Geographic Information Systems in Water Resources – Exercise 1

CUAHSI Virtual University, 2019
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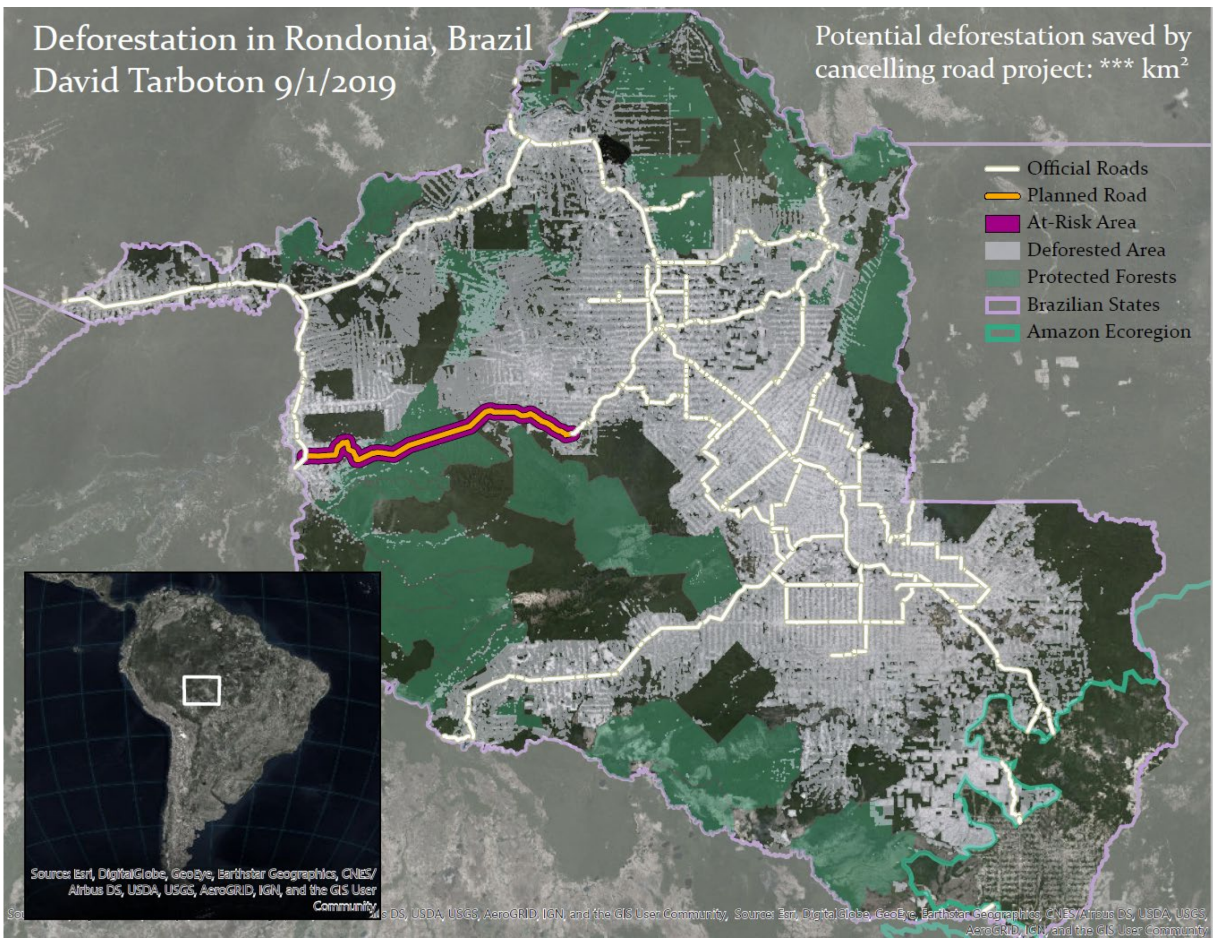
Part 1. Refresher on working with ArcGIS Pro

Objective. The objective of this part of the exercise is for us all to get to the same level in working with ArcGIS.

Work through the getting Started With ArcGIS Pro Lesson at https://learn.arcgis.com/en/projects/get-started-with-arcgis-pro/. Even if you are an expert in ArcGIS, this lesson serves as a useful refresher. (It did for me). If you are an expert, it should not take too long. If you are rusty or still learning, it will take longer, but establishes an important foundation.

At the end you should have a map layout similar to the below. Fill in the value you calculate in km^2 in the label on your map where I have ***.



To Turn in: A PDF document for part 1 with the map layout generated at the end of this exercise depicting the impact of deforestation in this part of Brazil and the potential reduction in deforestation by canceling the road project.

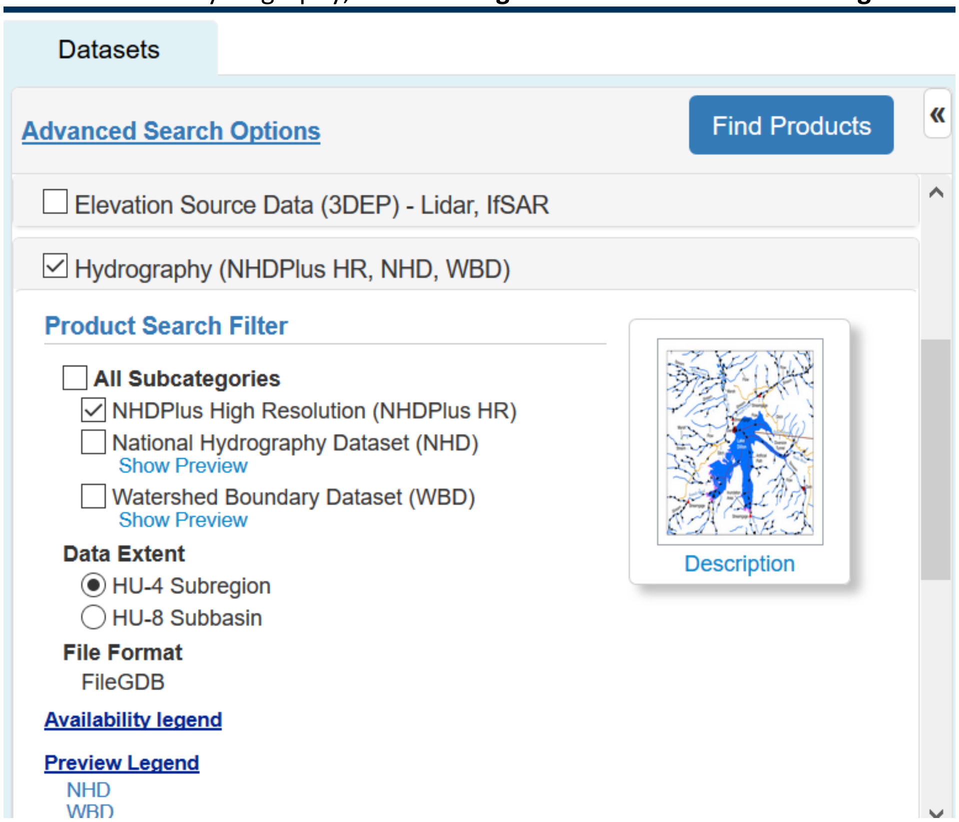
Part 2. Building a Watershed Base Map

Objective. This exercise is intended for you to build a base data set of geographic information for a watershed using the Little Bear – Logan watershed in Logan, Utah as an example. The base dataset comprises watershed boundaries and streams from the National Hydrography Dataset Plus (NHDPlus). In addition, you will create a point Feature Class of stream gage sites by inputting latitude and longitude values for the gages in an Excel table that is added to ArcMap and the geodatabase.

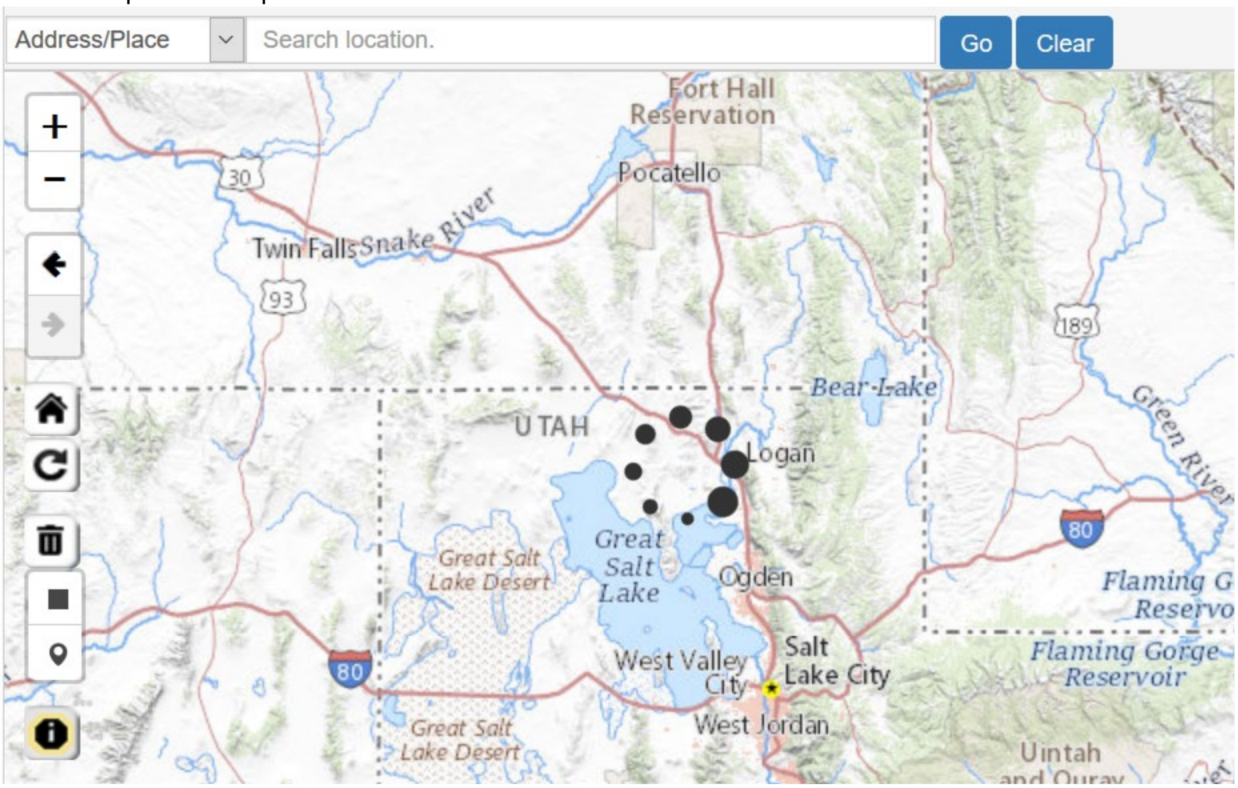
Getting Started

We'll begin by getting the NHDPlus data for the region we are interested in from the National Map.

1. Open the **National Map Viewer** https://viewer.nationalmap.gov/basic/.
2. At the left click Hydrography, **NHDPlus High Resolution** and **HU-4 subregion**.

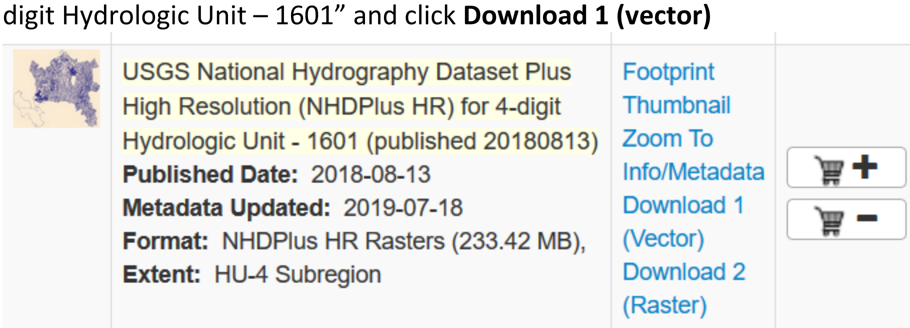


3. Zoom and pan the map to show northern Utah



4. Click **Find Products** in the Datasets tab on the left.

5. Find the result “USGS National Hydrography Dataset Plus High Resolution (NHDPlus HR) for 4-digit Hydrologic Unit – 1601” and click **Download 1 (vector)**



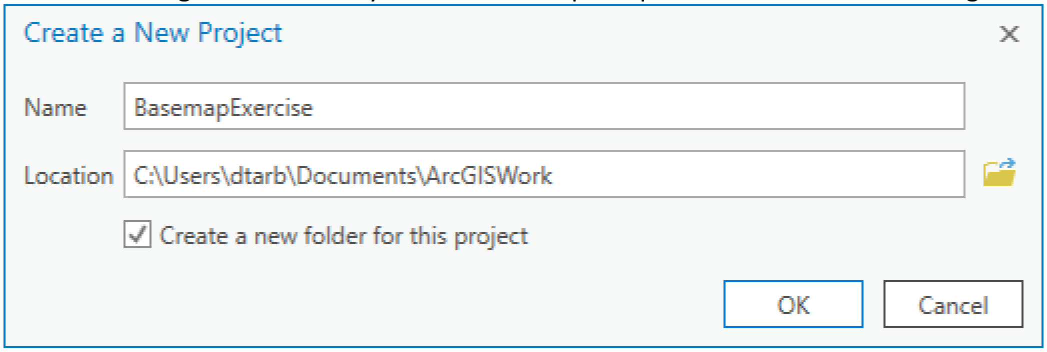
6. Save the file **NHDPLUS_H_1601_HU4_GDB.zip**.

ArcGIS Pro Project

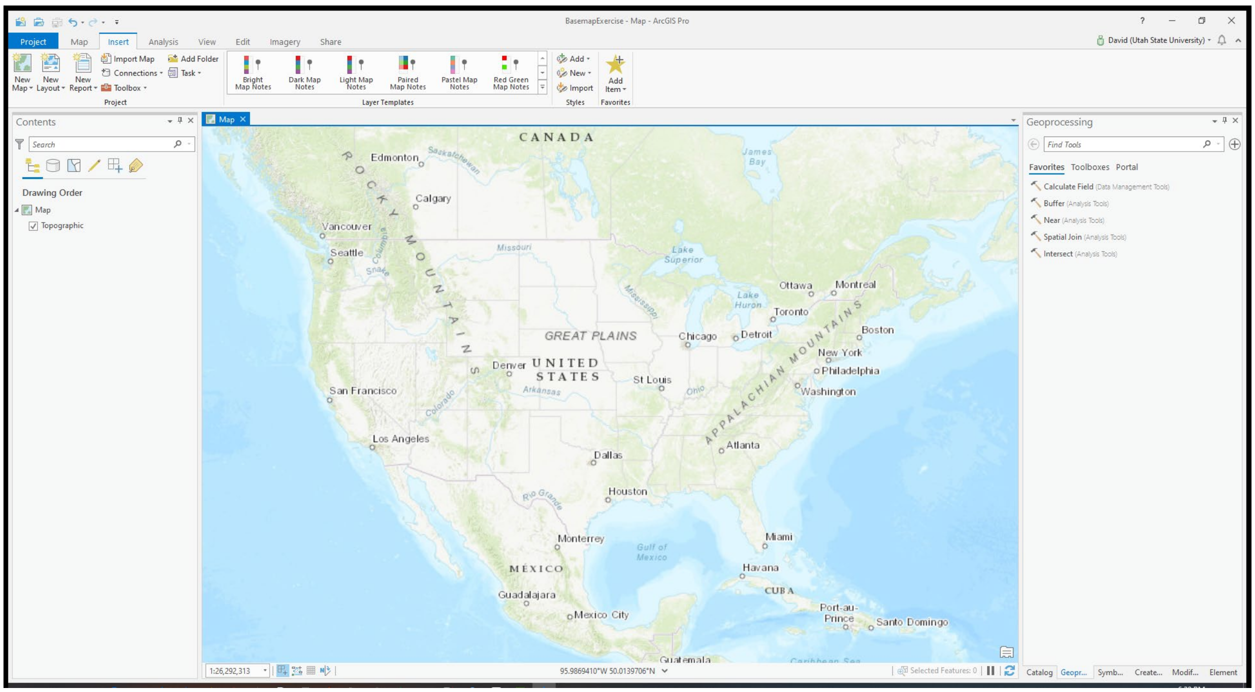
In this section we establish an ArcGIS Pro Map Project for the exercise, create a feature dataset and extract the watershed boundary feature class for the watershed of interest into this feature dataset. We also set the coordinate system to UTM Zone 12.

1. Open ArcGIS Pro and create a new **Blank Map Project**. I have called this **BasemapExercise**. It’s a good idea to just use one-word titles for projects because this is the name of the Geodatabase

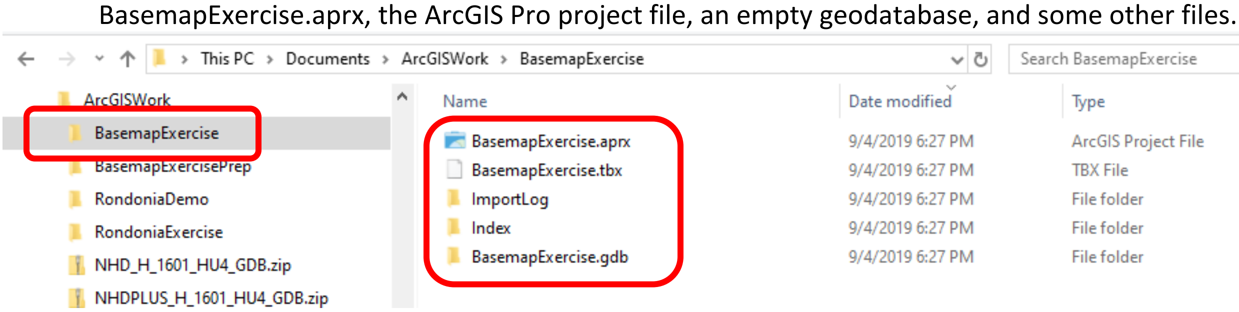
that you create within the project. In general, ArcGIS likes to have single word titles as the names for things or otherwise you have to interpret spaces and that can be ambiguous.



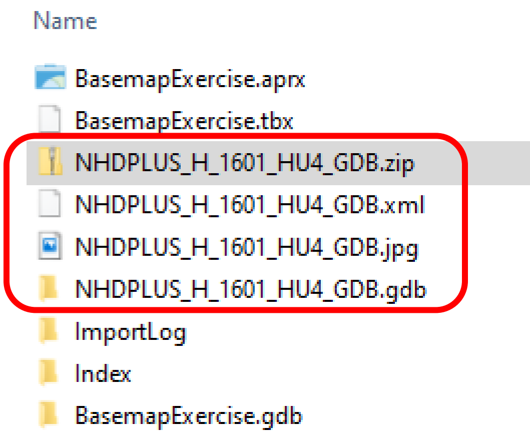
You should see ArcGIS open with a big topographic map of the United States as below



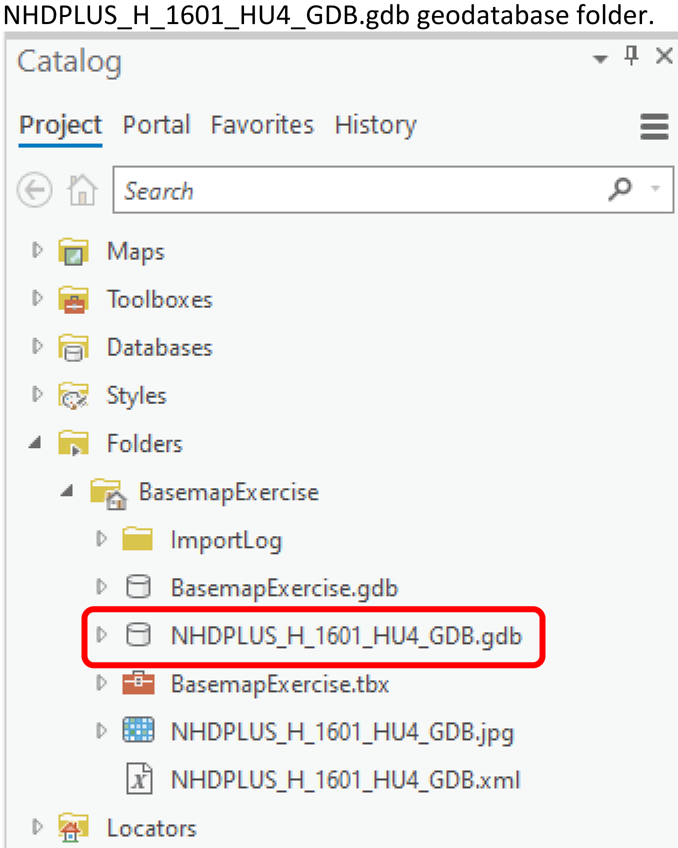
You should also find that a folder BasemapExercise has been created in the folder where you set the project to be saved. This will hold all the files for your work on this project. These include BasemapExercise.aprx, the ArcGIS Pro project file, an empty geodatabase, and some other files.



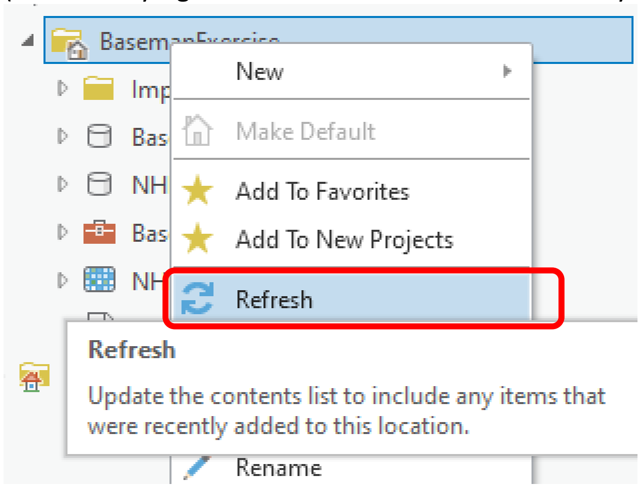
2. Move the file you downloaded (NHDPLUS_H_1601_HU4_GDB.zip) to this folder and **unzip** it.



