on the connectivity of the landscape and watersheds can be developed starting from raw digital elevation data, and that this enriched information can be used to compute watershed attributes commonly used in hydrologic and water resources analyses.

Learning objectives

- Do an online watershed delineation and then extract the data for that watershed to perform a more detailed analysis.
- Identify and properly execute the sequence of Hydrology tools required to delineate streams, catchments and watersheds from a DEM.
- Evaluate and interpret drainage area, stream length and stream order properties from Terrain Analysis results.
- Develop a Geometric Network representation of the stream network from the products of terrain analysis.
- Use Network Analysis to select connected catchments and determine their properties.

Computer and Data Requirements

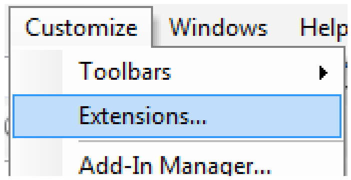
To carry out this exercise, you need to have a computer which runs ArcGIS 10.2 or higher and includes the Spatial Analyst extension. No data is required to start this exercise. All the necessary data will be extracted from ArcGIS.com services. To use these services you need an ArcGIS.com account that has been linked to an ArcGIS license.

The exercise is divided in to the following activities that each comprise a sequence of steps

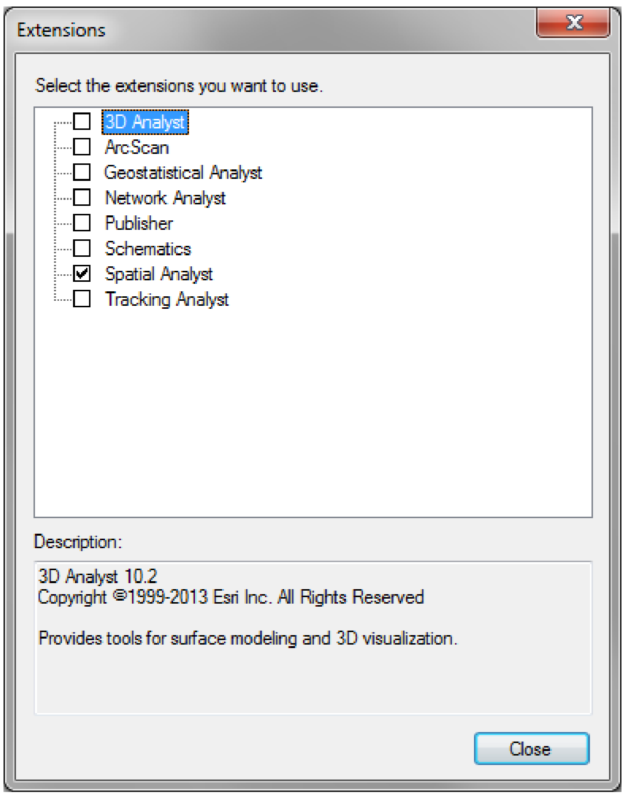
1. Online Watershed Delineation and Data Retrieval.
2. Hydrologic Terrain Analysis
3. Network analysis

Before we start

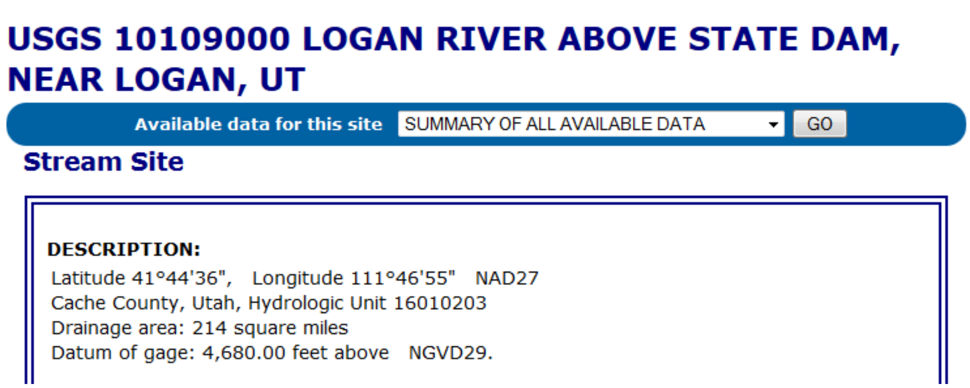
In ArcMap select **Customize → Extensions**



Select the Spatial Analyst extension. We will be using this during the exercise.



The USGS NWIS website for the Logan River: http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=10109000 gives the following information about the Logan River Stream Site.



Note the Latitude, Longitude and geographic coordinate system (NAD27). Note also the drainage Area.

Compute the latitude and longitude in decimal degrees in an Excel Spreadsheet.

	A	B	C	D	E	F	G	H	I
1	SiteID	LatDeg	LatMin	LatSec	LongDeg	LongMin	LongSec	LatDD	LongDD
2	10109000	41	44	36	111	46	55	41.74333	-111.78194

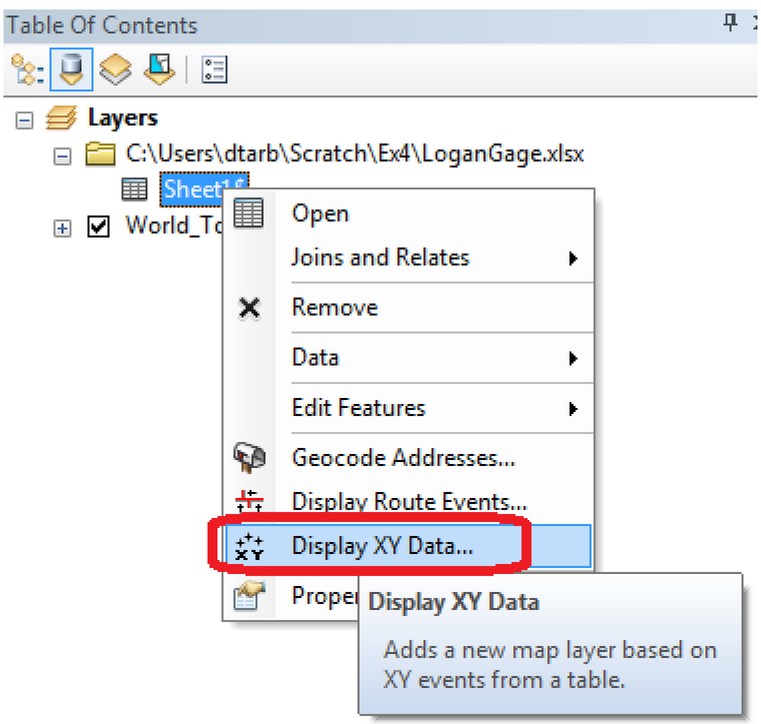
Online Watershed Delineation and Data Retrieval

1. Watershed draining to a stream gage

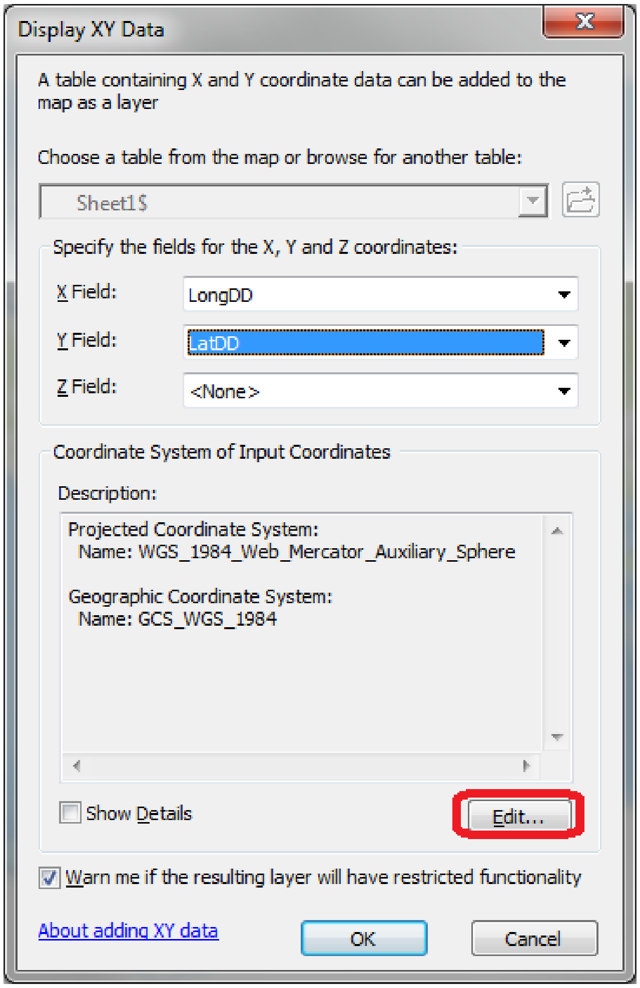
Open ArcMap. Click on the arrow part of the icon to **Add Basemap** and select **Topographic**. You should see a display of the World_Topo_map.

Click on the icon to **Add Data** and add the sheet from the spreadsheet with latitude and longitude of the Logan River Stream Gage.

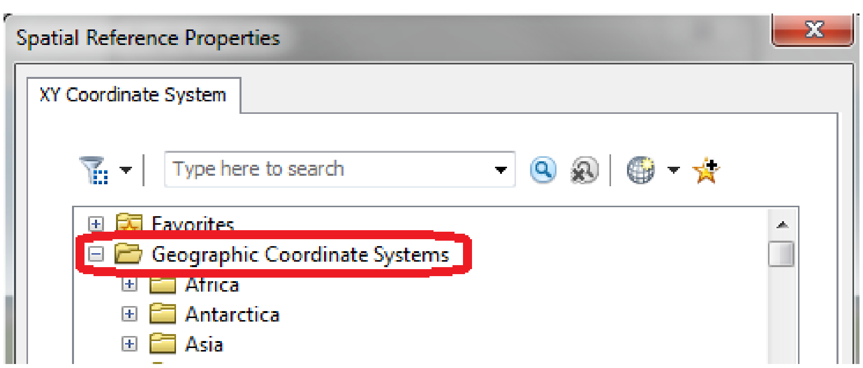
Right click on this spreadsheet layer and select **Display XY data**.

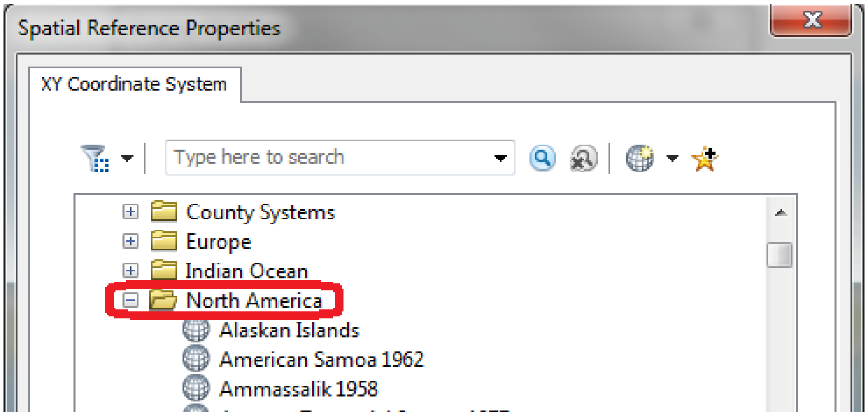


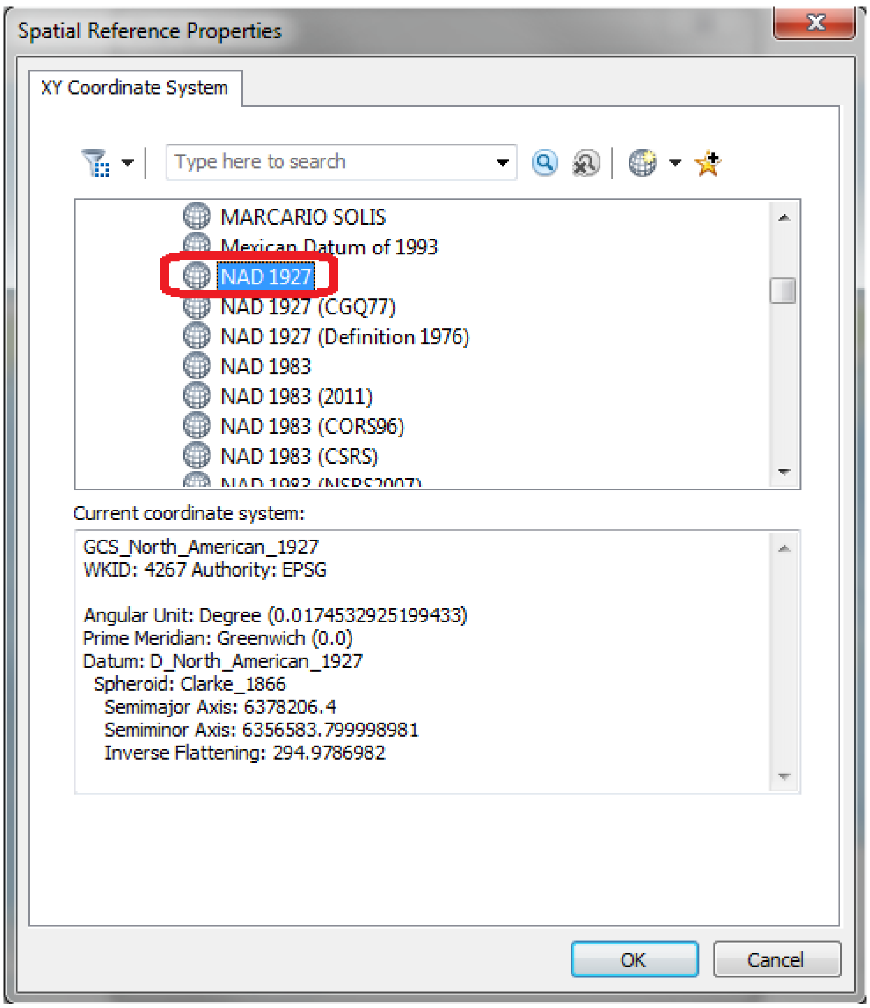
Set the X and Y fields. Recall that the USGS NWIS website indicated a NAD27 coordinate system. Click **Edit** to edit the coordinate system



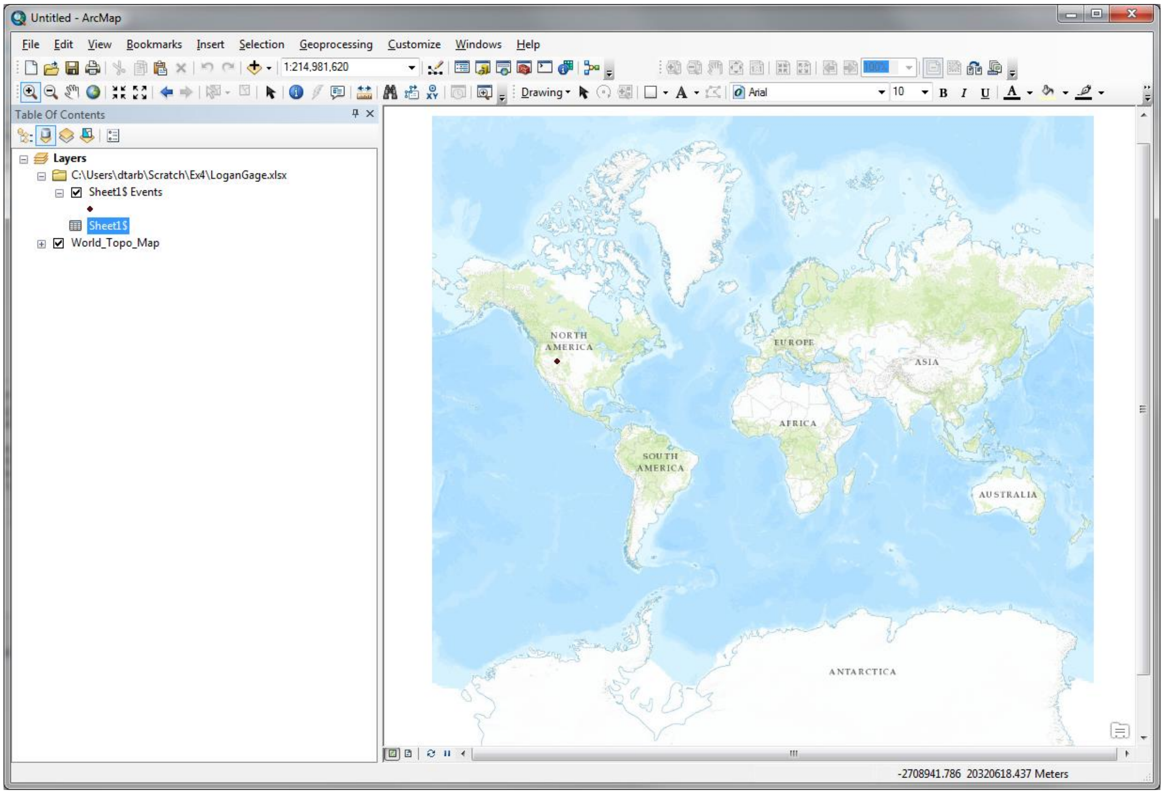
Locate **Geographic Coordinate Systems → North America → NAD1927** in the Spatial Reference Properties window and click OK.



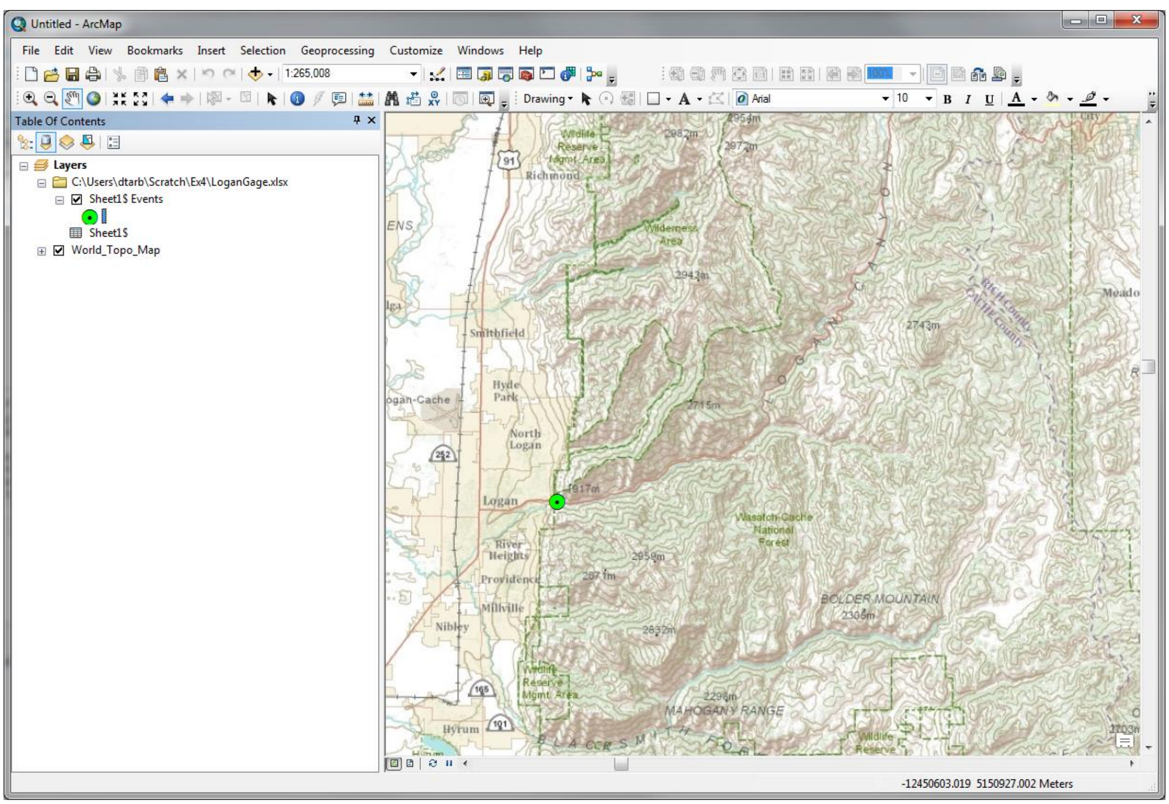




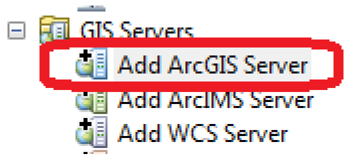
Click OK again to Display XY data and OK to acknowledge that the table will not have an Object-ID field. A dot should appear on your map showing you where the Logan River stream site is.



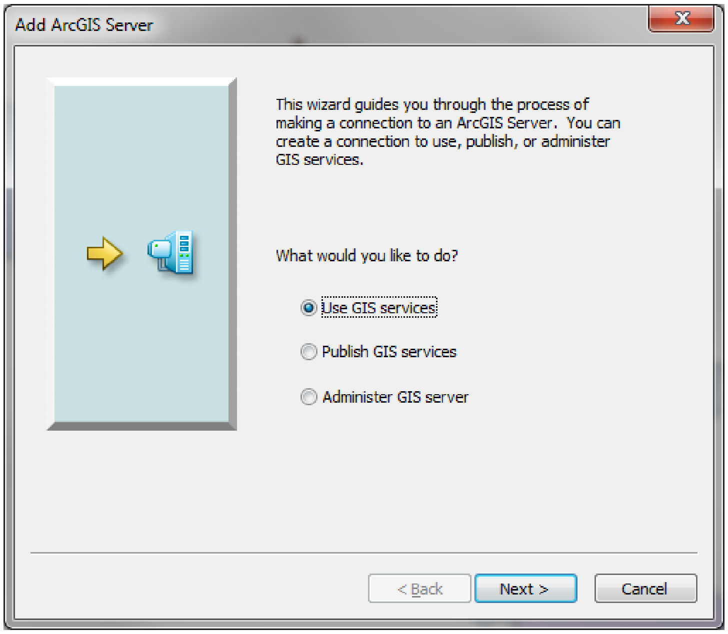
Zoom in on this to get a sense for the topography near Logan. I also changed the symbology of the point to make it easier to see.



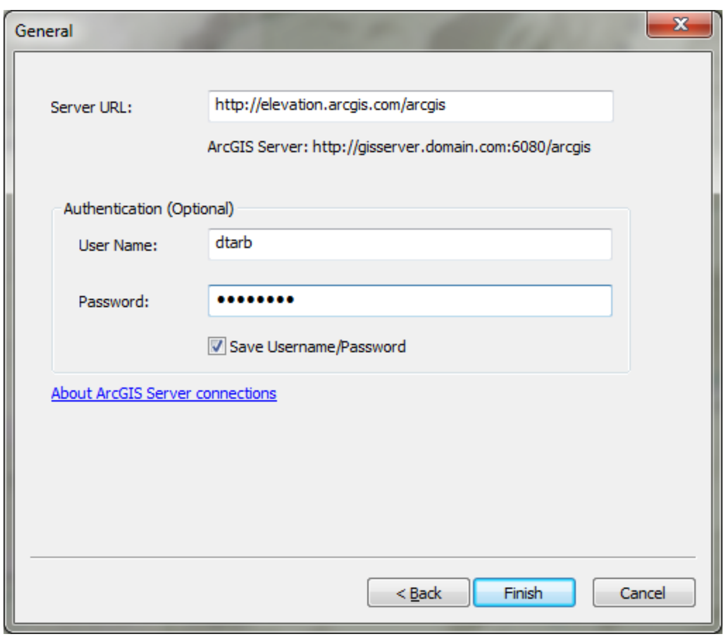
Open ArcCatalog. Double Click on Add ArcGIS Server



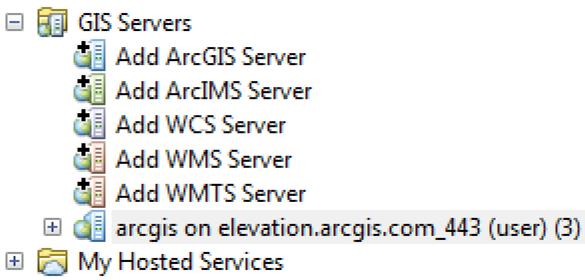
At the prompt check that Use GIS services is checked and click Next



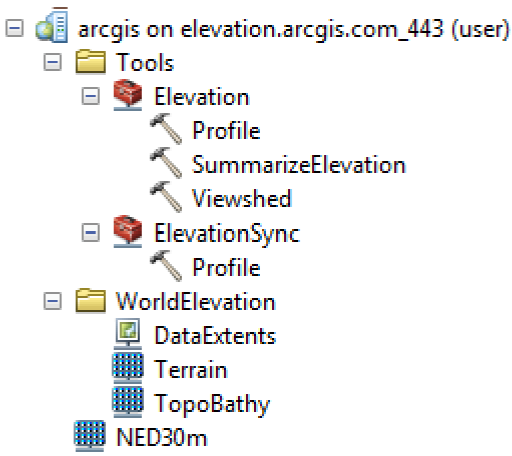
Enter the Server URL http://elevation.arcgis.com/arcgis and your ArcGIS.com user name and password. (with an older version of ArcGIS you may need to enter http://elevation.arcgis.com/arcgis/services)



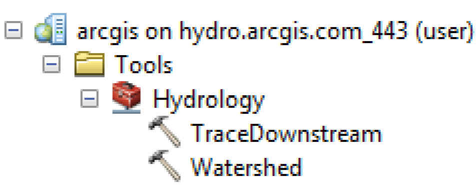
Note that your user name and password needs to have been associated with an ESRI license as arranged by one of the instructors. Click Finish. You should see arcgis on elevation.arcgis.com displayed in your Catalog under GIS Servers.



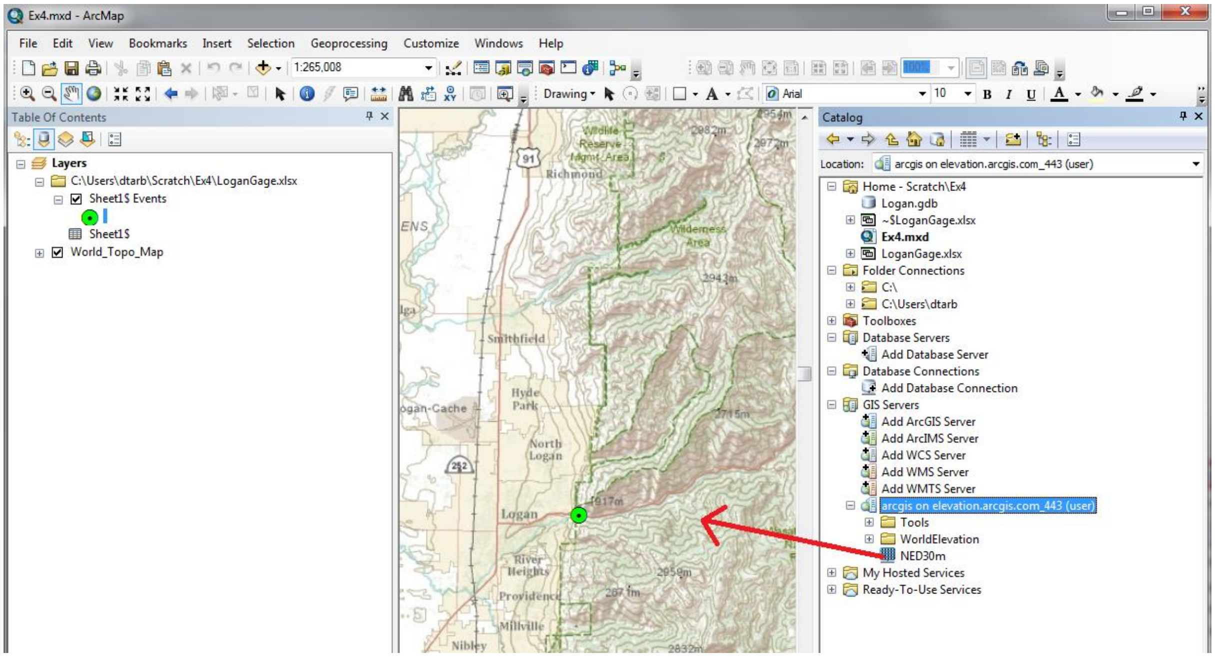
Expand the tool to see the services available



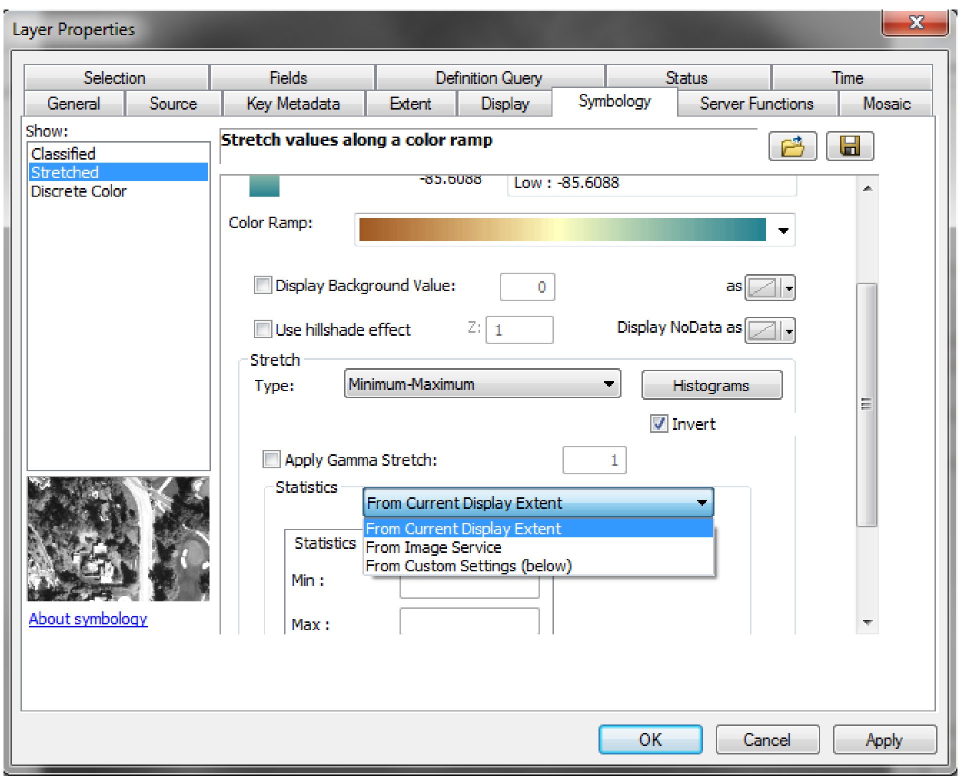
In a similar manner add the service http://hydro.arcgis.com/arcgis. After expanding the tools you should see the Watershed and TraceDownstream tools



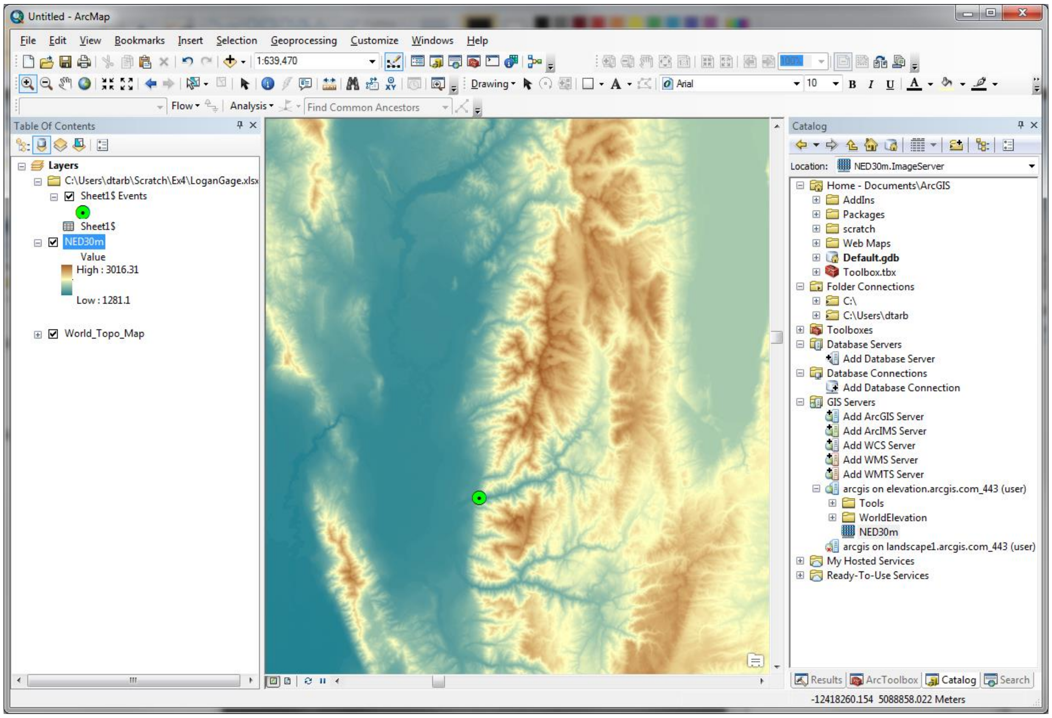
In elevation.arcgis.com **NED30m** is the USGS National Elevation Dataset digital elevation model. Drag and drop this onto your map to add this data. Close the coordinate systems warning.



The initial appearance is rather dark. Open Properties and Symbology. Change the color ramp and using the slider bar to expose the bottom of the Symbology Window set the Statistics to "From Current Display Extent" so that you get more differentiation within the display.

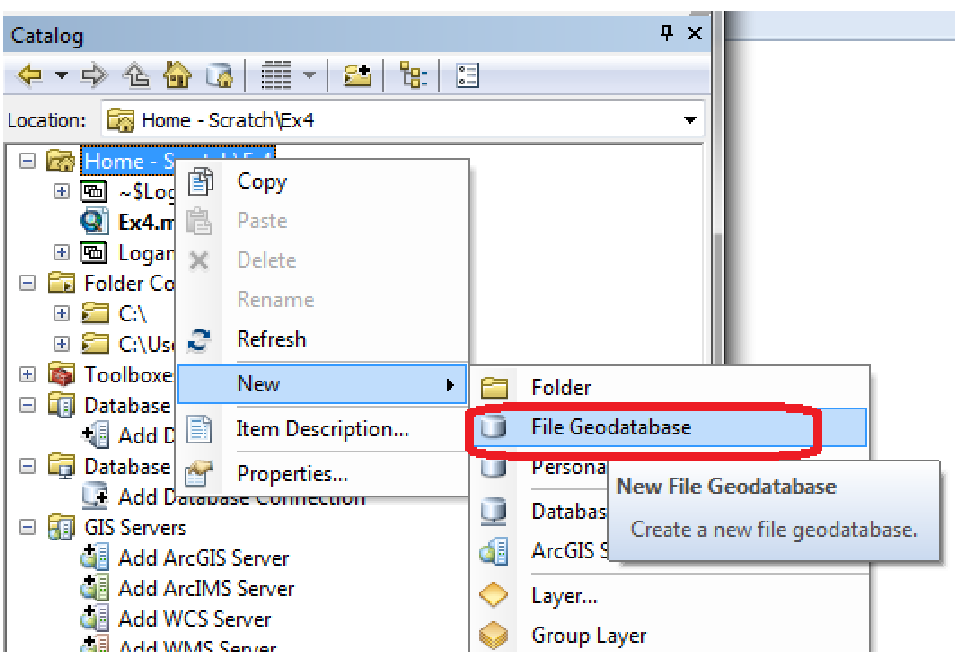


And here is the result, a fairly nice color shaded terrain map display.



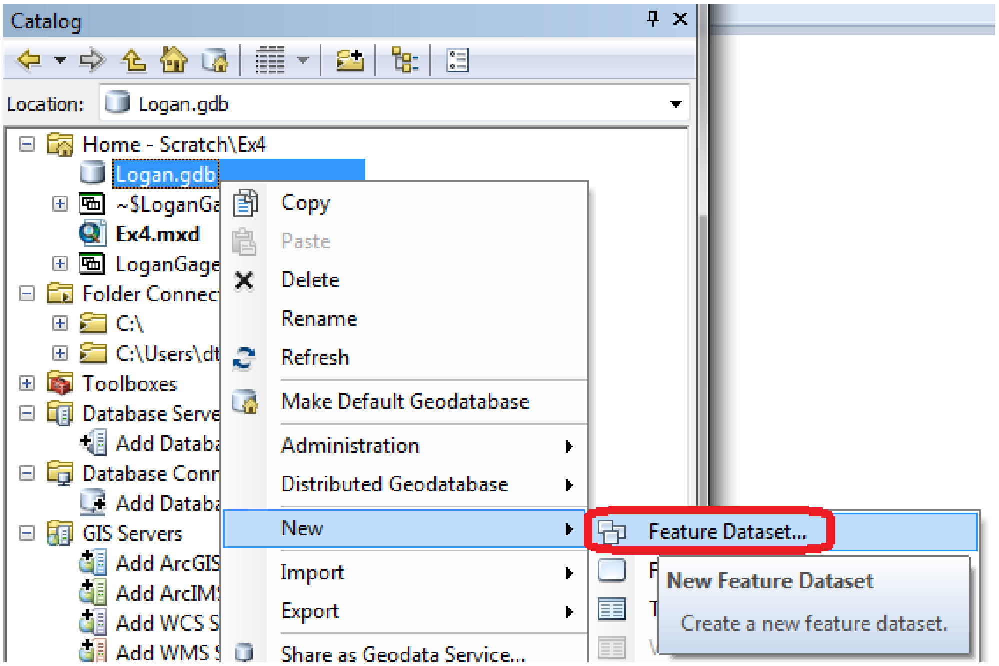
Now let's set up a folder and geodatabase for our work. First create a folder (e.g. C:\Users\dtarb\Dave\Ex4). Save the map document in this folder (Ex4.mxd). This serves to establish a place on disk where temporary files can be written and a Home location in Catalog. Without this some of the geoprocessing tools fail.

Right click in Catalog Home and create a New File Geodatabase

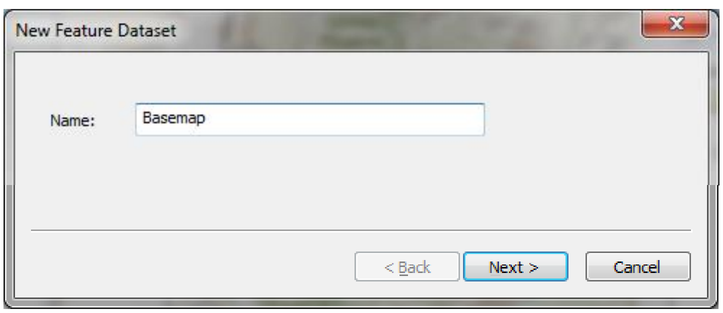


Set the name to **Logan.gdb**.

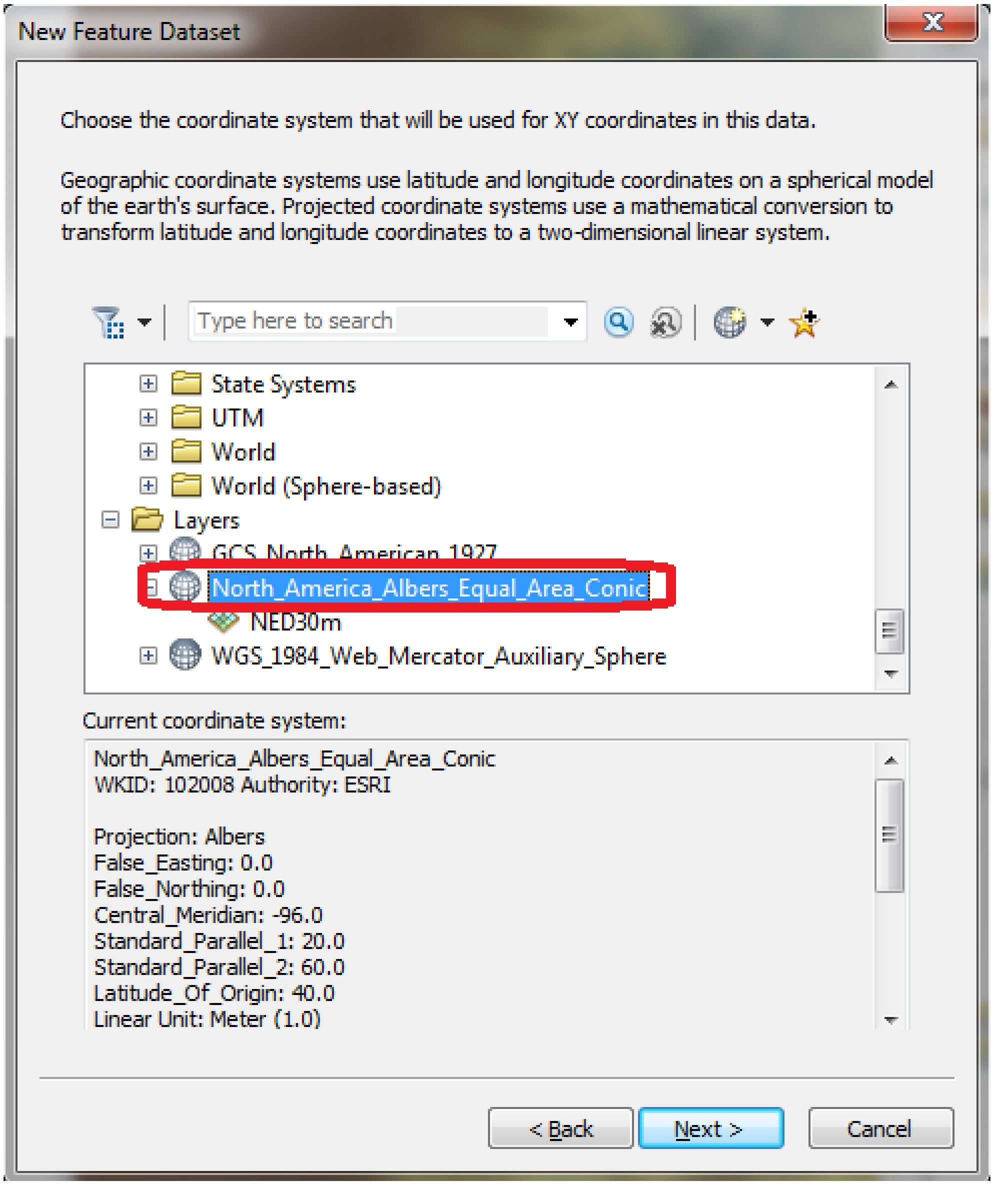
Right click Logan.gdb to create a new Feature Dataset



Set the name to **Basemap**. Click Next.

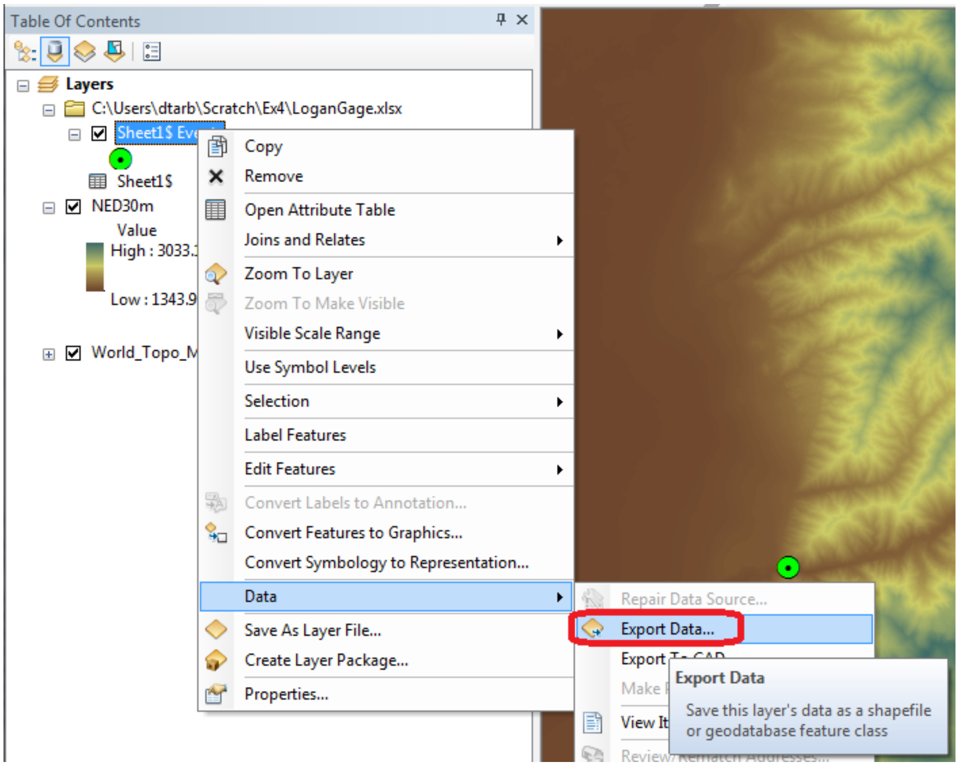


For the coordinate system scroll to the bottom and expand the Layers folder. Select **North_America_Albers_Equal_Area_Conic**. This is the coordinate system of NED30m, so we choose to use this for our work here. Click Next.

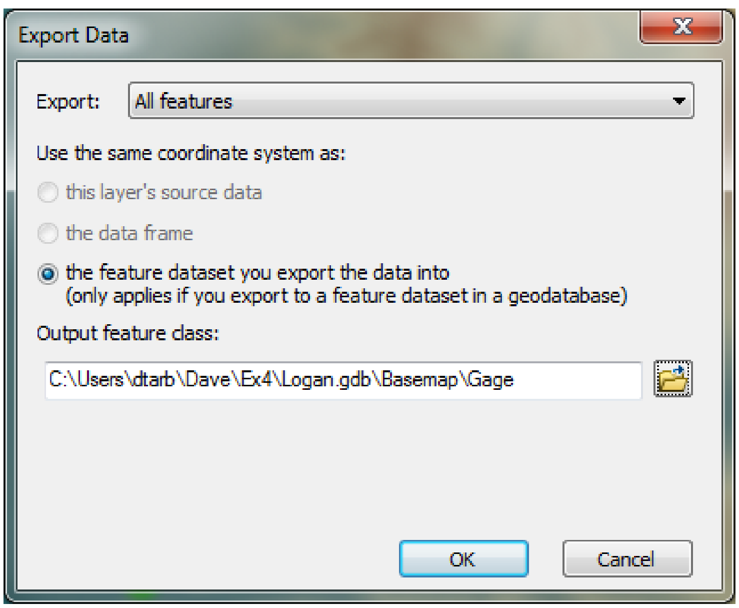


Click Next at the vertical coordinate system. We do not need to set a vertical coordinate system. Click Finish at XY Tolerance leaving the defaults. Now you have a feature dataset Basemap in the Logan geodatabase.

Right click on Sheet1$Events (the XY events layer from the gage site spreadsheet) and select Data / Export Data.

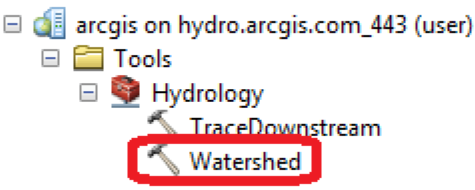


Set the Output feature class to **Gage** in the Basemap feature dataset and click OK.

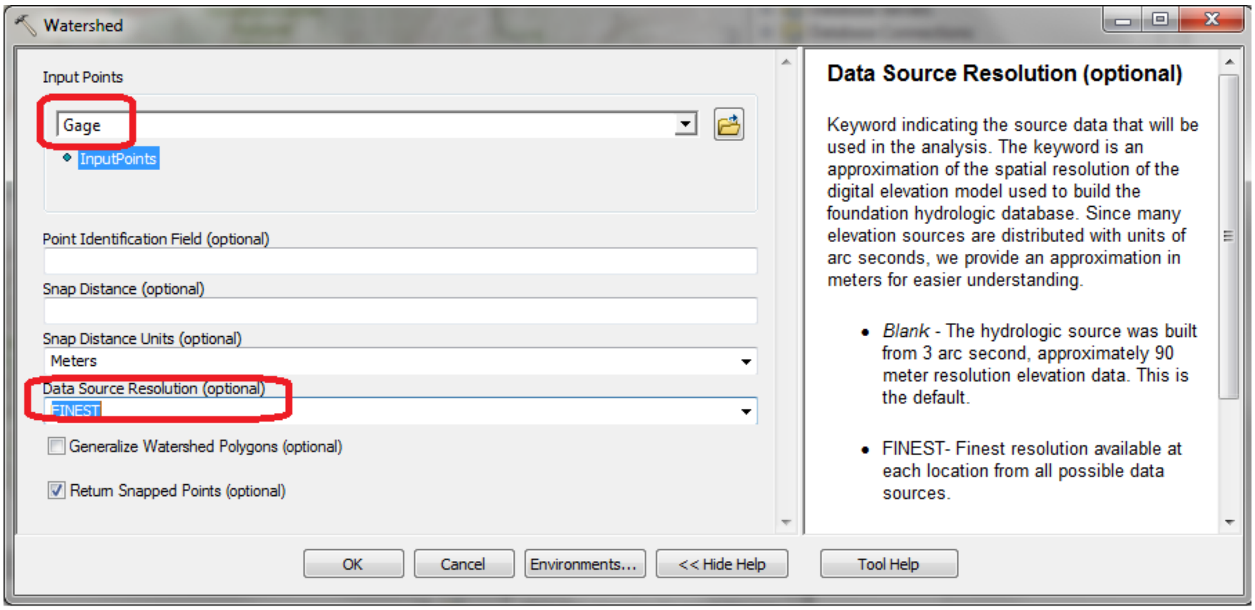


This serves to project the geographic coordinates of this site feature class to the North America Albers coordinate system of the Basemap feature dataset and also to make it a permanent feature class. Add it as a layer and remove the spreadsheet and XY Events layer (Sheet1$ Events).

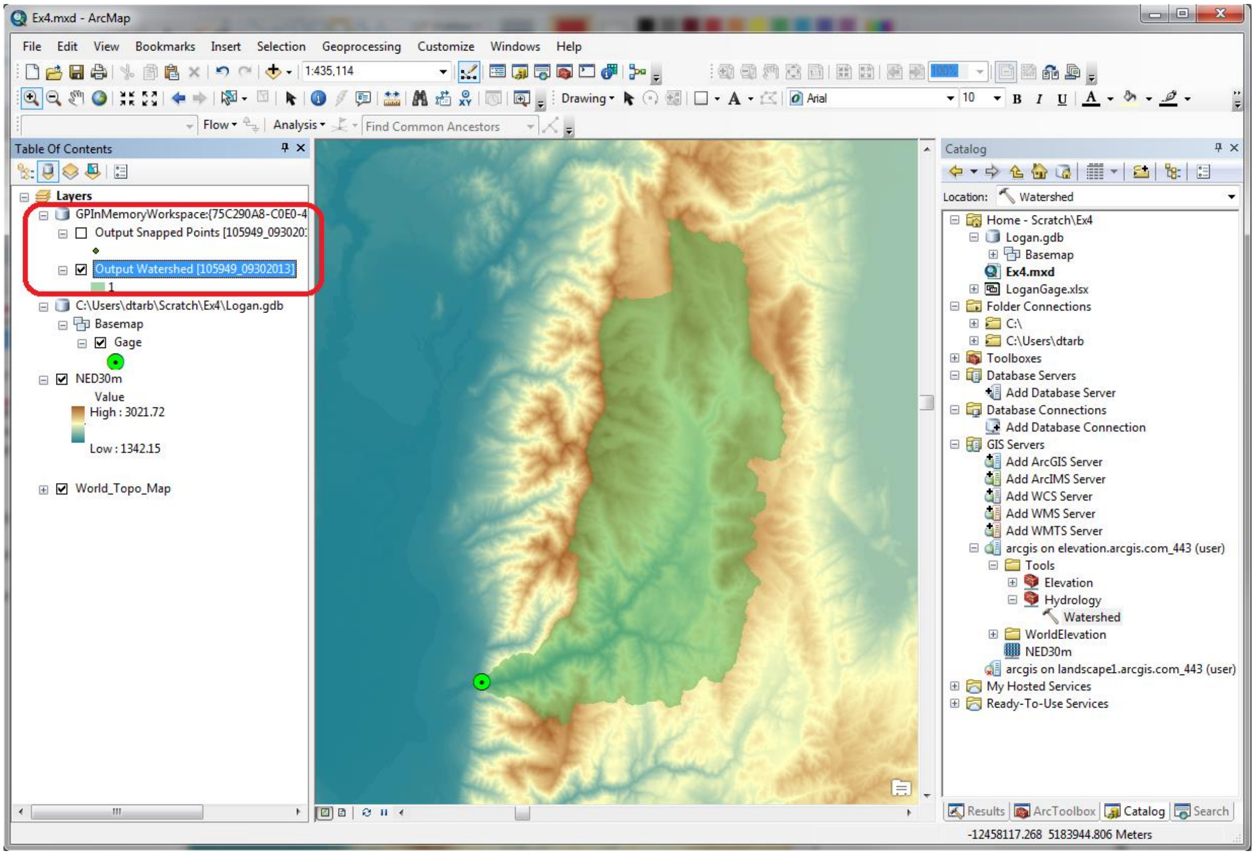
Now locate the Watershed tool in the Hydrology toolbox as part of hydro.arcgis.com in Catalog.



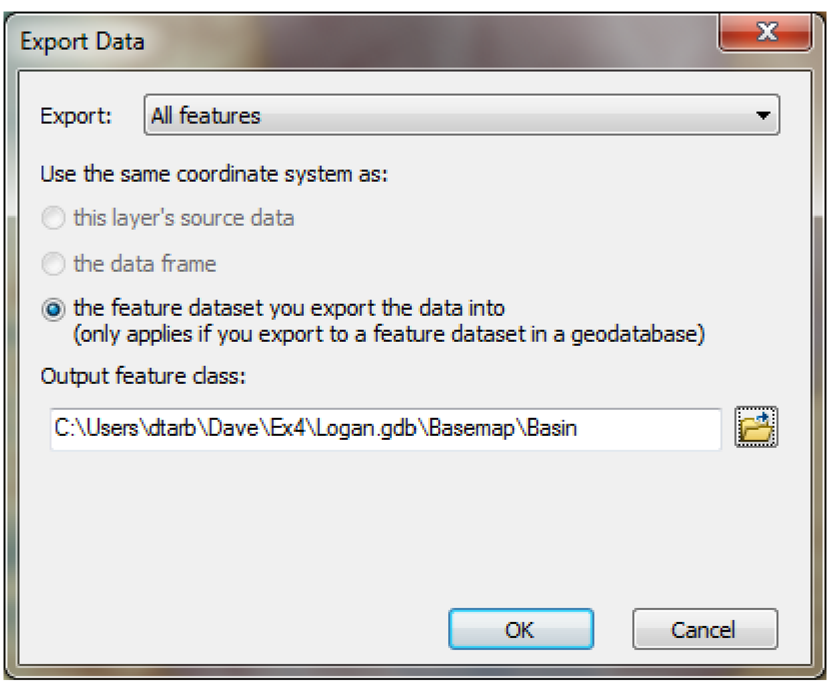
Open the **Watershed** tool and set Input Points to **Gage** (the Logan River stream site) and Data Source Resolution to FINEST. Leave other inputs at their defaults and click OK to run the tool.



When the tool completes you should have an Output Watershed that has been delineated using the online watershed delineation service. Notice that it appears in the GPInMemoryWorkspace part of the map document table of contents. Notice also that there is an Output Snapped Points feature class that contains the outlet point "snapped" or moved to be on the streams. We will use this later on. Note also that this tool does not use the DEM layer that we added. It operates on its own internally processed DEM and can in fact be run without a DEM layer in the map.



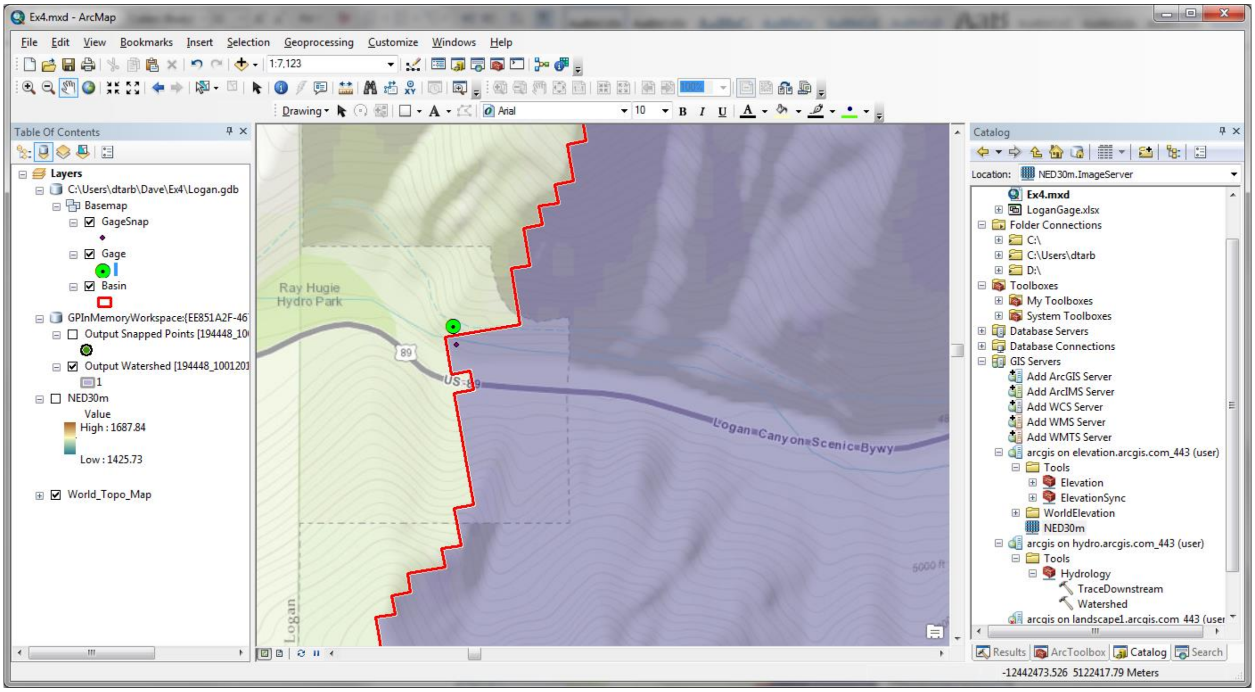
Right click on **Output Watershed** and select **Data → Export Data** to export this delineated watershed and set the output feature class as **Basin** in **Logan.gdb\Basemap**.



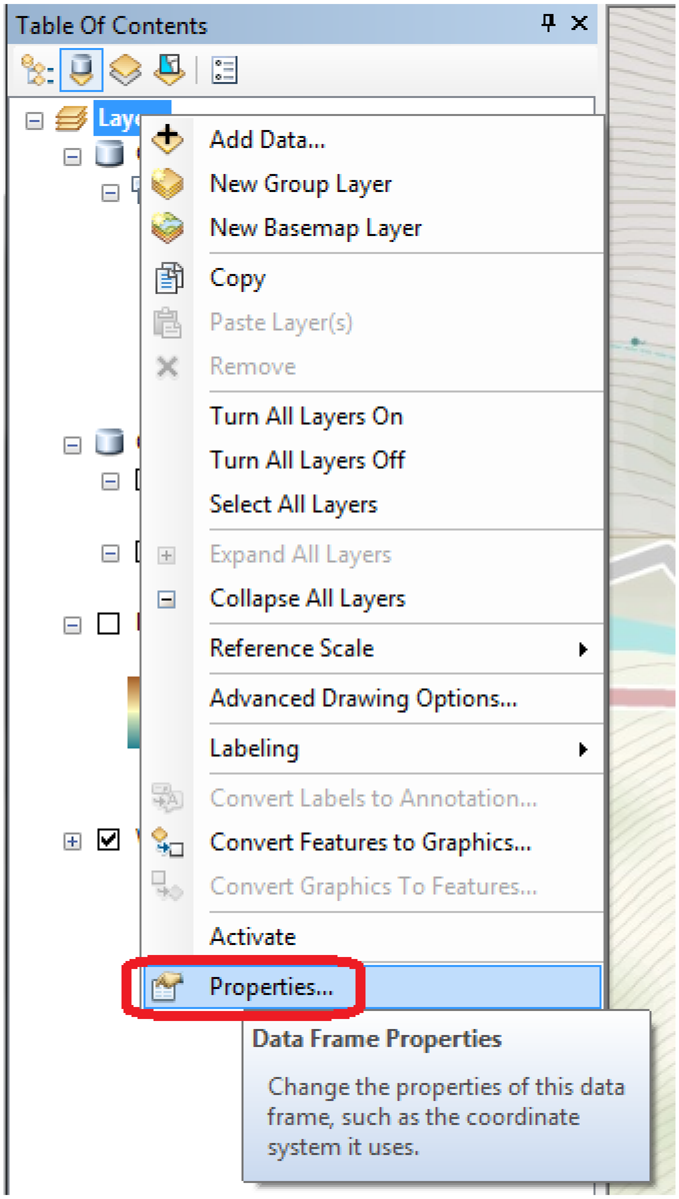
This saves the Basin locally on your computer. I symbolized this with a red outline.

Similarly save the Output Snapped Points in **Logan.gdb\Basemap\GageSnap** feature class. Saving these results locally retains them in case you need to restart ArcMap in which case the GPInMemoryWorkspace is lost.