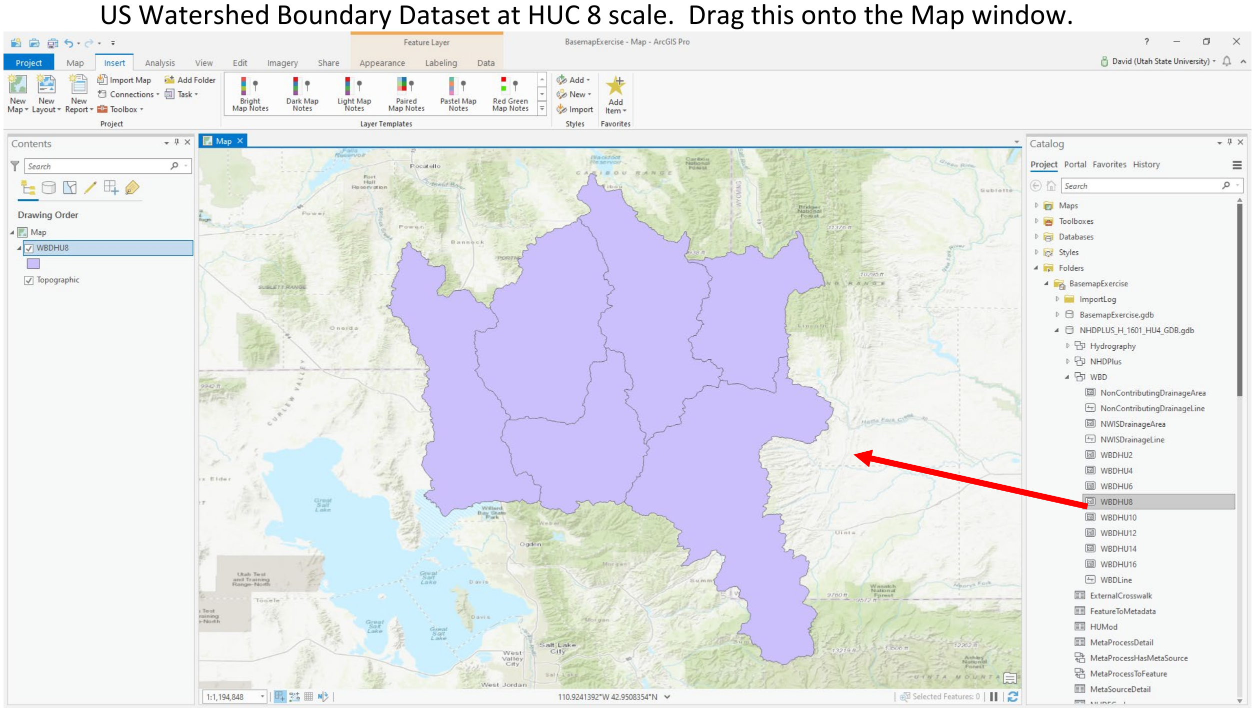
3. In ArcGIS Pro in the **Catalog** pane on the right expand Folders -> BasemapExercise to see the NHDPLUS_H_1601_HU4_GDB.gdb geodatabase folder.



(If necessary right click on the folder to Refresh – if you do not immediately see this folder.)



4. Expand the NHDPLUS_H_1601_HU4_GDB.gdb folder further intil you see **WBDHU8**. This is the US Watershed Boundary Dataset at HUC 8 scale. Drag this onto the Map window.

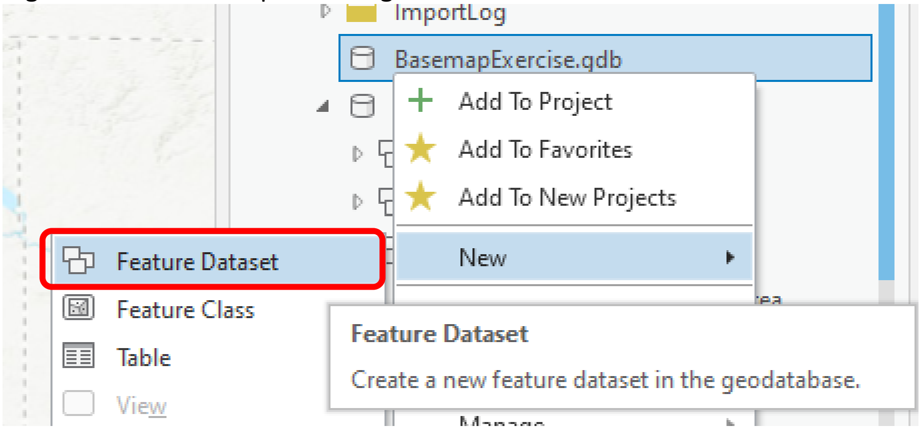


You should see the HUC 8 Watershed boundaries displayed.

5. Adjust the **Symbology** to have these just show the outline and thick green lines. (Click on the symbol in contents pane and change settings in the Symbology pane).

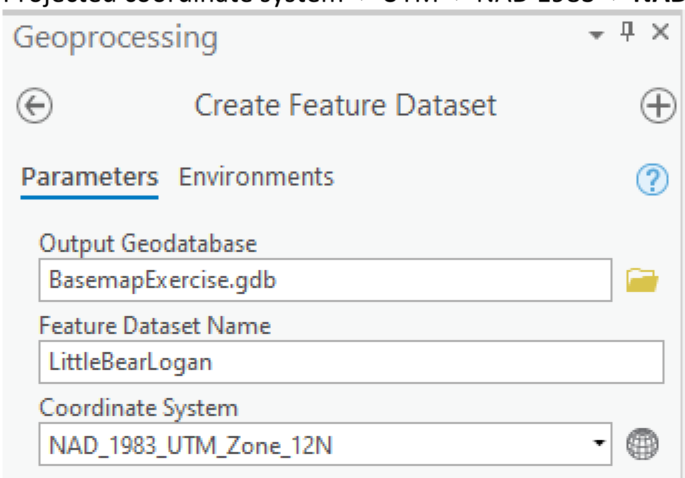
Now let's create a Feature Dataset in the BasemapExercise.gdb geodatabase to hold our basemap data. We will use a UTM Zone 12 coordinate system. **UTM zone 12** is the Universal Transverse Mercator coordinate system for this part of the world. If you examine the latitude and longitude coordinates at the bottom of the map, you will see that longitude is around 111W or -111°. UTM zones are numbered 1 to 60, each being 6 degrees wide from -180° to 180° longitude. If you work this out you find that UTM zone 12 is from -114° to -108°.

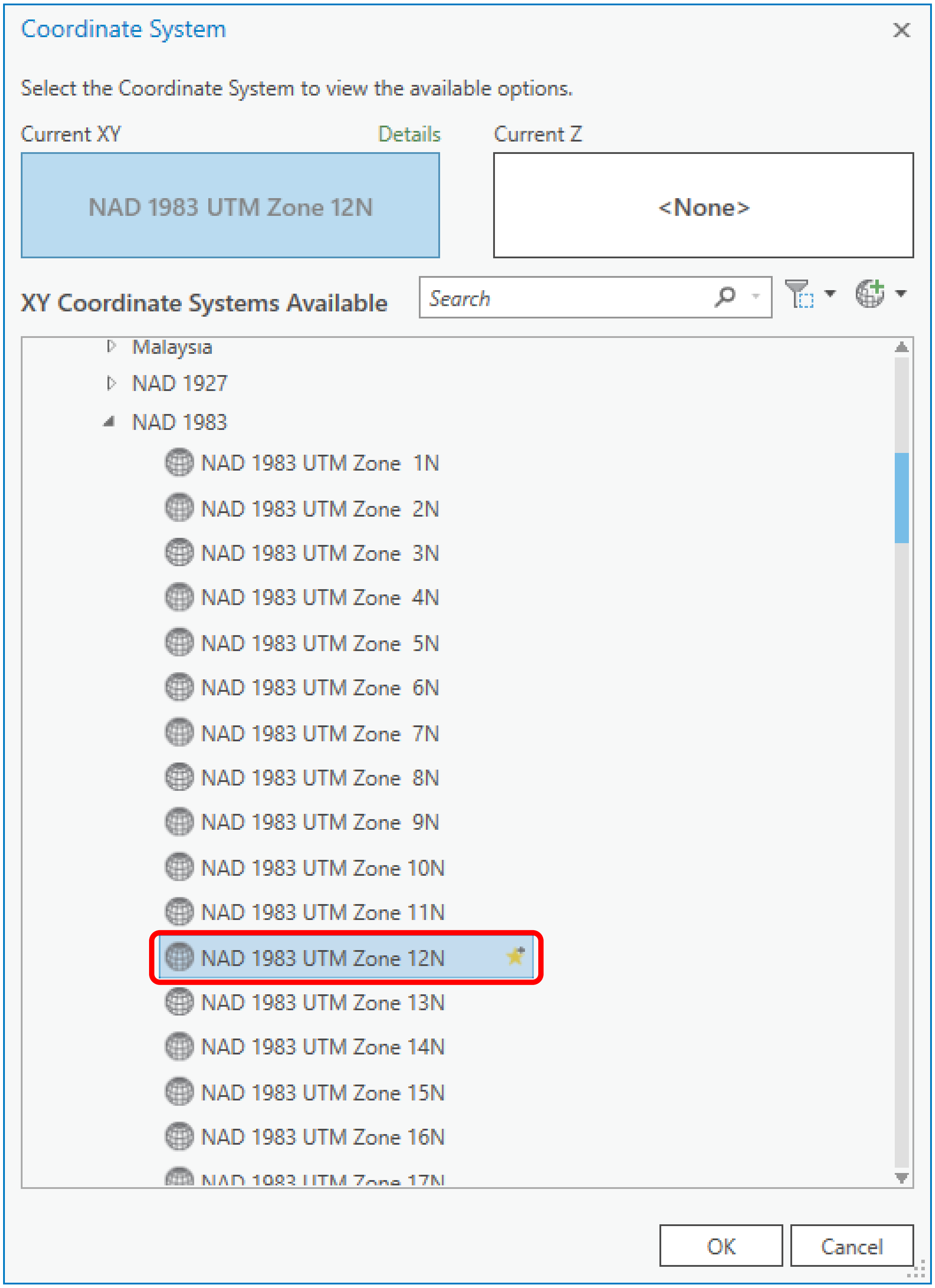
6. Right click on BasemapExercise.gdb and select **New -> Feature Dataset**.



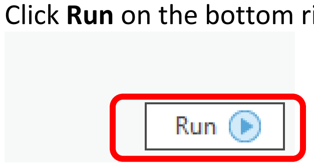
The Geoprocessing pane should open with the Create Feature Dataset tool.

7. Enter **LittleBearLogan** for the Feature Dataset Name and for Coordinate System choose Projected coordinate system -> UTM -> NAD 1983 -> **NAD 1983 UTM Zone 12N**.



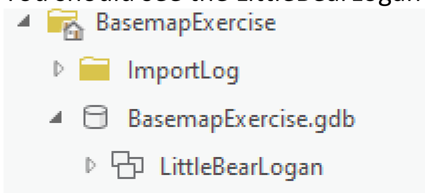


8. Click **Run** on the bottom right.

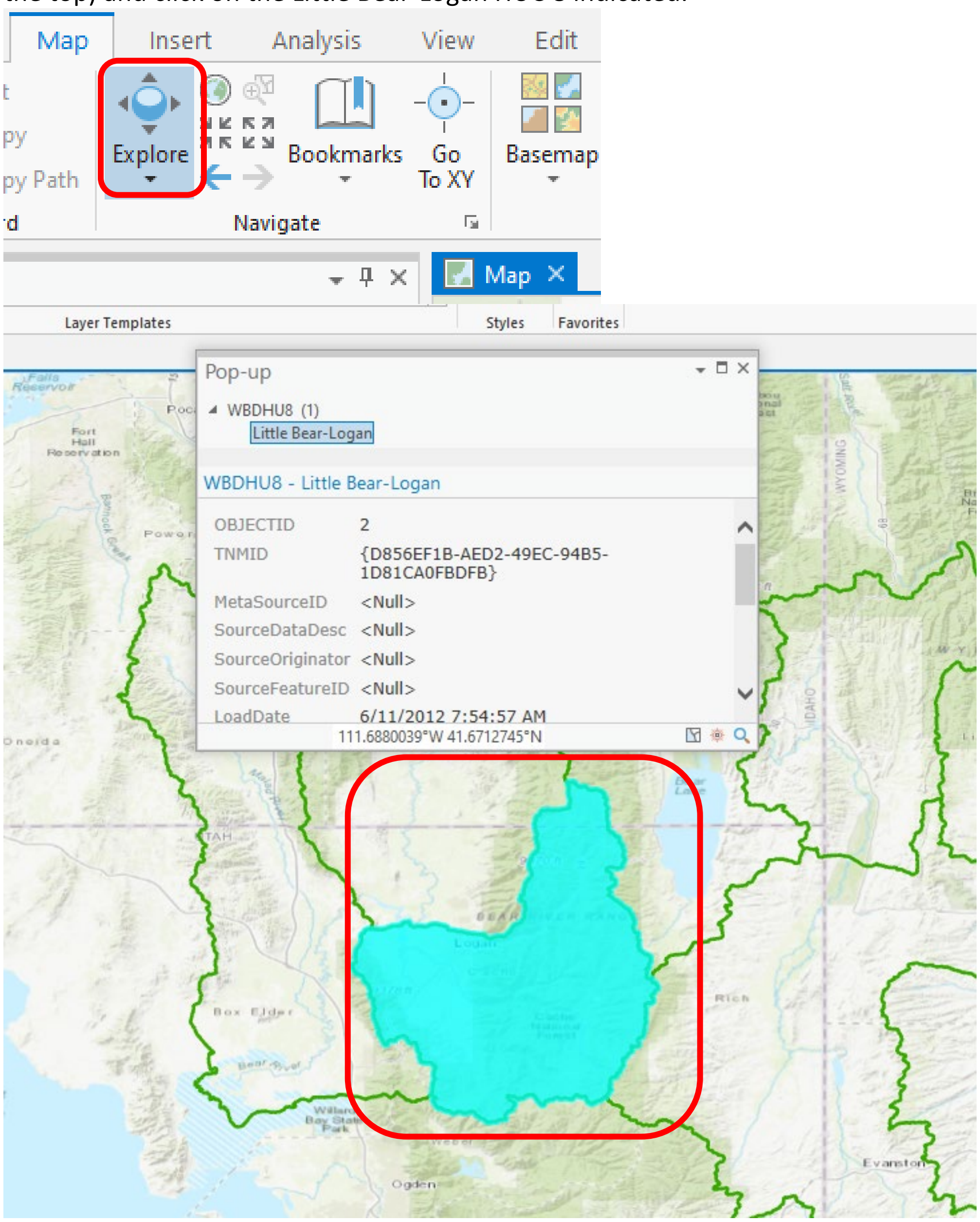


This runs the tool to create the Feature Dataset. One property of a feature dataset is that all the data it holds is in the same coordinate system. When we move data into this feature dataset, the UTM Zone 12 coordinate system will be inherited, i.e. the data will be converted (i.e. projected) to this coordinate system.

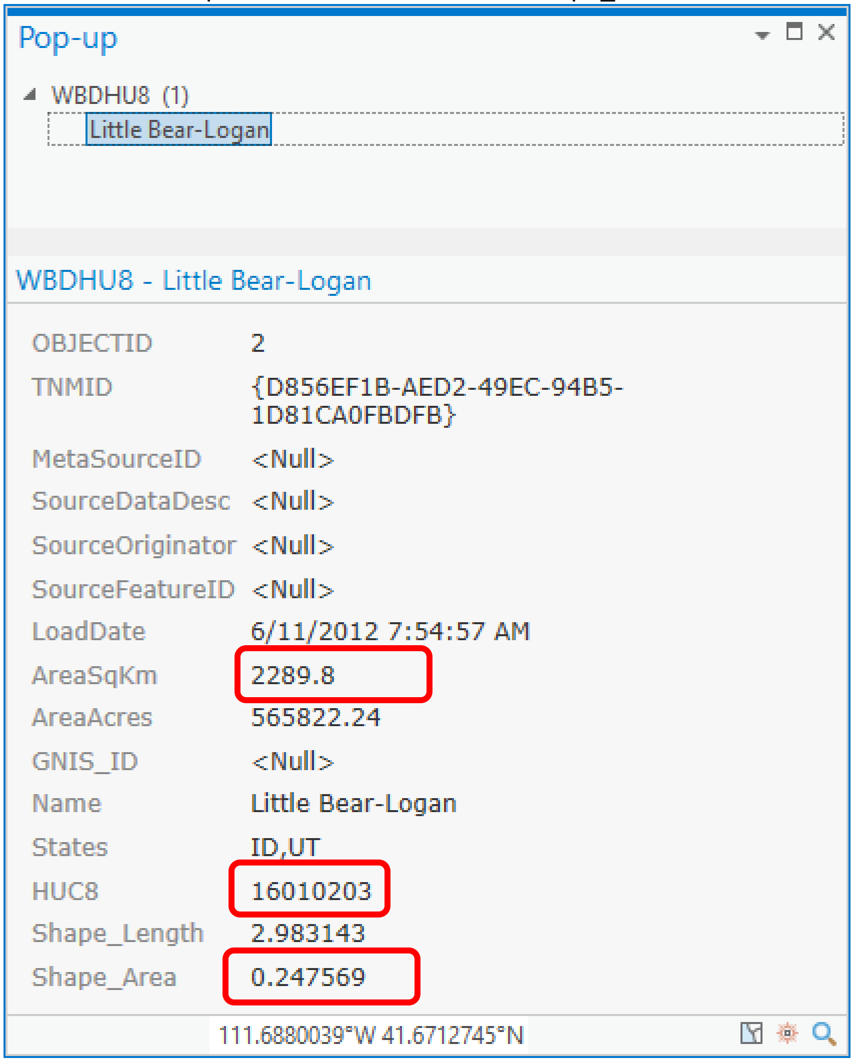
You should see the LittleBearLogan feature dataset in the catalog pane



9. Now in the map make sure the Explore tool is selected (you may need to select the Map tab at the top) and click on the Little Bear-Logan HUC 8 indicated.



The pop up that opens should show the attributes of this HUC 8. If you scroll down you see the attributes AreaSqKm with value 2289.8 and Shape_Area with value 0.248



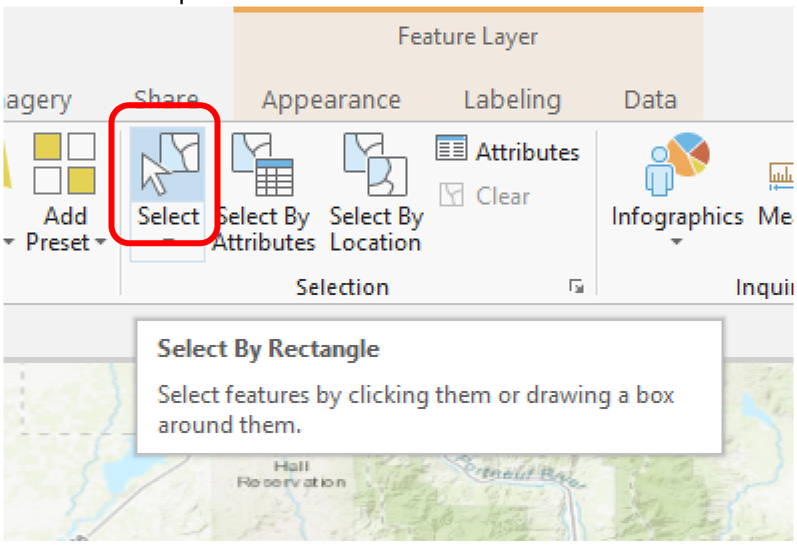
Shape_Area was computed by ArcGIS using the coordinate system of the geodatabase, which in this case is geographic coordinates (latitude and longitude). Area does not make a lot of sense here as the lengths N-S and E-W depend on latitude.

AreaSqKm was obtained from the data provider, and is believable.

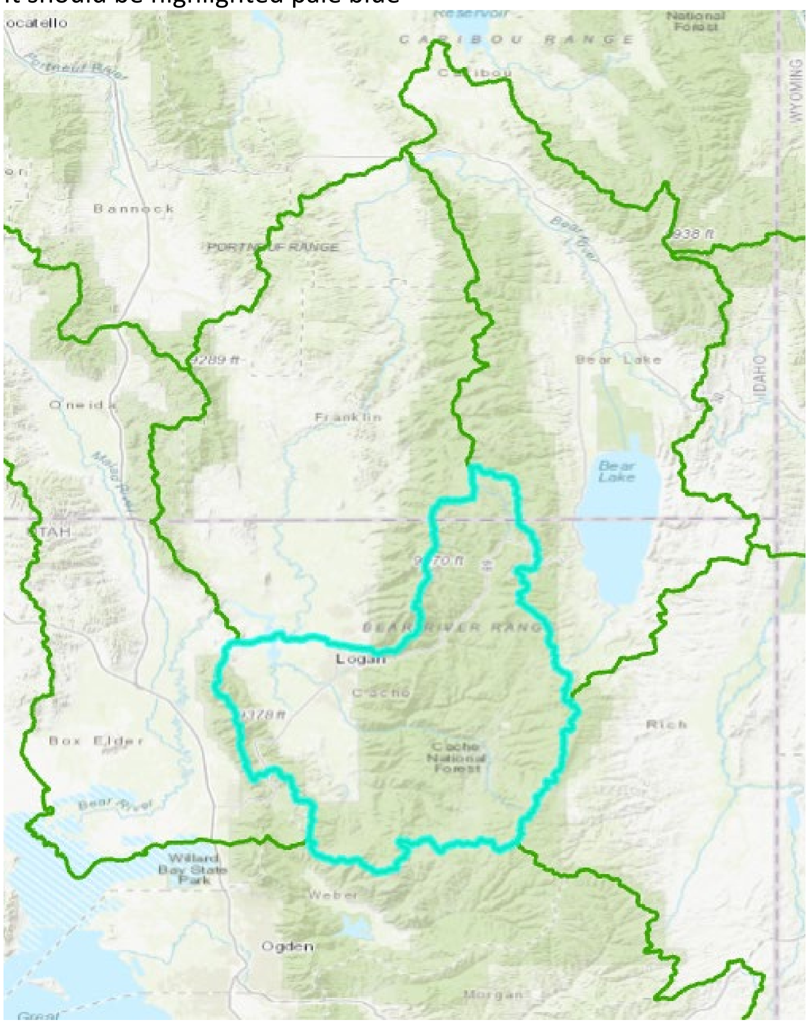
Be careful of this distinction.

Note also that the HUC8 code for this watershed is 16010203. This is the HUC8 identifier for the Little Bear-Logan subbasin. This area lies within Region 16, Subregion 01, Basin 02 and Subbasin 03 in the USGS drainage hierarchy, and is technically referred to as a **HUC8 subbasin**.

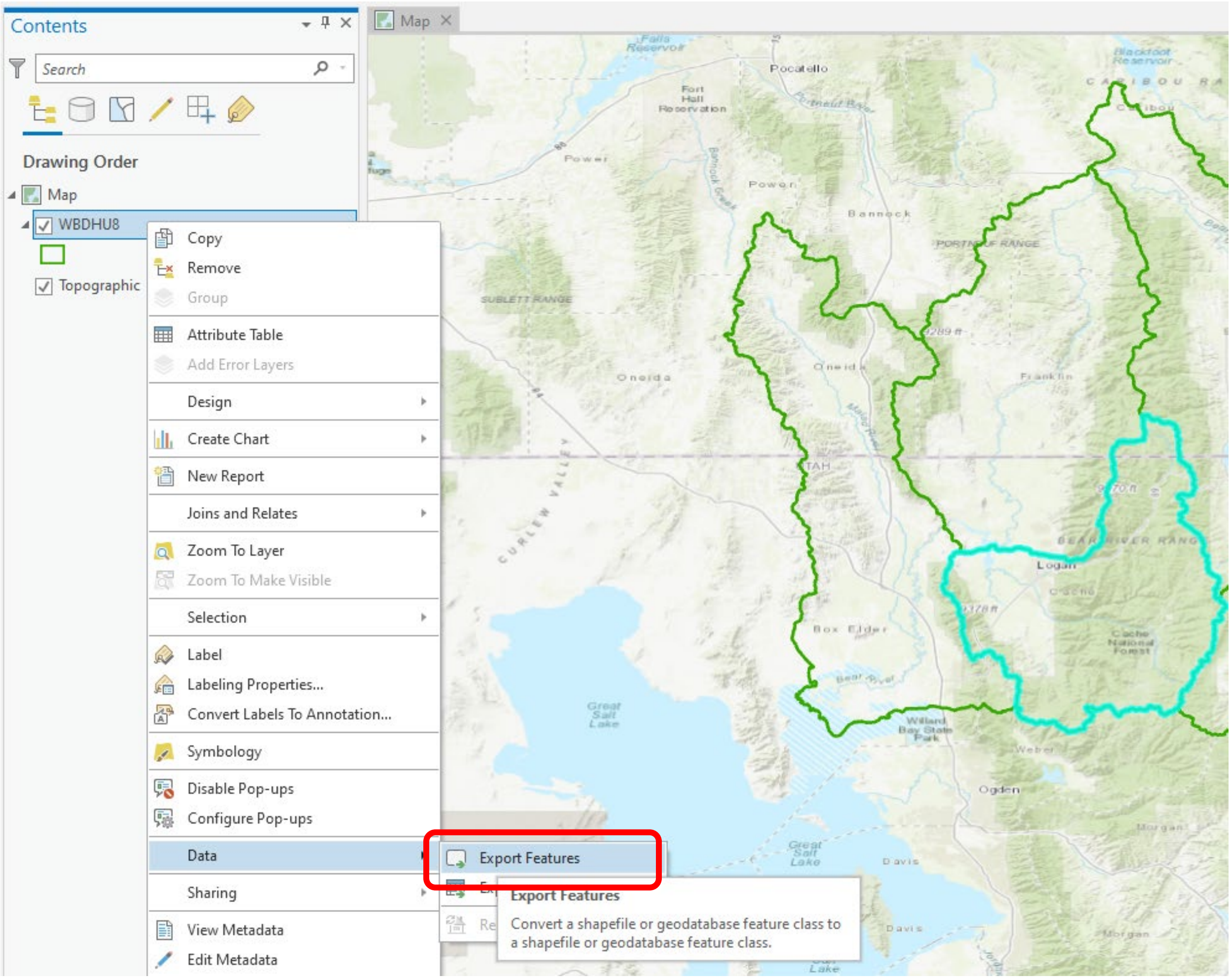
10. Now in the map window click the **Select** tool and select the Little Bear – Logan HUC 8.



It should be highlighted pale blue

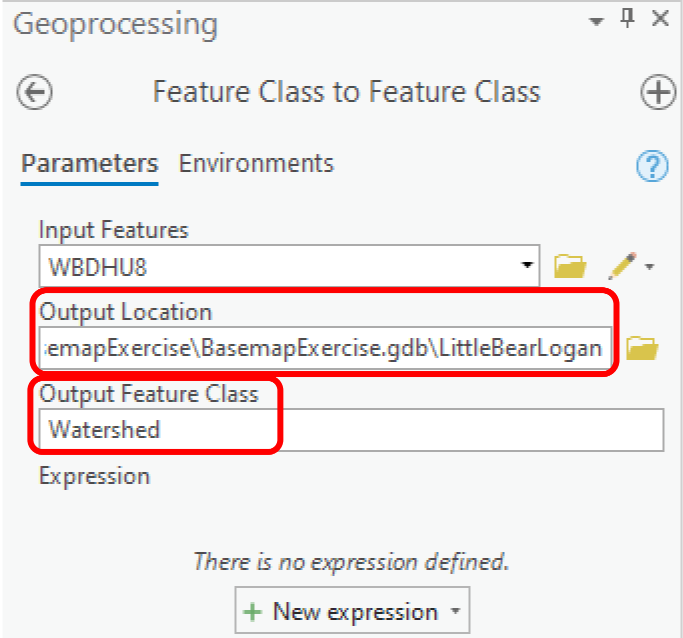


11. In Contents on the left, right click WBDHU8 -> Data -> **Export Features**.



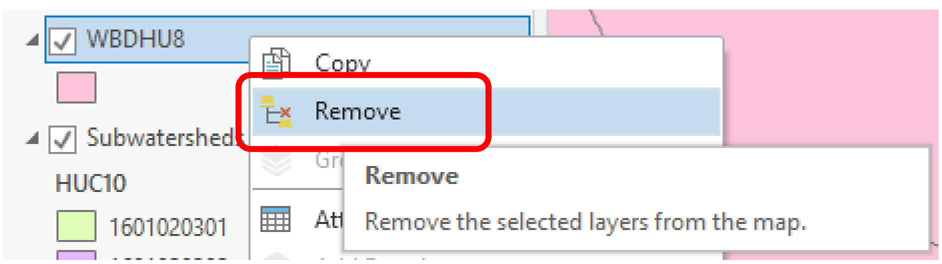
In the Geoprocessing pane on the right, the Feature Class to Feature Class tool should open.

12. Set Output Location to the **LittleBearLogan Feature dataset**. Pay attention. This is not the default. Name the output Feature Class Watershed. Click Run (bottom right)



The result should be a Feature Class "Watershed" added to the map and added to the LittleBearLogan feature dataset in the BasemapExercise.gdb geodatabase.

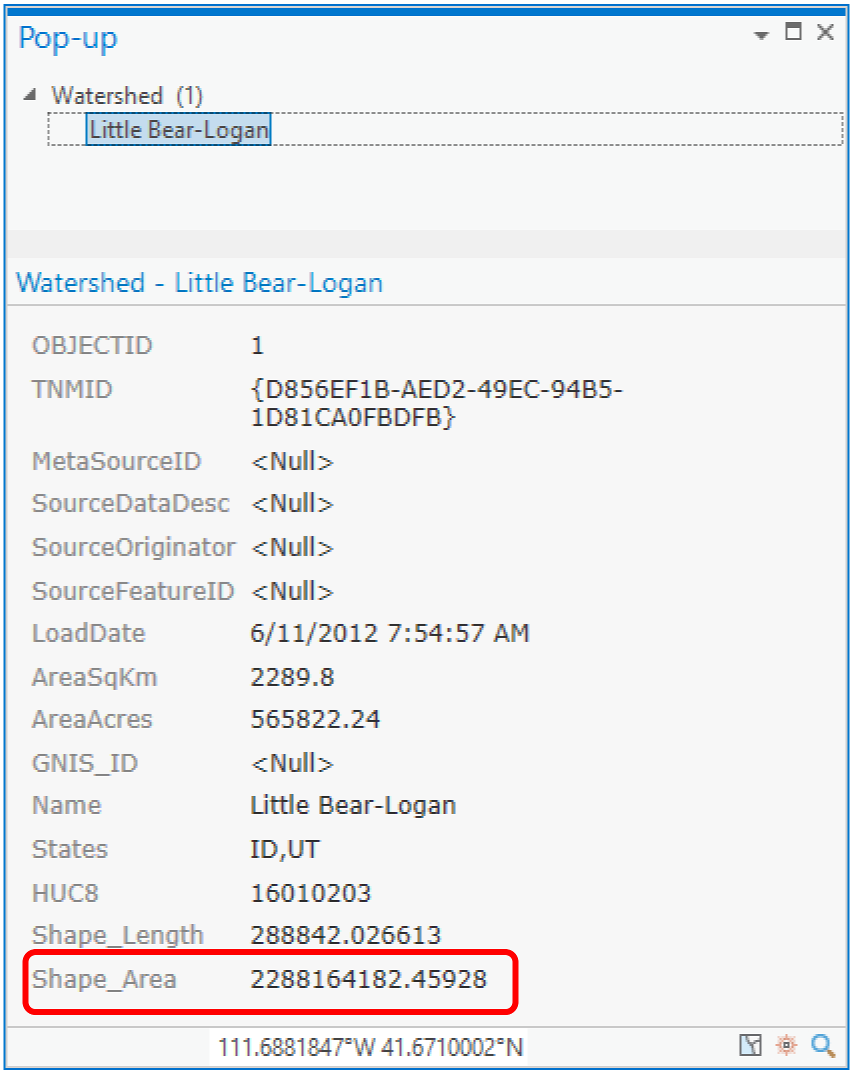
13. Clear selections and remove WBDHU8 from the map.



Note that in ArcGIS there is generally a distinction between Remove and Delete. Remove is a safe action that detaches a data set from a document. Delete is a less safe action, it actually deletes the object from disk.

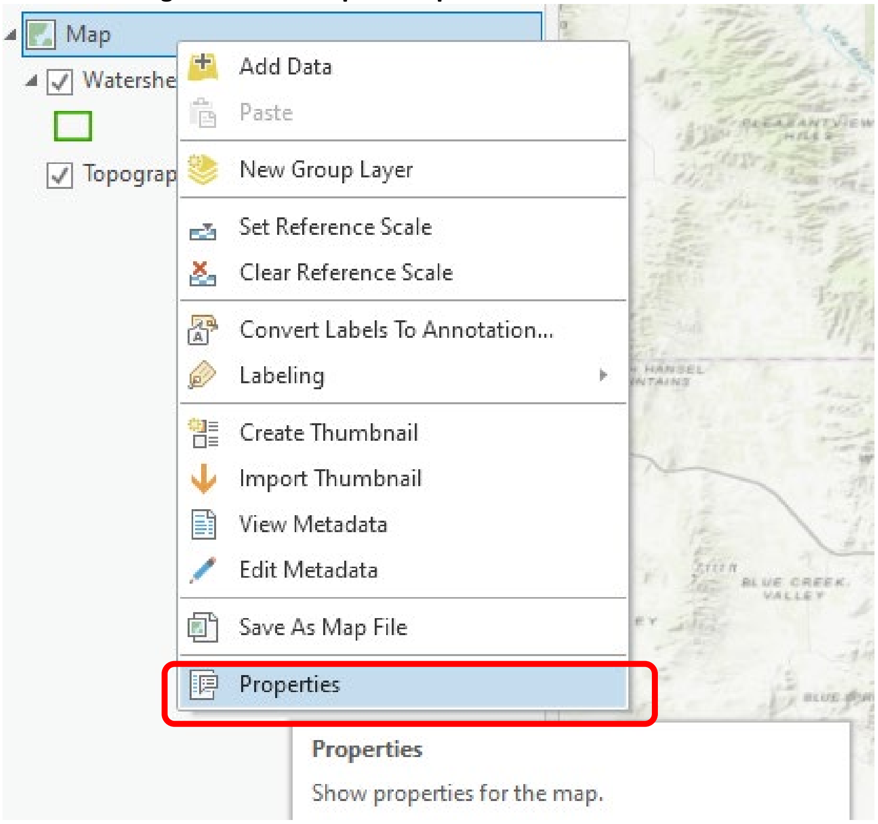
14. You should just see the outline of the single HUC8 watershed.

With the explore tool click on this Feature Class to see its attributes

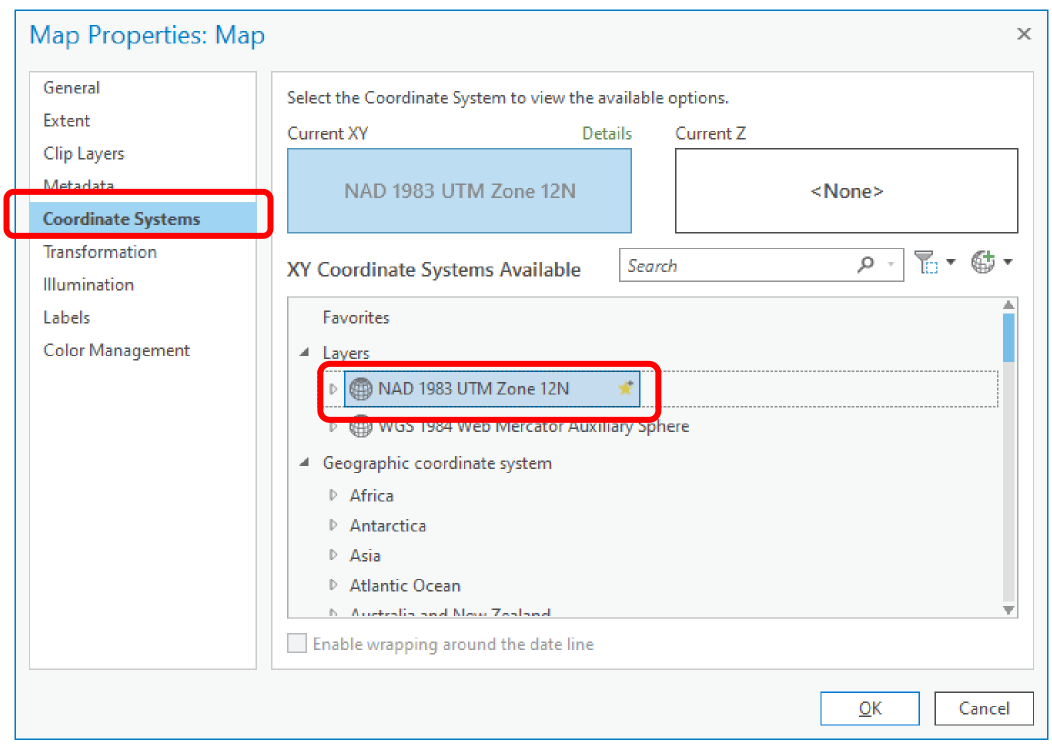


Note that the Shape_Area is 2288 million. The units are square meters (the units of the UTM zone 12 coordinate system). This is 2288 km^2, a number much closer to and consistent with that provided from the NHDPlus WBD dataset. This value of 2288 km^2 has been computed in the projected UTM coordinate system.

15. In contents right click on **Map -> Properties**



In the Map Properties window click on Coordinate Systems and expand Layers and select NAD 1983 UTM Zone 12N.



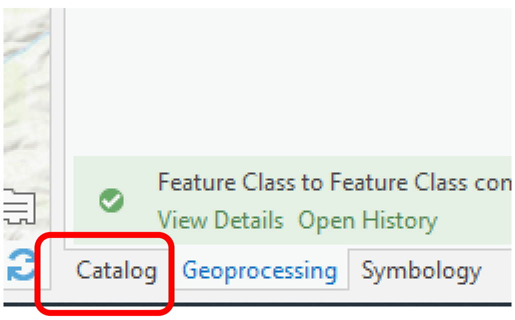
Click OK. You should note that the display adjusts and the watershed is a lot longer and narrower. The Map display is now showing its contents using UTM zone 12 coordinates, rather than geographic (latitude and longitude) coordinates. These are a truer representation of the actual shape of the watershed at this scale.

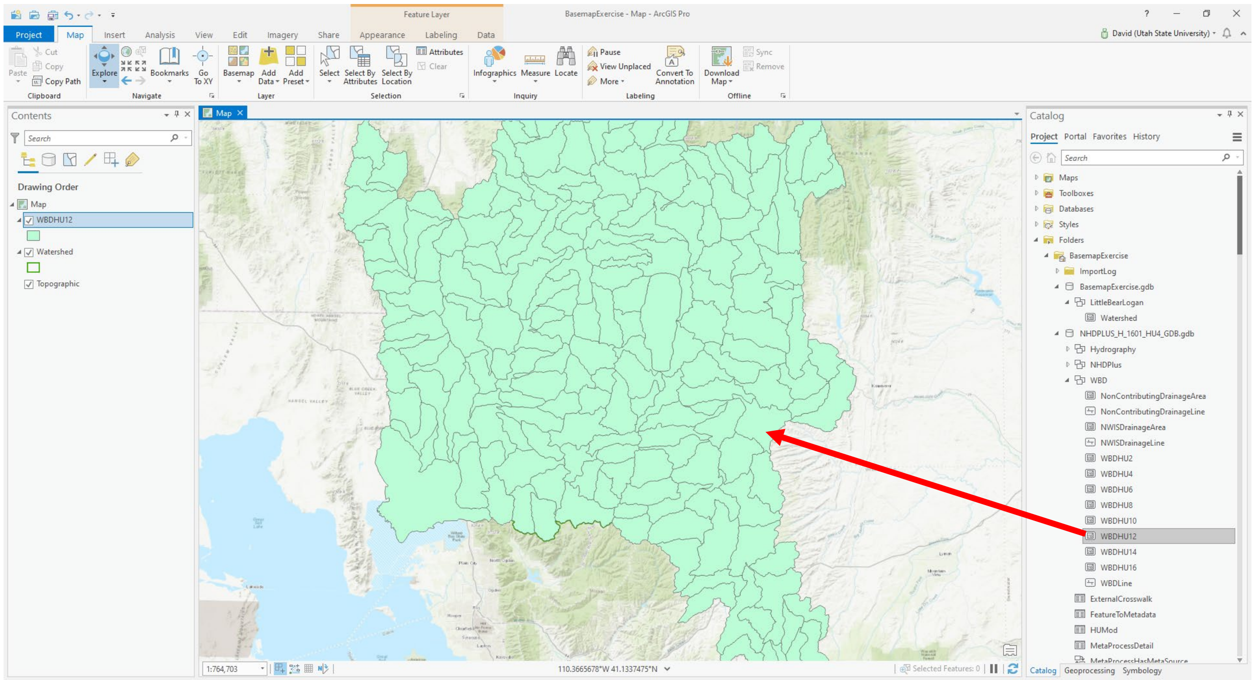
16. Save your project.

Selecting the Subwatersheds in the Study Area

Now let's add HUC12 subwatersheds to our project.

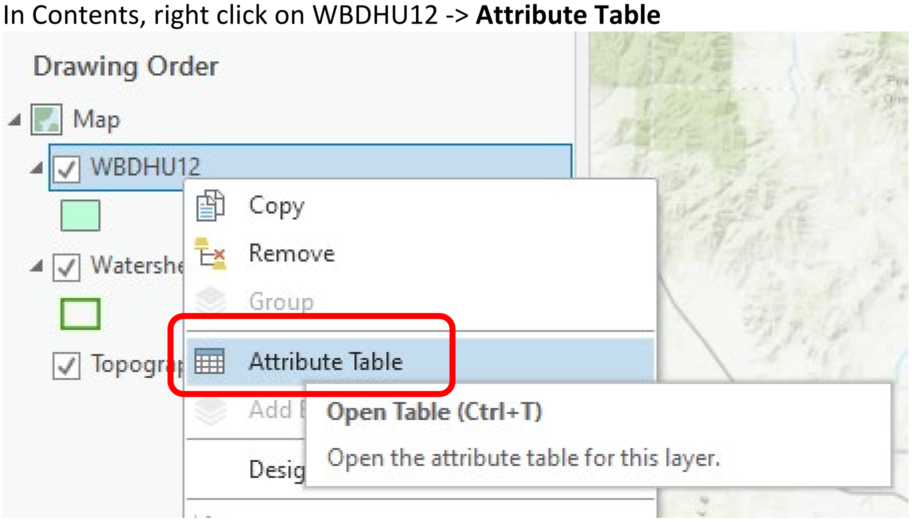
1. Go back to the **Catalog pane** on the right and drag the WBDHU12 feature class from the NHDPlus geodatabase onto the map.