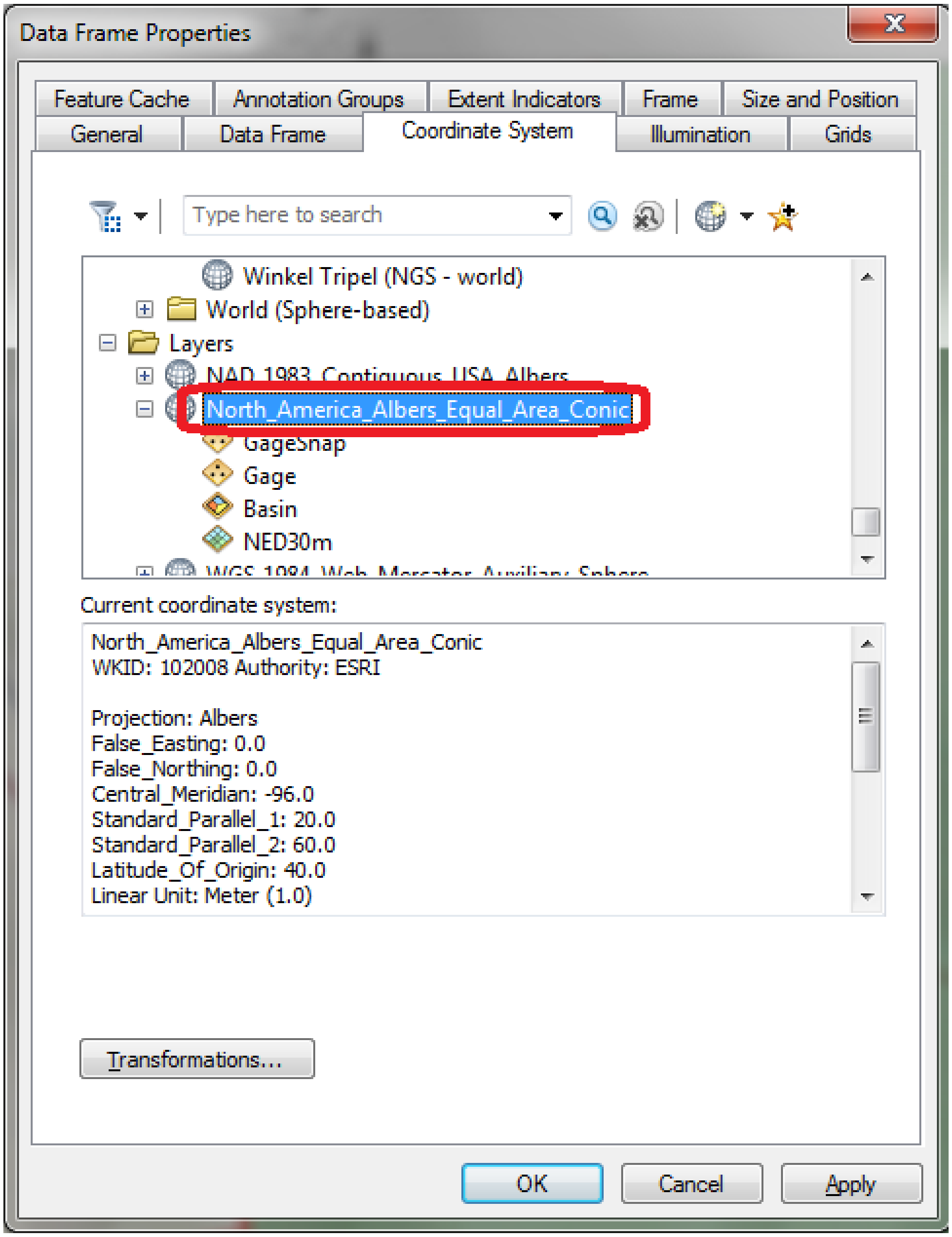
Zoom right in near the outlet.



Note that the GageSnap point is shifted slightly from the Gage point. This is to move it onto the stream flow path in the preprocessed NED30m DEM that underlies the watershed delineation. Note also that the watershed boundary has a stair step shape as it is based on DEM grid cells but that these are skewed relative to the map display. This is because the underlying NED30m DEM coordinate system is different from the display data frame. Let's re-orient the data frame to the coordinate system of the DEM. Right click on the data frame **Layers → Properties**



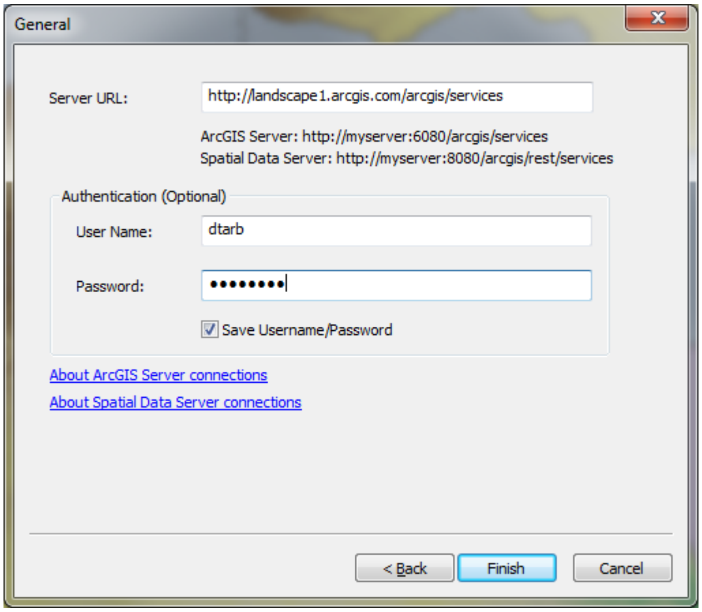
Select the **Coordinate System** tab and scroll to the bottom. Under Layers select North_America_Albers_Equal_Area and click OK.



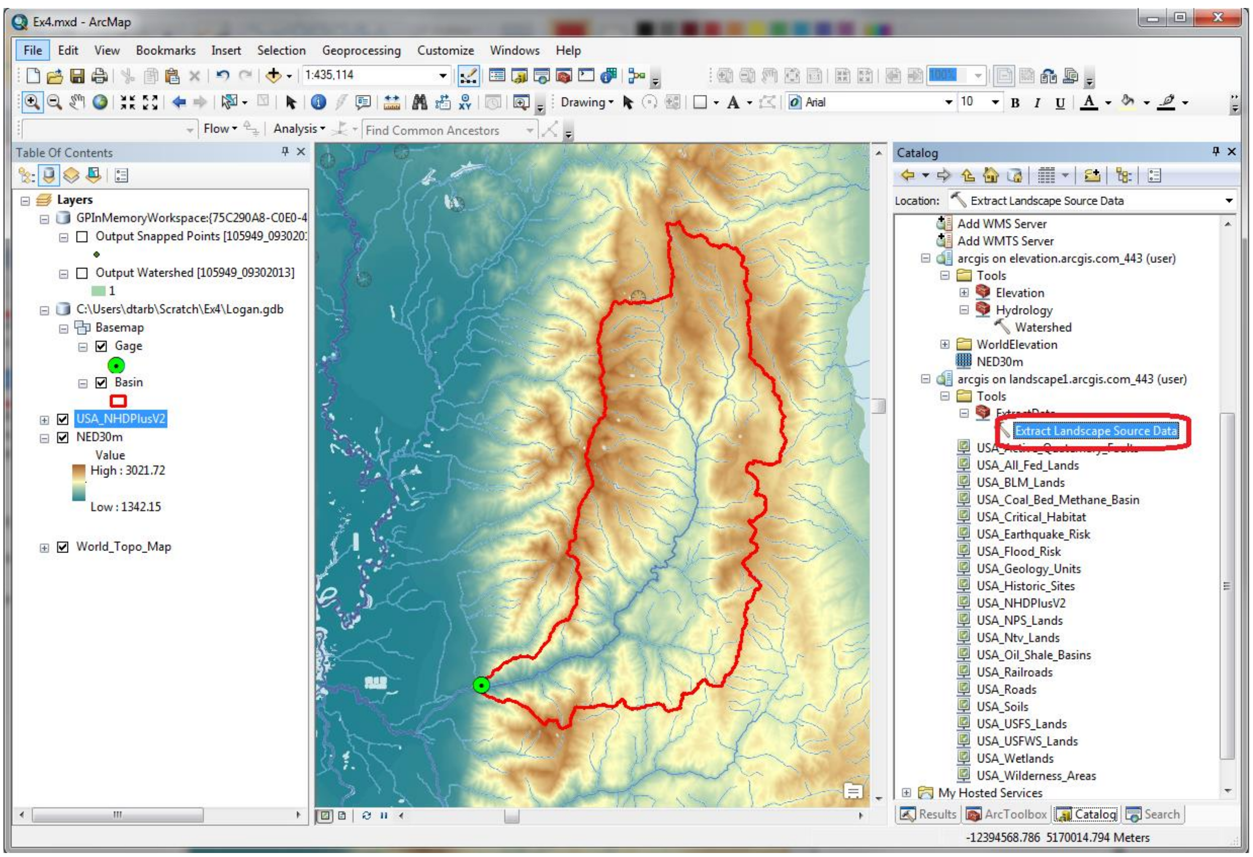
Click Yes to the warning. The DEM edges should now be aligned vertically. Remove the GPMInMemoryWorkspace layers as we have them saved locally and save the map document.

2. National Hydrography Data Service (NHDPlusV2)

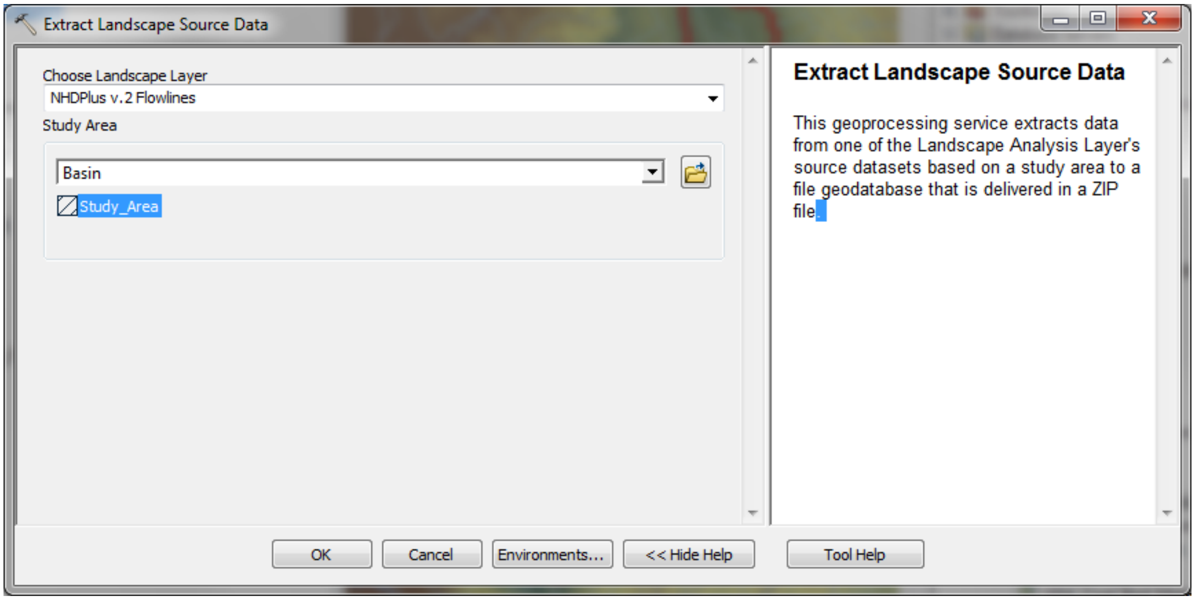
In **Catalog → GIS Servers** add the http://landscape1.arcgis.com/arcgis ArcGIS service as you did before for elevation services.



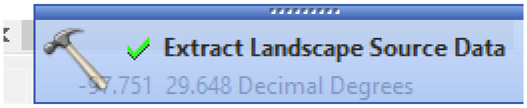
Add USA_NHDPlusV2 service layer to see the NHDPlus streams. You may need to expand the display to maximum extent and zoom in for the streams to appear.



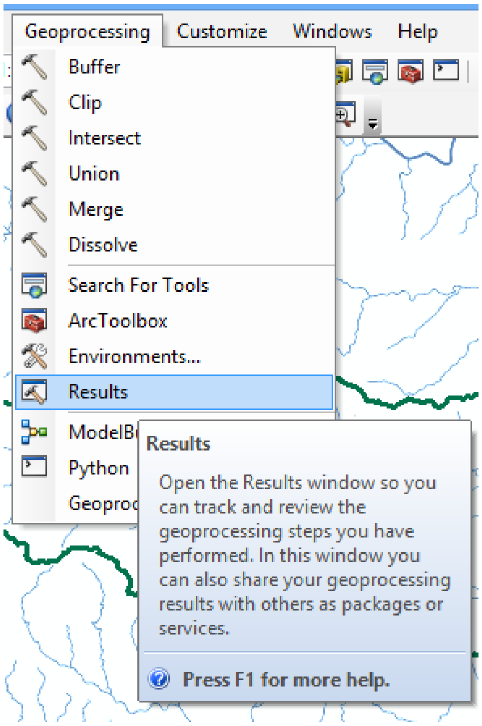
Under “Tools” in the Landscape 1 service, use “**Extract Landscape Source Data**” (see image above) and choose **NHDPlus V2 Flowlines** as the Landscape Layer and **Basin** as the study area.



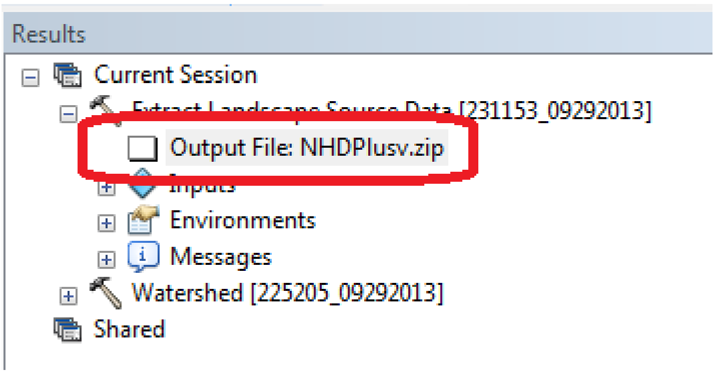
Wait until this message box appears.



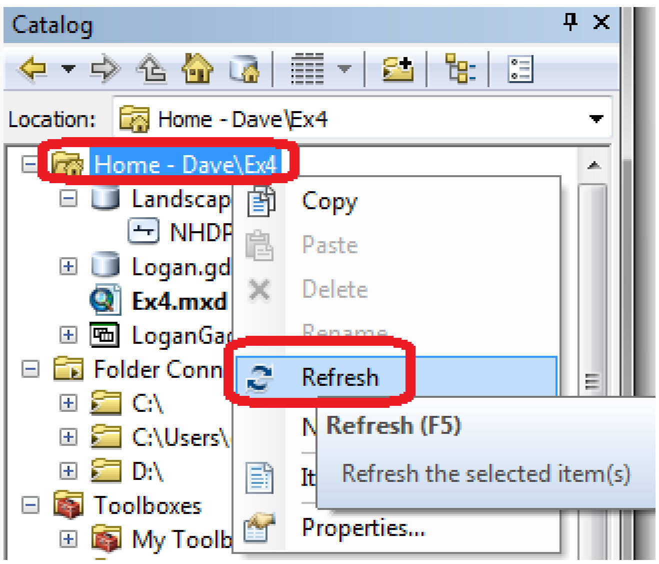
Open the Geoprocessing Results Window



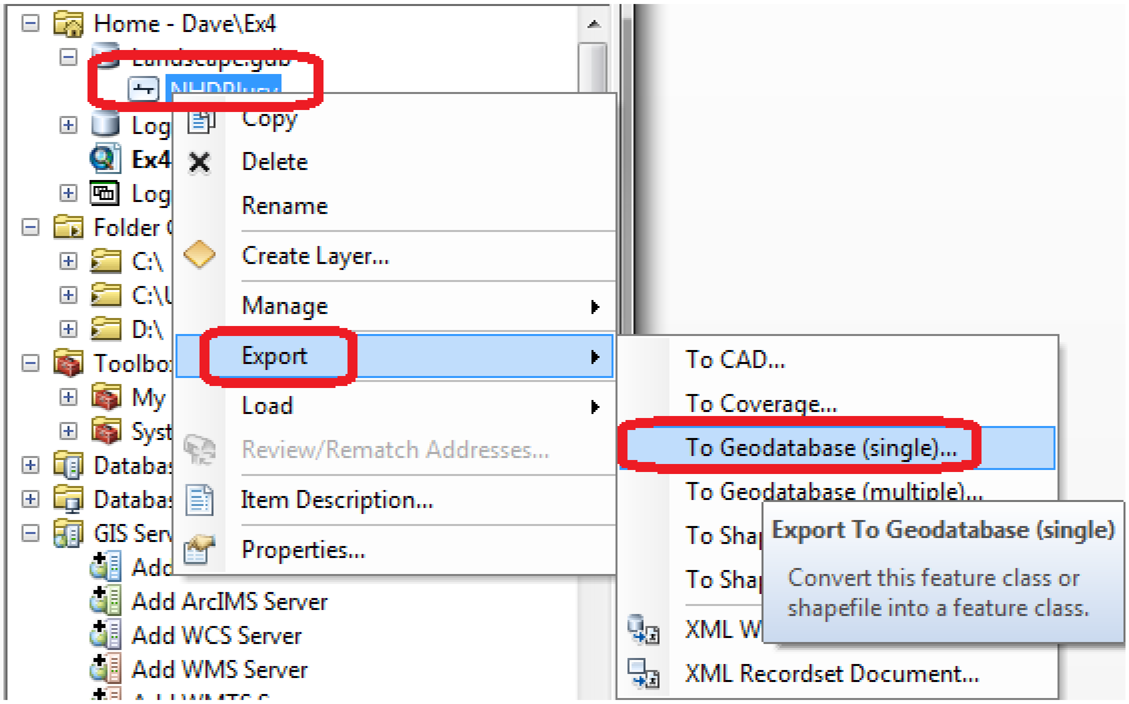
Identify the Output File **NHDPlusv.zip**.



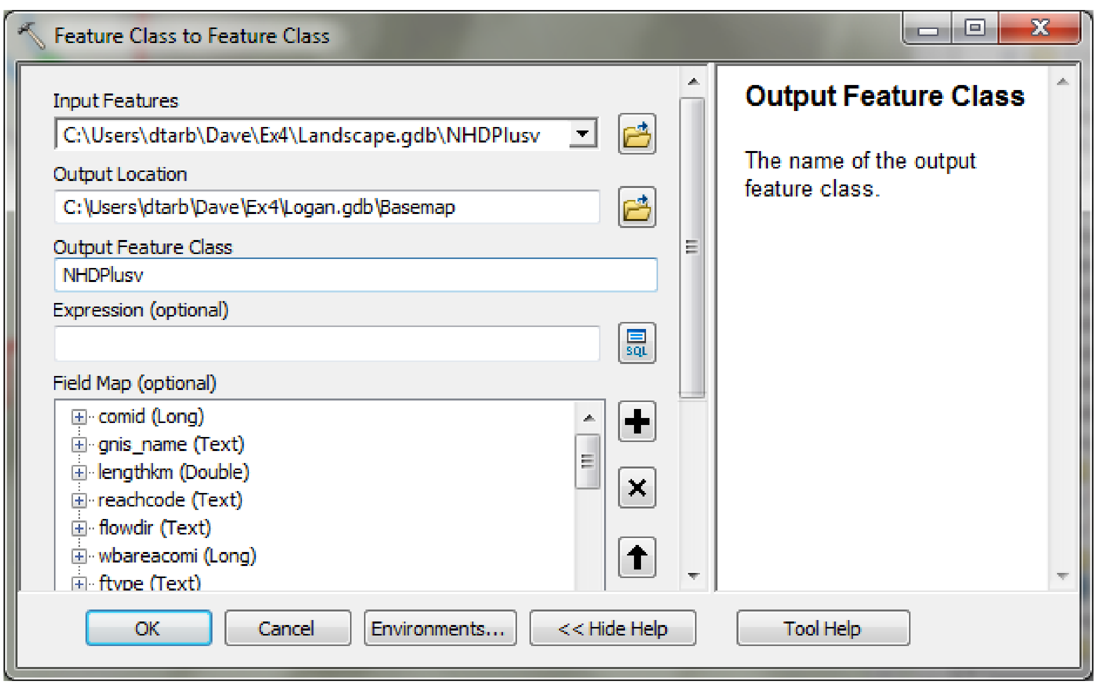
Double Click to open the output zip file and copy the geodatabase folder **Landscape.gdb** to the folder where you are working (e.g. C:\Users\dtarb\Dave\Ex4). In Catalog right click on your working folder and Refresh so that the Landscape.gdb is visible.



Right click on the NHDPlusv in Landscape.gdb and select **Export → To Geodatabase (single)**

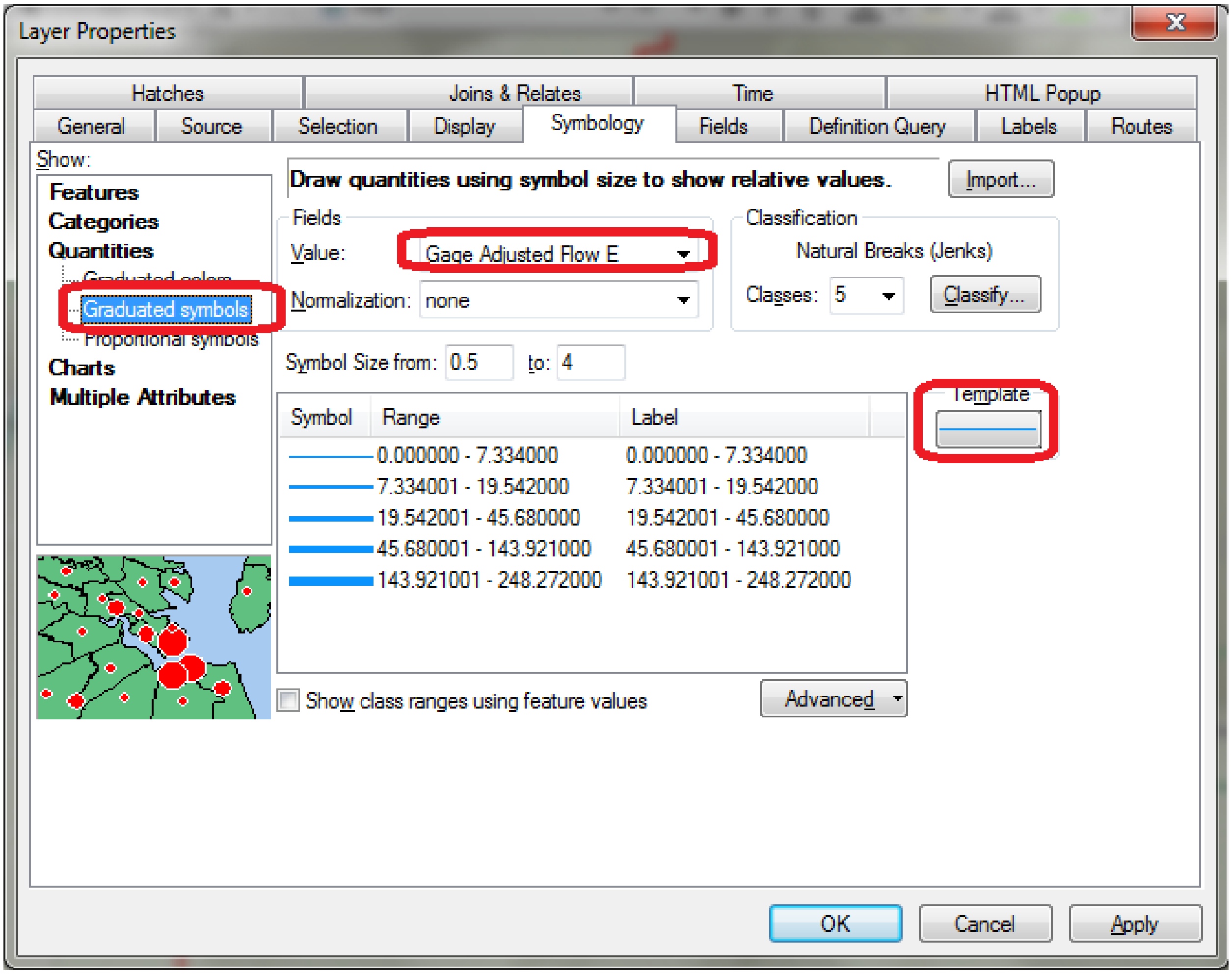


Set the Output Location to **Logan.gdb\Basemap** and Output Feature Class to **NHDPlusv**. Leave other inputs at their defaults.

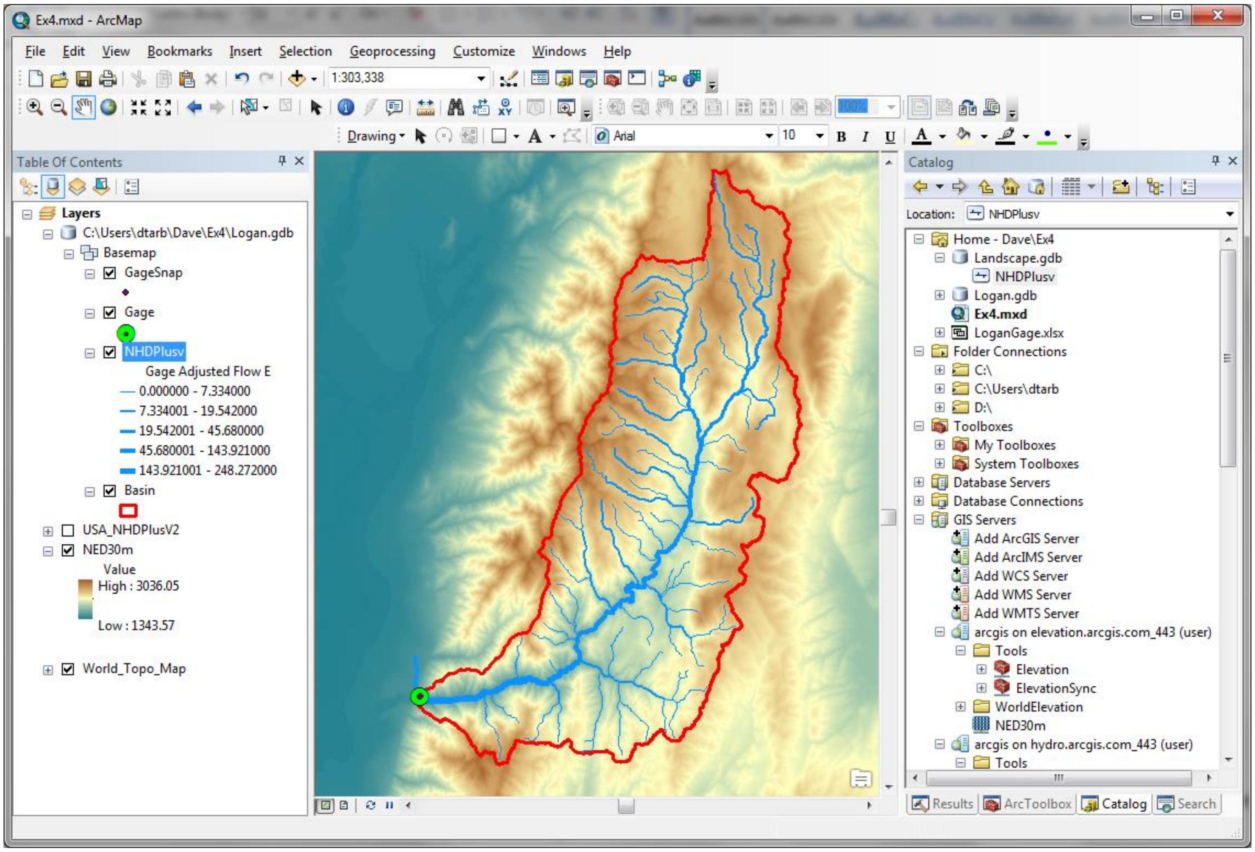


This serves to move the NHDPlusv features into our Basemap feature class converting the projection to be North_America_Albers_Equal_Area_Conic consistent with the rest of our data.

Symbolize **NHDPlusv** from **Logan.gdb** using Gage Adjusted Flow E to give a flow map.



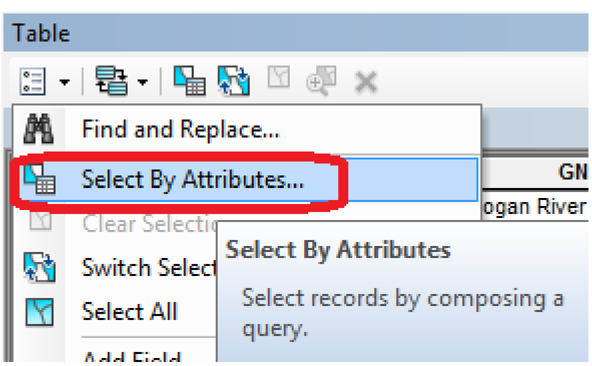
Turn off the NHDPlusv2 service. This is now a local set of NHDPlus vector streamlines for the Logan River Basin.



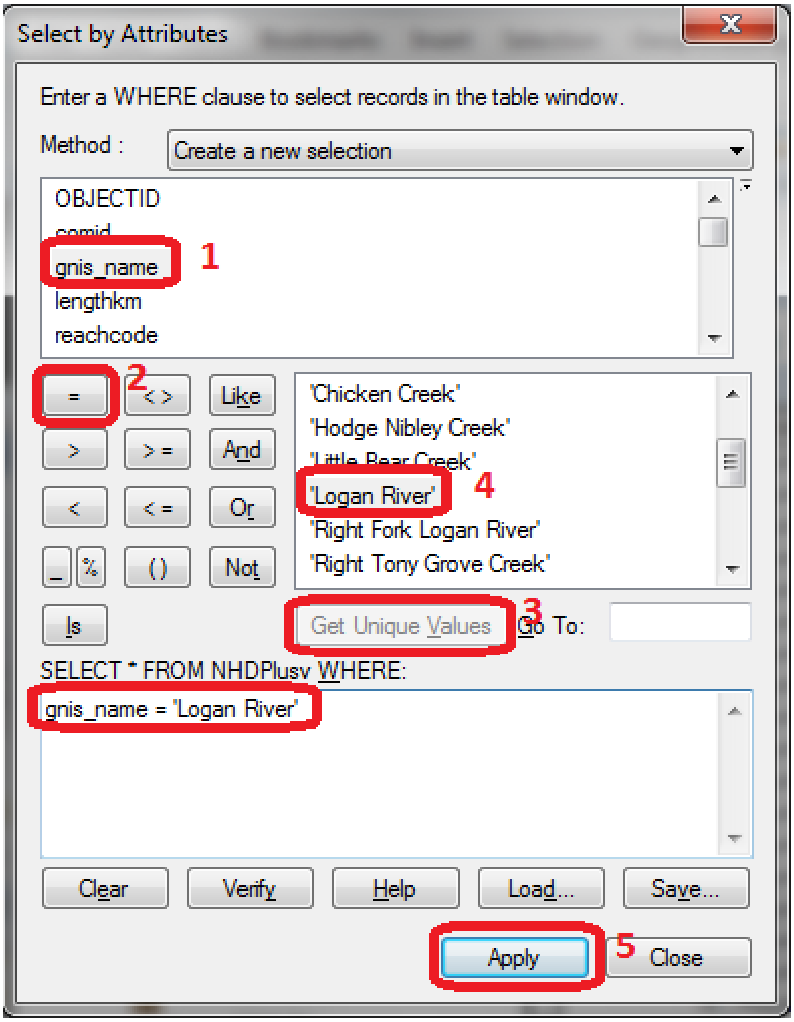
3. Main Stream Properties

Let's now identify the main stem of the Logan River and determine some of its properties.