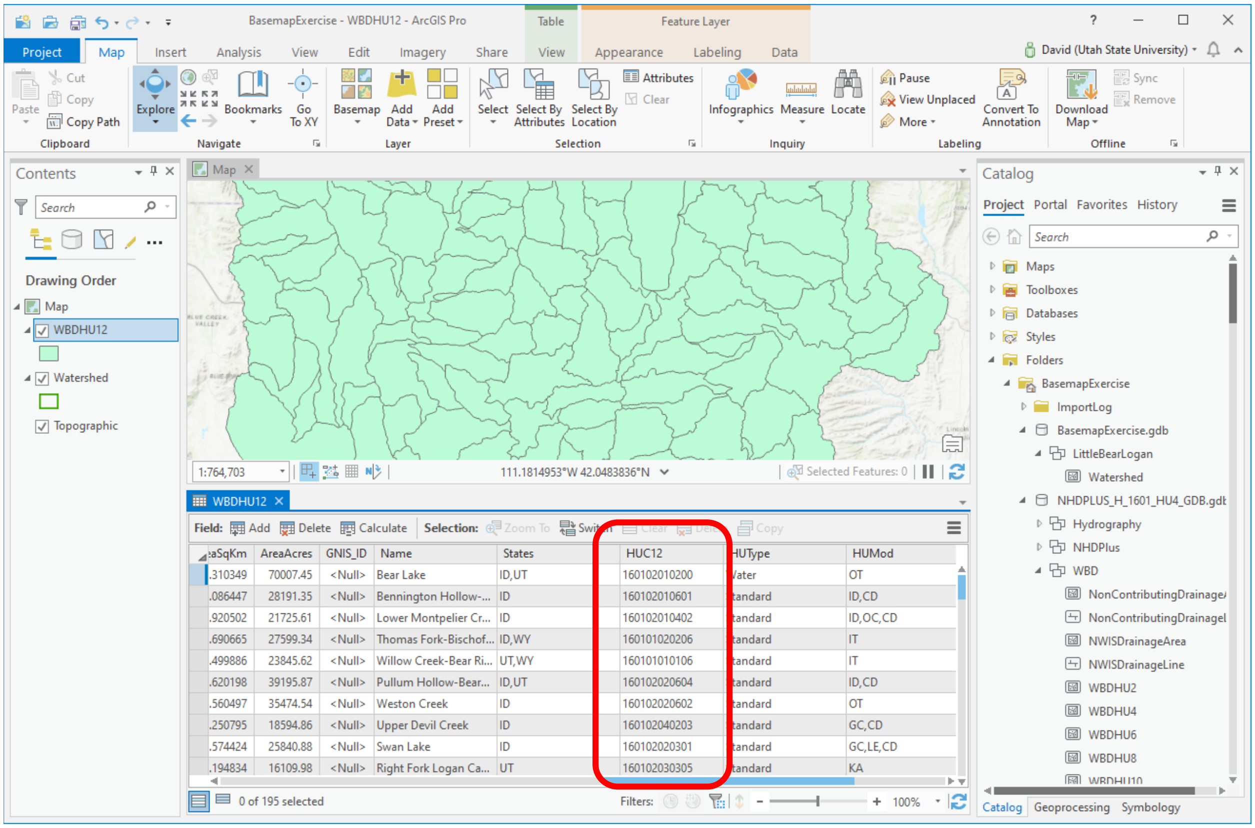


These HUC12 subwatersheds are smaller than the HUC8 subbasin already identified.

2. In Contents, right click on WBDHU12 -> **Attribute Table**



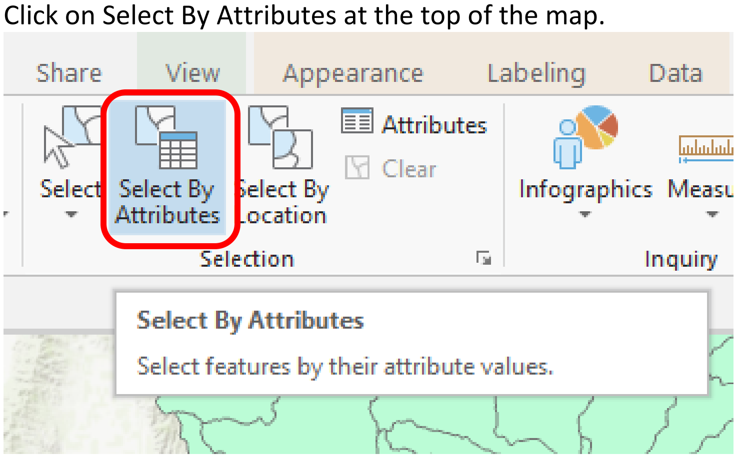
You should see the attribute table for this Feature Class in the bottom panel of the main display.



There is a column HUC12 that shows the HUC12 identifiers for each subwatershed. There are also several other useful fields, like ToHUC that gives the identifier of the next downstream HUC12 for subwatershed connectivity. You can read more about this dataset at https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution. Full documentation is not yet available, but NHDPlus Version 2 documentation mostly applies. http://www.horizon-systems.com/NHDPlus/NHDPlusV2_documentation.php. This dataset is still a bit of a work in progress.

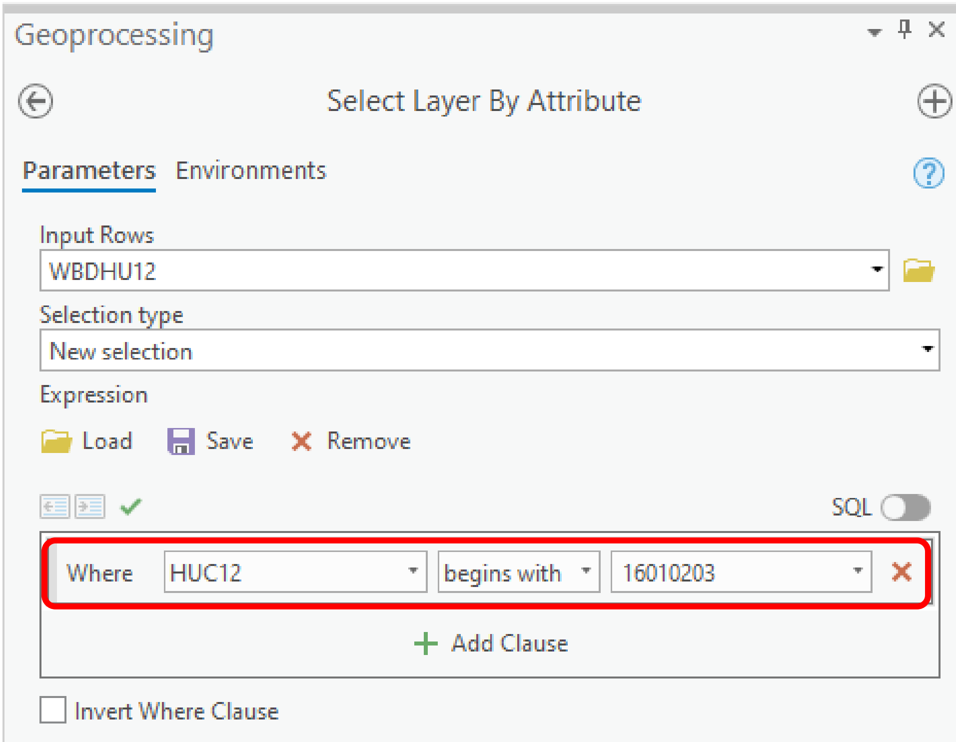
To find the HUC12 subbwatersheds within the Little Bear-Logan watershed we want all those that start with **16010203**. Recall that this is the HUC 8 identifier for this watershed.

3. Click on Select By Attributes at the top of the map.

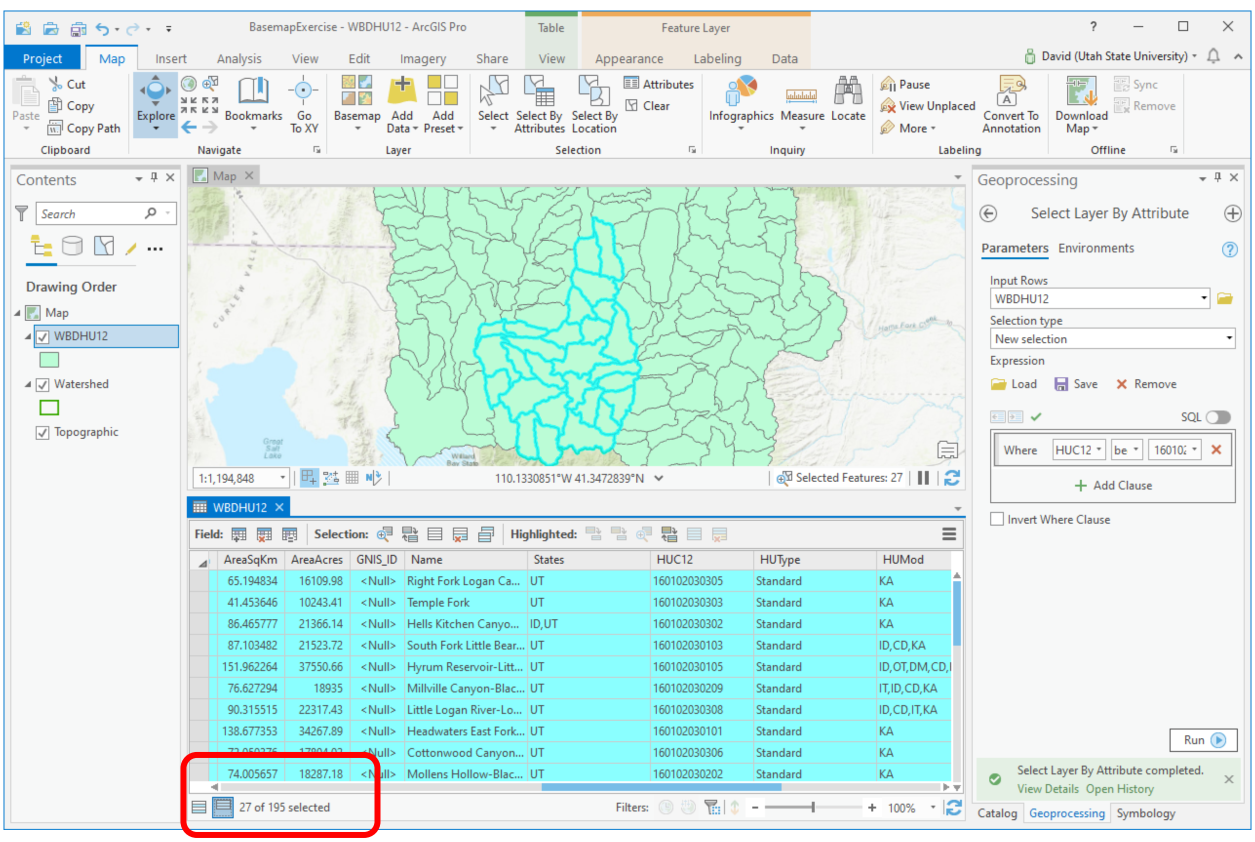


In the Geoprocessing pane on the right, the Select Layer By Attribute tool should open.

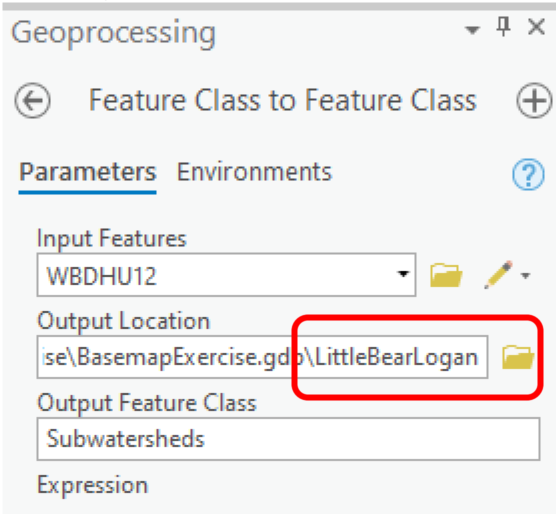
4. Click New Expression and set Where **HUC12 begins with 16010203**, and Run.



You should see just the subwatersheds belonging to this HUC8 selected. At the bottom left you can toggle the table to display just the rows of the selected Features in the feature class.

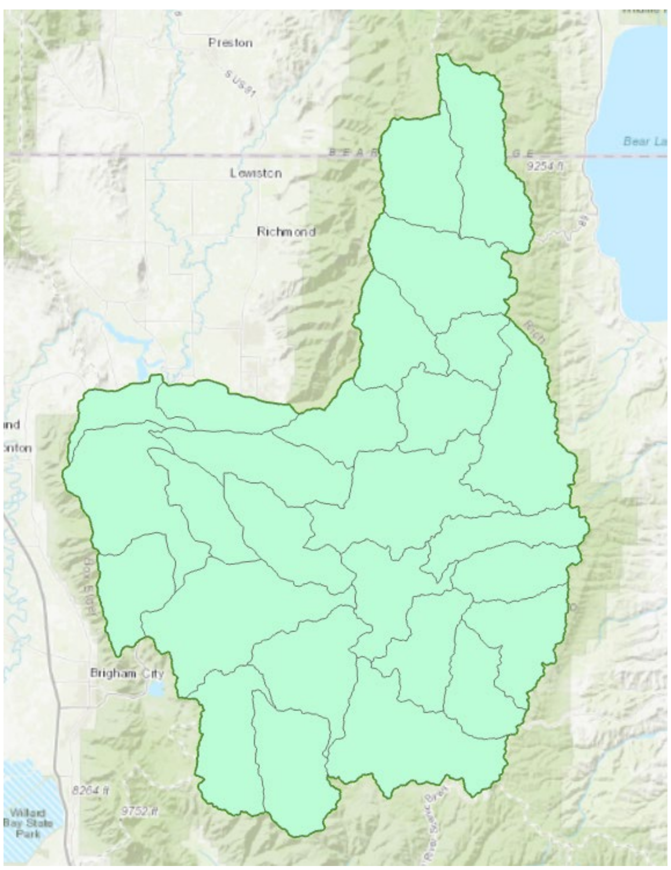


5. Right Click WBDHU12 -> Data -> **Export Features** and save the Selected Features in a Feature Class “**Subwatersheds**” in the **LittleBearLogan** Feature dataset using the Feature Class to Feature Class tool that opens. Again remember to set the Output Location to the Feature Dataset you want.

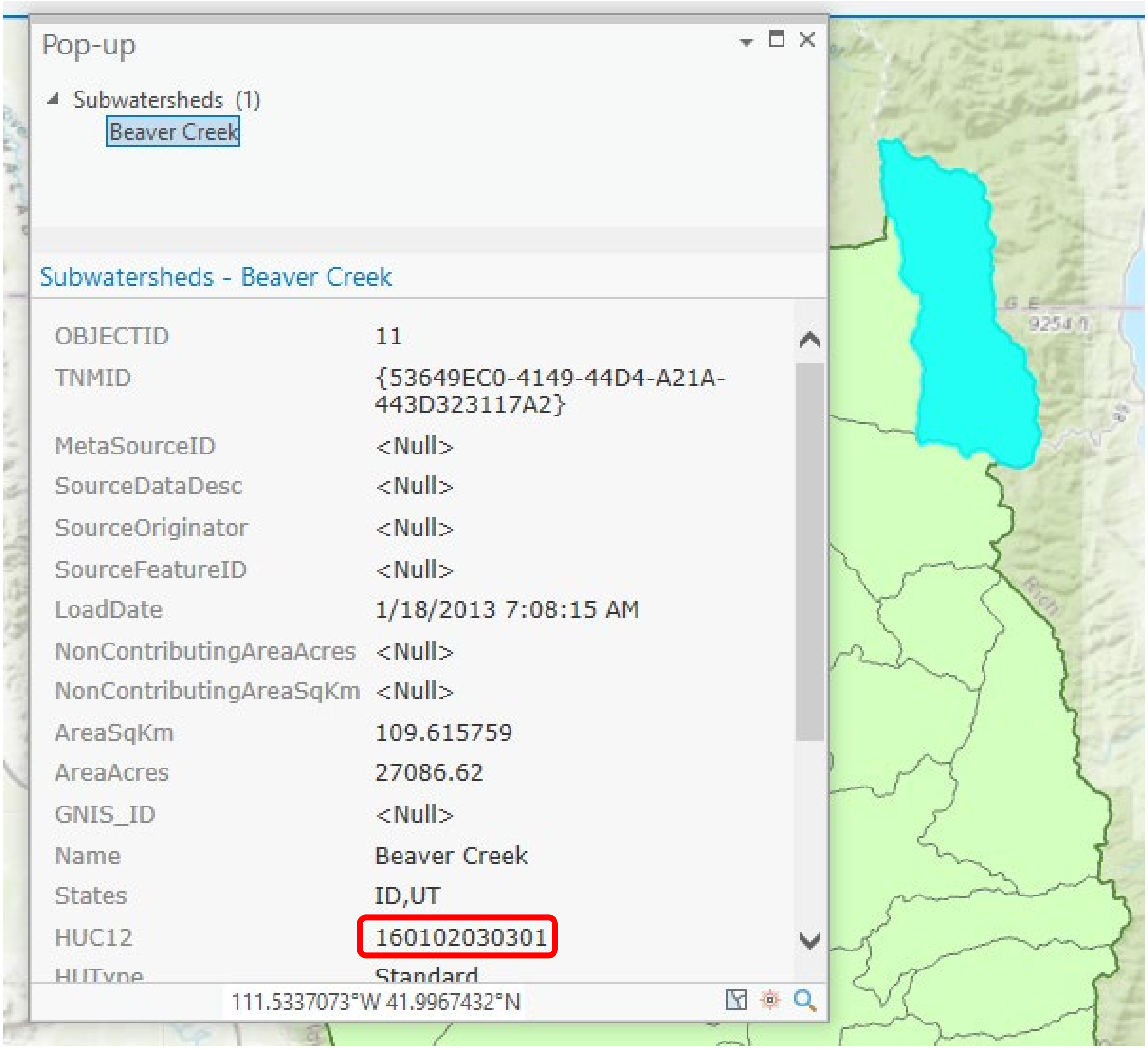


Note that when Features are selected a Geoprocessing tool generally acts only on those selected features.

The result should be a new Feature Class “Subwatersheds” added to the map and Feature Dataset. Clear selections and remove WBDHU12 from the map.



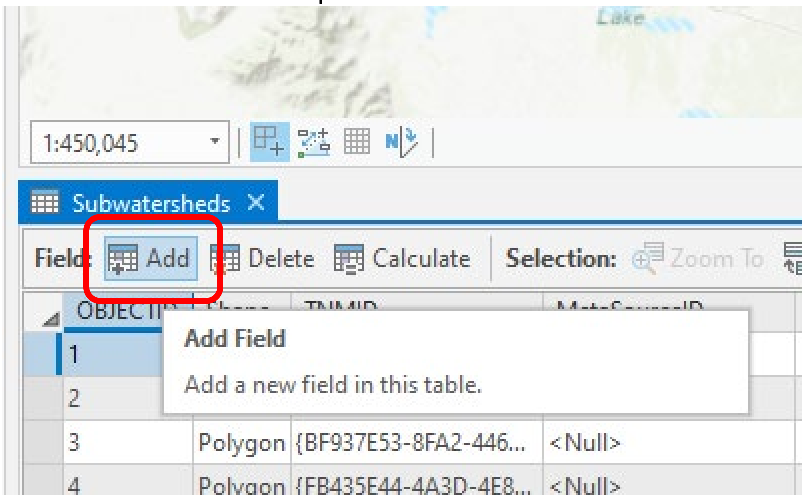
6. Click on the North-Eastern subwatershed on the map



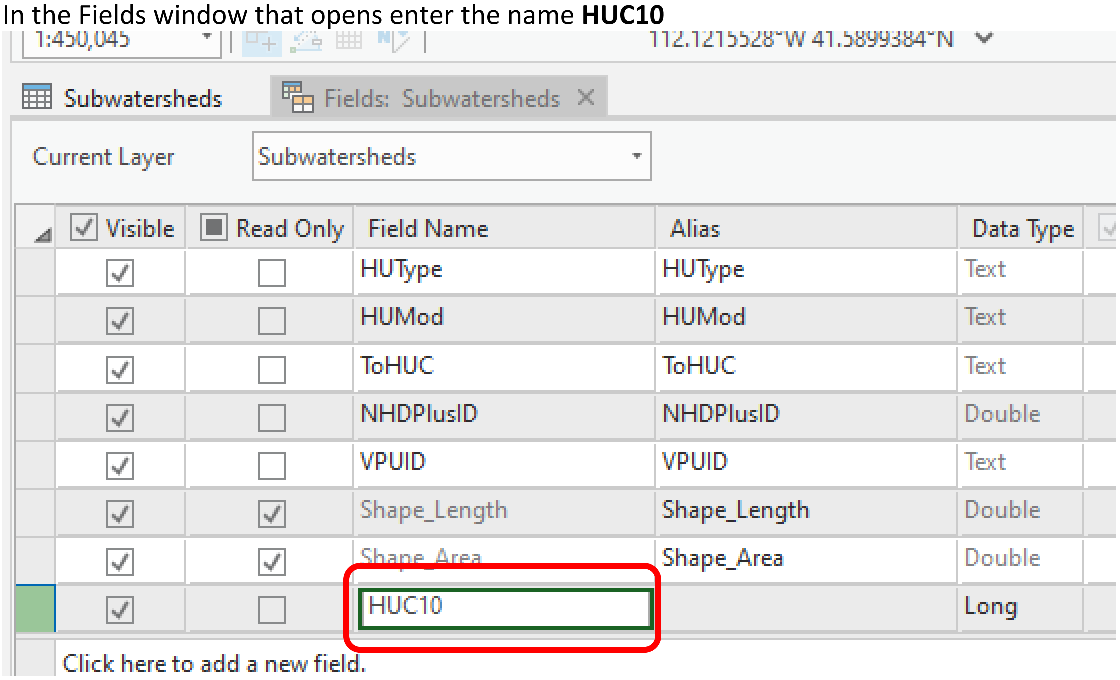
This is HUC12 number 160102030301. The position of this in the USGS drainage hierarchy is: Region 16, Subregion 01, Basin 02, Subbasin 03, Watershed 03, Subwatershed 01, thus making the HUC8 number 16010203 as we used earlier, and the additional subdivision to the HUC12 level yielding the 27 Subwatersheds in this Subbasin.

7. Open the attribute table for Subwatersheds. Note that while there is a field HUC12 in this table. There is no field that identifies HUC10 watersheds. Let's create one.

8. Click **Add Field** near the top of the table window.

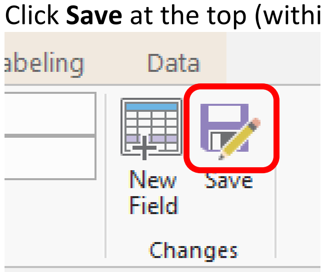


9. In the Fields window that opens enter the name **HUC10**

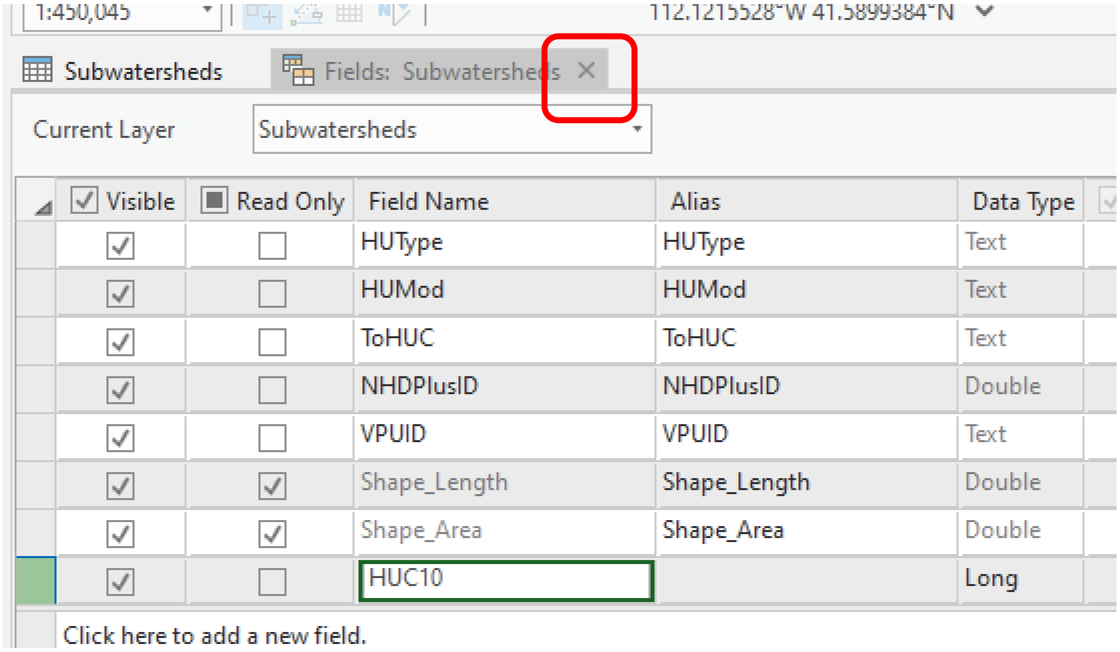


Leave the Data Type as Long (this means a 64 bit integer to the computer) and other entries at their defaults.

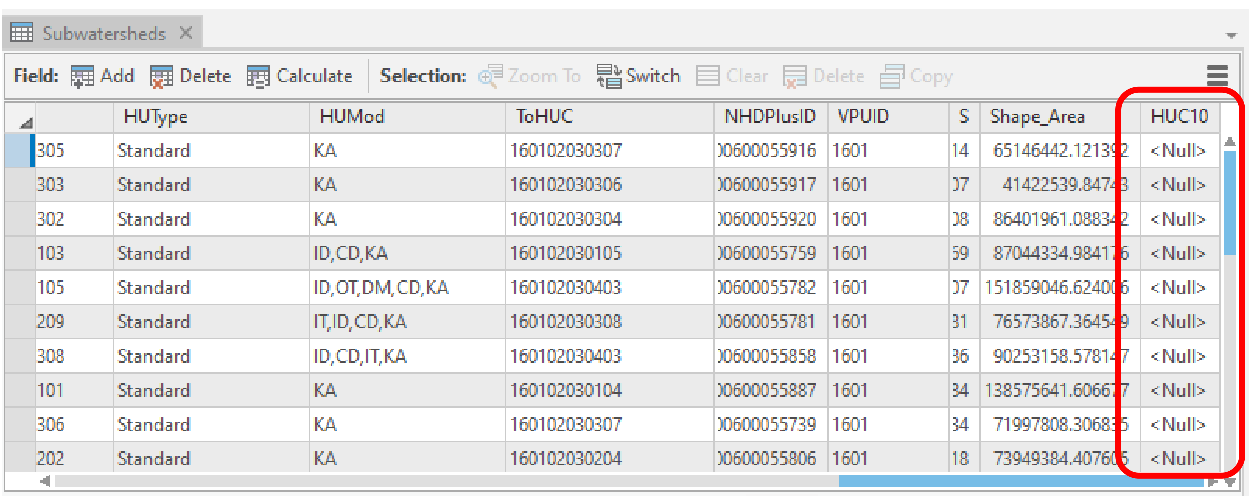
10. Click **Save** at the top (within the Fields ribbon tab).



11. **Close** the Fields window

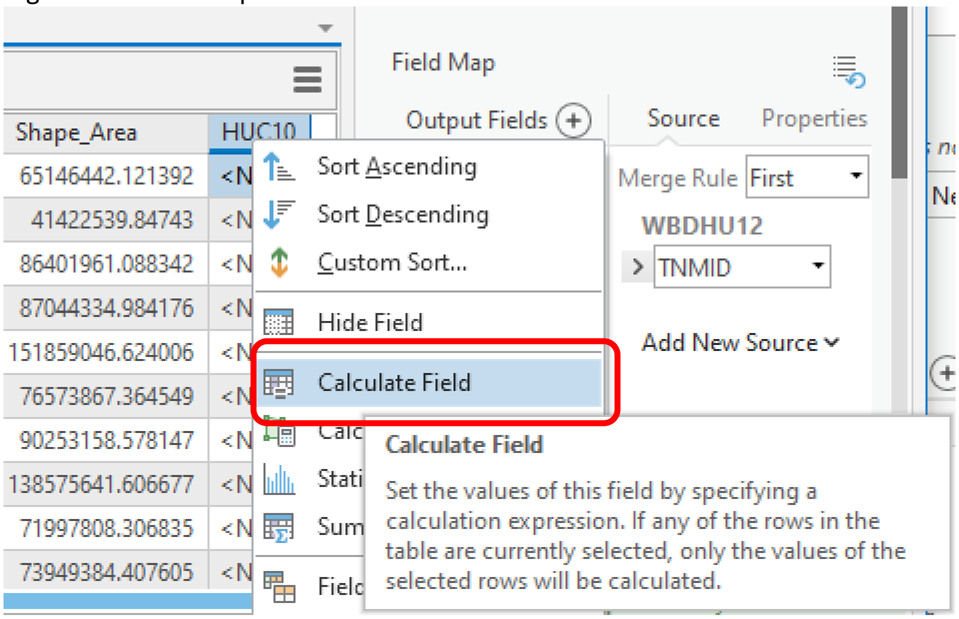


There should now be a column HUC10 in the Subwatersheds table, filled with <Null> content.



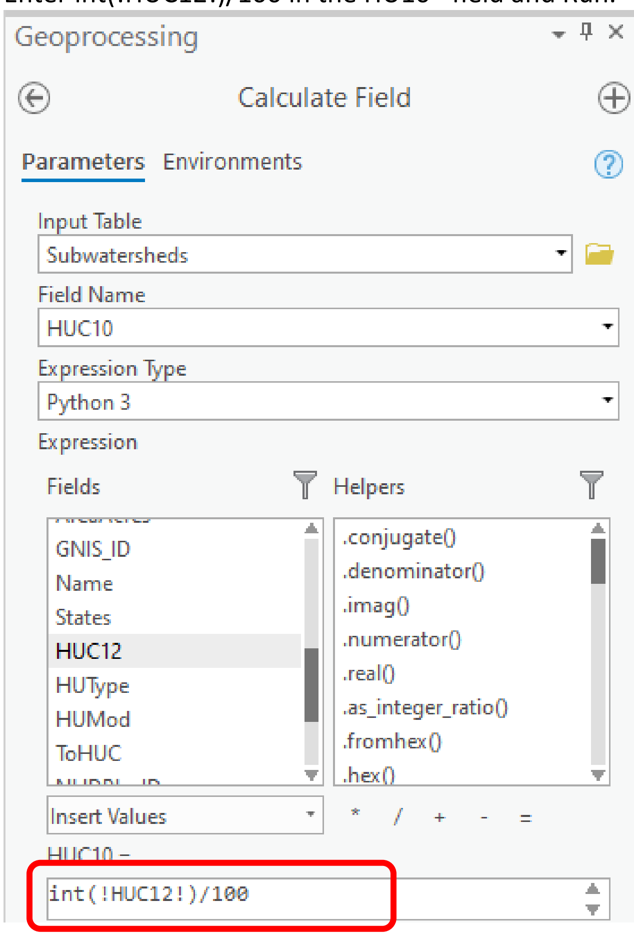
	HUType	HUMod	ToHUC	NHDPlusID	VPUID	S	Shape_Area	HUC10
305	Standard	KA	160102030307	)0600055916	1601	14	65146442.12139	<Null>
303	Standard	KA	160102030306	)0600055917	1601	)7	41422539.8474	<Null>
302	Standard	KA	160102030304	)0600055920	1601	)8	86401961.08834	<Null>
103	Standard	ID,CD,KA	160102030105	)0600055759	1601	59	87044334.98417	<Null>
105	Standard	ID,OT,DM,CD,KA	160102030403	)0600055782	1601	)7	151859046.6240	<Null>
209	Standard	IT,ID,CD,KA	160102030308	)0600055781	1601	31	76573867.36454	<Null>
308	Standard	ID,CD,IT,KA	160102030403	)0600055858	1601	36	90253158.57814	<Null>
101	Standard	KA	160102030104	)0600055887	1601	34	138575641.6066	<Null>
306	Standard	KA	160102030307	)0600055739	1601	34	71997808.30683	<Null>
202	Standard	KA	160102030204	)0600055806	1601	18	73949384.40760	<Null>

12. Right click on the top of this column and Click **Calculate Field**



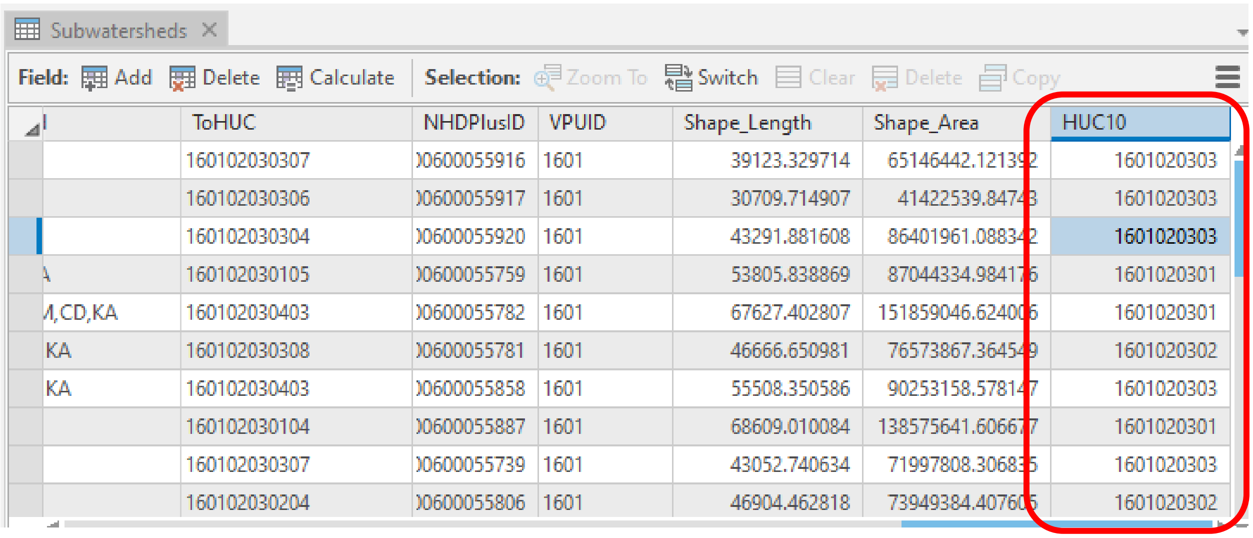
The Calculate Field Geoprocessing tool should open

13. Enter int(!HUC12!)/100 in the HU10= field and Run.



This is the Python programming language expression for dividing by 100, and by virtue of integer truncation getting 10 digit HUC values from 12 digit HUC values. The int() is to convert (coerce) the text HUC12 value into an integer before the divide by 100.

The result should be 10 digit HUC10 values in the HUC10 column. These will be used to symbolize the display.

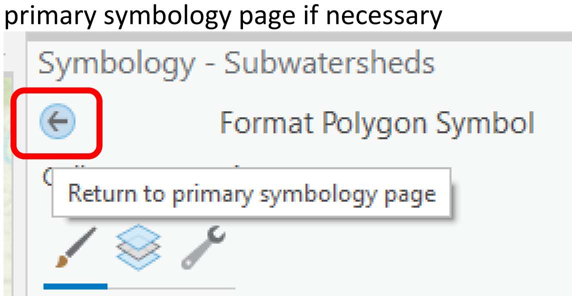


	ToHUC	NHDPlusID	VPUID	Shape_Length	Shape_Area	HUC10
	160102030307	0600055916	1601	39123.329714	65146442.121392	1601020303
	160102030306	0600055917	1601	30709.714907	41422539.84743	1601020303
	160102030304	0600055920	1601	43291.881608	86401961.088342	1601020303
A	160102030105	0600055759	1601	53805.838869	87044334.984176	1601020301
M,CD,KA	160102030403	0600055782	1601	67627.402807	151859046.624006	1601020301
KA	160102030308	0600055781	1601	46666.650981	76573867.364549	1601020302
KA	160102030403	0600055858	1601	55508.350586	90253158.578147	1601020303
	160102030104	0600055887	1601	68609.010084	138575641.606677	1601020301
	160102030307	0600055739	1601	43052.740634	71997808.306835	1601020303
	160102030204	0600055806	1601	46904.462818	73949384.407605	1601020302

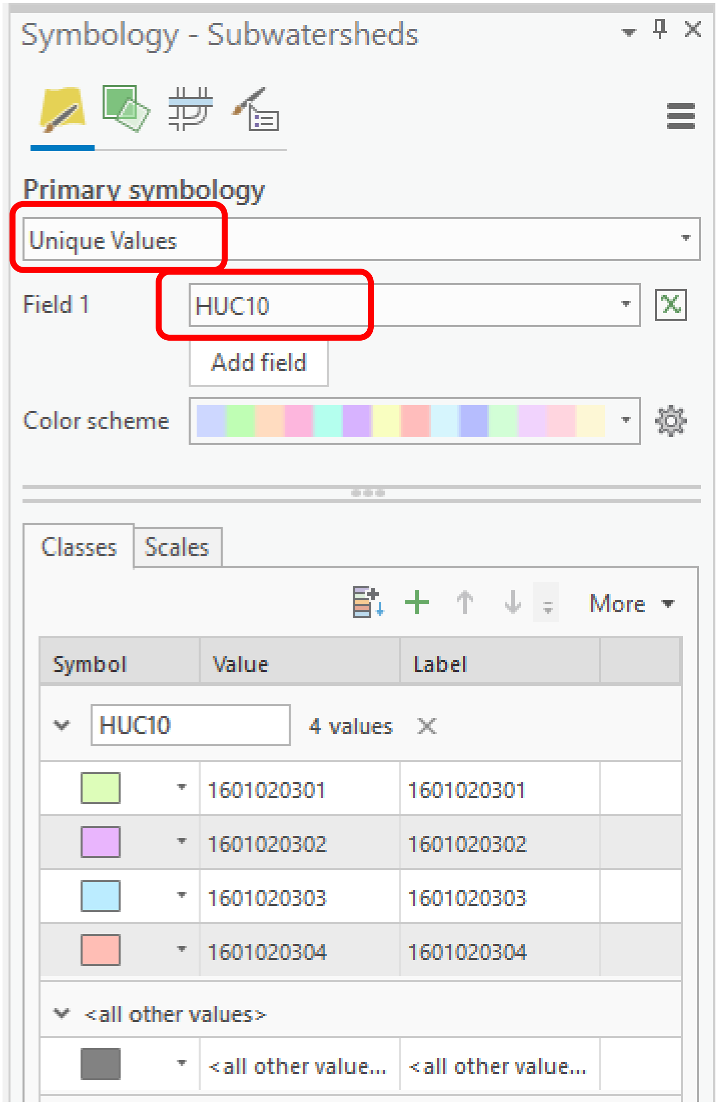
Close the Subwatersheds table (for now).

Lets symbolize this dataset using this newly created field.

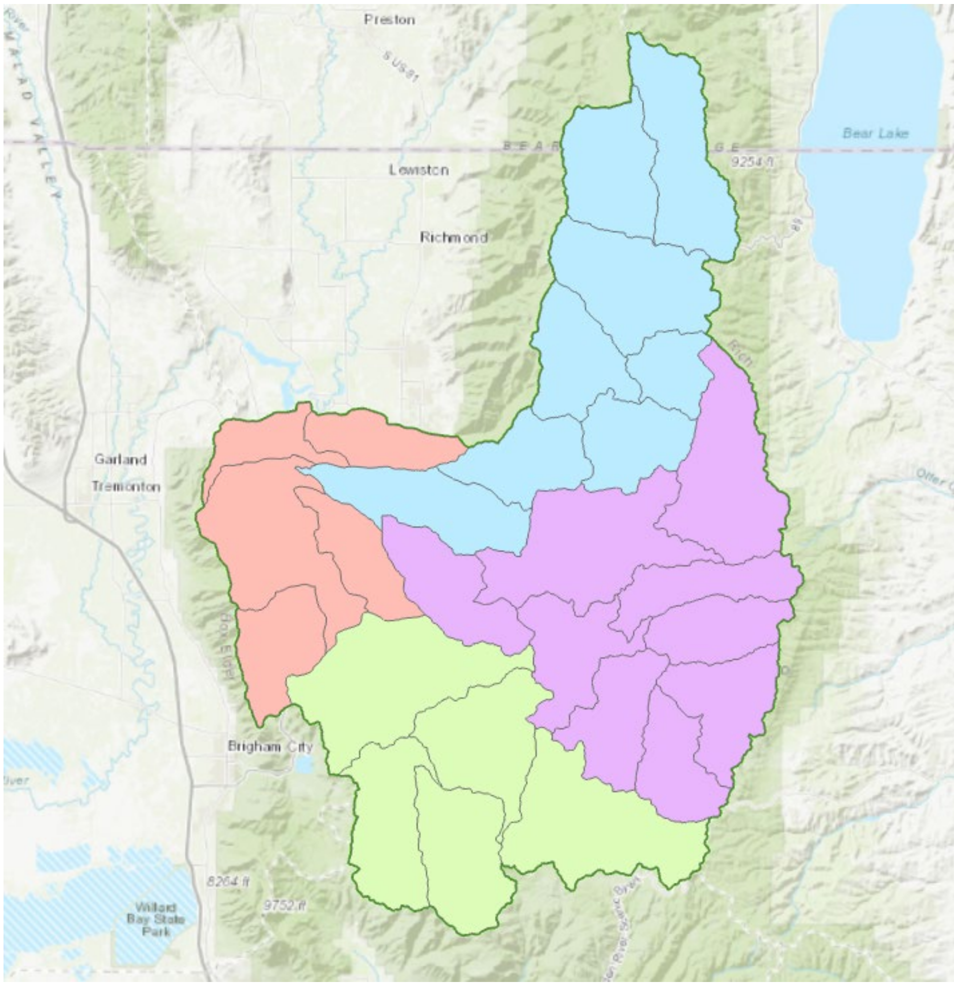
14. Click on the Subwatersheds symbol in Contents to open the Symbology pane. Return to the primary symbology page if necessary



Select Unique Values and HUC10



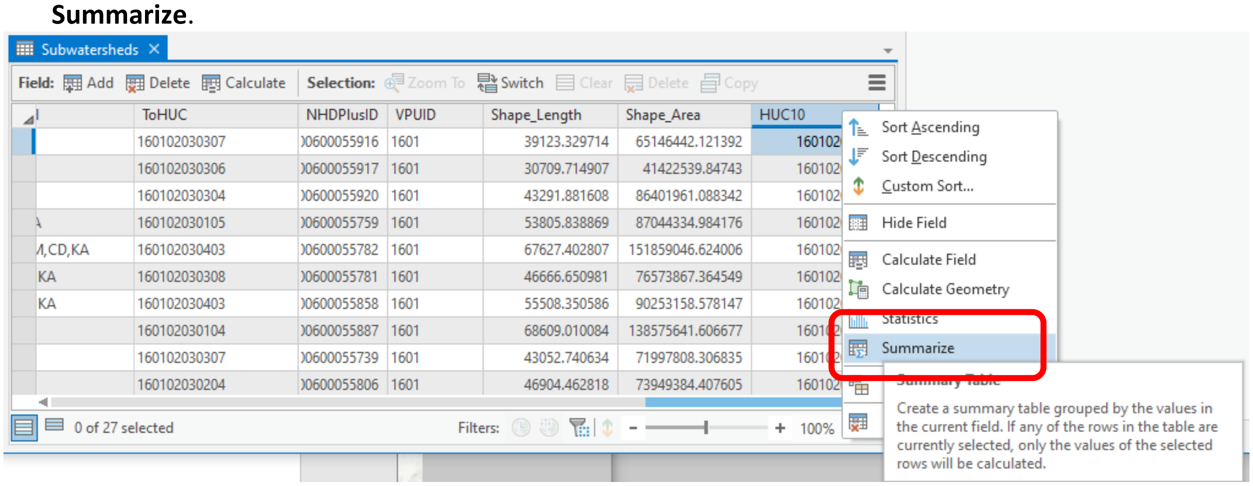
The result should be a nice display of the HUC10 watersheds and HUC12 subwatersheds.



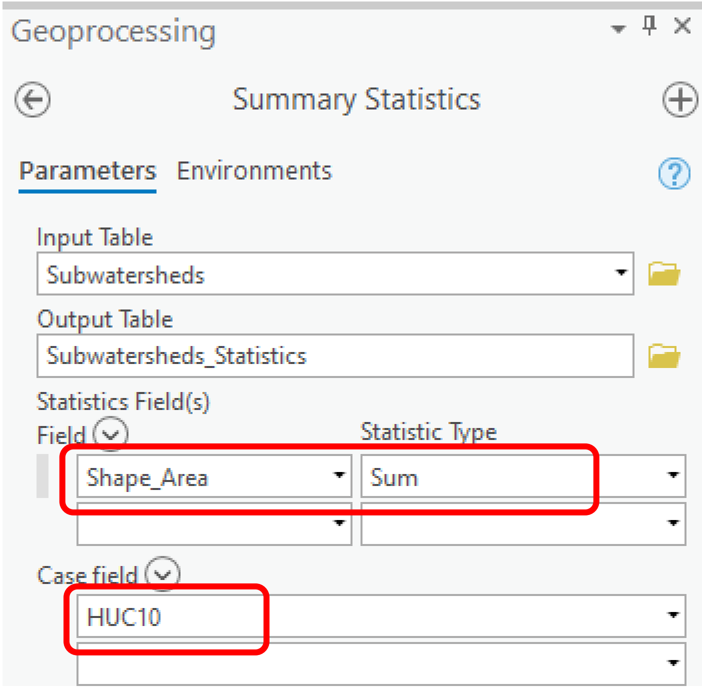
Note that using USGS drainage hierarchy terminology we have one HUC 8 subbasin, with four HUC10 watersheds and 27 HUC12 subwatersheds.