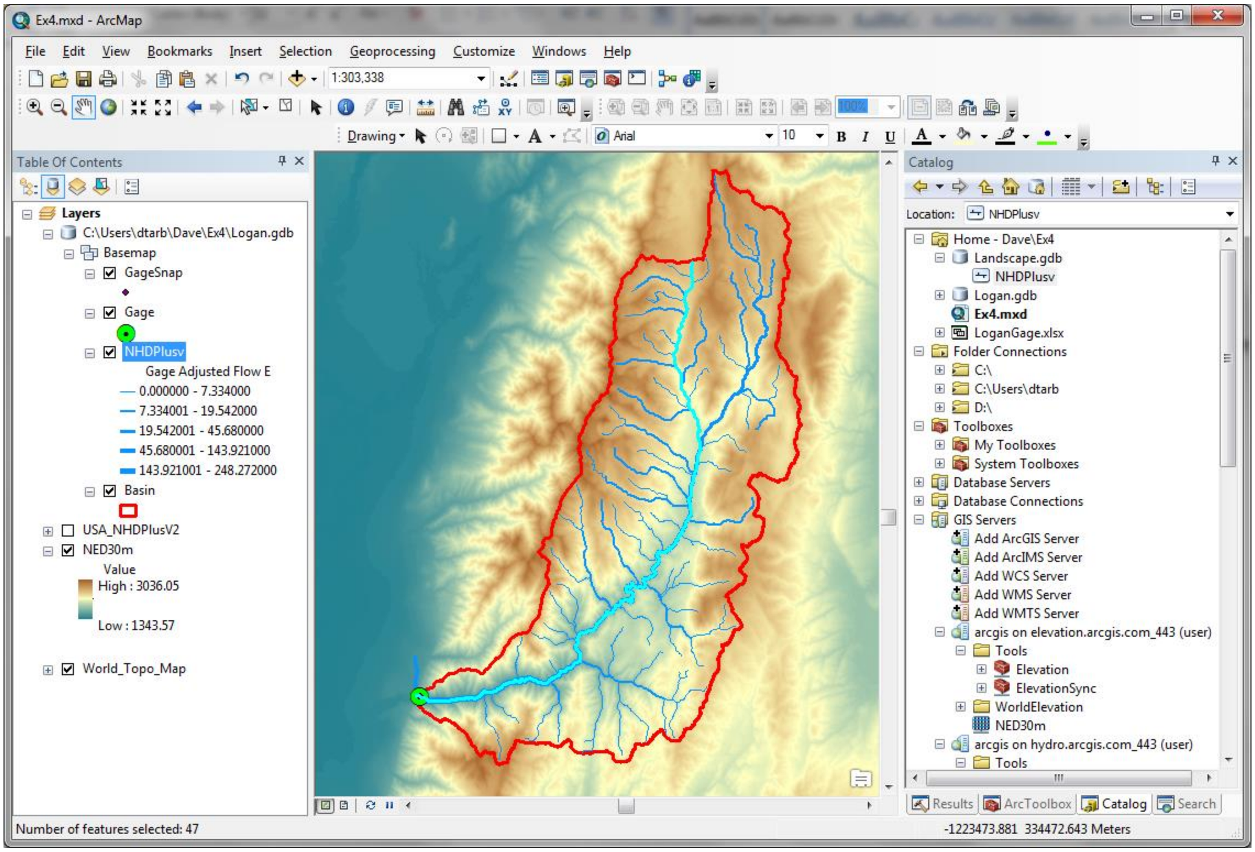
Open the attribute table for NHDPlusv. **Select By Attributes**



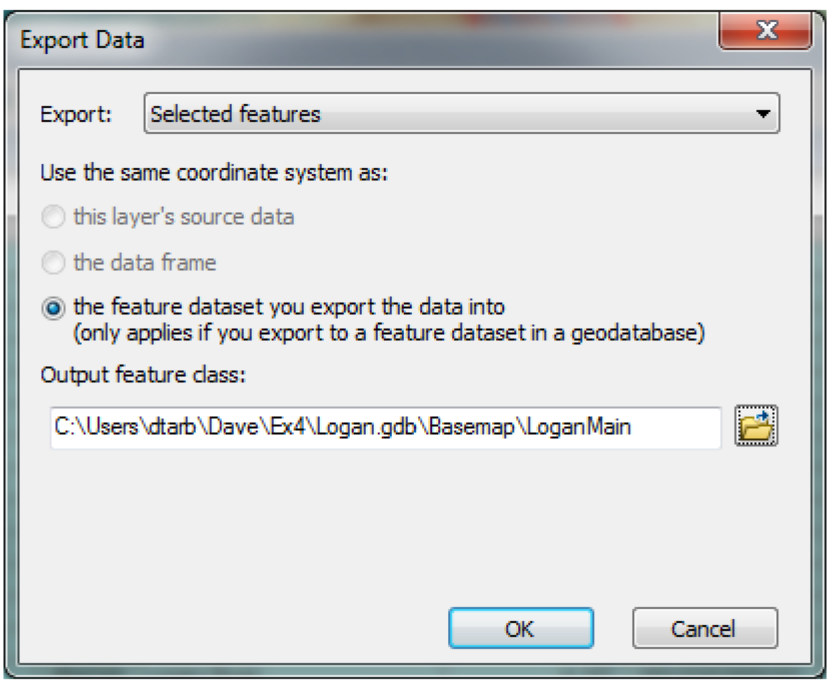
Configure the Query to select where gnis_name = 'Logan River'



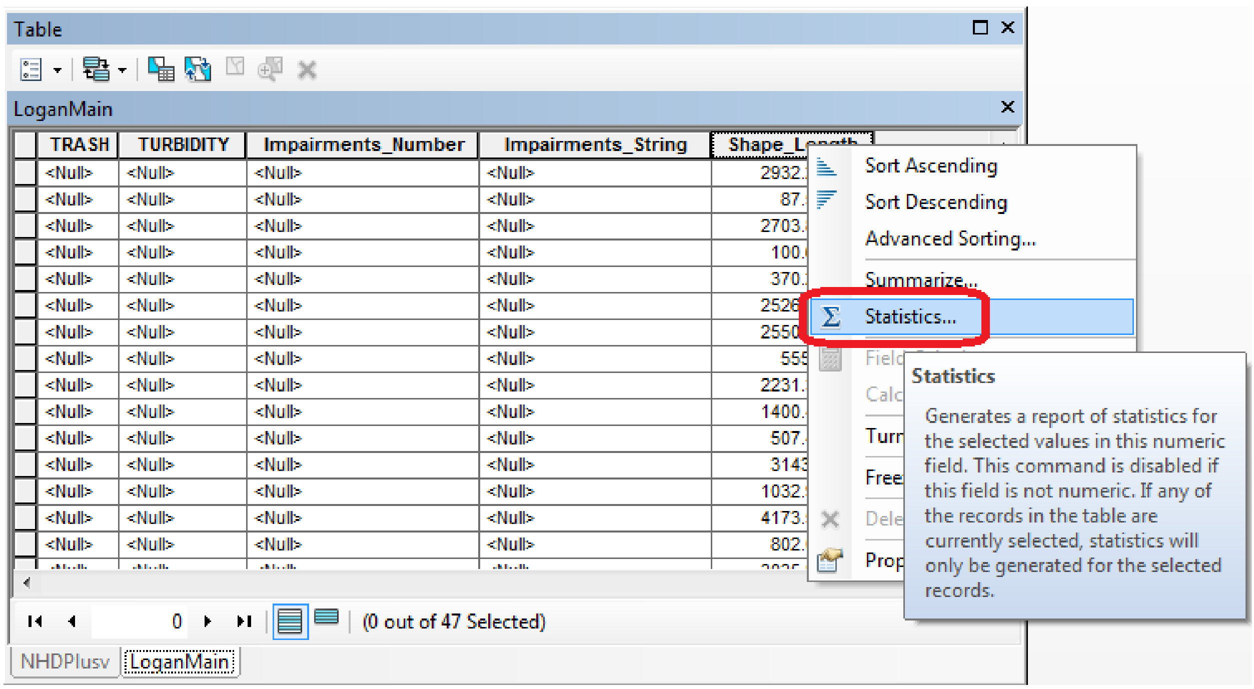
The Logan River main stream should be selected. Close the attribute table.



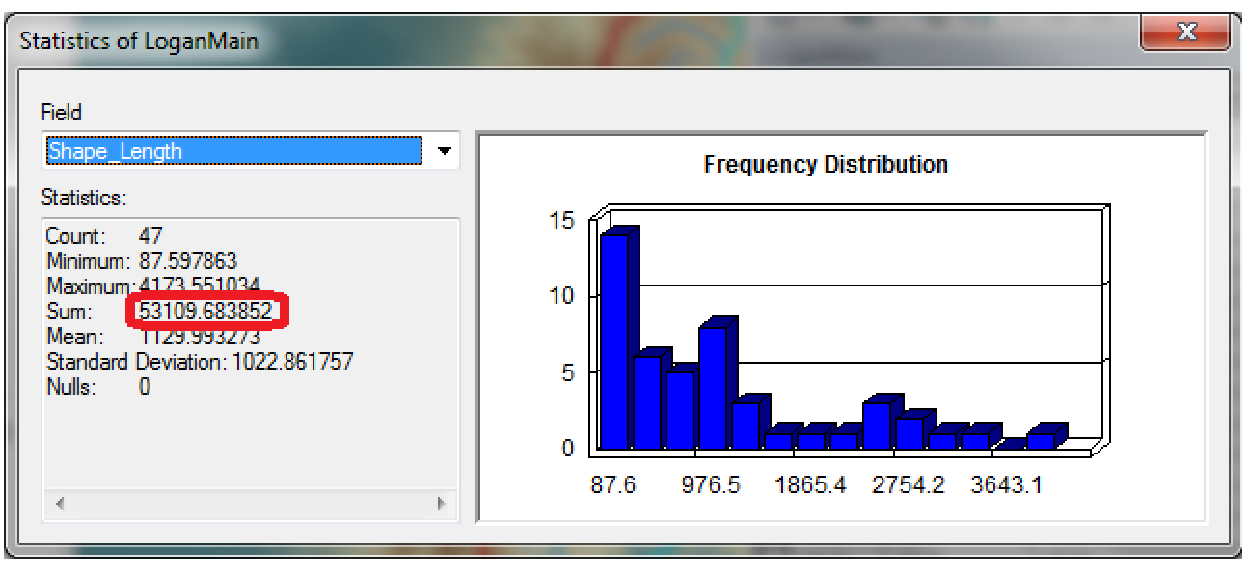
Right click **NHDPlusv** layer and select **Data → Export Data** and save the selected features as **LoganMain** in the **Logan.gdb\Basemap** feature dataset.



This is a feature representing just the Logan River. Let's examine its length. Open the attribute table of **LoganMain**. Note that there are multiple columns that give length. **Length (km)** is length in km from the NHD. **Shape_Length** is the far right column and is the length evaluated by ArcGIS when the data was loaded into the geodatabase. All geodatabase features have geometry measures (e.g. length or area). The units of **Shape_Length** are the units of the feature dataset coordinate system, which are meters in this case. You should note consistency between **Length (km)** and **Shape_Length** once units are converted. There is also a column **Shape_Leng**. This also came from NHDPlus and is incomplete. You can ignore this. Right click on the column header "Shape_Length" of the far right column and select **Statistics.**

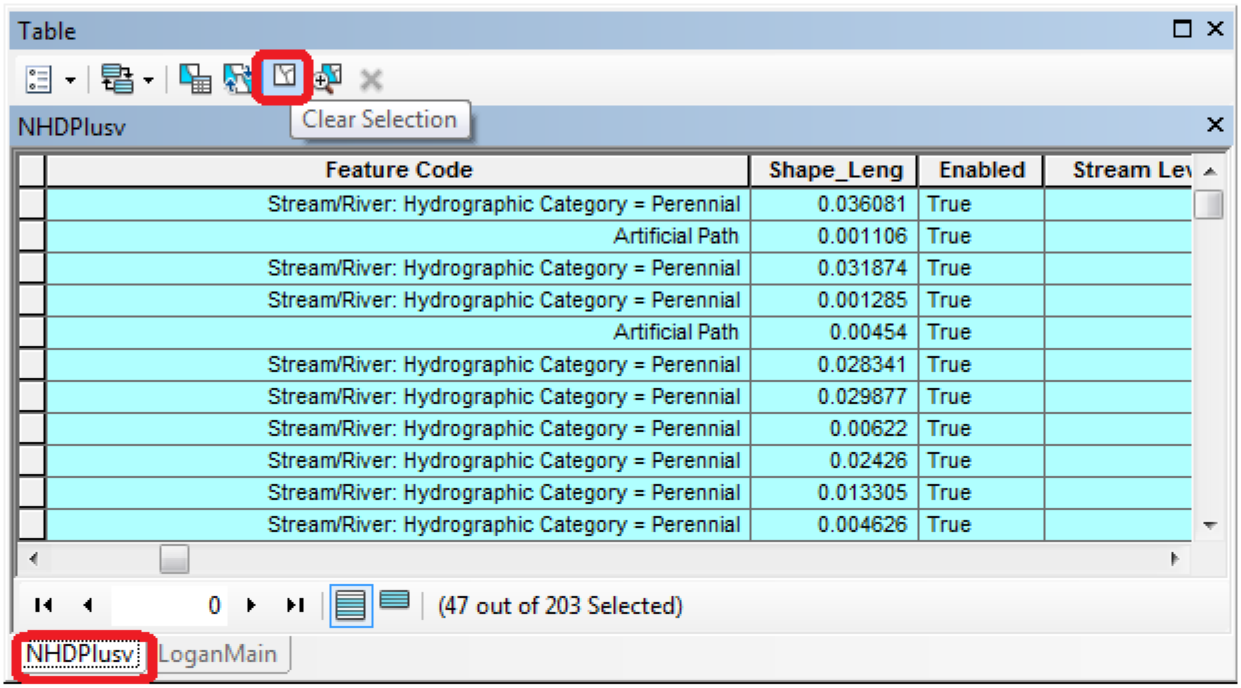


The following Statistics report is generated.



Note the value of **Sum**. This is the length of LoganMain (the Logan River main stream) in meters.

Now switch to the NHDPlusv tab in Table and click Clear Selection to clear the selection of Logan River main stream segments.



Locate the column **Shape_Length** (far right), right click and select **Statistics** noting the value of Sum. This is the total length of streams in the Logan River Basin.

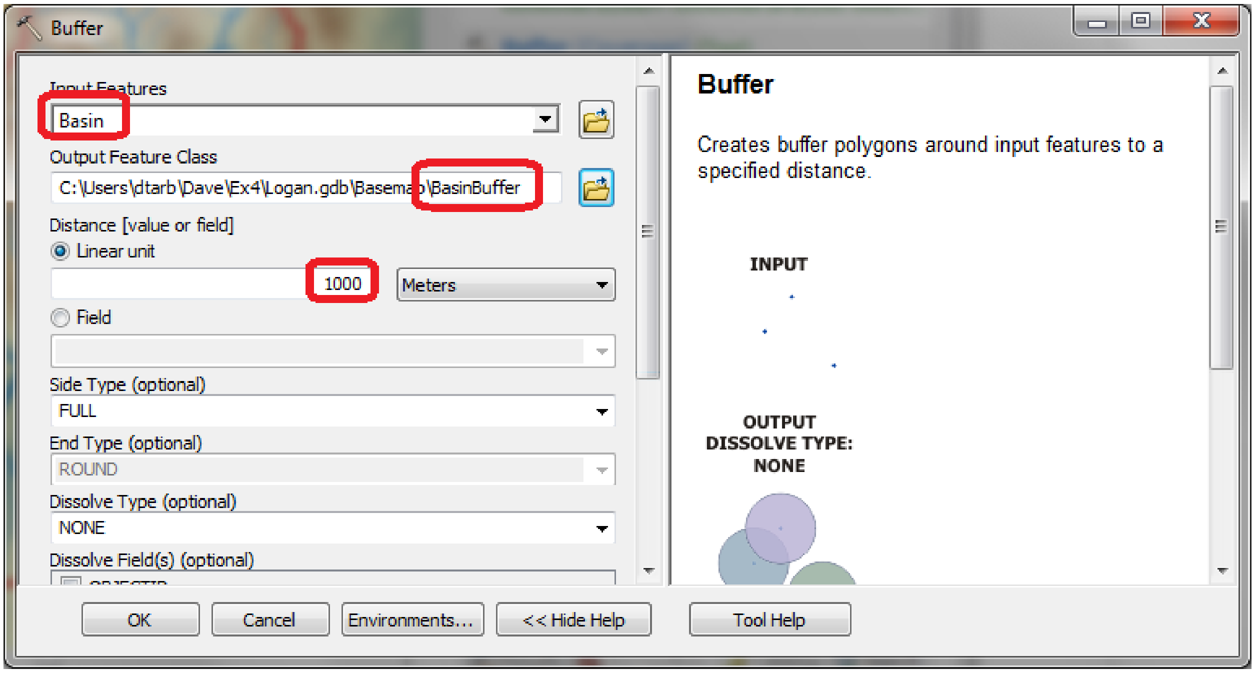
Open the attribute table for Basin and look for the far right column **Shape_Area**. This is the Basin area in m^2. Drainage density is (Total Channel Length)/(Basin Area).

To turn in. Report the main stream length, total stream length, basin area and drainage density for the Logan River Basin as determined from NHDPlus flowlines.

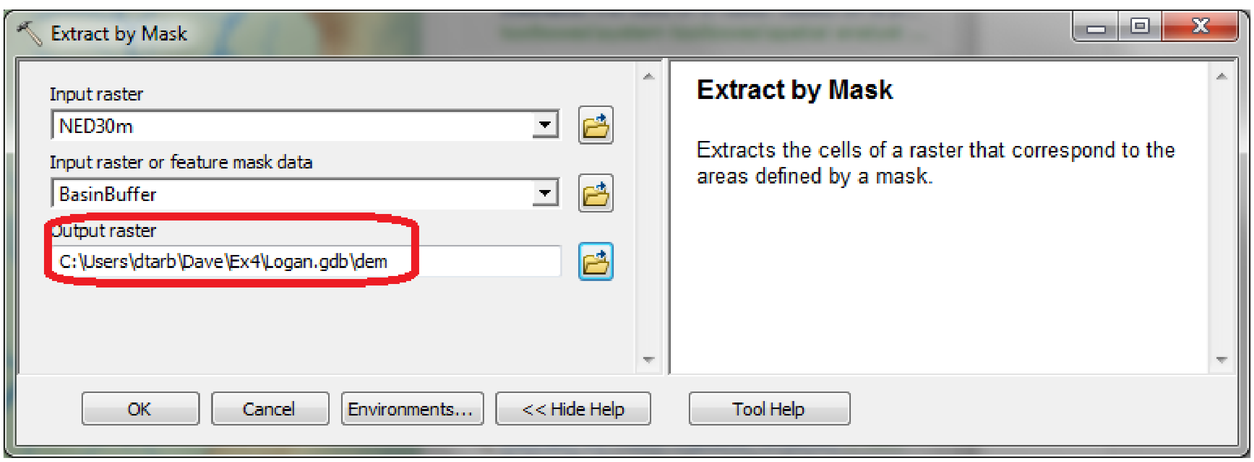
4. Digital Elevation Model

So far we have delineated the watershed and extracted NHDPlus streams for this watershed. Next we want to extract the DEM for this area. Here we want the DEM over an area slightly bigger than the watershed. Let's use a 1 km buffer.

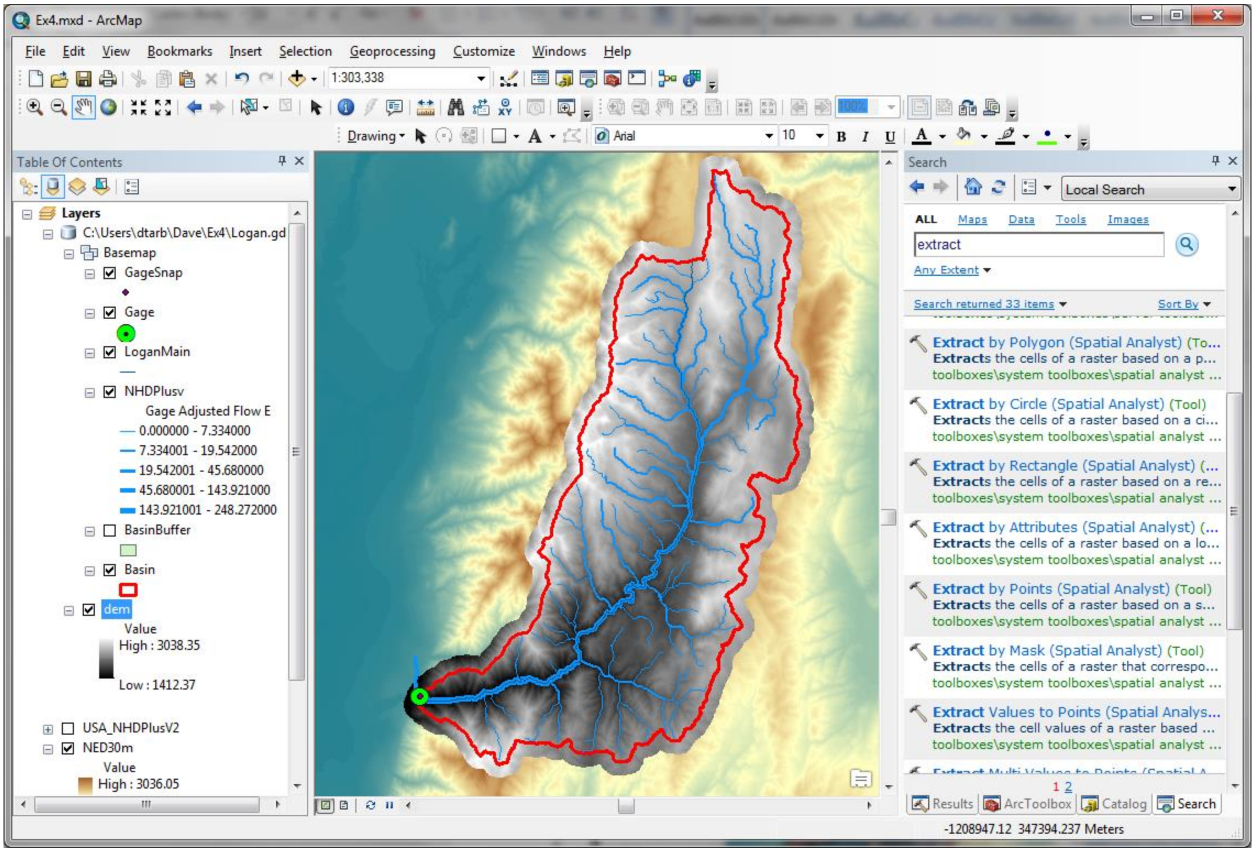
Search for the **Buffer (Analysis)** tool and set the inputs as follows



Next search for the **Extract by Mask (Spatial Analyst)** tool and set the inputs as follows. Save the output raster in **Logan.gdb\dem**.



The result is a DEM just over the buffered area.



At this point you have extracted all the data you need locally and are ready to begin Hydrologic Terrain Analysis.

To turn in. Prepare a layout showing the topography, Basin Outline, NHDPlusv streams and Logan River Main stem stream for the Logan River Basin. Include a scale bar and North arrow and appropriate title, labeling and legend so that the map is self-describing.

To turn in. The number of columns and rows, grid cell size, minimum and maximum elevation values in the Logan DEM.

Remove the NED30m and USA_NHDPlusV2 layers as these are no longer needed and save your map document.

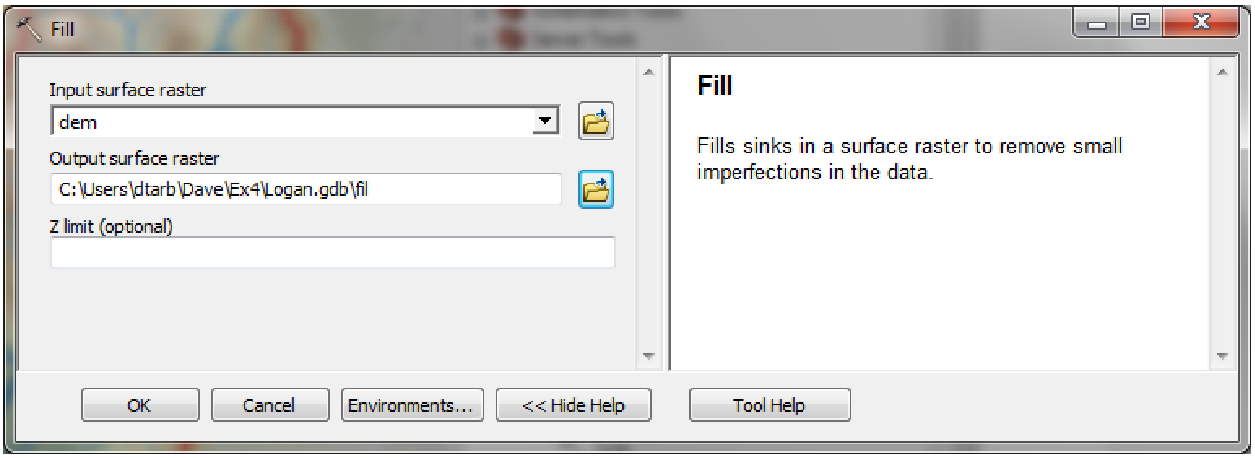
Hydrologic Terrain Analysis

This activity will guide you through the initial hydrologic terrain analysis steps of Fill Pits, calculate Flow Direction, and calculate Flow Accumulation (steps 1 to 3). The resulting flow accumulation raster then allows you to identify the contributing area at each grid cell in the domain, a very useful quantity fundamental to much hydrologic analysis. Next an outlet point will be used to define a watershed as all points upstream of the outlet (step 4). Focusing on this watershed streams will be defined using a flow accumulation threshold within this watershed (step 5). Hydrology functions will be used to define separate links (stream segments) and the catchments that drain to them (steps 6 and 7). Next the streams will be converted into a vector representation (step 8) and more Hydrology toolbox functionality used to evaluate stream order (step 9) and the subwatersheds draining directly to each of the eight stream gauges in the example dataset (step 10). The result is quite a comprehensive set of information about the hydrology of this watershed, all derived from the DEM.

1. Fill

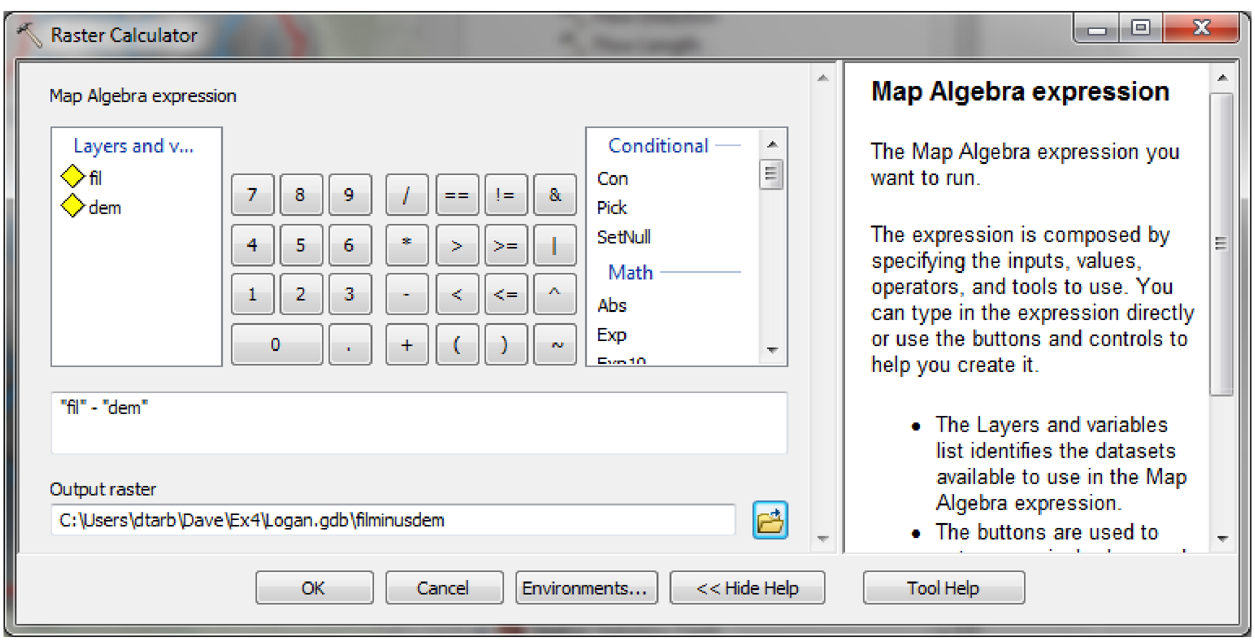
This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill function modifies the elevation value to eliminate these problems.

Select **Spatial Analyst Tools → Hydrology → Fill**. Set the input surface raster as dem and output surface raster as fel in Logan.gdb.

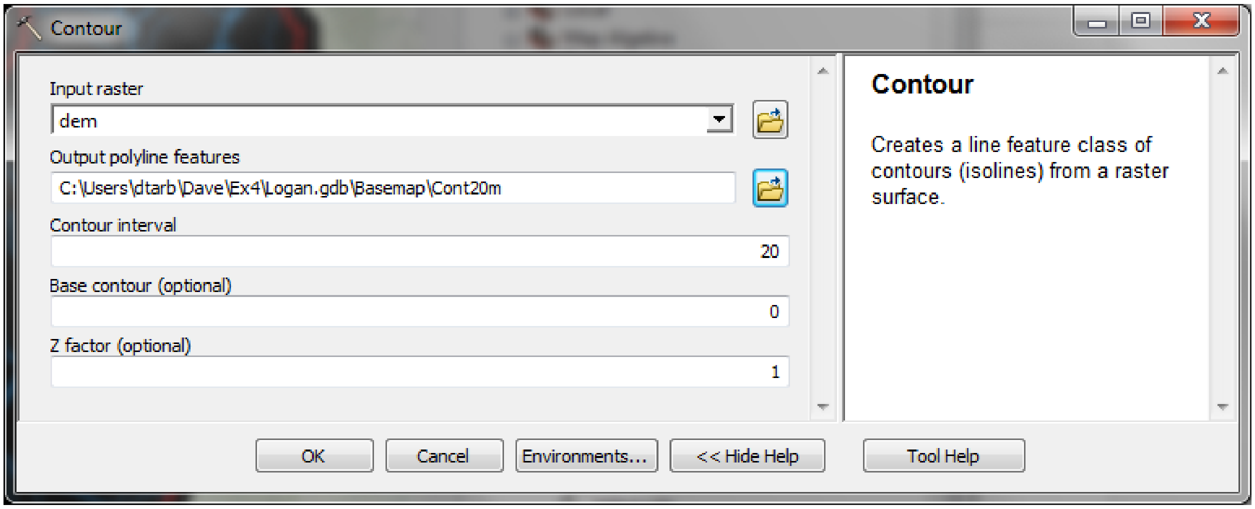


Press **OK**. Upon successful completion of the process, the “fil” layer is added to the map.