Let's determine the area of each of these HUC10 watersheds.

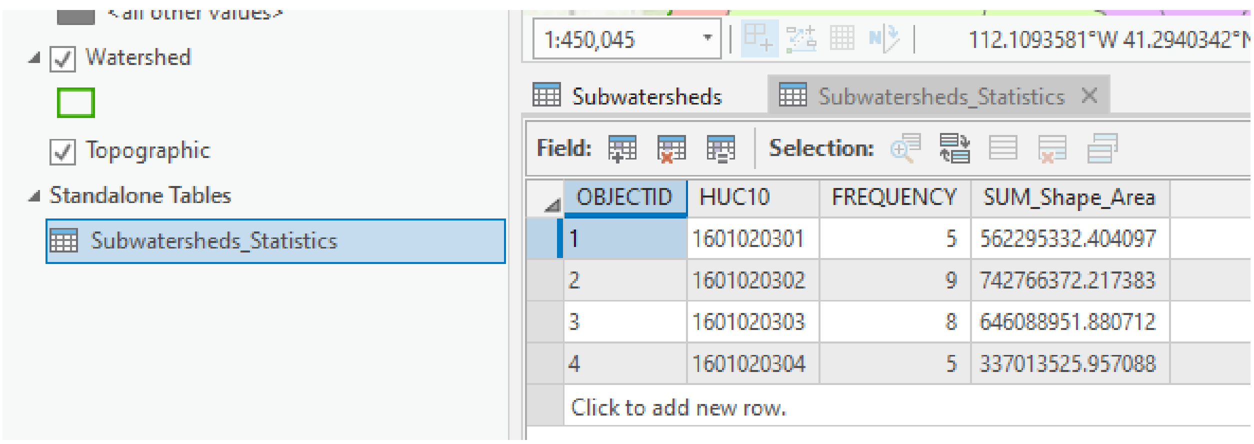
15. Open the Subwatersheds attribute table and right click on the top of HUC10 column and select **Summarize**.



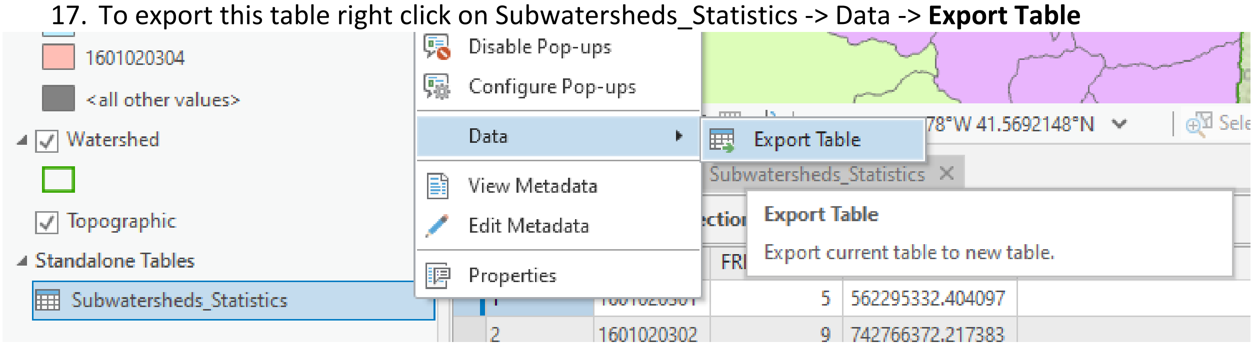
16. The Summary Statistics Geoprocessing tool should open. Set the Statistics Field to Shape_Area and Statistic Type to Sum. Check that the Case field is HUC10 and Run.



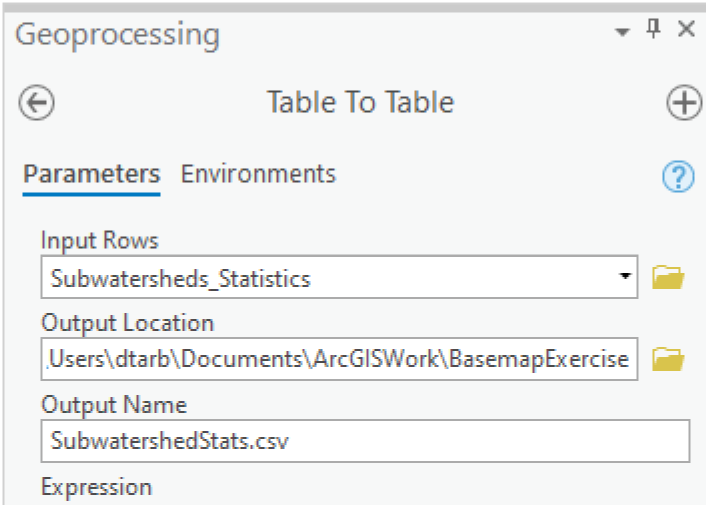
The result should be a new table "Subwatersheds_Statistics" that shows the summed area and Frequency (count of the number of HUC12 watersheds in each statistic) for each HUC10.



17. To export this table right click on Subwatersheds_Statistics -> Data -> **Export Table**



18. In the Table to Table Geoprocessing tool that opens set the Output Location to the BasemapExercise folder (i.e. outside of the Geodatabase) and Output Name to SubwatershedStats.csv. Click Run.



You should obtain a comma separated values (csv) file that you can open and work with in Excel to format nicely for presentation.

19. Save your project.

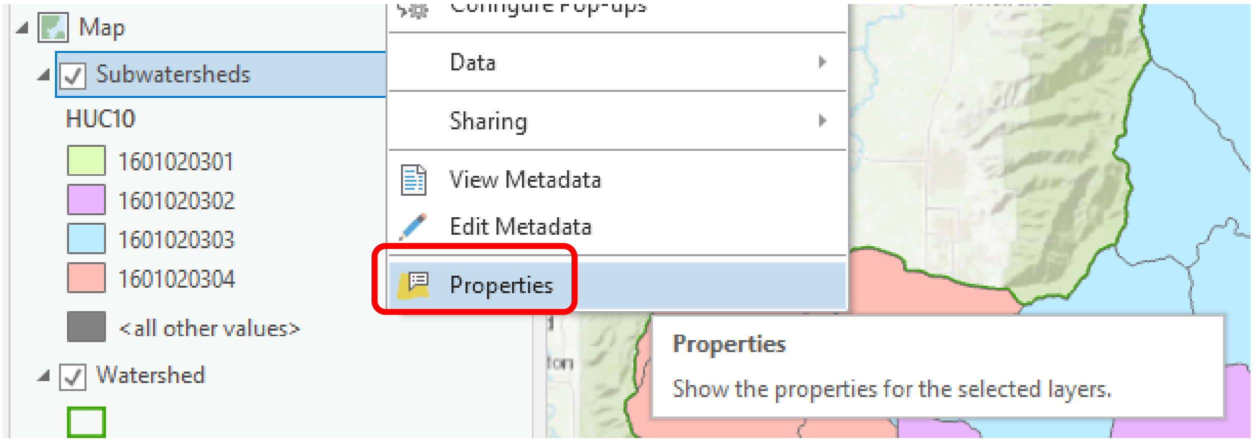
To turn in: Make a layout map of the Little Bear-Logan subbasin with its HUC10 and HUC12 watersheds and subwatersheds. Include a scale, north arrow and appropriate title and legend information.. Prepare a table (Excel is probably easiest) summarizing the area and number of HUC12 subwatersheds in each HUC10 watershed.

Note that maps, tables and documents that you turn in should be clearly labeled so that they may be unambiguously interpreted with a title, scale, north arrow and appropriate title and legend information.

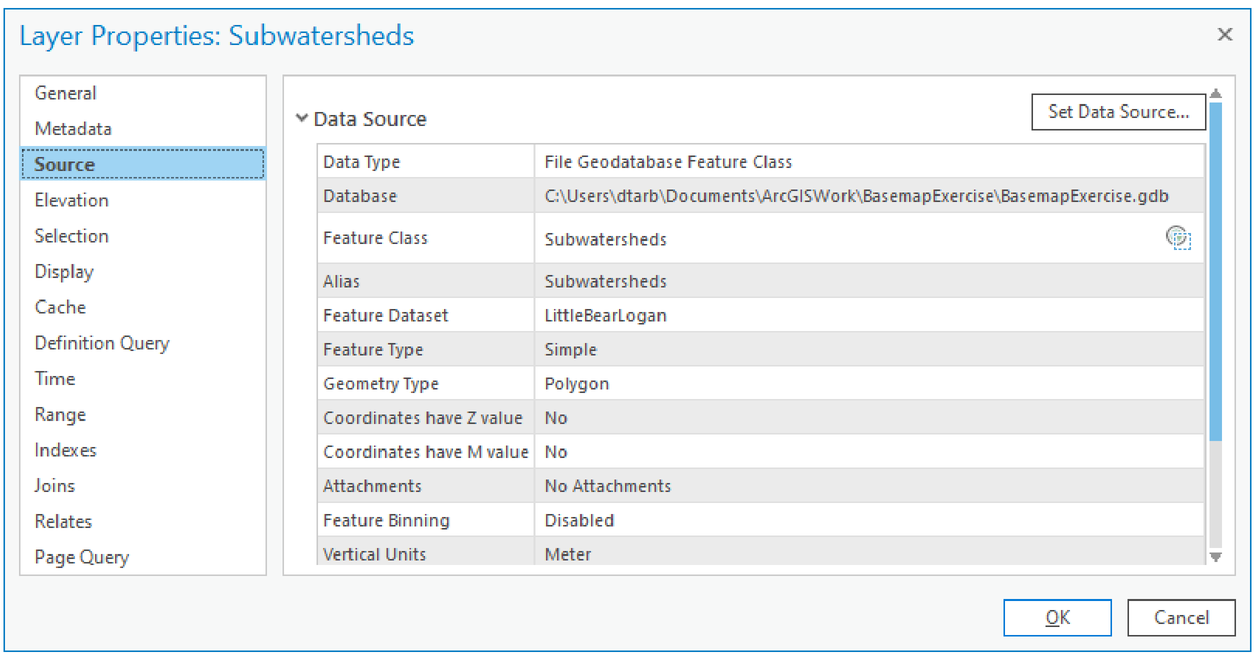
Where is My Stuff?

As you work with data in ArcGIS it is important to keep track of where it is, so it does not get scattered around your computer and lost.

1. Right click on Subwatershed and select **Properties**.

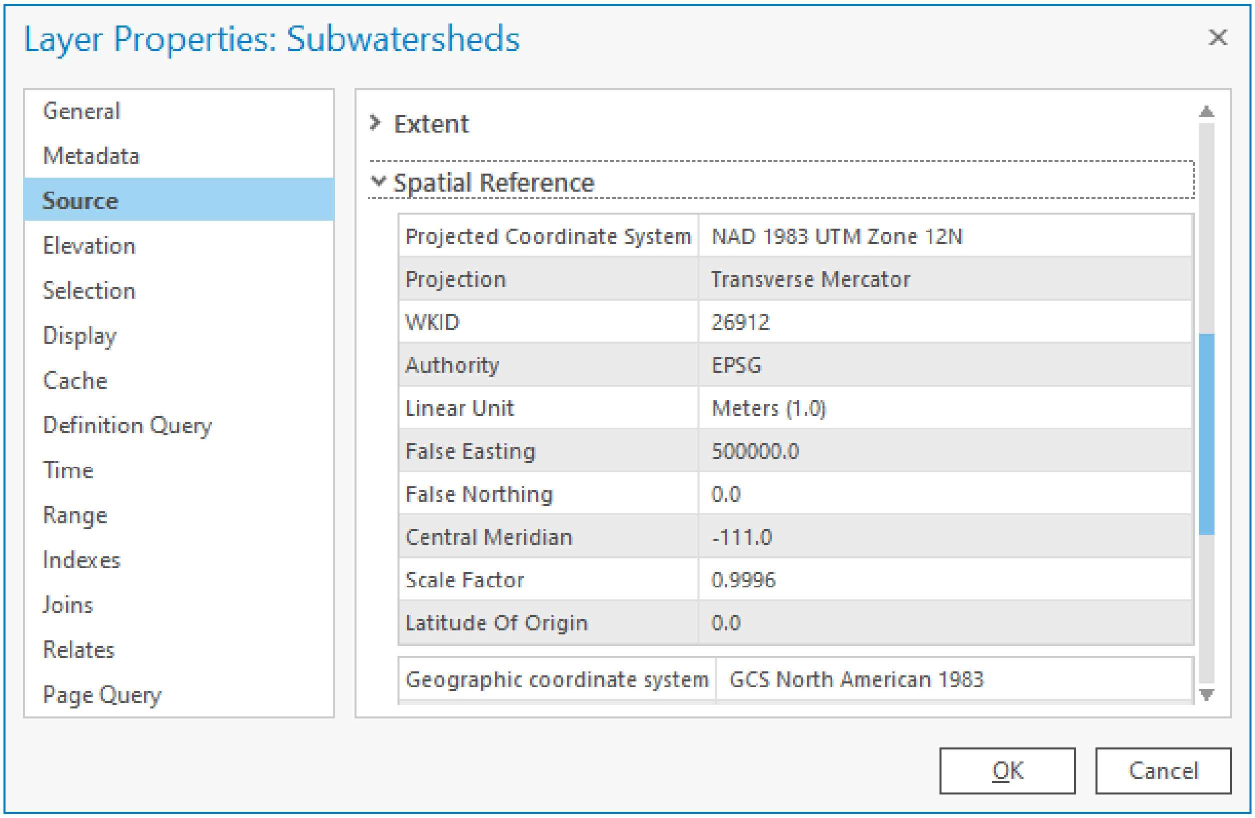


Select the Source tab

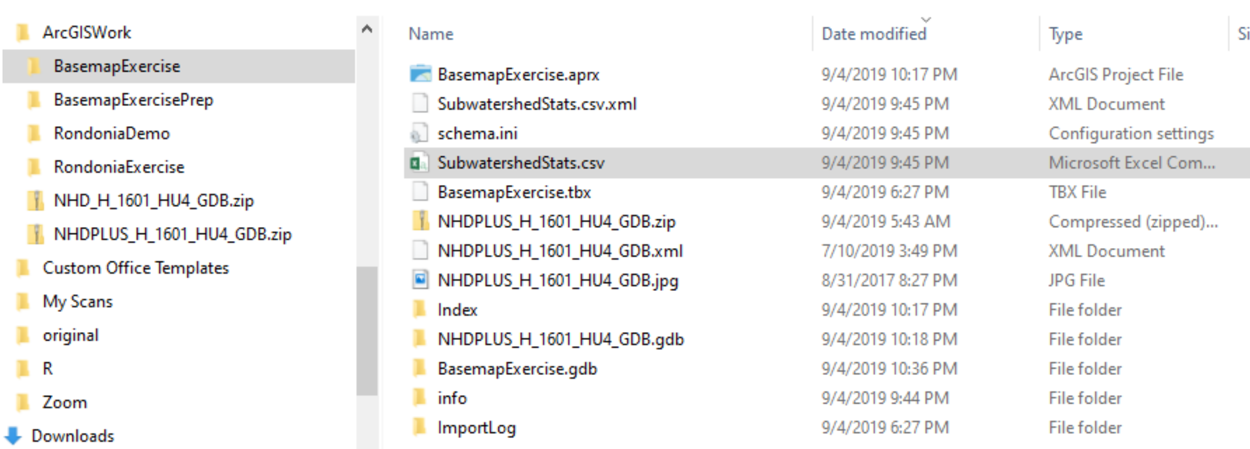


Notice that this Feature Class you created is in the LittleBearLogan Feature Dataset in the BasemapExercise.gdb Geodatabase in the location where you created it. It comprises Simple Features (no topology) that are Polygons (have X and Y values) but have no Z or M values, which deal with elevation and measure, respectively.

Scrolling down you can examine the Spatial Reference and confirm that the coordinate system being uses is NAD 1983 UTM Zone 12N, that also has an identifier WKID 26912 from EPSG. WKID stands for Well Known Identifier and EPSG is the acronym for the European Petroleum Survey Group that originally developed a registry of coordinate systems.



If you look at your BasemapExercise folder on disk that was created when you created the project you will see a number of files, including BasemapExercise.gdb, which is the folder that holds this data in File Geodatabase format.



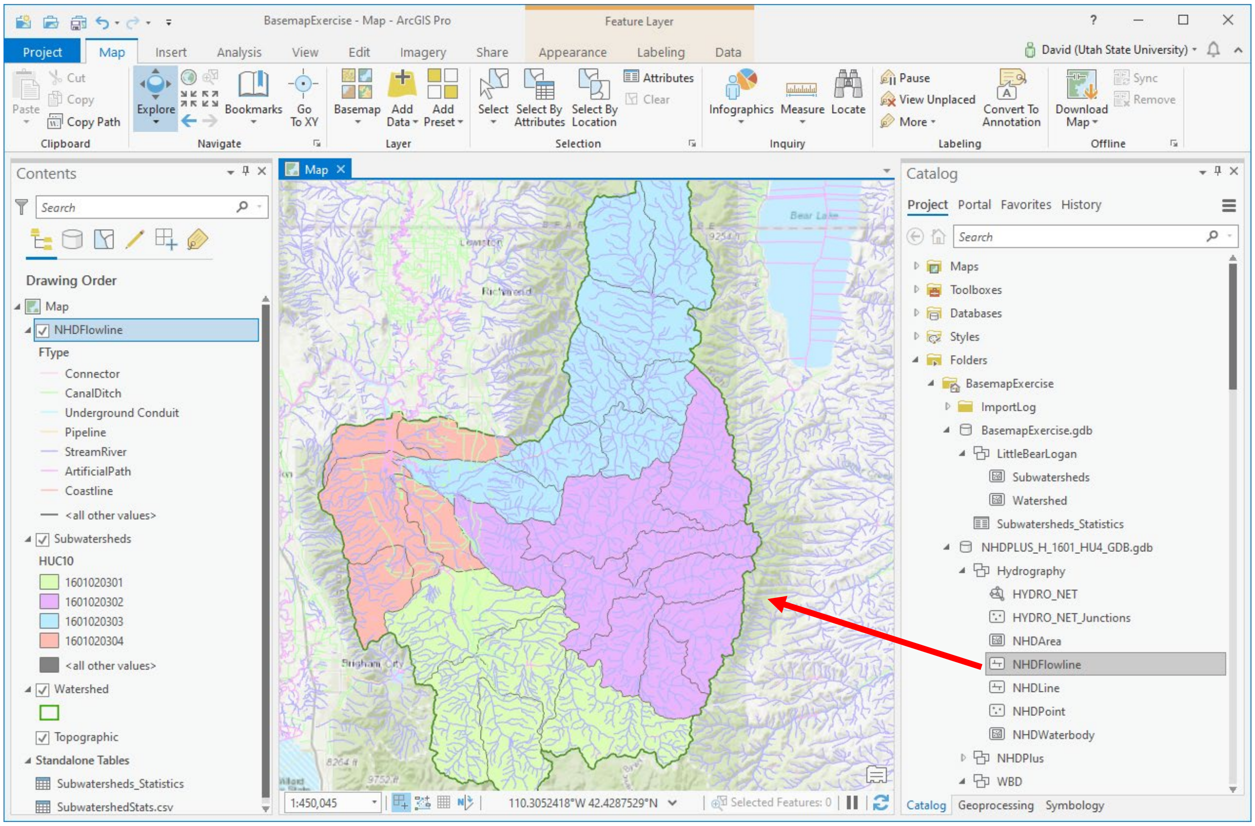
You do not need to do anything with these files, this is just pointed out to let you know where on disk your stuff is stored. If you need to move these files to another computer (e.g. from the PC lab to a thumb drive) or to a different location on your computer, the integrity of the project will generally be maintained if you move all these files together retaining the relative folder structure.

2. Save your project.

Flowlines

In addition to watershed boundaries, the NHDPlus geodatabase includes flowlines and estimates of streamflow that we will now add

1. In the Catalog pane locate **NHDPlus_H_1601_HU4_GDB.gdb -> Hydrography -> Flowline** and add to the map.



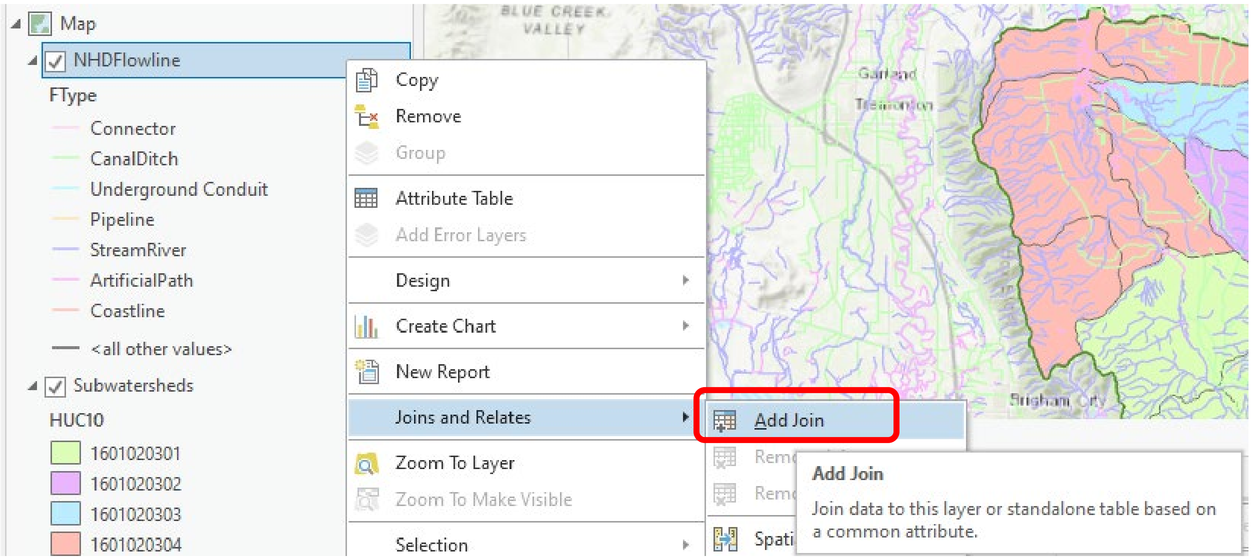
2. Also add **NHDPlusEROMMA**. This is a table, so nothing is added to the map. This holds NHDPlus Enhanced Runoff Model (EROM) data that you can read about in the NHDPlus documentation if interested.