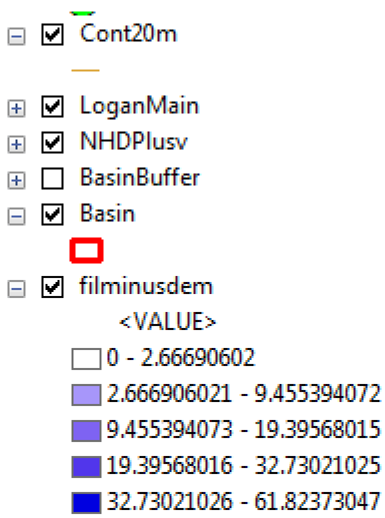
Let's examine the impact of Fill on the DEM. Select **Spatial Analyst Tools → Map Algebra → Raster Calculator** and evaluate **fil - dem**.



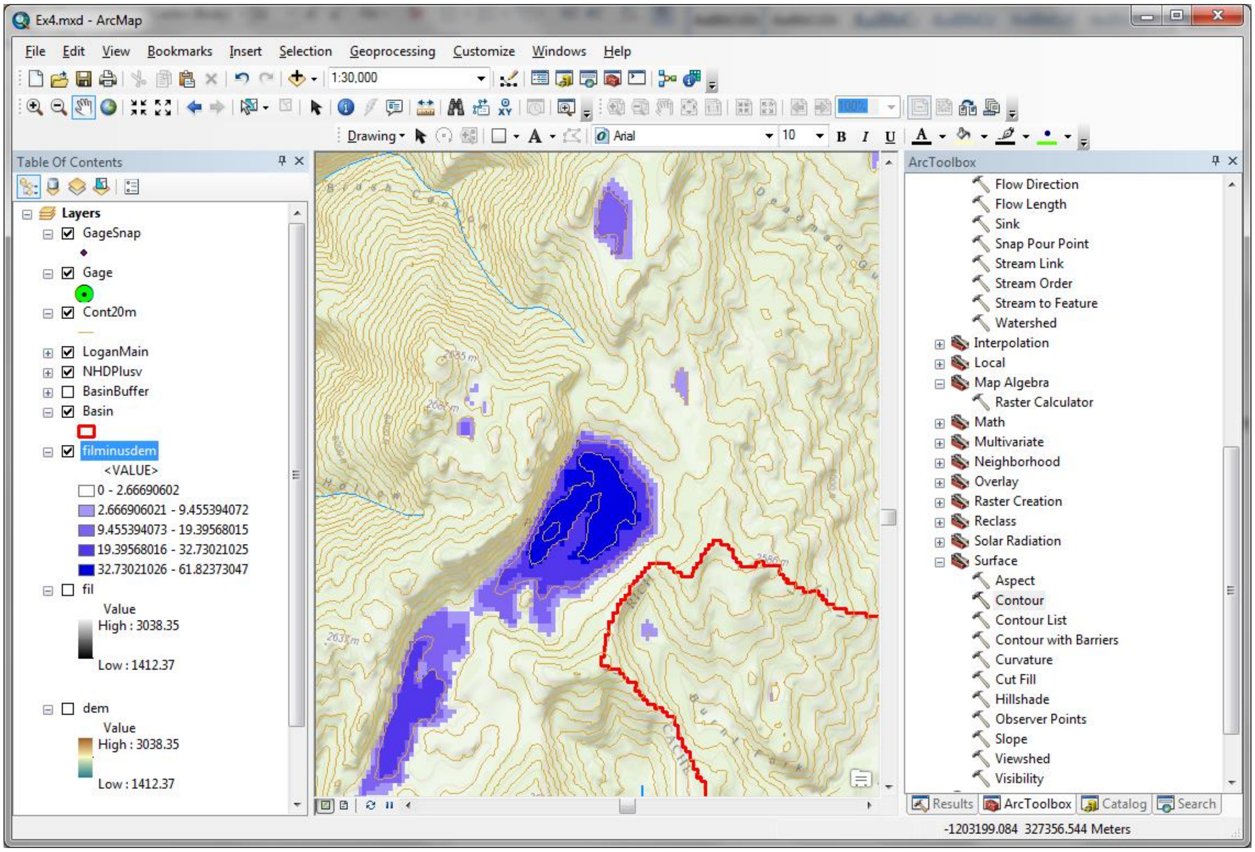
Select **Spatial Analyst Tools → Surface → Contour**. Set the inputs as follows to determine 20 m contours of the original DEM, **dem**.



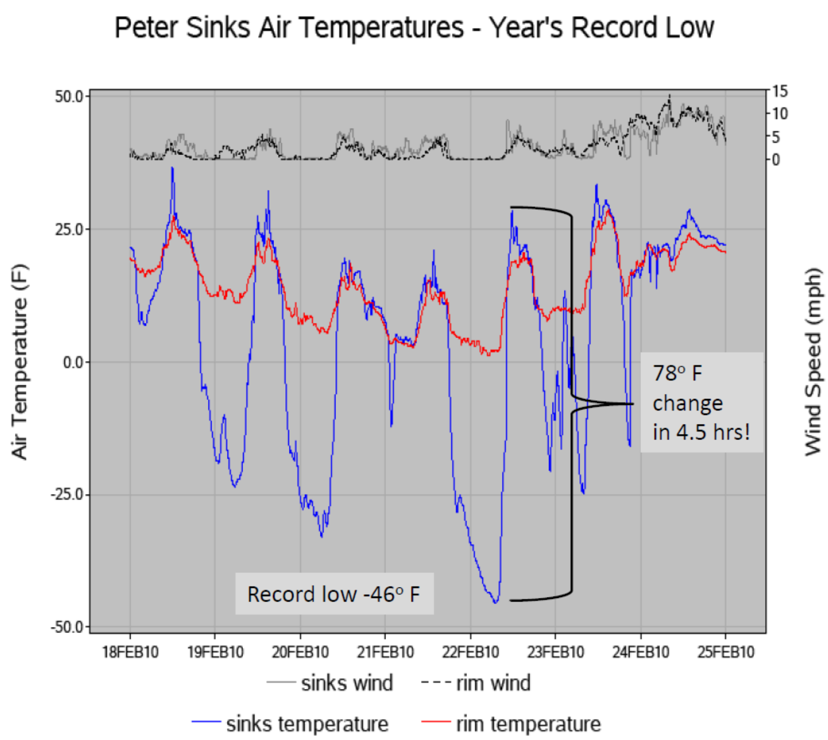
Symbolize the **fil - dem** and contour layers similar to



and zoom in on the deepest Sink. The image below shows the deepest sink, with topographic map background.



This is Peter Sink. It is a real topographic feature, not an artifact, so it is a bit erroneous to fill it. Nevertheless for the sake of a complete watershed we fill it. The website http://twdef.usu.edu/Peter_Sinks/Sinks.html gives details on the record low temperatures that have been recorded here.



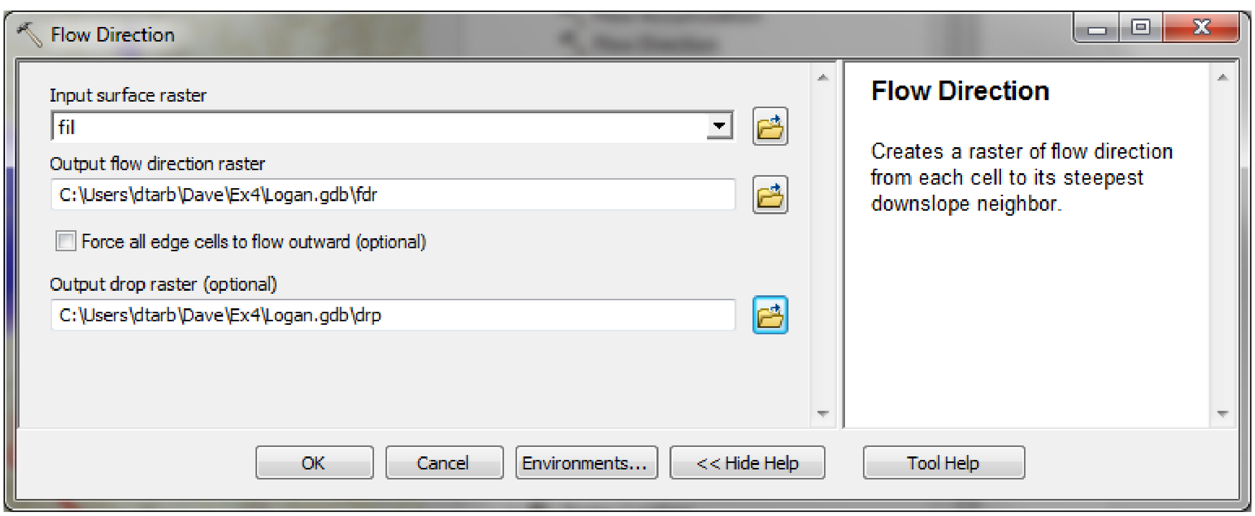
To turn in. A layout showing the deepest sink in the Logan River basin. Report the depth of the deepest sink as determined by fil-dem.

2. Flow Direction

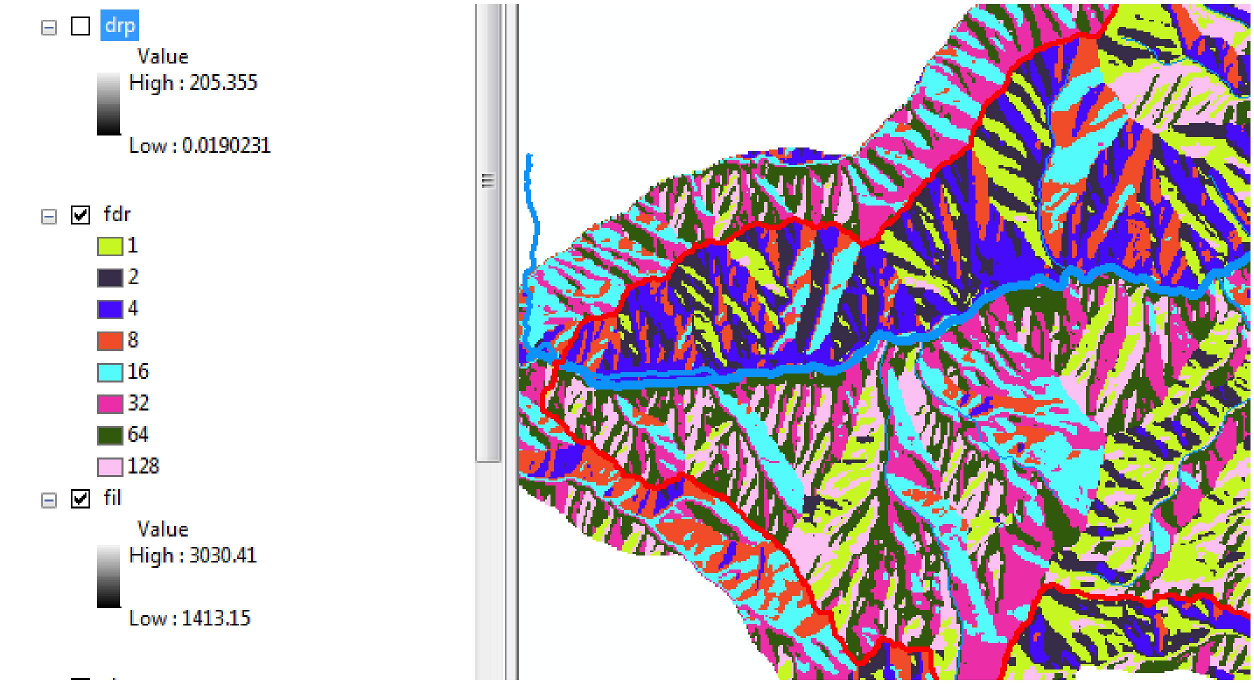
This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

Select **Spatial Analyst Tools → Hydrology → Flow Direction**.

Set the inputs as follows, with output "fdr" and "drp".



Press OK. Upon successful completion of the process, the flow direction grid "fdr" and percentage drop grid "drp" are added to the map.



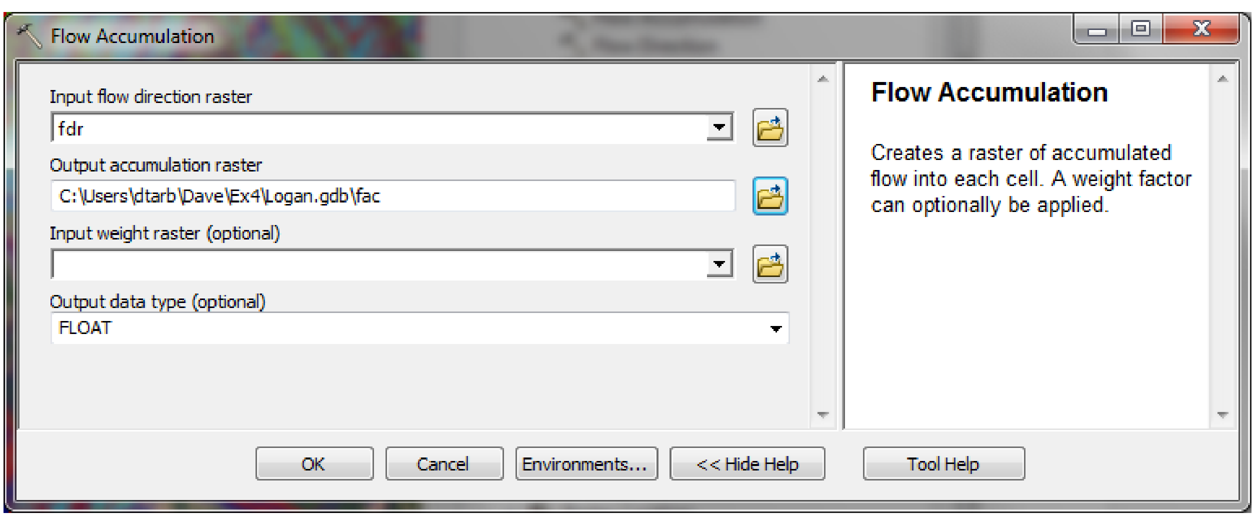
To turn in: Make a screen capture of the attribute table of fdr and give an interpretation for the values in the Value field using a sketch.

3. Flow Accumulation

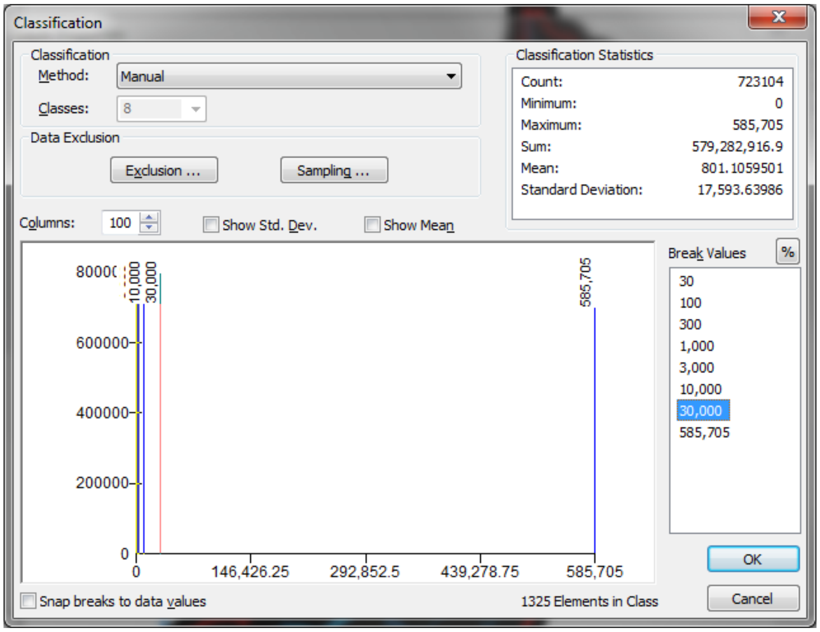
This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

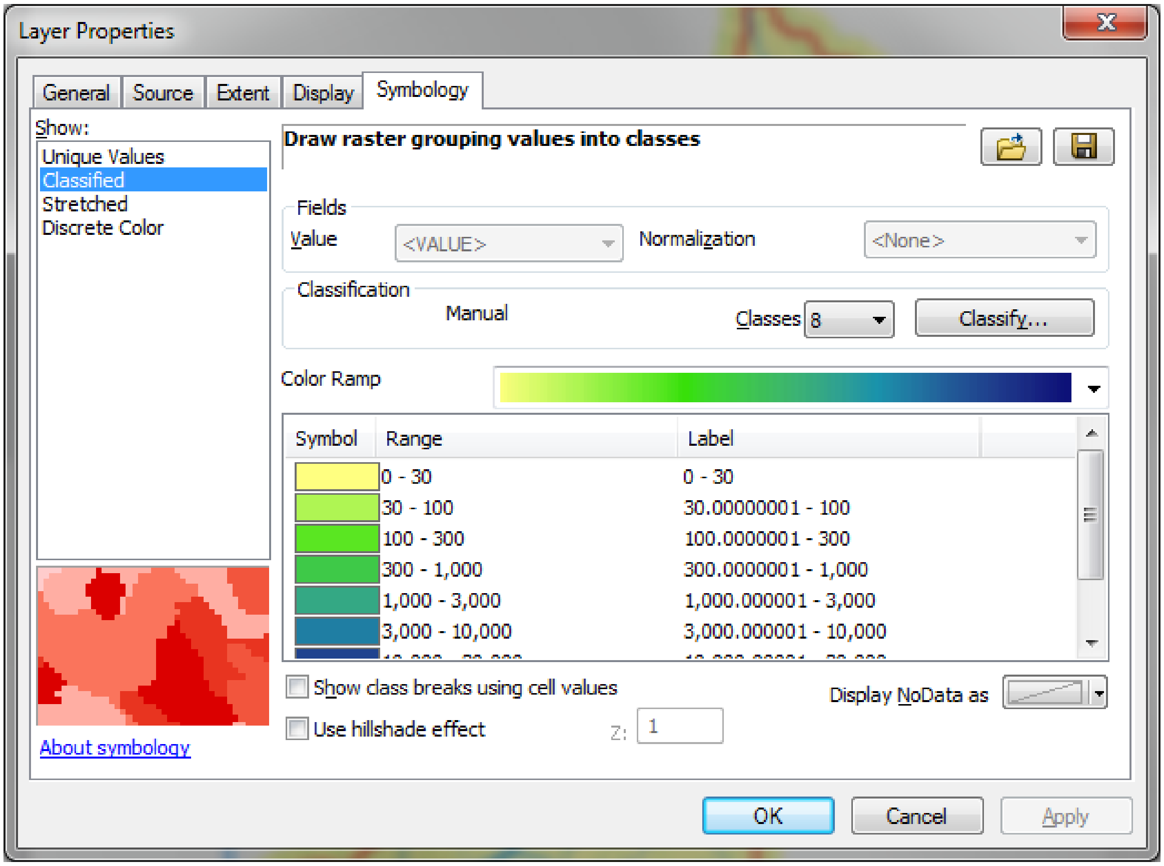
Select **Spatial Analyst Tools → Hydrology → Flow Accumulation**.

Set the inputs as follows

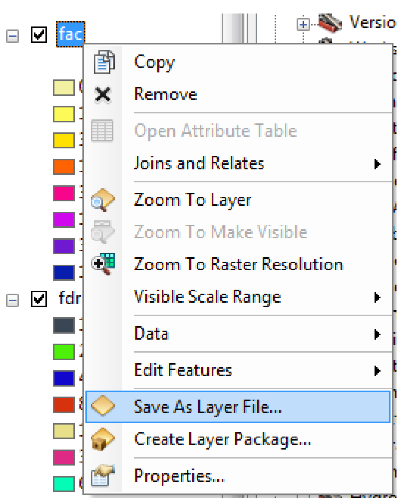


Press OK. Upon successful completion of the process, the flow accumulation grid “fac” is added to the map. This process may take **several minutes** for a large grid, so take a break while it runs! Adjust the symbology of the Flow Accumulation layer "fac" to a classified scale with multiplicatively increasing breaks that you type in, to illustrate the increase of flow accumulation as one descends into the grid flow network. Use 8 classes and hit the “Classify” Button to enable you to select “Manual” method and to type in your class breaks into the window in the lower right hand corner.



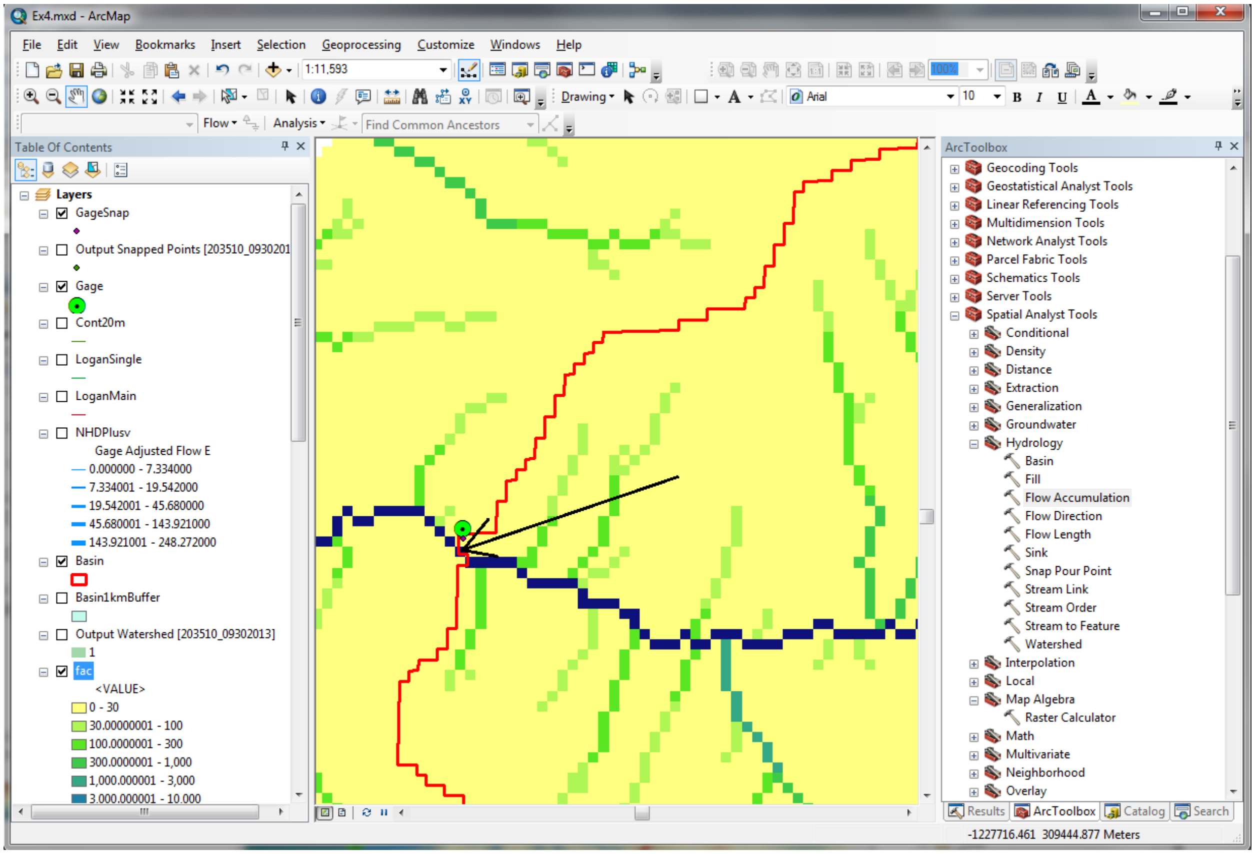


After applying this layer symbology you may right click on the "fac" layer and Save As Layer File



The saved Layer File may be imported to retrieve the symbology definition and apply it to other data.

Pan and zoom to the outlet where the river leaves the watershed. Turn off unnecessary layers and arrange layer order so that you can see the Basin feature class on top of the fac layer. Use the identify tool to determine the value of "fac" at the point where the main stream exits the area defined by the Basin polygon. This location is indicated in the following figure.



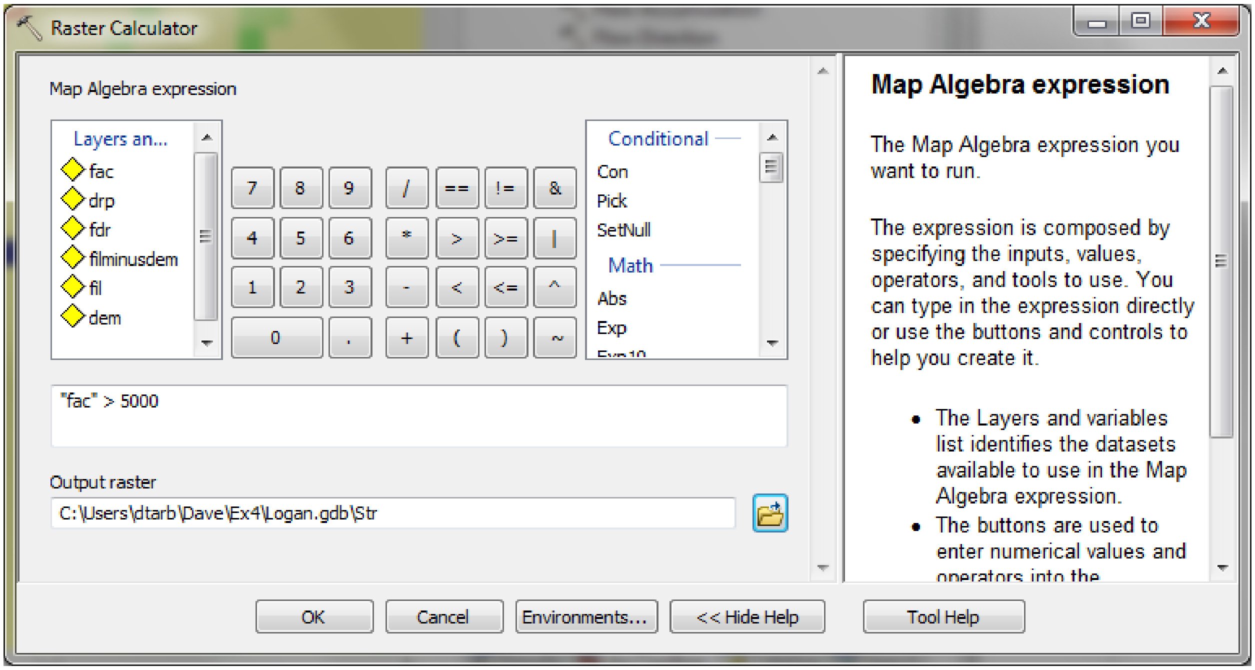
The value obtained represents the drainage area in number of 30.92 x 30.92 m grid cells. Calculate the drainage area in km^2. Compare this drainage area to the drainage area reported by the USGS at the Logan River stream site (214 mi^2) and to the area of the Basin feature class obtained from the online service watershed delineation.

To turn in: Report the drainage area of the Logan River basin in both number of 30.92 m grid cells and km^2 as estimated by flow accumulation. Report the area of the Logan River basin in km^2 as calculated by the arcgis.com watershed function. Report the area of the Logan River basin in km^2 as reported by the USGS for the Logan River stream site. Discuss reasons for any differences.

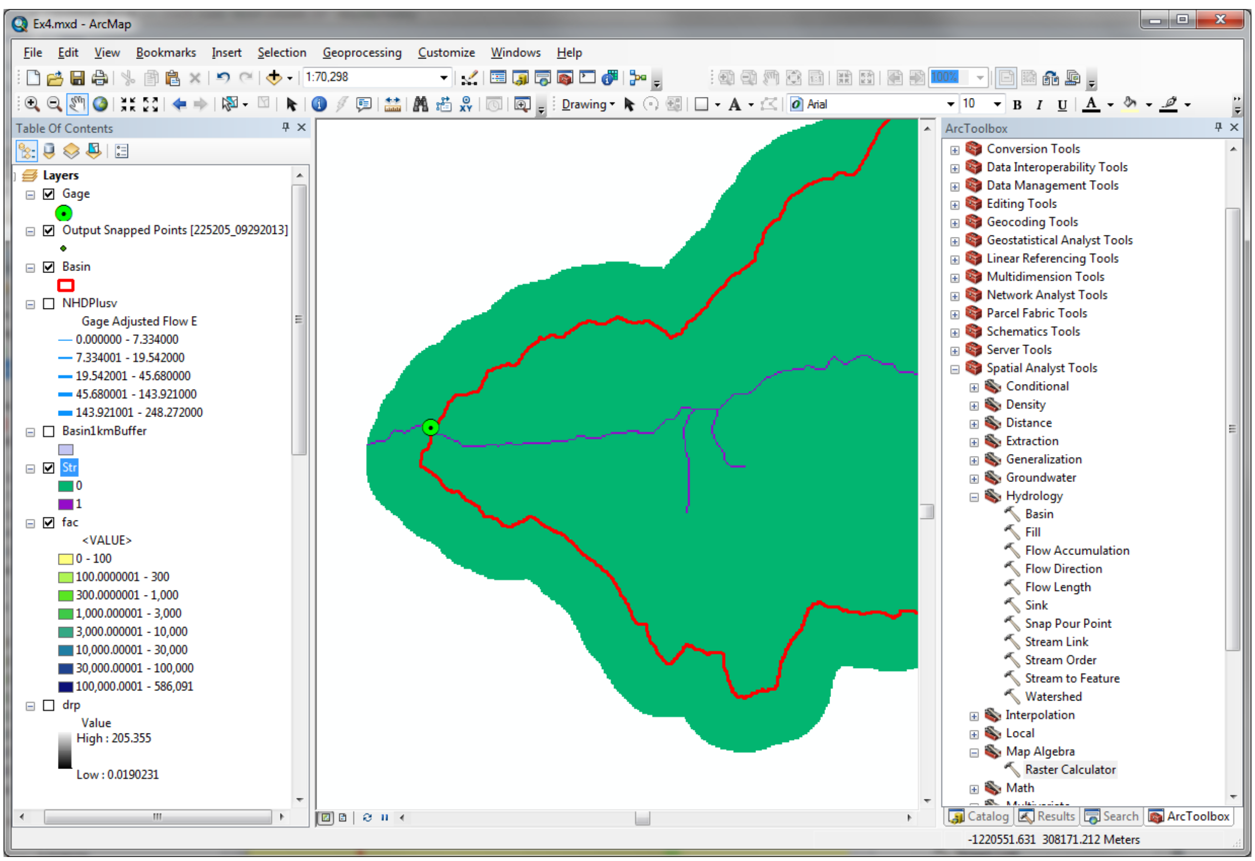
4. Stream Definition

Let's define streams based on a flow accumulation threshold within this watershed.