3. Open the table **NHDPlusEROMMA** and examine its columns.

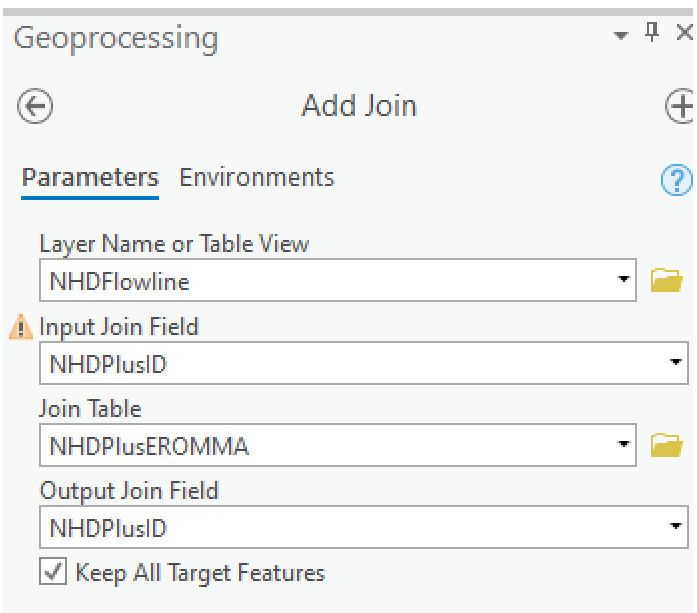
   You should see **FlowEstEGageAdjustedMA**. This is mean annual streamflow in cfs adjusted for nearby stream gages. This is an estimate of streamflow in each stream segment.

   You should also see **NHDPlusID**. This is a unique identifier for NHDPlus flowline reaches. NHDPlusID is also a field in the attribute table of NHDFlowline. We will use this field to **Join** these tables and then extract a subset of reaches that includes flow data.

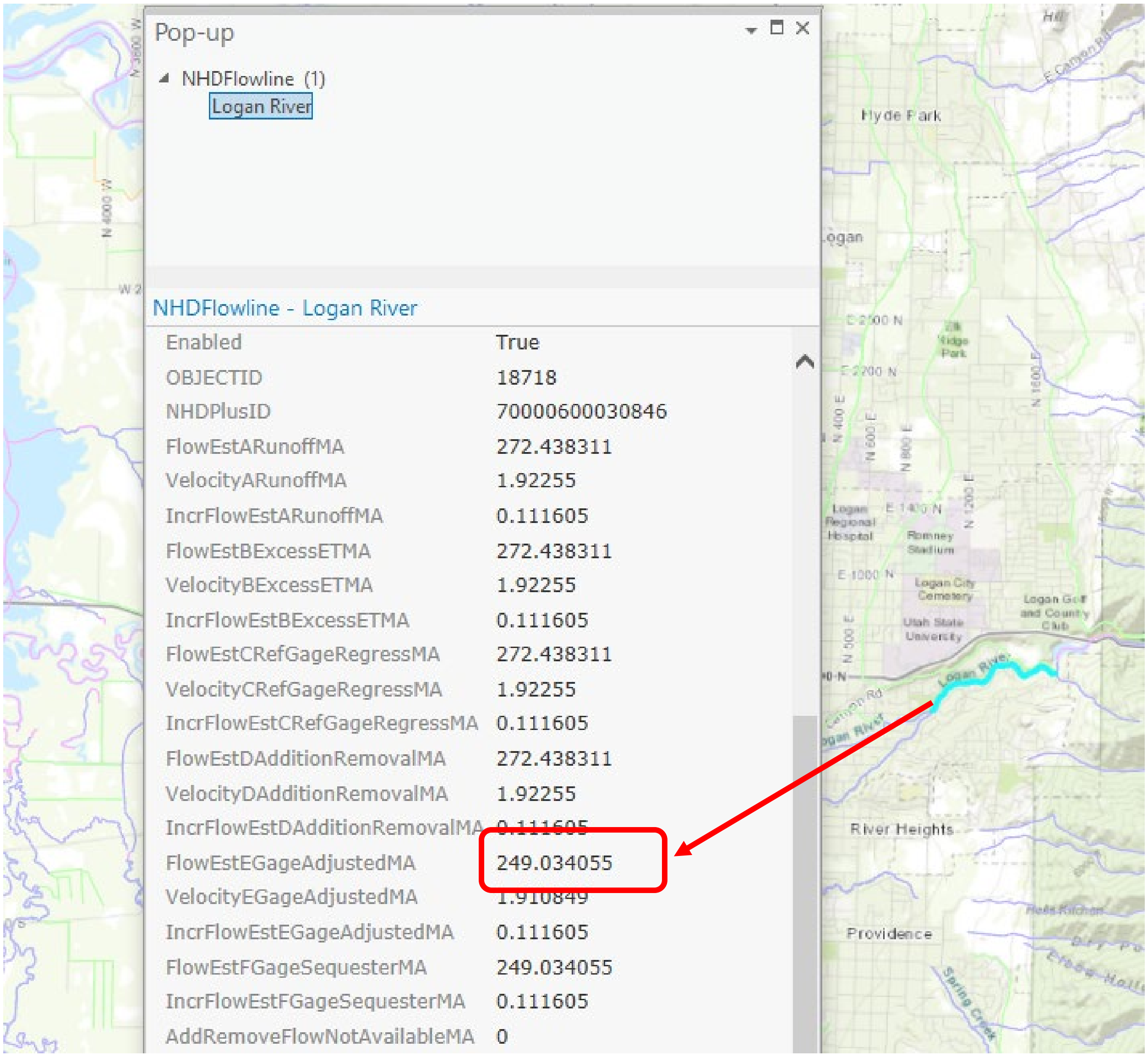
4. Right click on NHDFlowline -> Joins and Relates -> **Add Join**



5. In the Add Join Geoprocessing tool that opens set Input Join Field NHDPlusID, Join Table NHDPlusEROMMA, and Output Join Field NHDPlusID. Click Run.



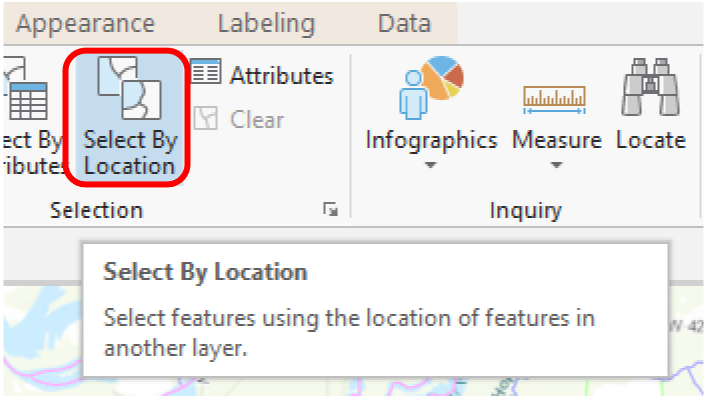
6. Now zoom in on a specific stream reach (e.g. the Logan river near Logan) and use the explore button to examine attribute values.



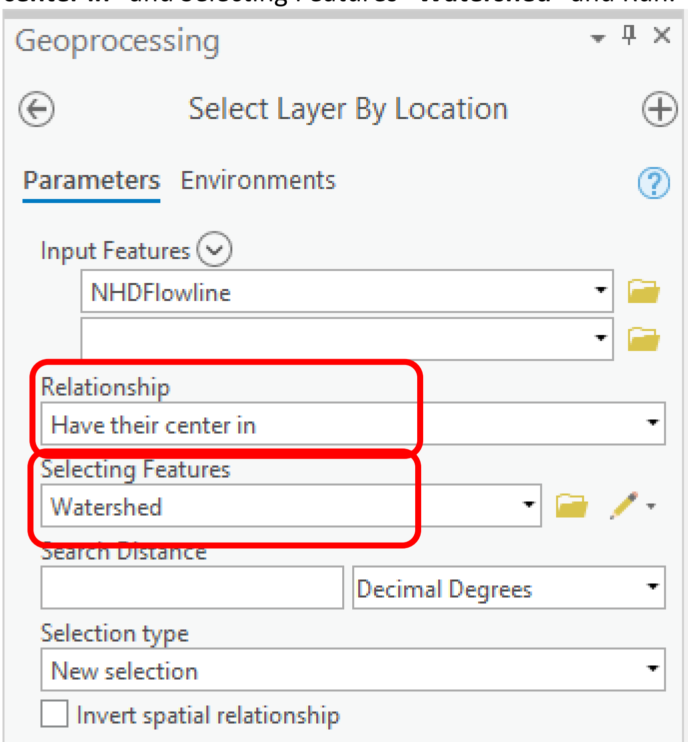
Gage adjusted streamflow such as the value of 249 cfs can be identified from the joined NHDPlusEROMMA table.

Next, a spatial query is used to select just the flowlines in the LittleBear-Logan watershed.

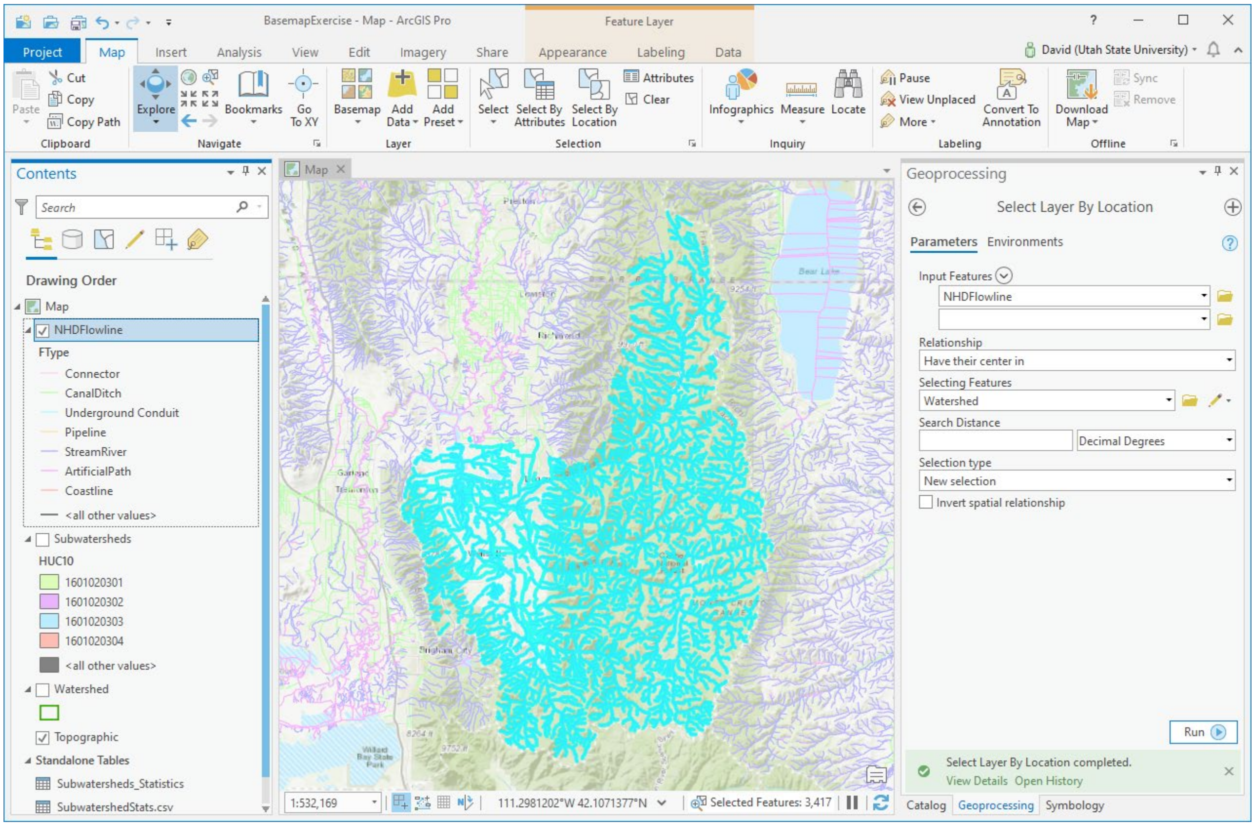
7. At the top of the map, click **Select By Location**



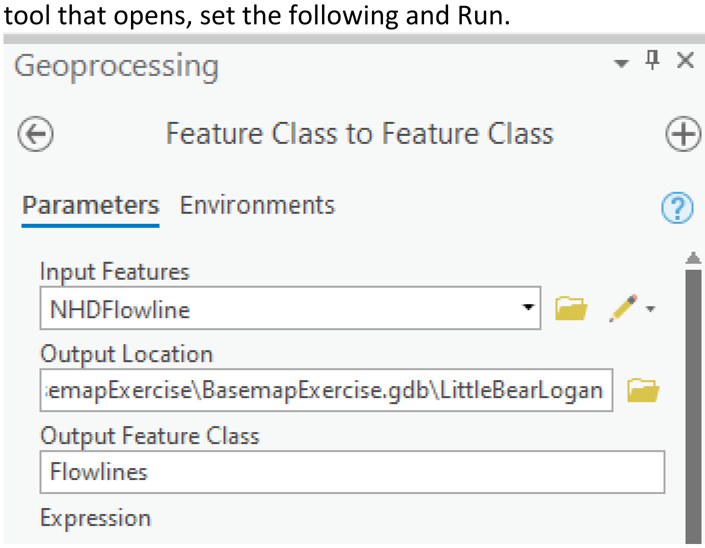
8. In the Select Layer By Location Geoprocessing tool that opens use Relationship "**Have their center in**" and Selecting Features "**Watershed**" and Run.



Zoom to selection in the contents to see that all flowlines within the Little Bear-Logan watershed have been selected.



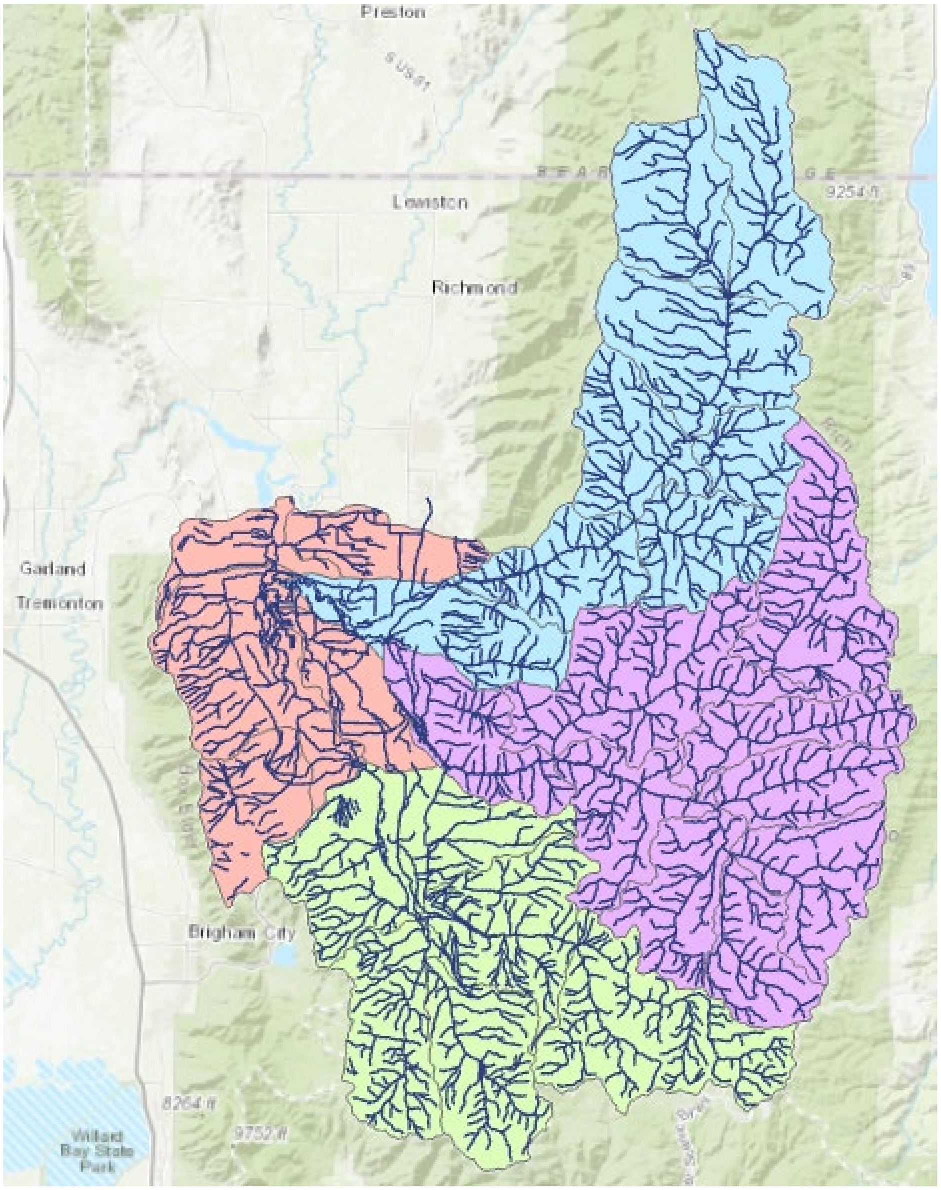
9. Save these features (with joined streamflow values) to the LittleBearLogan feature dataset using NHDFlowline -> Data -> **Export Features**. In the Feature Class to Feature Class Geoprocessing tool that opens, set the following and Run.



A Flowlines feature class should be added to the map.

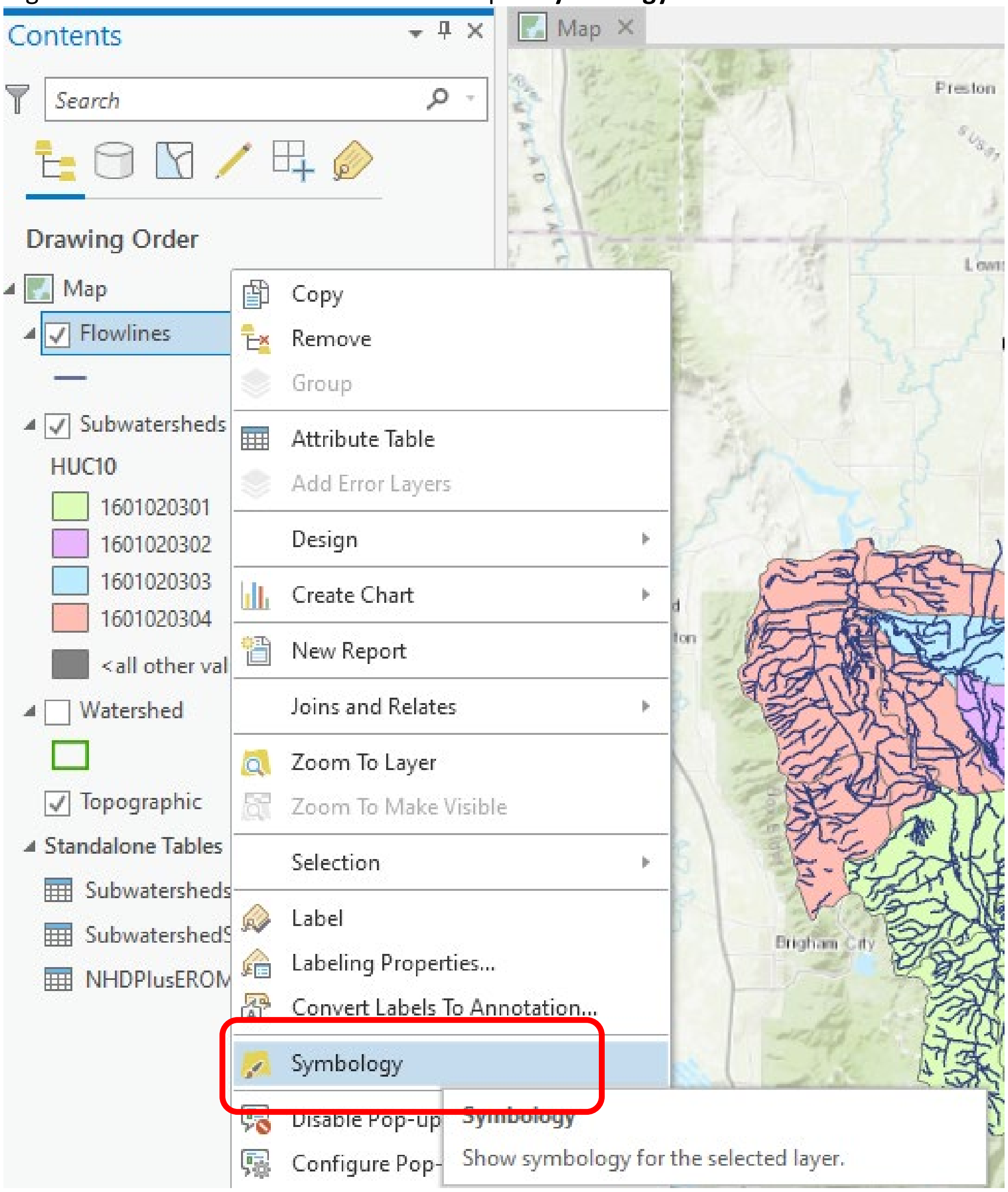
Note that this process acts only on the selected features, so serves to subset the NHDFlowline feature class. Also the data is projected to UTM coordinate system as it enters the LittleBearLogan feature dataset, and the joined table values are included. There is a lot going on in this single command.