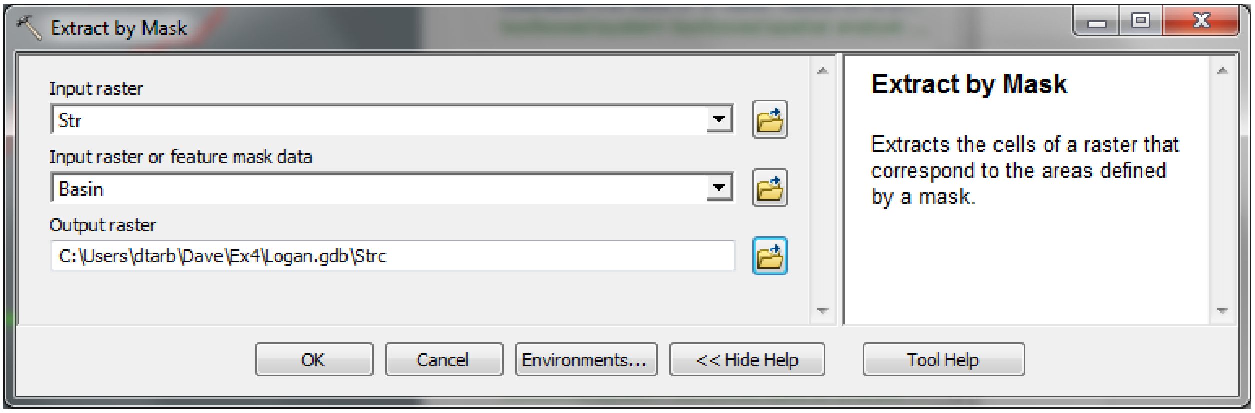
Select **Spatial Analyst Tools → Map Algebra → Raster Calculator** and enter the following expression, using the name **Str** for the output raster.



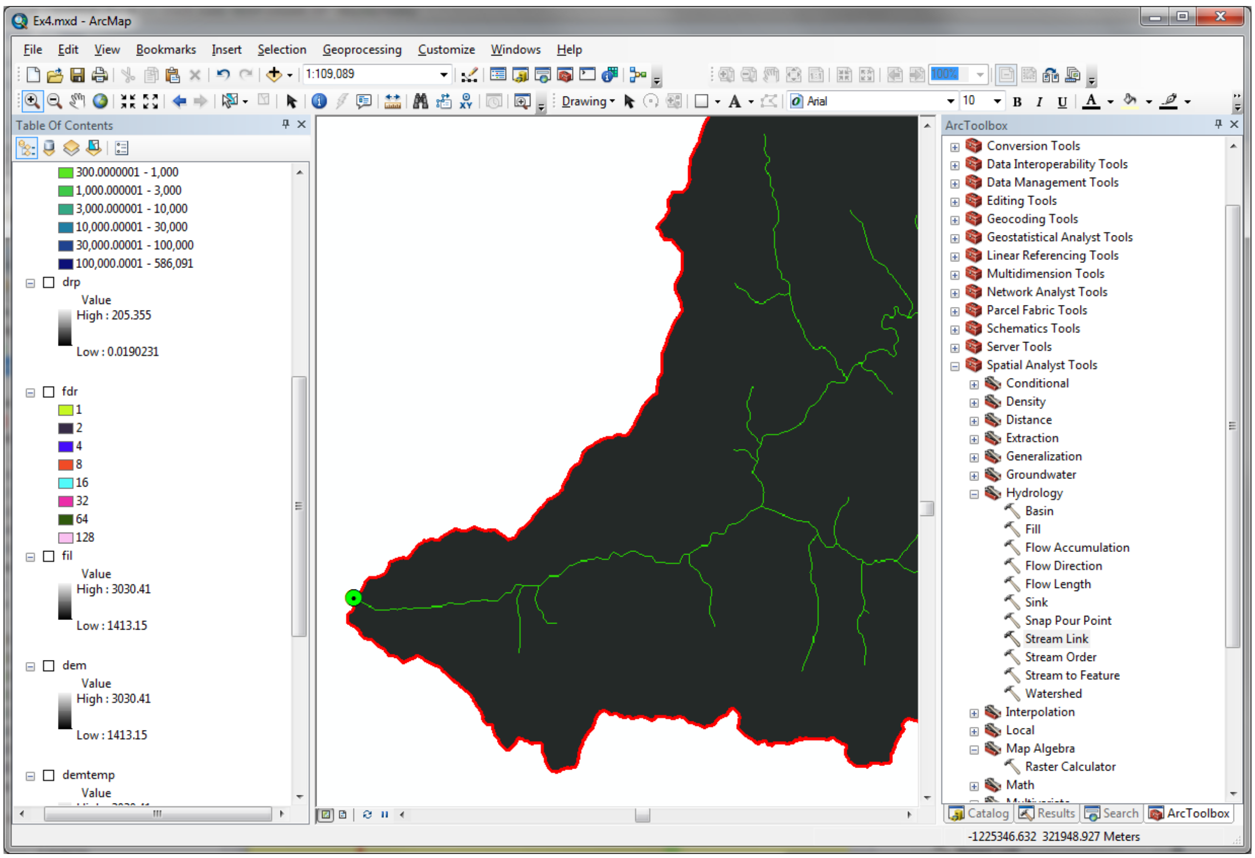
The result is a raster representing the streams delineated over our watershed.



This extends across the buffer area at the downstream end. To ensure that our streams are within the watershed we want lets clip this. Locate the **Extract by Mask (Spatial Analyst)** tool and set the inputs as follows



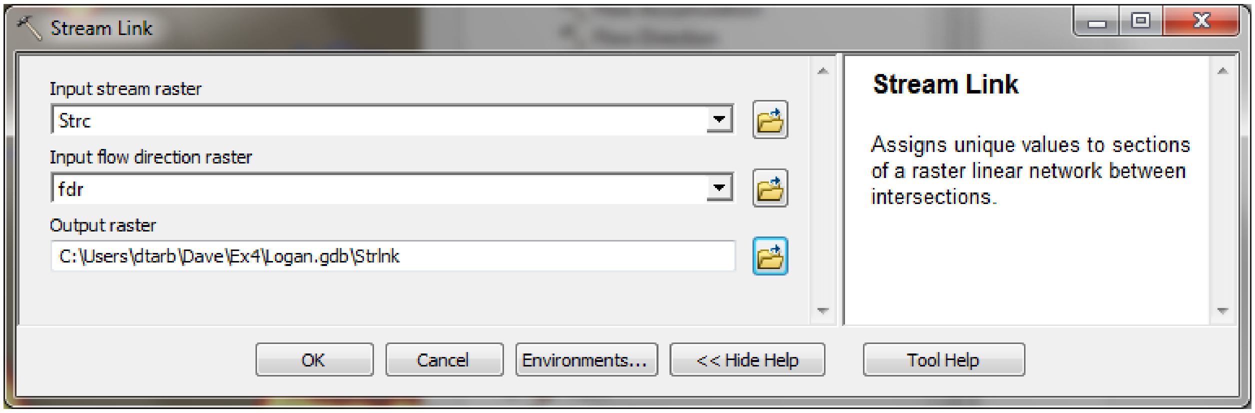
The result is a stream raster entirely within the Logan River Basin.



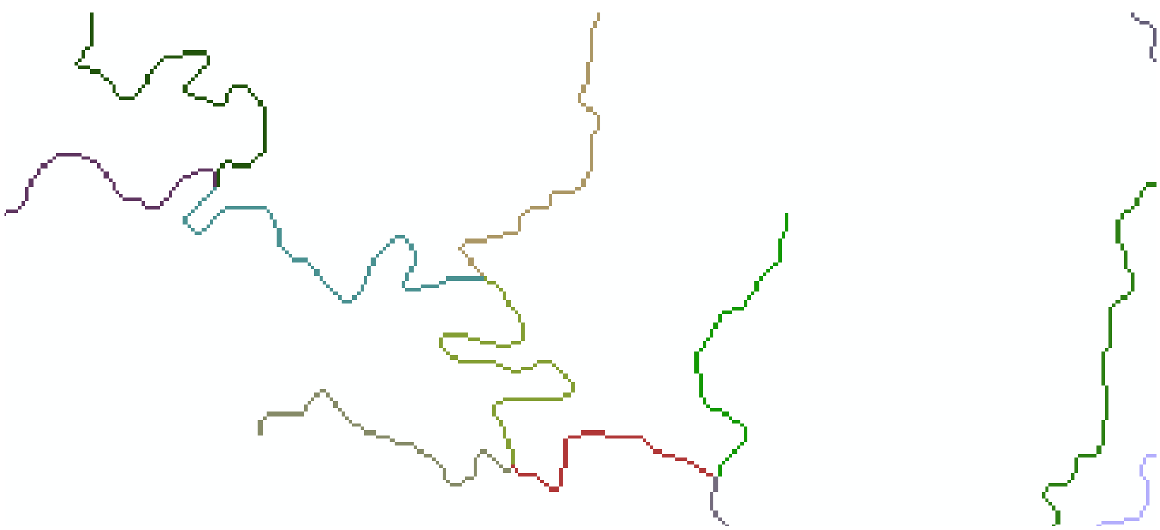
5. Stream Links

This function creates a grid of stream links (or segments) that have a unique identification. Either a link may be a head link, or it may be defined as a link between two junctions. All the cells in a particular link have the same grid code that is specific to that link.

Select **Spatial Analyst Tools → Hydrology → Stream Link.** Set the inputs as follows and click OK.



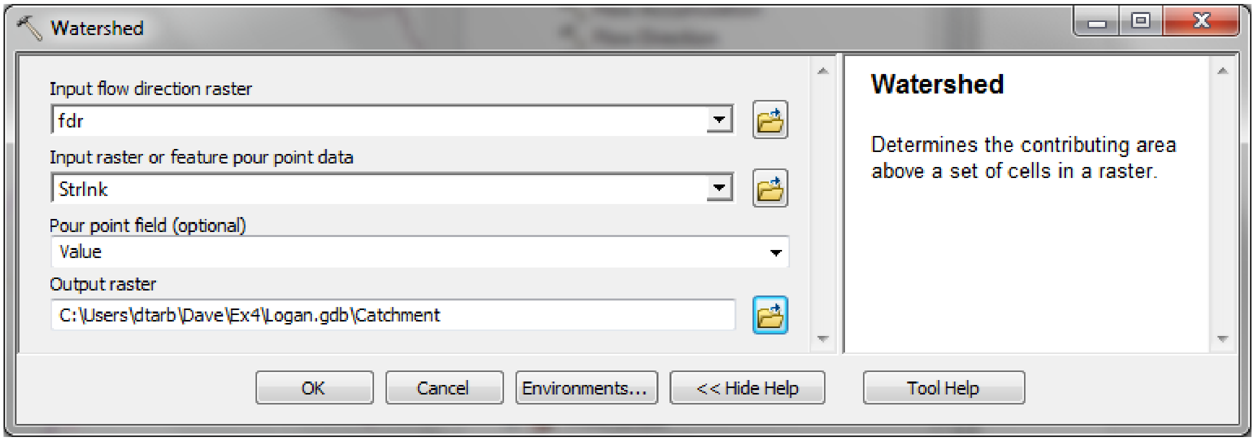
The result is a grid with unique values for each stream segment or link. Symbolize **StrLnk** with unique values so you can see how each link has a separate value.



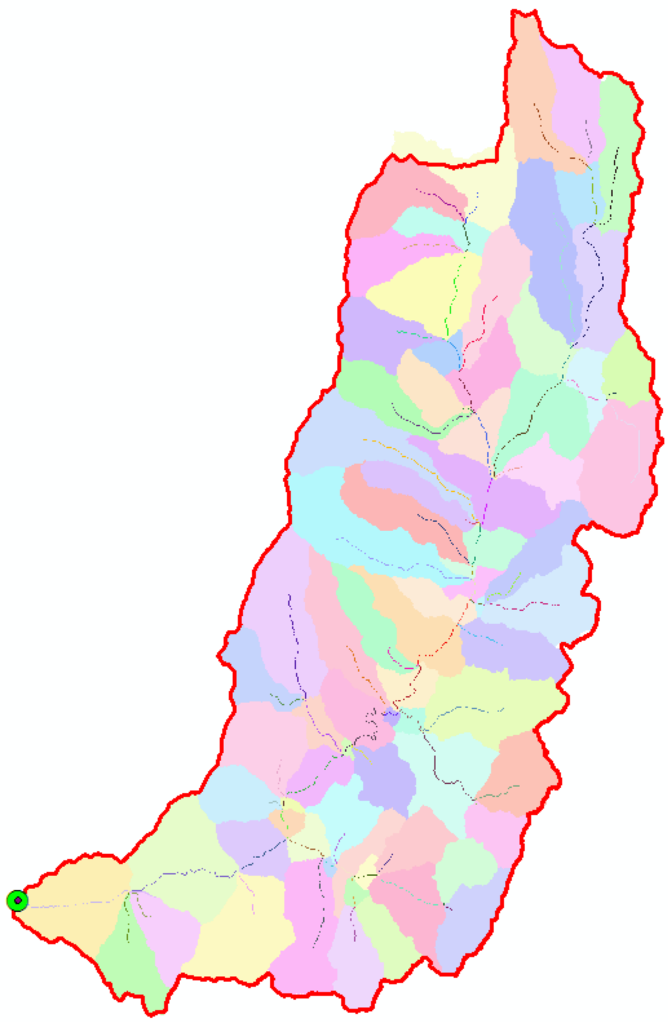
6. Catchments

The Watershed function also provides the capability to delineate catchments upstream of discrete links in the stream network.

Select **Spatial Analyst Tools → Hydrology → Watershed.** Set the inputs as follows. Notice that the Input raster or feature pour point data is the StrLnk grid. This results in the identification of catchments draining to each stream link. Click OK.



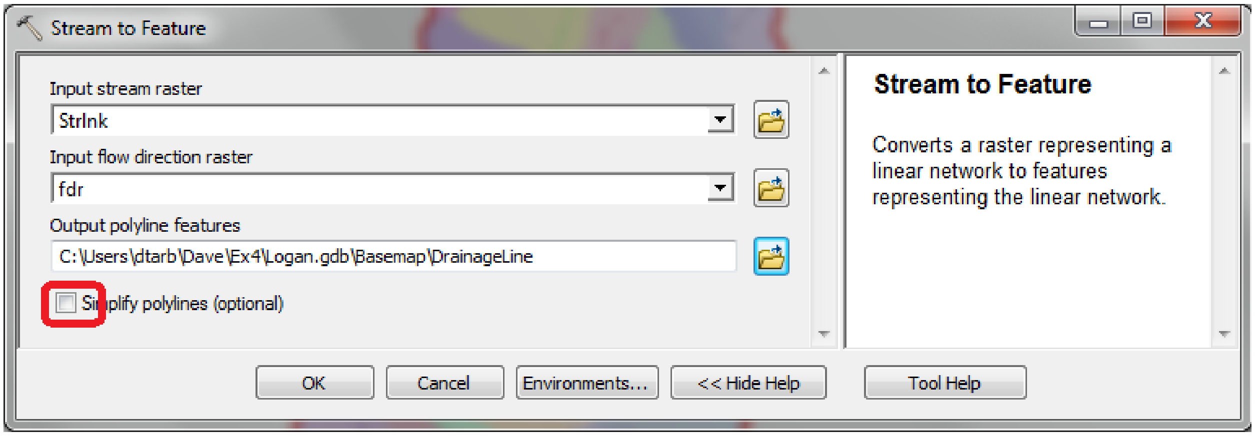
The result is a Catchment grid where the grid cells in the area draining directly to each link are assigned a unique value the same as the link it drains to. This allows a relational association between lines in the StrLnk grid and Area's in the Catchment grid. Symbolize the Catchment grid with unique values so you can see how each catchment has a separate value.



7. Conversion to Vector

Let's convert this raster representation of streams derived from the DEM to a vector representation.

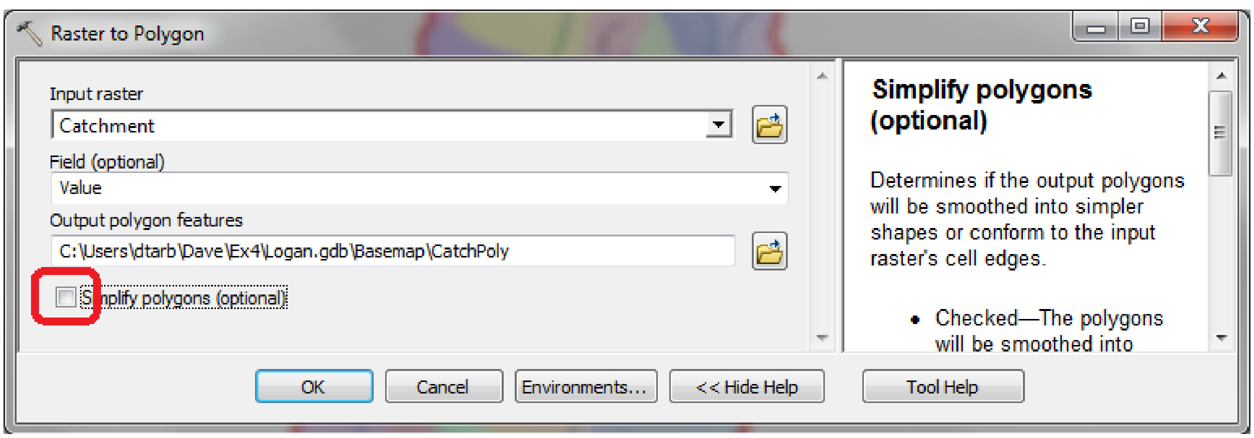
Select **Spatial Analyst Tools → Hydrology → Stream to Feature.** Set the inputs as follows. Note that I named the output **DrainageLine** in the **Logan.gdb\BaseMap** feature class.



Note here that we uncheck the Simplify polylines option. The simplification can cause streams to "cut corners" that can result in errors.

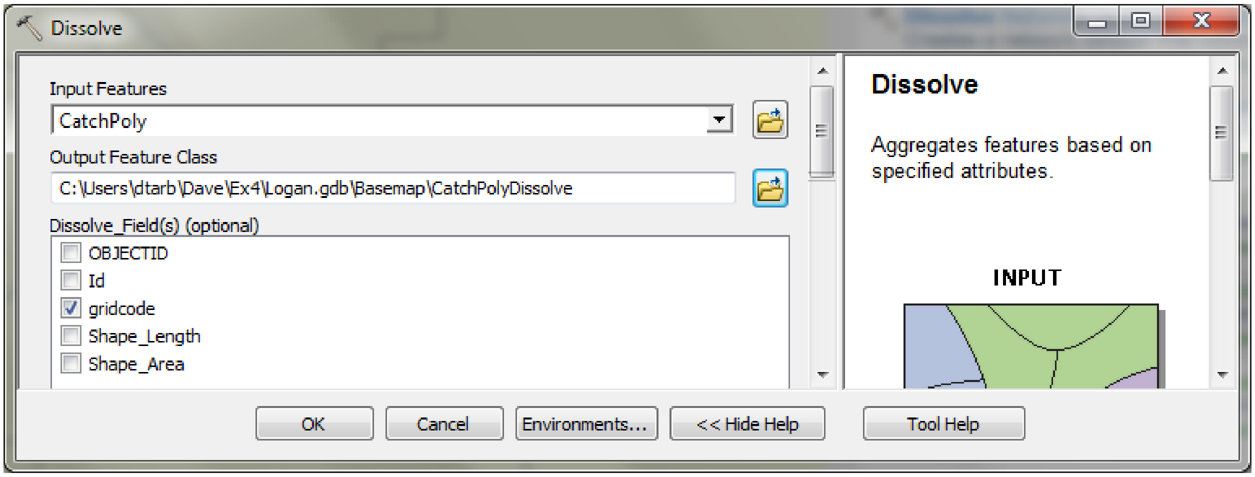
The result is a linear feature class "DrainageLine" that has a unique identifier associated with each link.

Select **Conversion Tools → From Raster → Raster to Polygon**. Set the inputs as follows again avoiding simplification of polygons



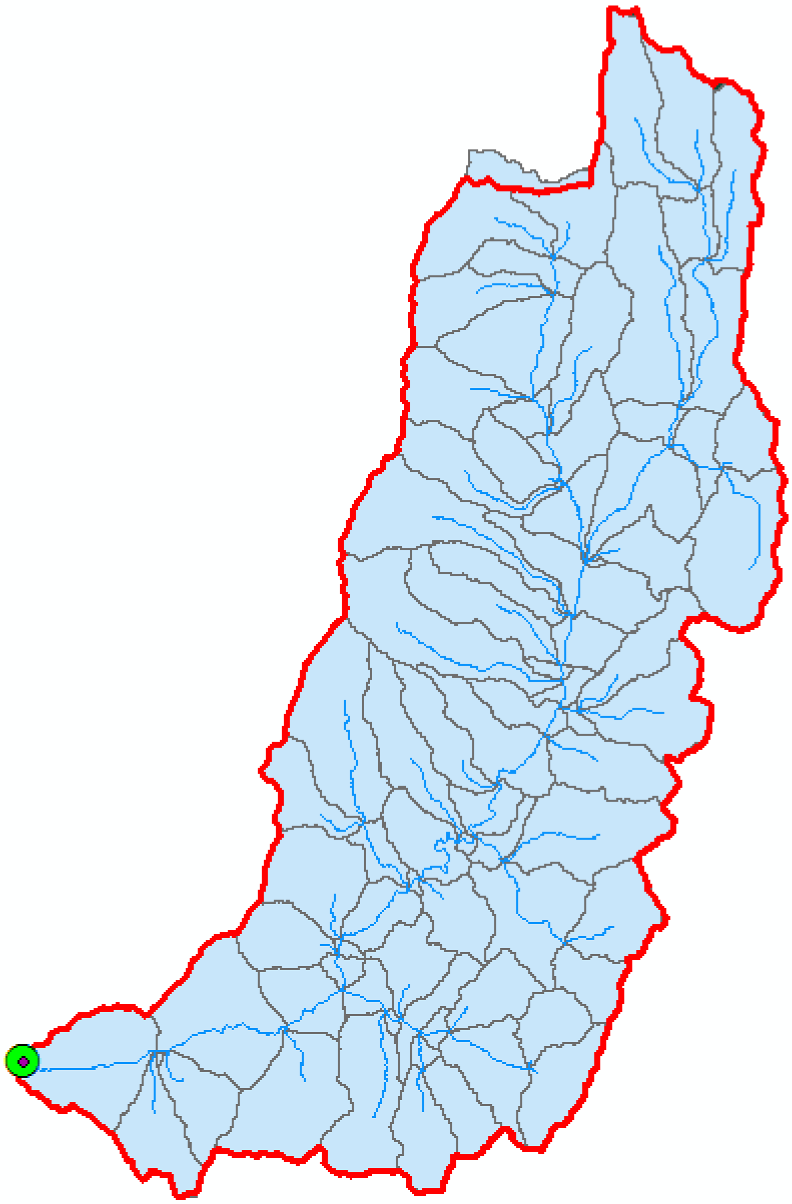
The result is a Polygon Feature Class of the catchments draining to each link.

Due to the geometry of grid cells in Catchment, you may get multiple polygons for a single Catchment grid code value. Locate the **Dissolve (Data Management)** tool and set the following inputs.



This merges all polygons with the same gridcode value and results in a one to one association between DrainageLine features and CatchPolyDissolve reatures.

The feature classes DrainageLine and CatchPolyDissolve represent the connectivity of flow in this watershed in vector form and will be used later for Network Analysis, that is enabled by having this data in vector form.



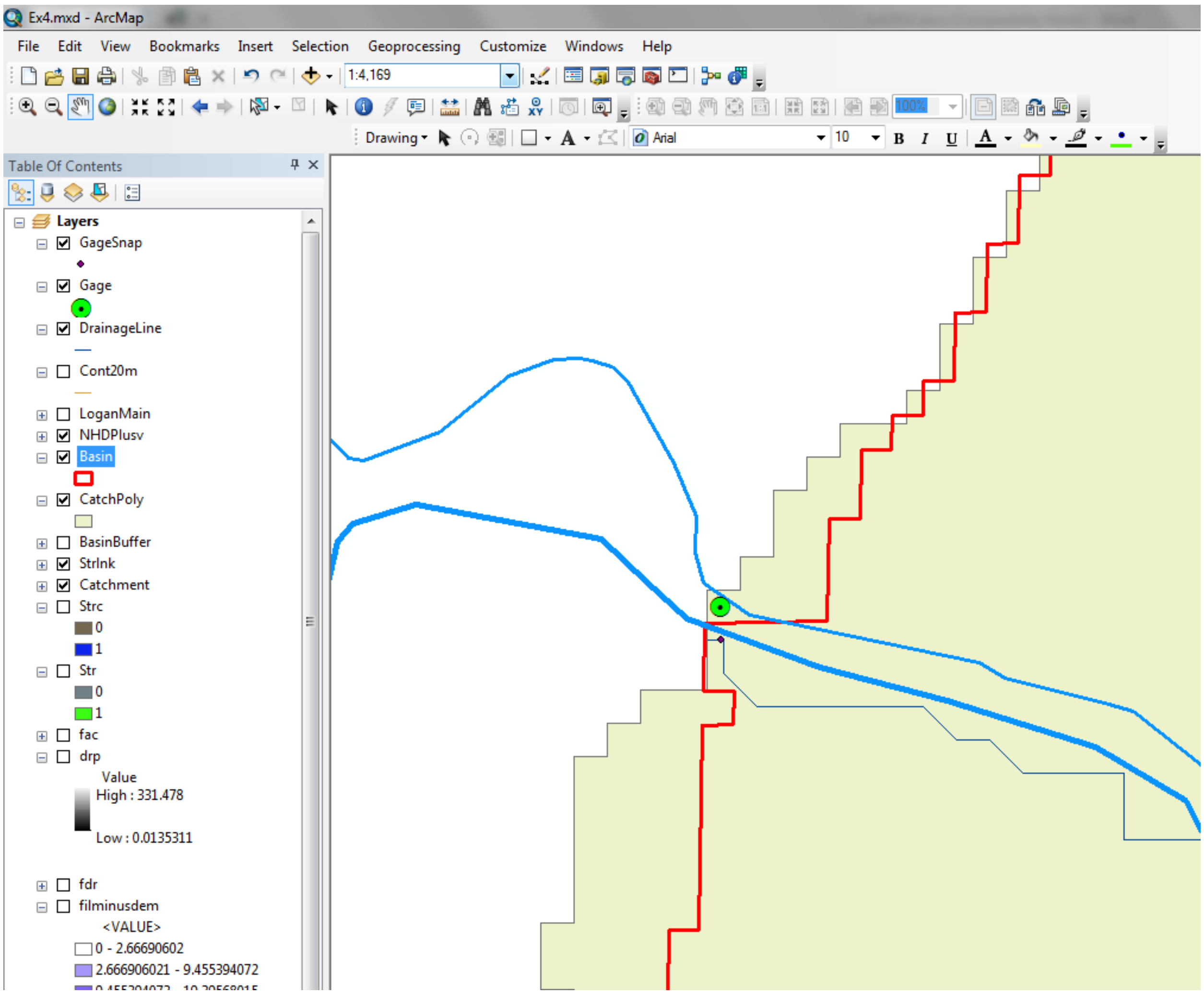
To turn in: Describe (with simple illustrations) the relationship between StrLnk, DrainageLine, Catchment and CatchPoly attribute and grid values. What is the unique identifier in each that allows them to be relationally associated?

Network Analysis

Some of the real power of GIS comes through its use for Network Analysis. A Geometric Network is an ArcGIS data structure that facilitates the identification of upstream and downstream connectivity. Here we step through the process of creating a geometric network from the vector stream network representation obtained above, and then use it to determine some simple aggregate information.

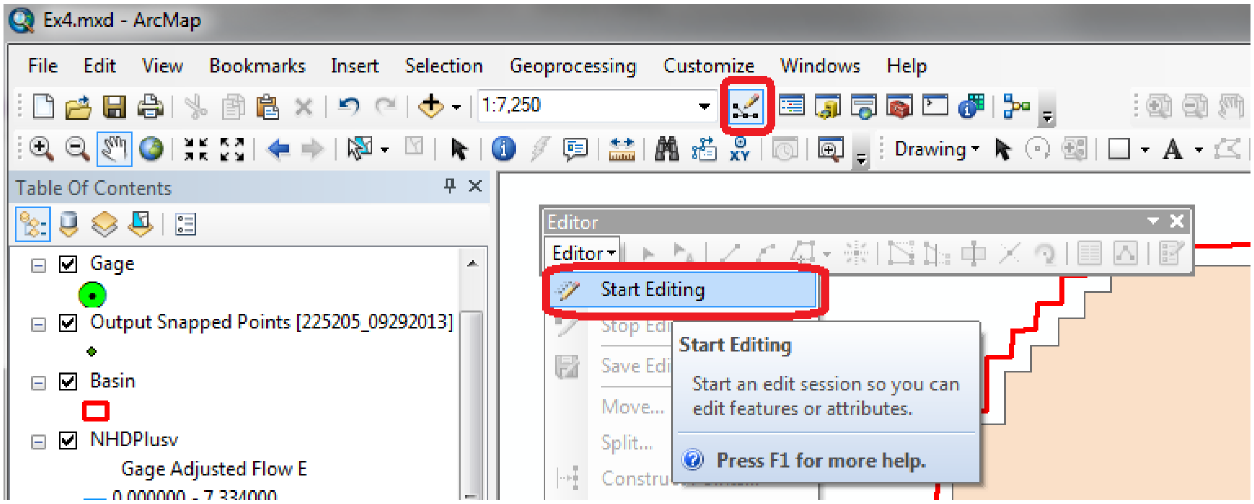
1. Creating a Geometric Network

Zoom in to near the Outlet. You will see that there is not perfect agreement between the NHDPlus streams and the DrainageLine stream we delineated. These are due to differences between the raster DEM and vector mapping of NHD.