10. Remove NHDFlowline and clear selections.
    Your map should be similar to

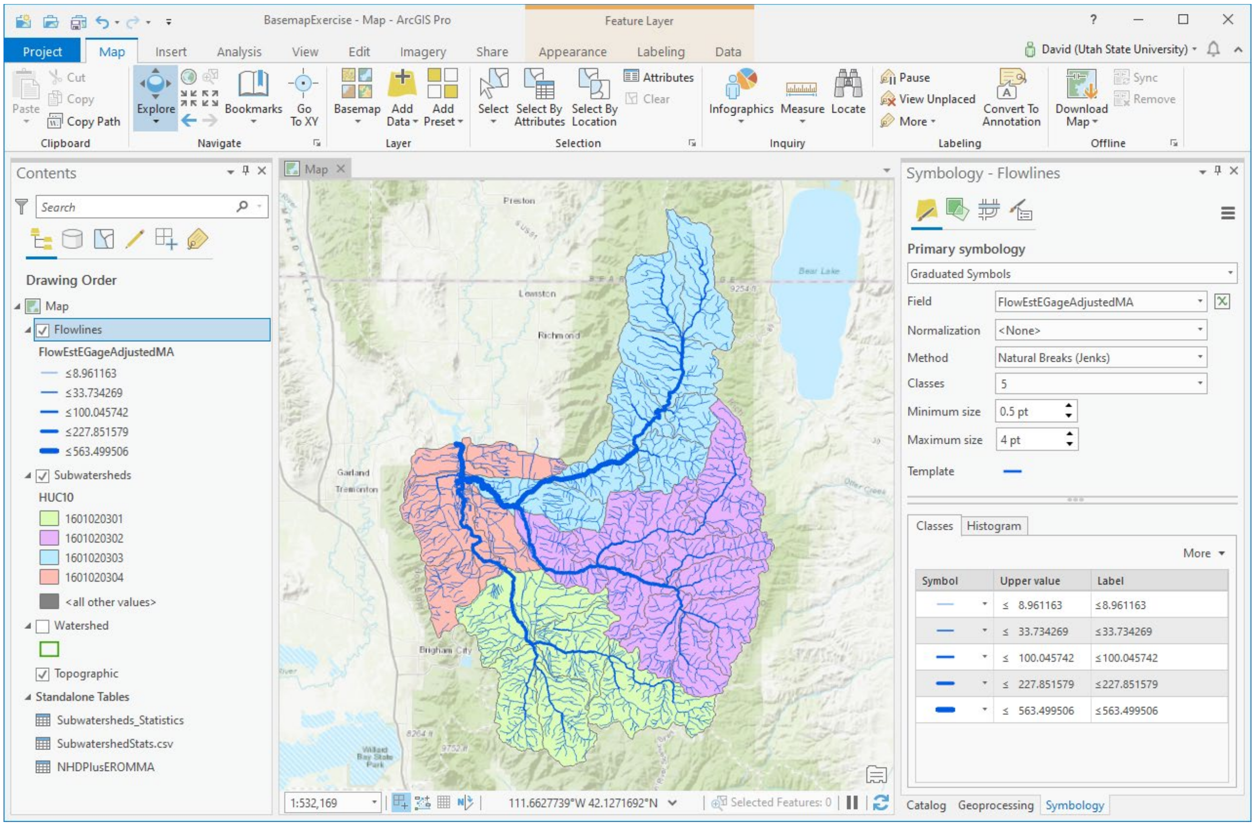


With flow attributes associated with each stream, we can symbolize the streams using estimated mean annual flow.

11. Right click on **Flowlines** in Contents and open **Symbology**



Set symbology as below



Pretty Cool !

To turn in: Make a layout map of the Little Bear-Logan subbasin with its watersheds and NHDPlus streams symbolized using estimated mean annual flow. Include a scale, north arrow and appropriate title and legend information.

12. **Save** your project.

Stream gages

Now you are going to build a new Feature Class yourself of stream gage locations in the Little Bear-Logan subbasin. I have extracted information from the USGS website at https://maps.waterdata.usgs.gov/mapper/index.html

SiteID	SiteName	Latitude	Longitude	DASqMile	MAFlow (cfs)
10105900	Little Bear River at Paradise, UT	41°34'32"	111°51'16"	182	92
10113500	Blacksmith Fork Ab Up And L Co.'S Dam Nr Hyrum, UT	41°37'25"	111°44'17"	263	126
10109000	Logan River Above State Dam, Near Logan, UT	41°44'36"	111°46'55"	214	238

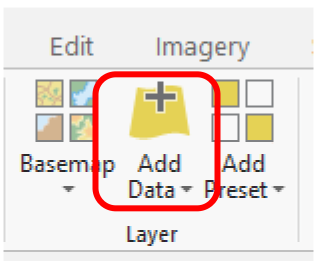
1. Develop a table containing an ID and the long, lat coordinates of the gages
   The coordinate data is in geographic degrees, minutes, & seconds. These values need to be converted to decimal degrees for the 3 pairs of longitude and latitude values. This is something that has to be done carefully because any errors in conversions will result in the stations lying well away from their proper location. I suggest that you prepare an Excel table showing the gage longitude and latitude in degrees, minutes and seconds, convert it to long, lat in decimal degrees:

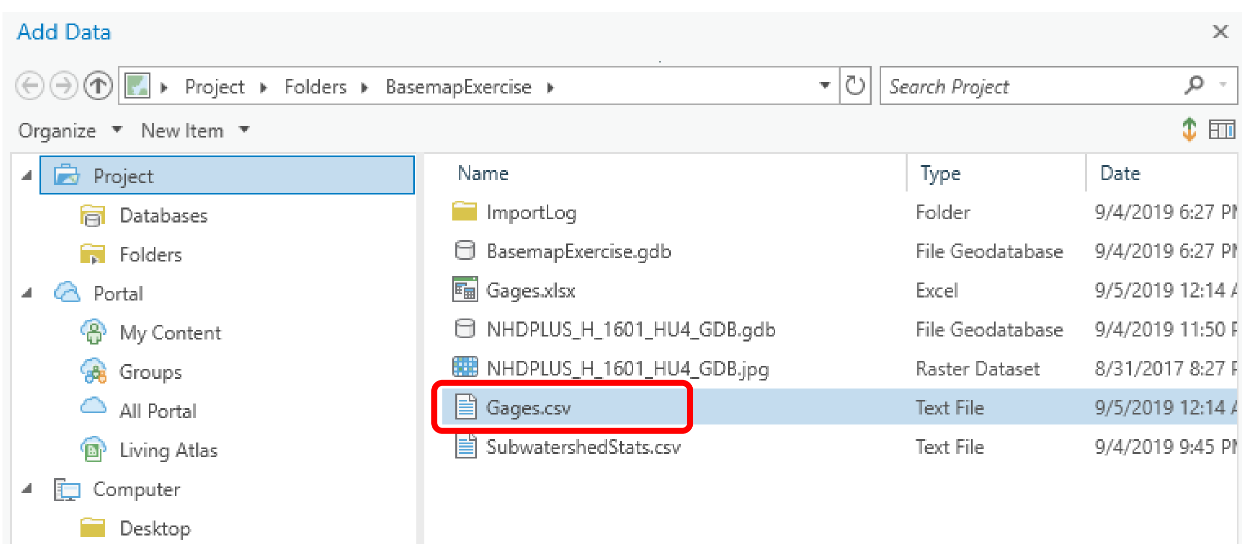
$$Decimal\ Degrees\ (DD) = Degrees + \frac{Min}{60} + \frac{Seconds}{3600}$$

   Remember that West Longitude is negative in decimal degrees. Shown below is a table that I created using Excel. Be sure to include at least 5 digits following the decimal point for Longitude and Latitude data in decimal degrees (LonDD and LatDD). Then save the data from Excel to a comma separated variables (csv) file.

SiteID	SiteName	Latitude	Longitude	DASqMile	MAFlow	Latdeg	Latmin	Latsec	Londeg	Lonmin	Lonsec	Latdd	Londd
10105900	Little Bear River at Paradise, UT	41°34'32"	111°51'16"	182	92	41	34	32	111	51	16	41.57556	-111.85444
10113500	Blacksmith Fork Ab Up And L Co.'S	41°37'25"	111°44'17"	263	126	41	37	25	111	44	17	41.62361	-111.73806
10109000	Logan River Above State Dam, I	41°44'36"	111°46'55"	214	238	41	44	36	111	46	55	41.74333	-111.78194

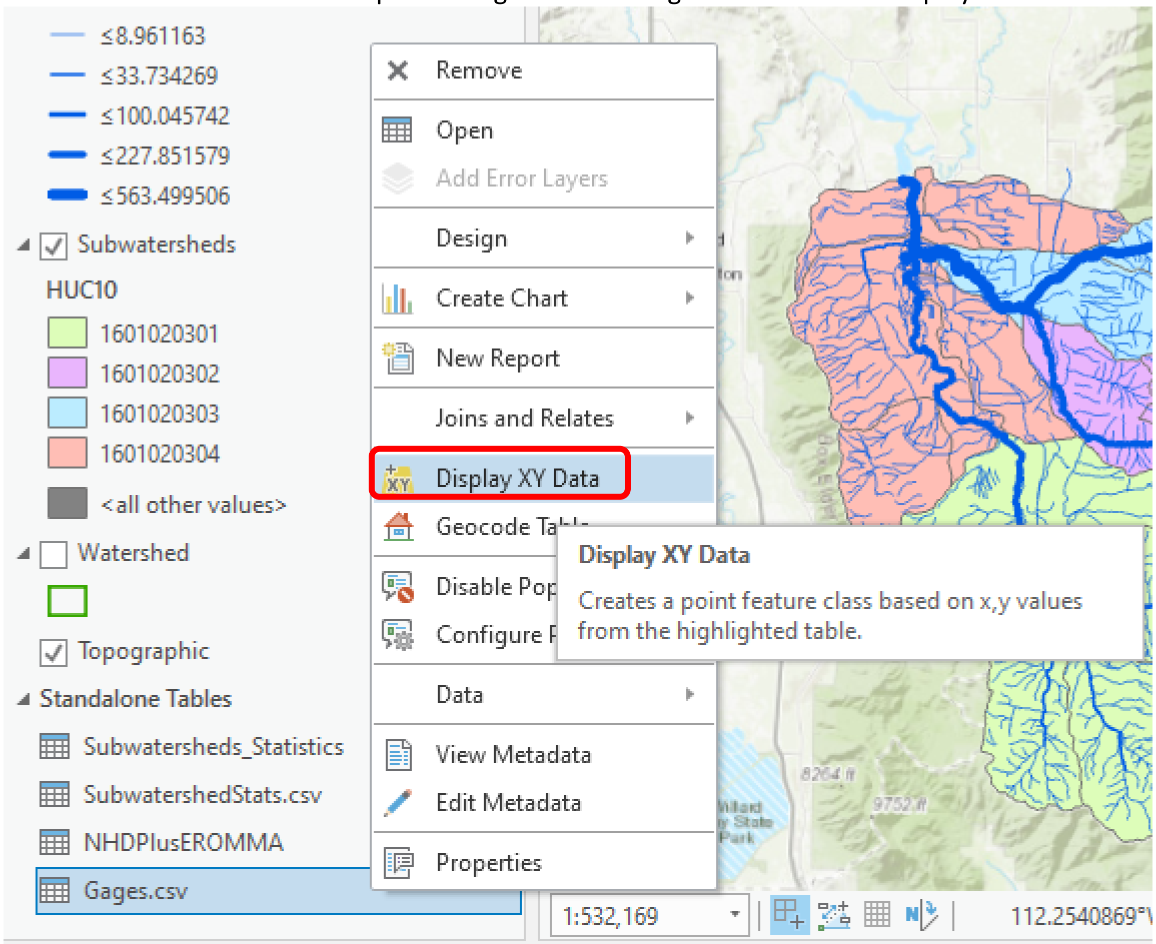
2. Add the CSV table to ArcGIS Pro. Click Add Data and pick Gages.csv



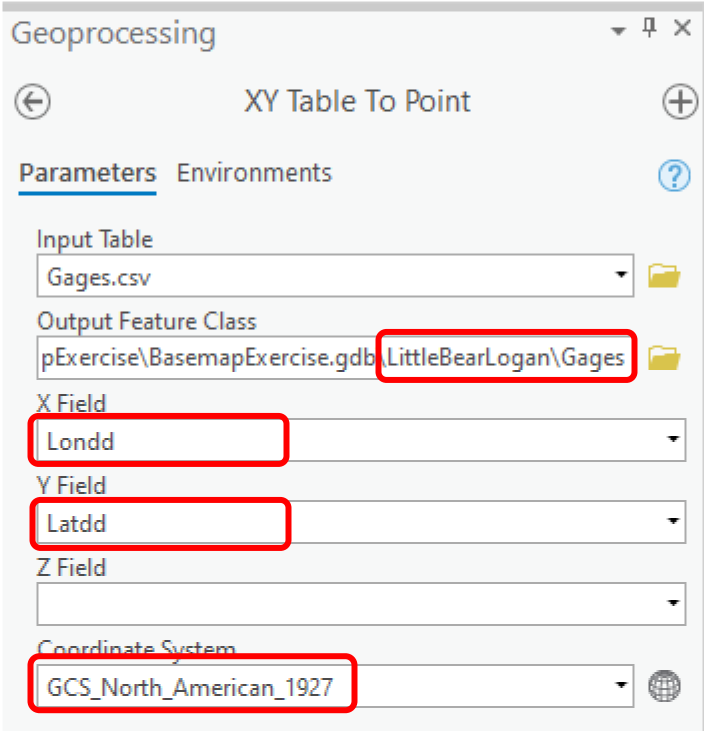


Gages.csv should appear that the bottom of Contents.

3. Convert from tabular values to points. Right click on Gages.csv and select Display XY Data.



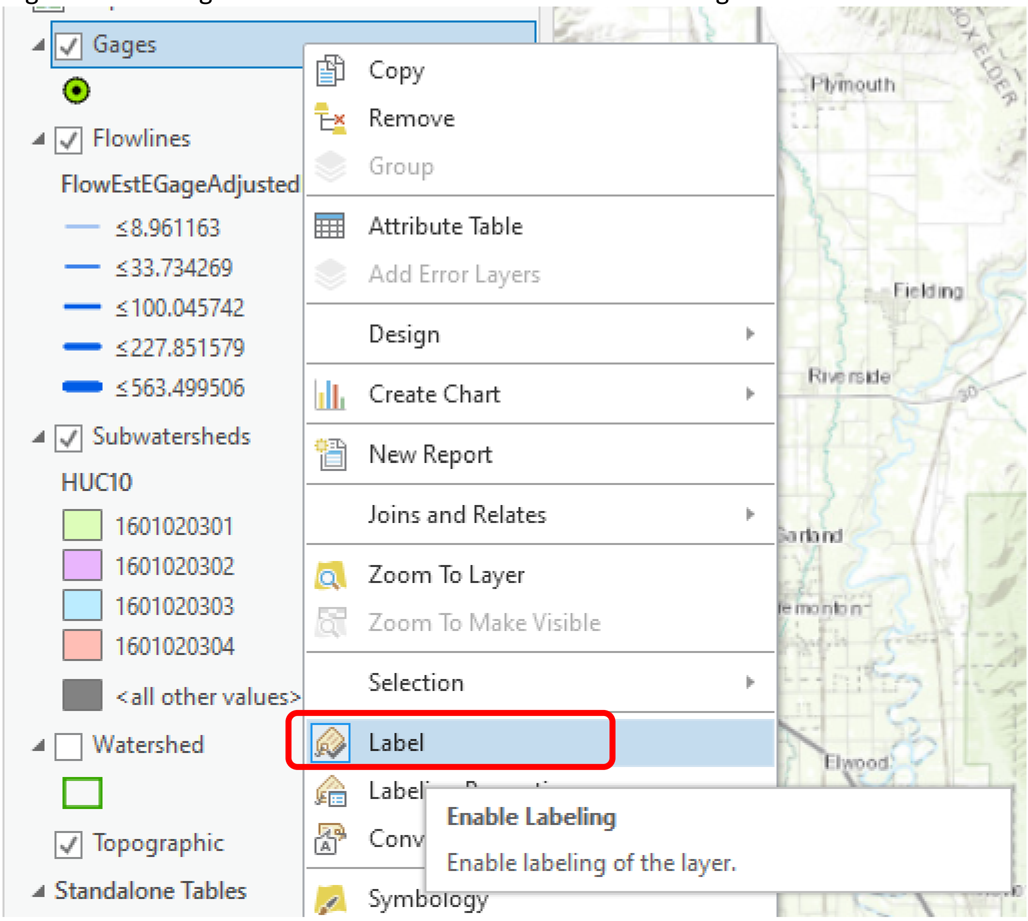
4. In the XY Table to Point Geoprocessing tool that opens, use the following settings and click Run.

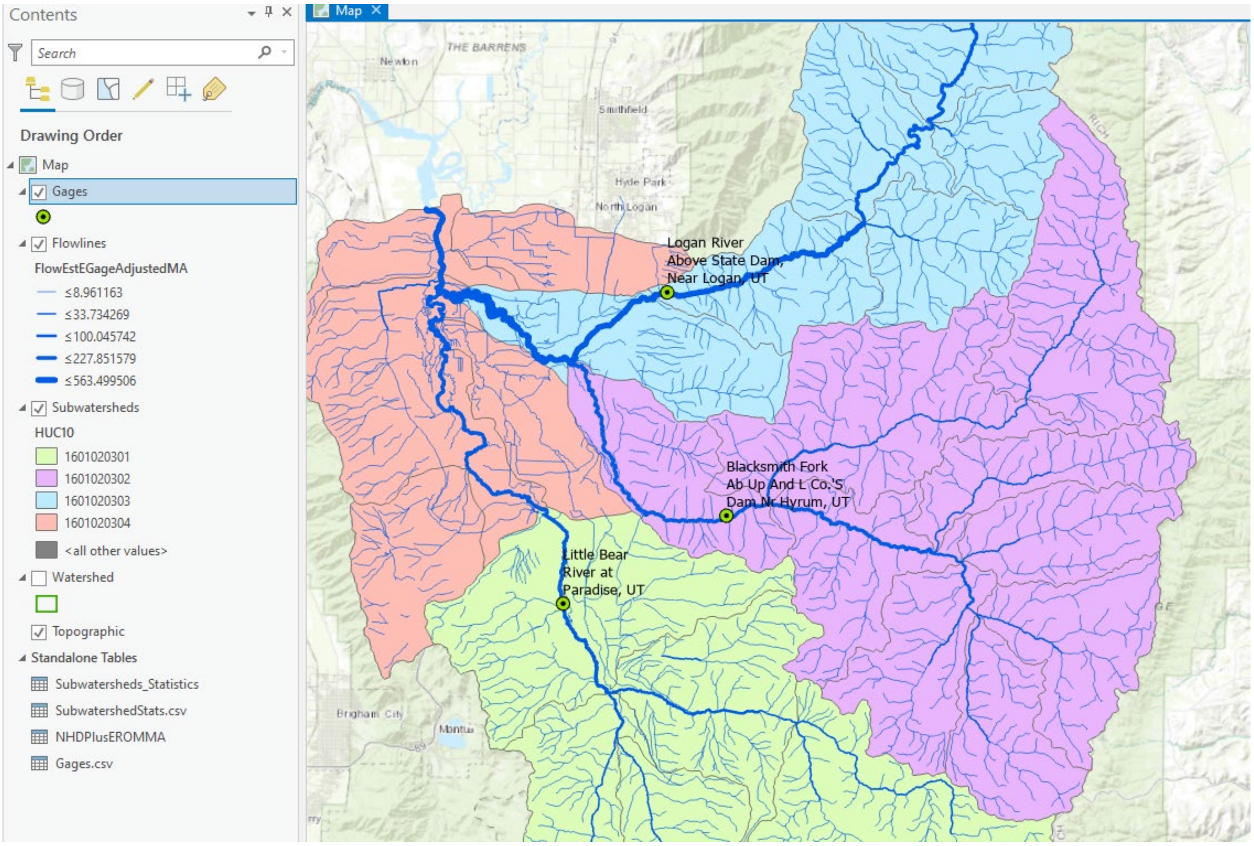


Note that the Gages feature class was saved in LittleBearLogan feature dataset.
Also I used a NAD 1927 coordinate system as I had noted on the USGS website that this was the coordinate system used by the USGS for gage locations. This can be found in Geographic Coordinate System -> North America -> USA and Territories.

The stream gages should appear as points on the map. Symbolize them to your taste.

5. Right click on Gages in Contents and **Label** to Enable Labeling





You may need to adjust label parameters to change font, color or field displayed.

Zoom in to near each gage and use identify to see the gage streamflow as well as NHDPlus FlowEstEGageAdjustedMA streamflow in the reach adjacent to each gage. Prepare a table that compares gage and estimated streamflow for these three gages.

Well done! In this exercise we started with NHDPlus high resolution data produced by US Federal Government agencies and shared using the National Map. We identified and selected the subset of data applicable to our area of interest (HUC 8 Subbasin) and extracted and loaded this data into a Geodatabase feature dataset with a coordinate system chosen for this area. This ensures that the data is all consistent and will work together smoothly. We added to this data, using data produced in Excel and performed some simple analyses such as summing the area over HUC10 watersheds and comparing information spatially. This illustrates some of the potential that GIS provides through the analysis of spatially located information – the "science of where" to borrow the phrase used by ESRI.

To turn in: Make layout map of the Little Bear-Logan subbasin with NHDPlus streams and streamflow gages labeled. Include a scale, north arrow and appropriate title and legend information.

To turn in: Table comparing gage mean annual flow and NHDPlus mean annual flow for the three stream gages in the Little Bear-Logan subbasin.

Summary of Items to be Turned in:

<u>Part 1.</u>

A PDF document for part 1 with the map layout generated at the end of this exercise depicting the impact of deforestation in this part of Brazil and the potential reduction in deforestation by canceling the road project.

<u>Part 2.</u>

A separate single PDF or Wordprocessor document with the following

1. *Make a layout map of the Little Bear-Logan subbasin with its HUC10 and HUC12 watersheds and subwatersheds. Include a scale, north arrow and appropriate title and legend information.. Prepare a table (Excel is probably easiest) summarizing the area and number of HUC12 subwatersheds in each HUC10 watershed.*

2. *Make a layout map of the Little Bear-Logan subbasin with its watersheds and NHDPlus streams symbolized using estimated mean annual flow. Include a scale, north arrow and appropriate title and legend information.*

3. *Make layout map of the Little Bear-Logan subbasin with NHDPlus streams and streamflow gages labeled. Include a scale, north arrow and appropriate title and legend information.*

4. *Table comparing gage mean annual flow and NHDPlus mean annual flow for the three stream gages in the Little Bear-Logan subbasin.*

Note that maps, tables and documents that you turn in should be clearly labeled so that they may be unambiguously interpreted with a title, scale, north arrow and appropriate title and legend information.