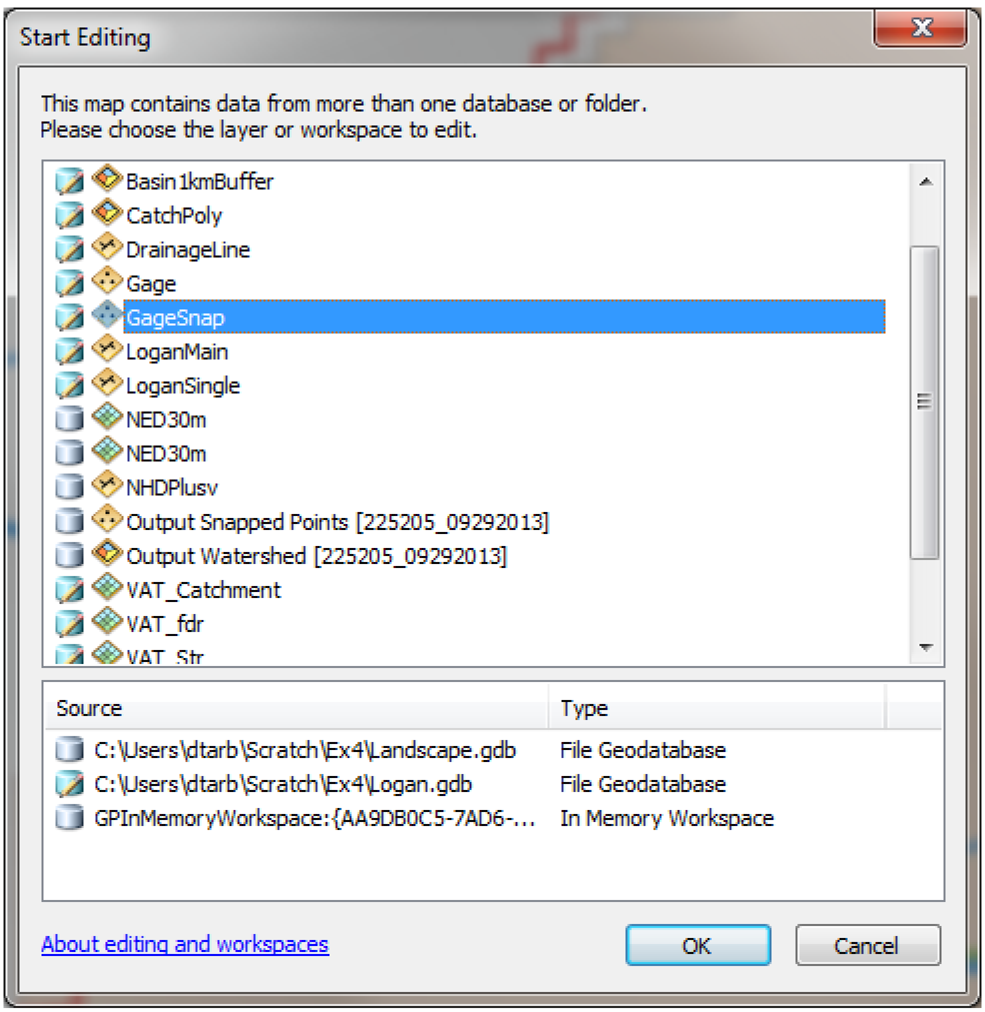


To perform Network Analysis we need an outlet at the downstream end of our stream. Here we use the point in the **GageSnap** feature class determined from the initial Watershed delineation. This needs to be edited to move right on to the downstream end of the stream network.

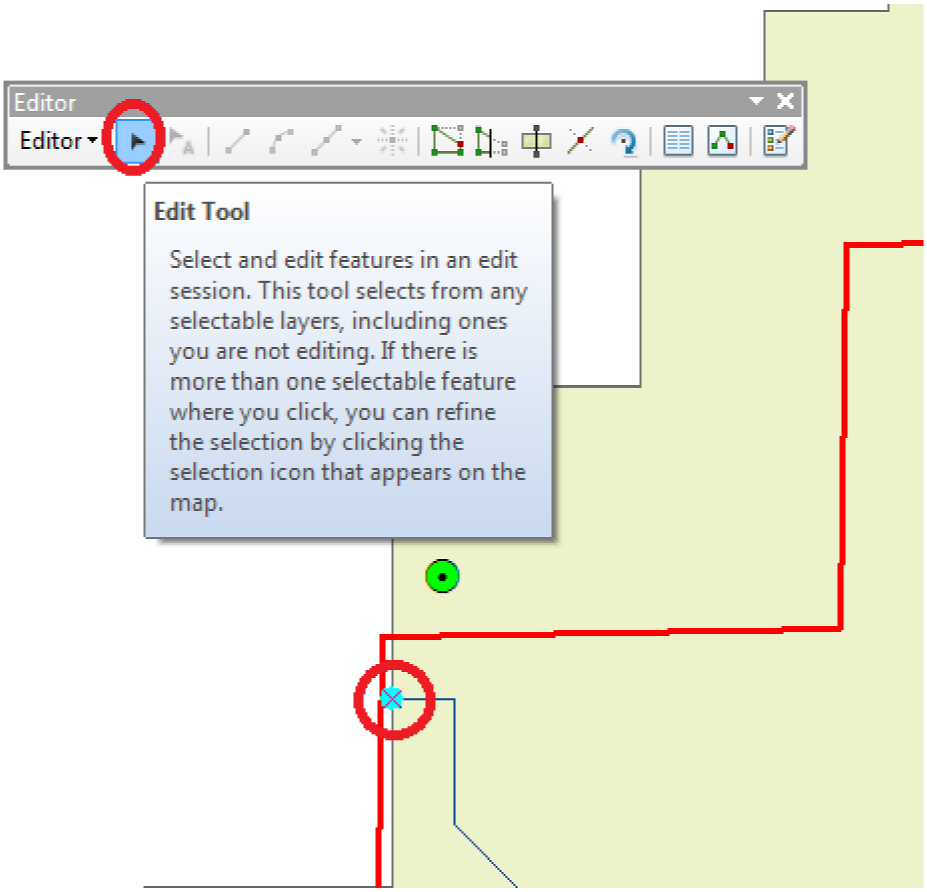
Select Start Editing on the Editor Tool. You may get a window that indicates that the map contains data from more than one database of folder. This will occur if you have not removed the unnecessary layers along the way. If this occurs select the layer "GageSnap" as indicated below and click OK.



Select GageSnap as the Layer to edit

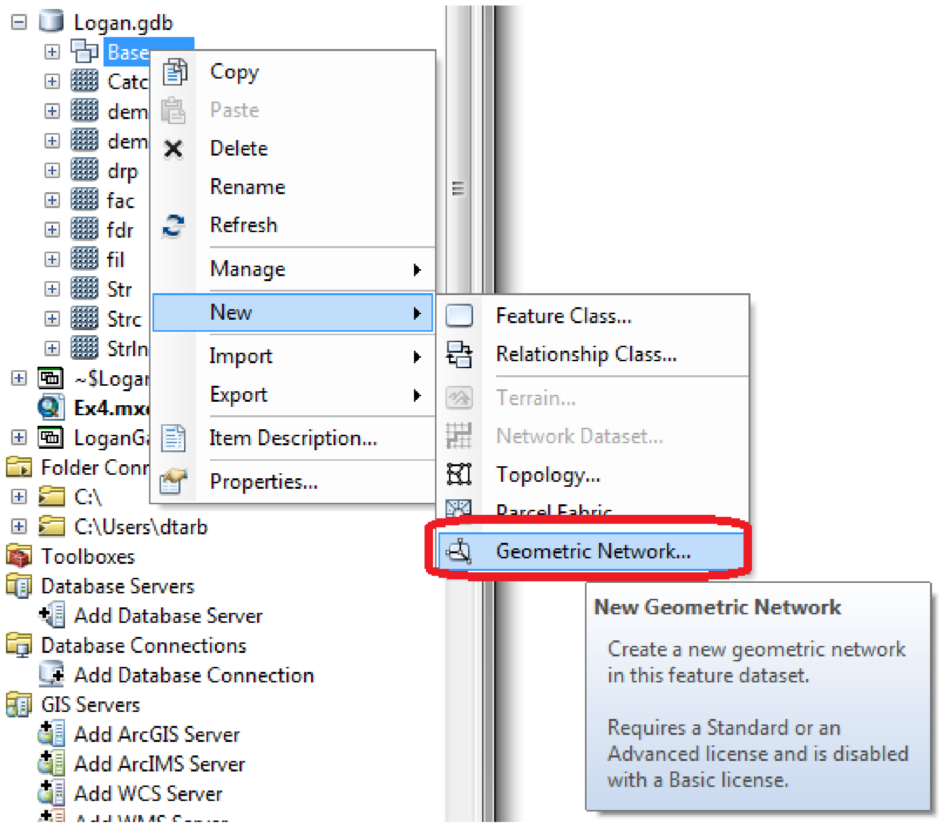


You may encounter a warning that certain layers are not editable. This can be ignored since the layer GageSnap is not on the list of not editable layers. Click Continue at the warning (if you get it). Click on the GageSnap point and drag it until it lines up with the DrainageLine Endpoint as shown below. It should snap right on. You may need to turn some other layers off and zoom in to control the snapping.

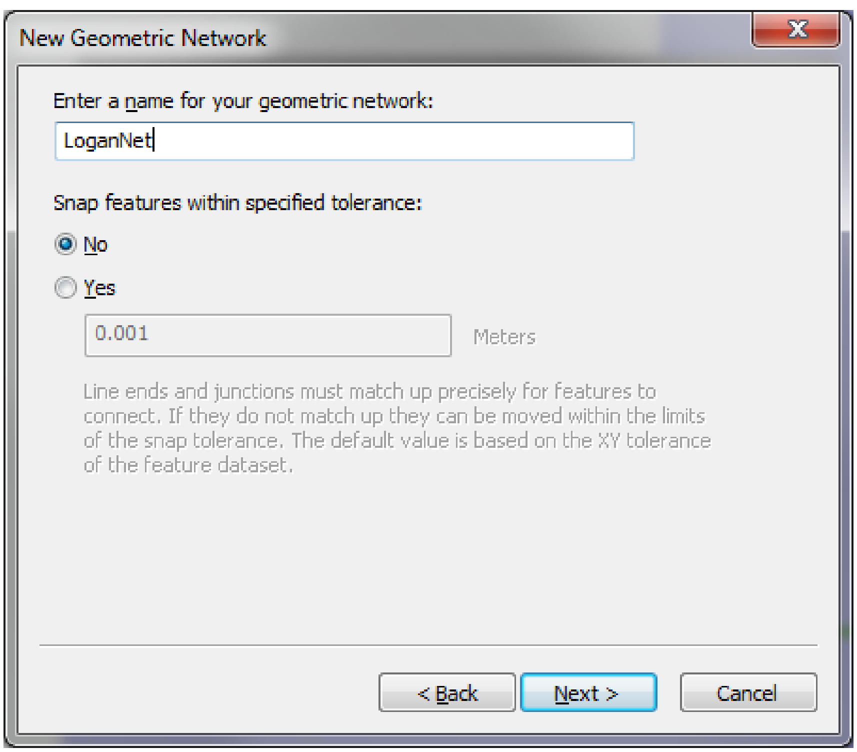


Select Stop Editing and Save on the Editor.

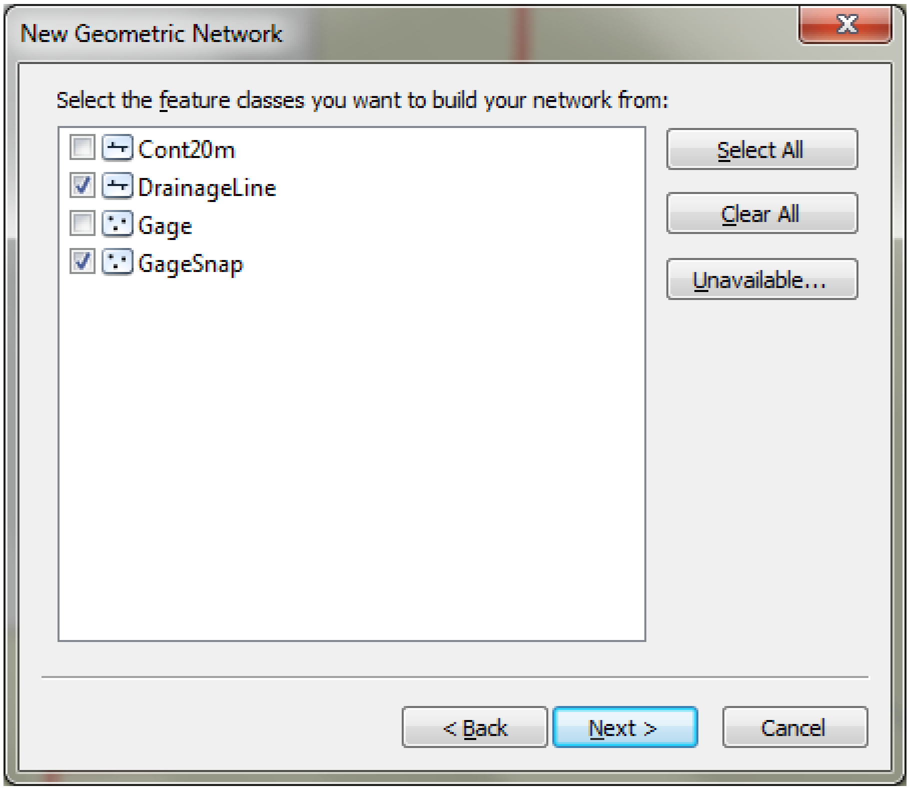
Now open the Catalog window and right click on **Logan.gdb\BaseMap → New Geometric Network**



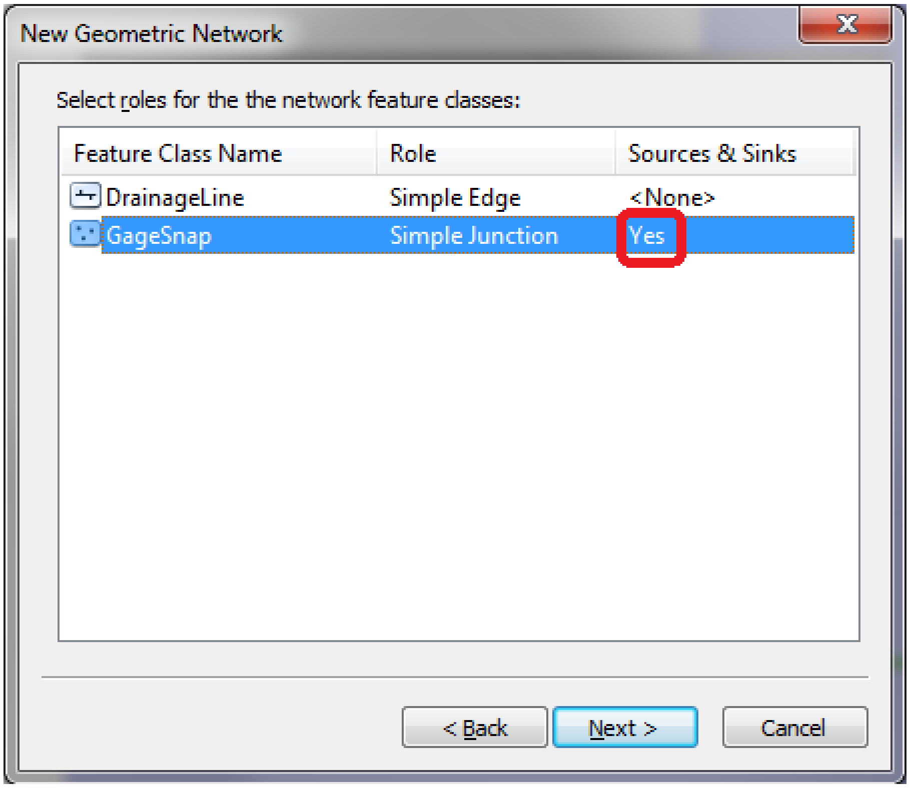
Click Next on the New Geometric Network screen. Enter the name **LoganNet**, then click Next.



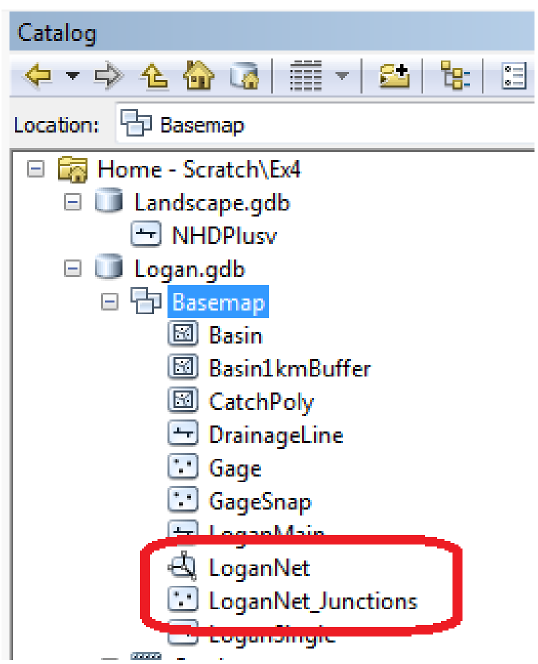
Select the features **DrainageLine** and **GageSnap**. These will be used to create a Geometric Network. Click Next.



At the prompt to Select roles for the network feature class switch the role under Sources and Sinks for GageSnap to Yes. This will be used as a Sink for the network. This is a location that receives flow. Click Next.

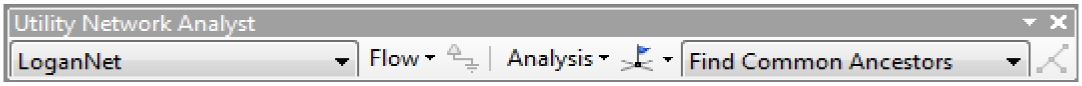


Do not add any weights. At the prompt about weights, just click Next. Click Finish at the summary prompt. The result is a Geometric Network LoganNet that can be used to perform network operations

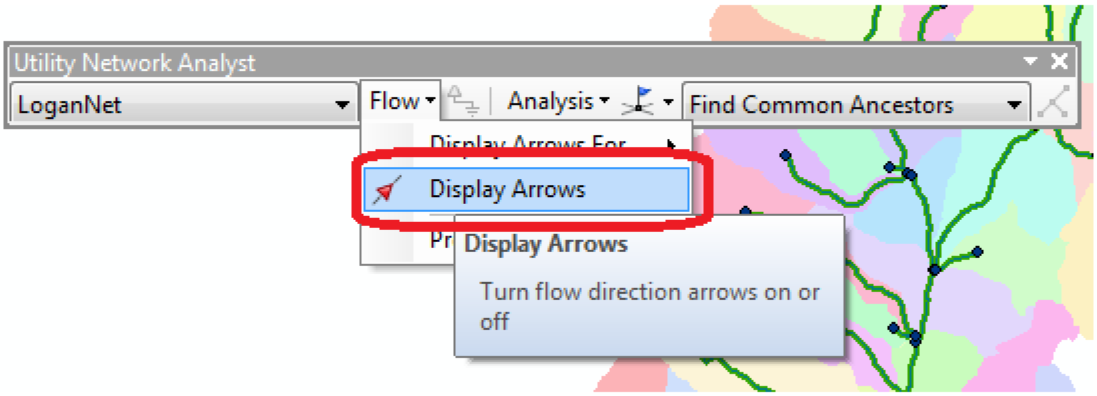


Note that multiple instances of GageSnap and DrainageLine may have been added to your display. Remove the extras to avoid confusion.

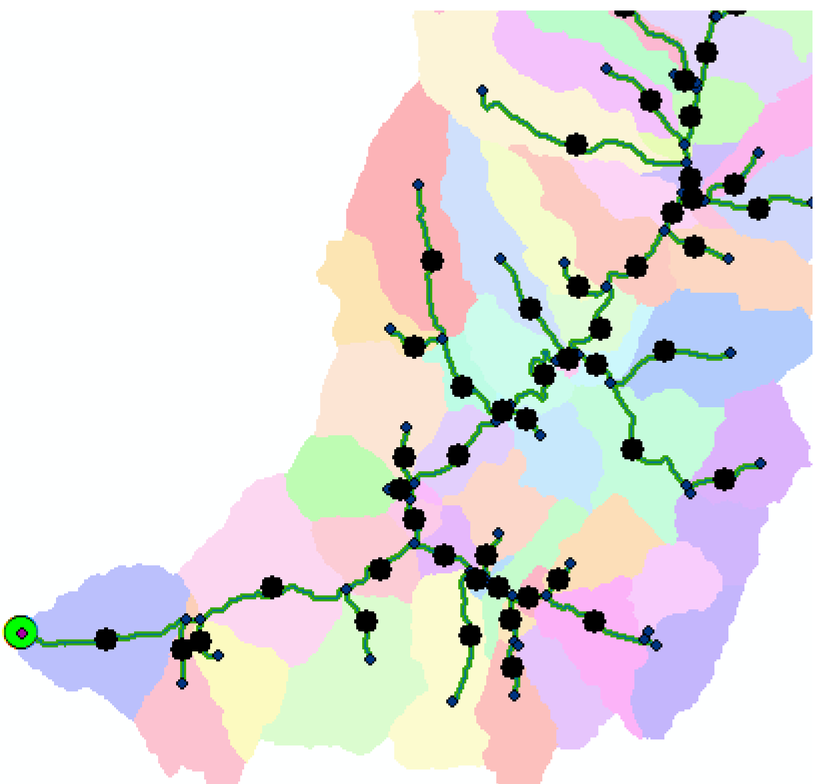
Select **Customize → Toolbars → Utility Network Analyst** from the main menu to activate the Utility Network Analyst toolbar



Click on **Flow → Display Arrows** on the Utility Network Toolbar

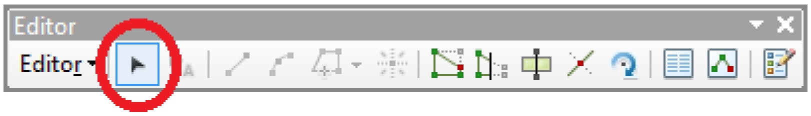


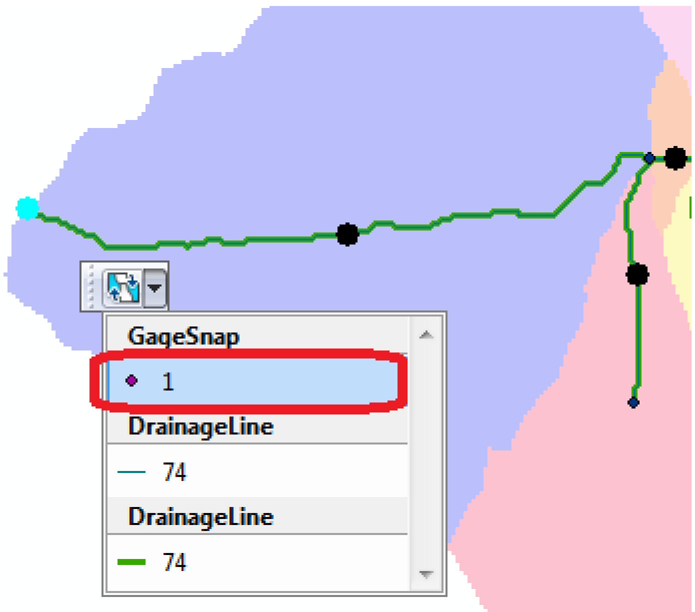
The result is a set of black dots on each network link. These indicate that flow direction for the network is not assigned.



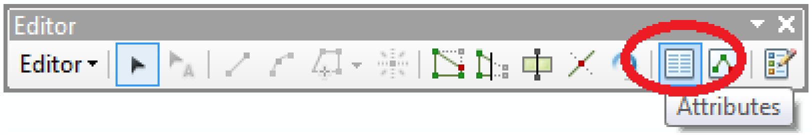
To assign network flow direction the Outlet needs to have a property called AncillaryRole set to be the encoding for Sink.

Open the Editor toolbar and select Start Editing. Select layer GageSnap if prompted and click Continue if there is a warning. Use the Editor Edit Tool to select the point at the outlet in the GageSnap Feature Class (There is only one point) and select it in the dropdown that appears

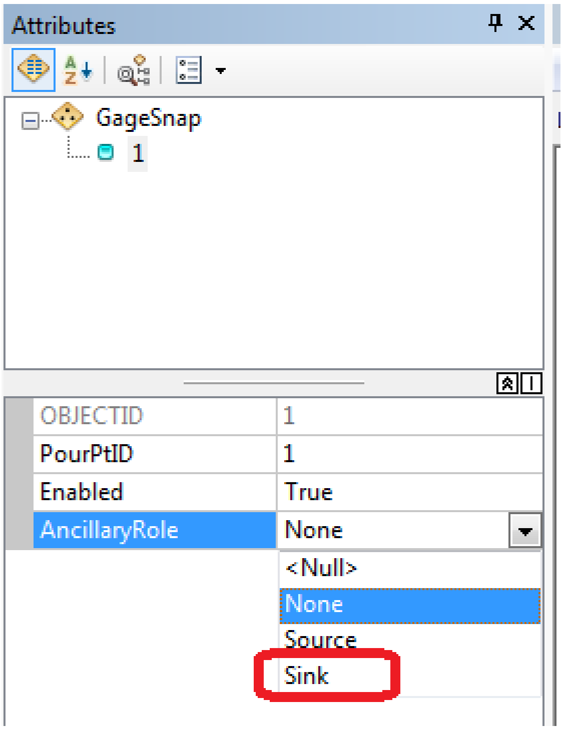




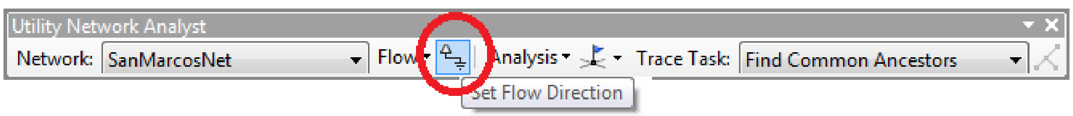
Click on the Attributes button on the Editor Toolbar to open the attributes display panel.



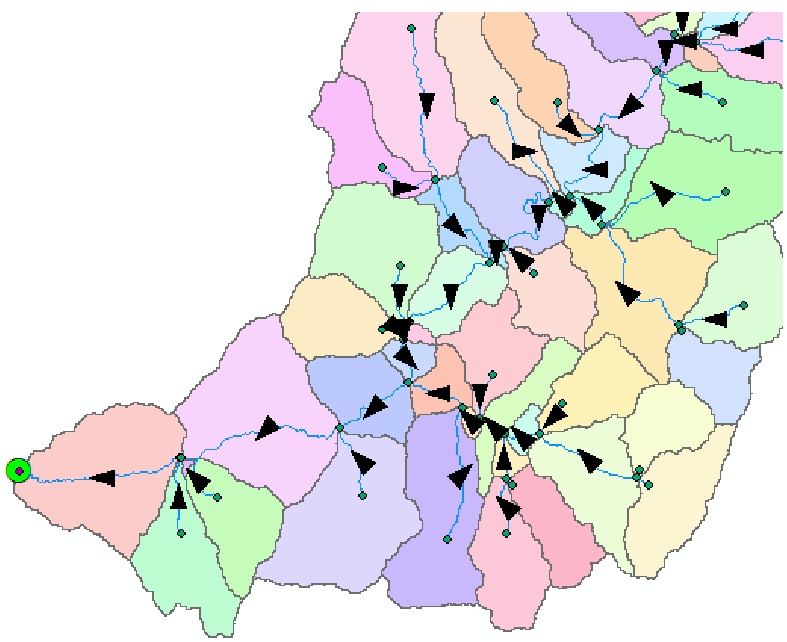
The panel should show that the AncillaryRole for this point is "None". Change it to Sink.



Click on the Set Flow Direction Tool on the Utility Network Analysts toolbar.

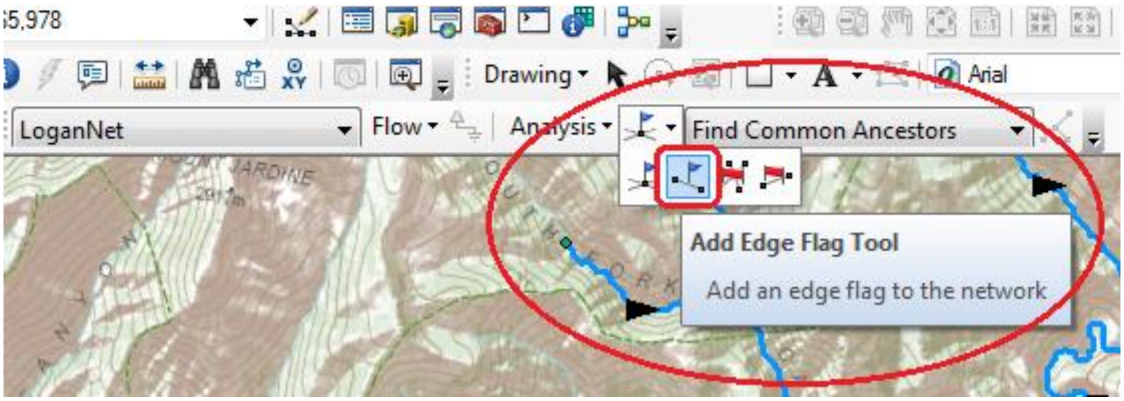


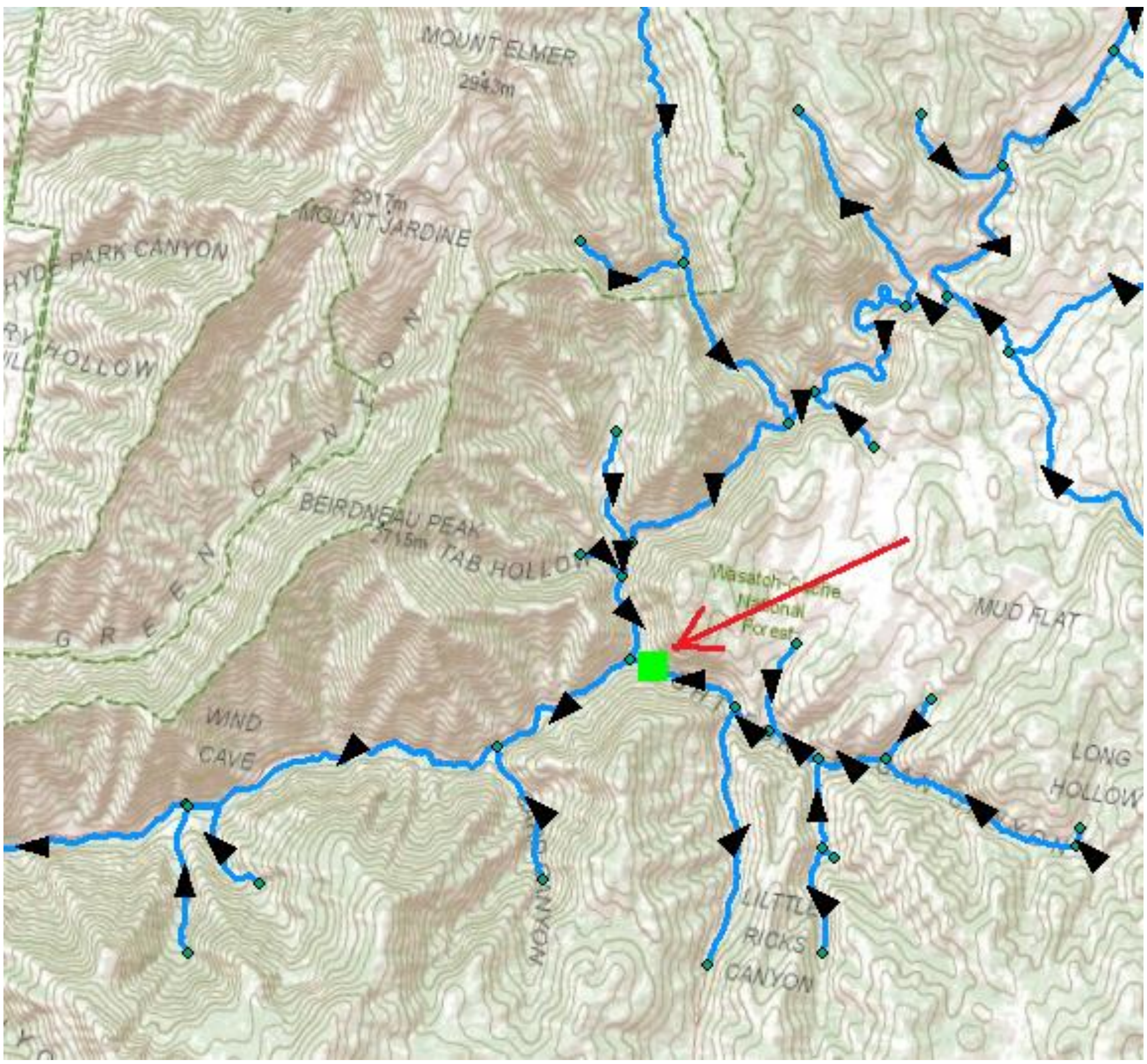
You should see the black dots switch to arrows indicating that Flow in the network is now set towards the designated Sink at the outlet. This network is now ready for Analysis. Stop Editing, saving edits.



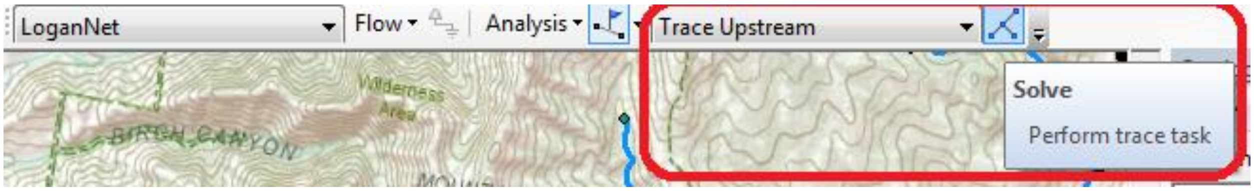
2. Analysis using a Geometric Network

Zoom to a tributary of interest, say right hand fork, just up Logan Canyon and place an edge flag near the junction with the main stem using the Utility Network Analyst Add Edge Flag Tool.

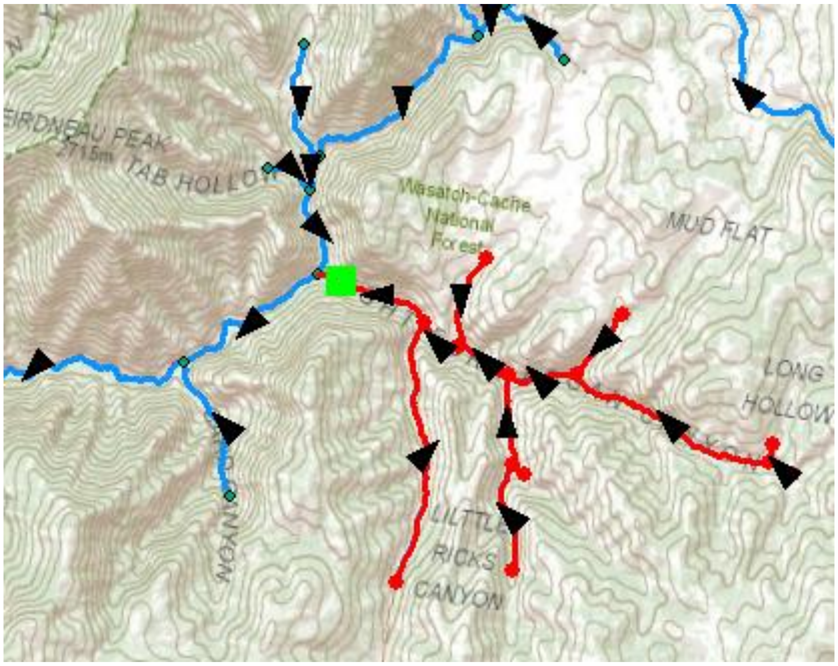




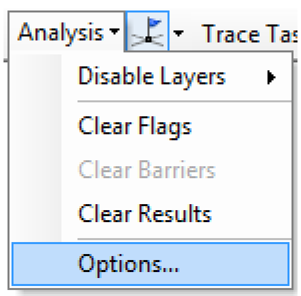
Set the Trace Task to Trace Upstream and press Solve.



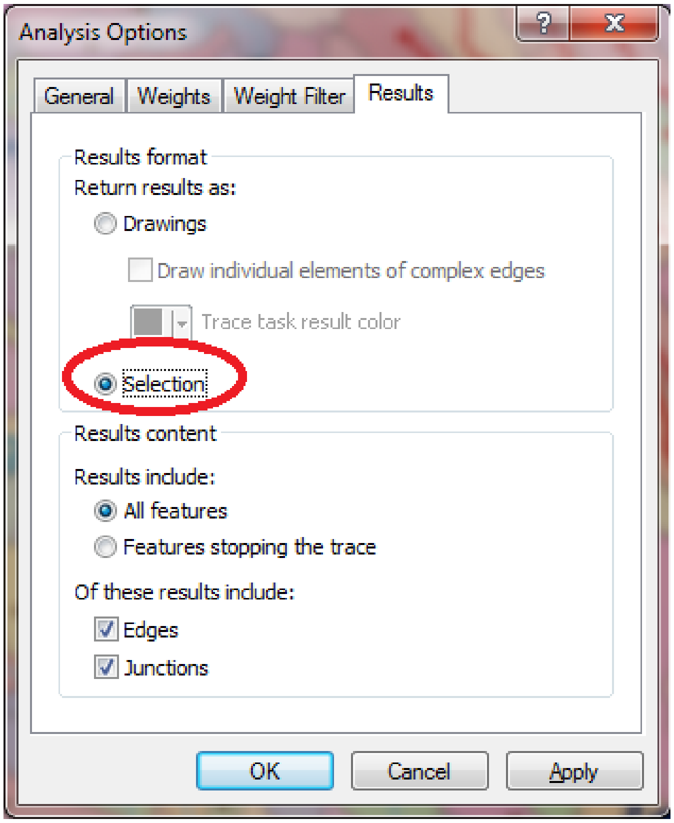
The result is a highlighting of the link that has the edge flag and all links upstream.

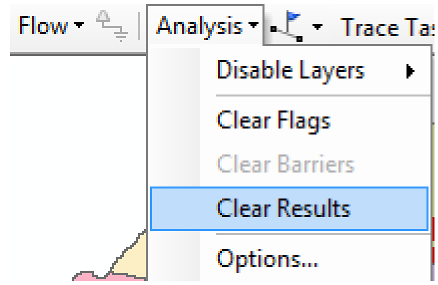


Select Analysis → Options

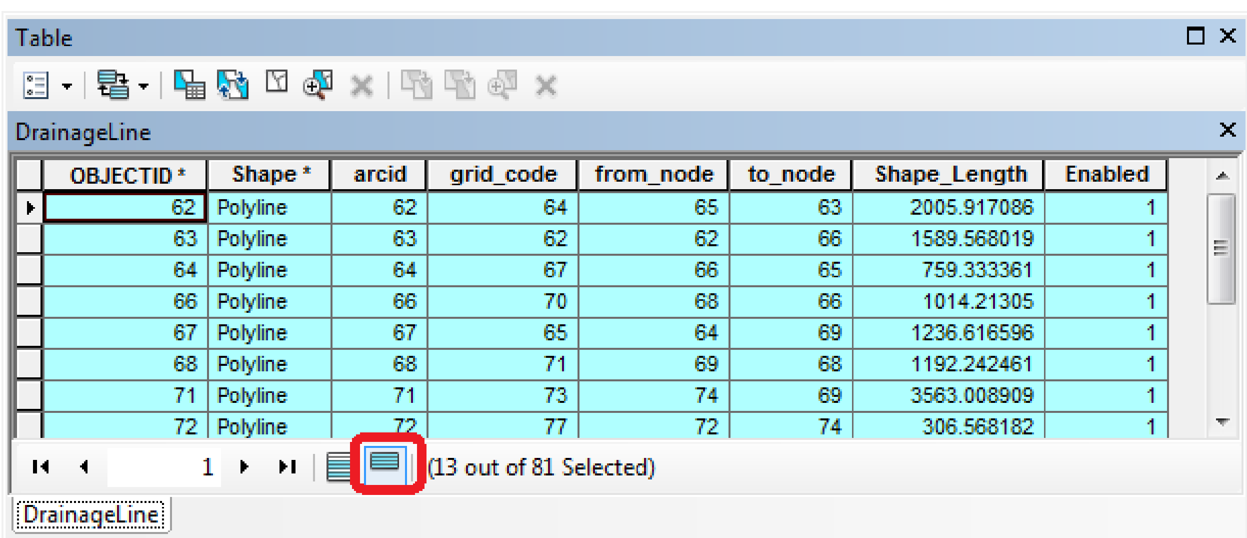


Switch the Results format to Selection. Select Analysis Clear Results and run the trace again.



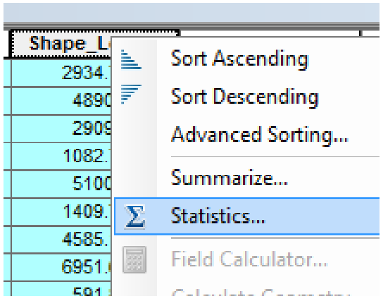


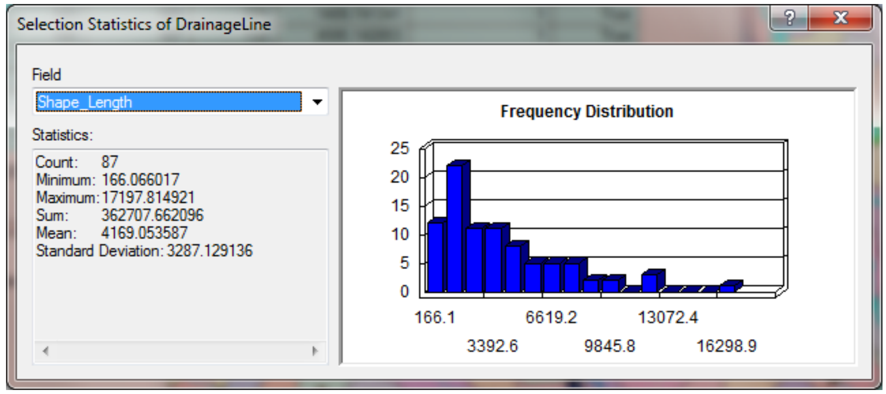
Now the upstream features are selected. Open the Drainage Line feature class attribute table and show selected records



OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	Enabled
62	Polyline	62	64	65	63	2005.917086	1
63	Polyline	63	62	62	66	1589.568019	1
64	Polyline	64	67	66	65	759.333361	1
66	Polyline	66	70	68	66	1014.21305	1
67	Polyline	67	65	64	69	1236.616596	1
68	Polyline	68	71	69	68	1192.242461	1
71	Polyline	71	73	74	69	3563.008909	1
72	Polyline	72	77	72	74	306.568182	1

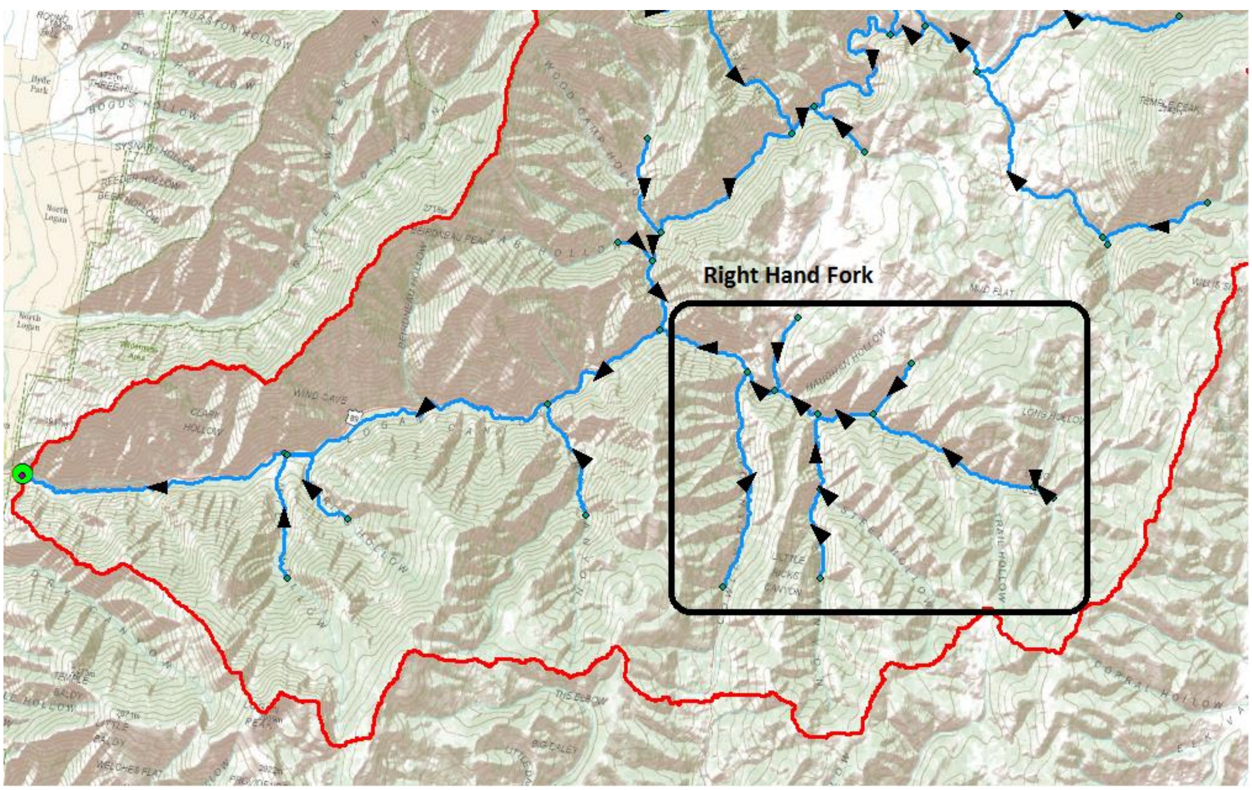
Right click on column header **Shape_Length → Statistics**

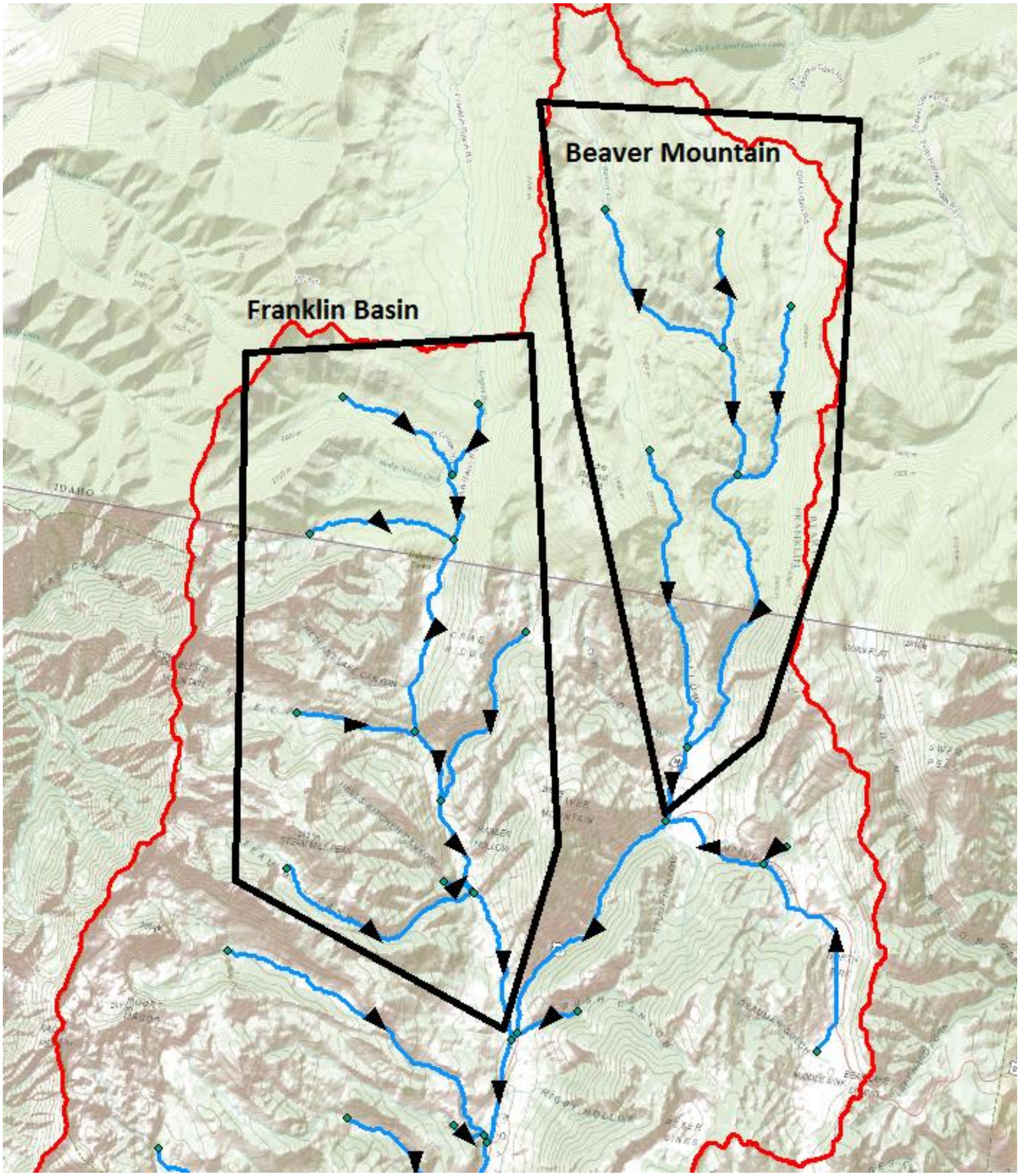




Record the total length (sum) and number of stream links in the Logan River Right Hand Fork. Switch the Trace Task to **Trace Downstream** and press **Solve** again. Notice how the selected stream links switch to those downstream from the flag. Select **Clear Selection** and **Analysis Clear Flags** to remove the trace results. Three tributaries of interest in the Logan River Watershed are indicated:

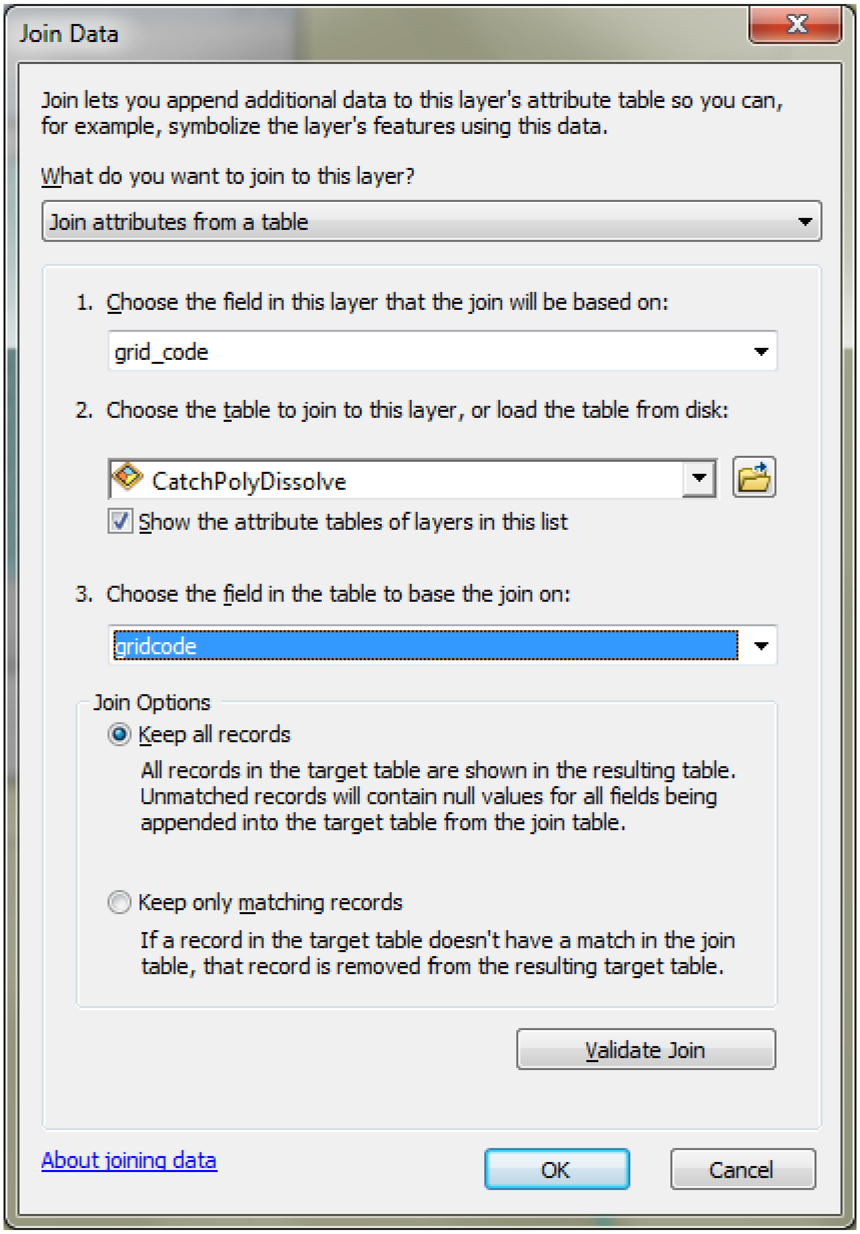
- Right Hand Fork
- Franklin Basin
- Beaver Mountain





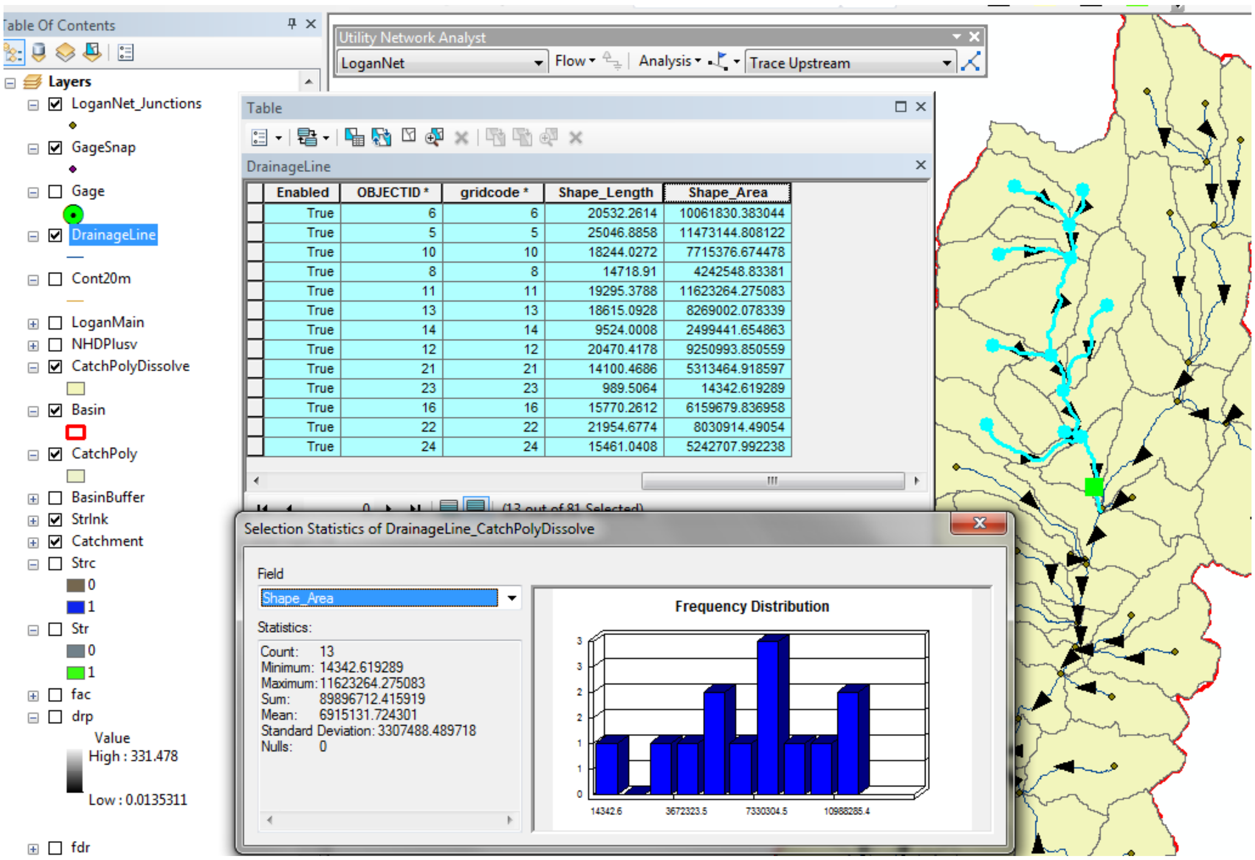
Use Flags and the Trace tool to determine the total length of streams in each of these tributaries. Also determine the distance from the junction of these tributaries with the main stem downstream to the outlet.

Join the CatchPolyDissolve attribute table to the DrainageLine table.

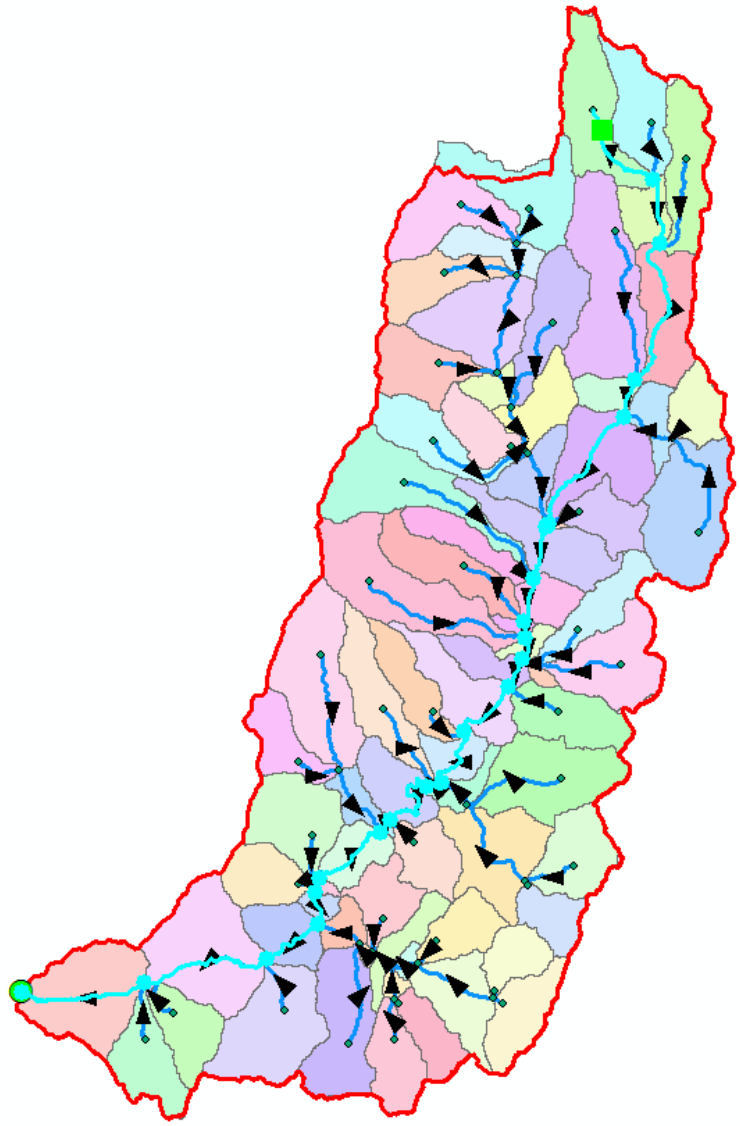


This provides access to the area draining directly to each stream link. Use Trace Upstream to select all the links in a tributary and evaluate the total area upstream of each using **Shape_Area → Statistics.**

For example based on a Trace Upstream from the Flag at the Franklin Basin Tributary the area draining Franklin Basin is determined to be 89.897 km^2 in the following figure.



You can also, by placing a flag at an upstream link determine the flow path (and its length) from any distant link to the outlet. Evaluate the length of the longest flow path by choosing a link that appears to have the longest flow path (a bit of trial and error may be necessary). Prepare a layout that illustrates the longest flow path in the Logan River basin.



To turn in: A table giving for each of the tributaries identified above the number of upstream stream links, the total length of upstream stream links, the total upstream area, drainage density (total length/total area), number of downstream links along path to outlet, distance to outlet along the streams.

A layout illustrating the longest flow path in the Logan River Basin and giving the length in km.

OK. You are done!

Summary of Items to turn in.

1. *Report the main stream length, total stream length, basin area and drainage density for the Logan River Basin as determined from NHDPlus flowlines.*

2. *Prepare a layout showing the topography, Basin Outline, NHDPlusv streams and Logan River Main stem stream for the Logan River Basin. Include a scale bar and North arrow and appropriate title, labeling and legend so that the map is self-describing.*
3. *The number of columns and rows, grid cell size, minimum and maximum elevation values in the Logan DEM.*
4. *A layout showing the deepest sink in the Logan River basin. Report the depth of the deepest sink as determined by fil-dem.*
5. *Make a screen capture of the attribute table of fdr and give an interpretation for the values in the Value field using a sketch.*
6. *Report the drainage area of the Logan River basin in both number of 30.92 m grid cells and km^2 as estimated by flow accumulation. Report the area of the Logan River basin in km^2 as calculated by the arcgis.com watershed function. Report the area of the Logan River basin in km^2 as reported by the USGS for the Logan River stream site. Discuss reasons for any differences.*
7. *Describe (with simple illustrations) the relationship between StrLnk, DrainageLine, Catchment and CatchPoly attribute and grid values. What is the unique identifier in each that allows them to be relationally associated?*
8. *A table giving for each of the tributaries identified above the number of upstream stream links, the total length of upstream stream links, the total upstream area, drainage density (total length/total area), number of downstream links along path to outlet, distance to outlet along the streams.*
9. *A layout illustrating the longest flow path in the Logan River Basin and giving the length in km.*