Watershed Analysis of the Blue Ridge Mountains in Northwestern Virginia
Mason Fredericks
December 6, 2018

Purpose

The Blue Ridge Mountain range is one of the most popular mountain ranges in the United States. As a part of the larger Appalachian mountain range of the northeastern United States, the Blue Ridge Mountains are known for their natural, beautiful blue tint along the horizon. This watershed analysis is done in order to prepare for a trip in the coming months and to create a better understanding of the area before arriving. By finding the areas and perimeters of the three watersheds for the area of interest, it allows for precipitation and discharge to be determined, among other variables.

Data Collection

- Downloaded a DEM and hydrological data from the USGS National Map Viewer. The DEM is a 1/3 Arc-second, 1 x 1 degree DEM that was created in 2016. The hydrological data is NHD data also published in 2016 and provides flow lines for rivers and streams in the two HU-4 subregions my area of interest covers.
- Downloaded a 7.5' grid that contains the quadrangles for the state of Virginia and will allow for more accuracy in location.
    - Also found from https://viewer.nationalmap.gov/basic/
- Downloaded a State Boundary shapefile to help better determine locations. This is useful because the Area of Interest is close to the border of West Virginia and Virginia.
- https://viewer.nationalmap.gov/basic/

Data Preprocessing

The data files downloaded from the USGS The National Map Online Map Viewer Data Downloader all came in compressed .zip files. To unzip these data files, I went to the Windows File Explorer and selected the file that needed to be unzipped. After that, I right-clicked on the folder and selected "Extract All…" which allowed for the data to be uncompressed and used as feature classes and shapefiles in ArcMap.

For the two HU-4 subregions, I used the attribute table to select the perennial rivers in the subregion. This selected the streams and rivers that are seen year-round, and removes some of the clutter from the map. To do this, as mentioned earlier, I went to the attribute table of both of the two Subregions and selected the perennial rivers using the Select by Attribute tool (see Figure 1.) Once the data for the subregion was selected, I selected the layer and went to Data → Export Data, and chose to export the selected features as a layer in this map (see Figure 2). This creates a new shapefile for the major rivers of the two NHD Hydrography boundaries – one for HU-4 area 207 named *major_rivers_207* and one for HU_4 area 208 named

major_rivers_208. This process had to be done for both of the HU-4 subregions in order to select the rivers contained within those subregions.
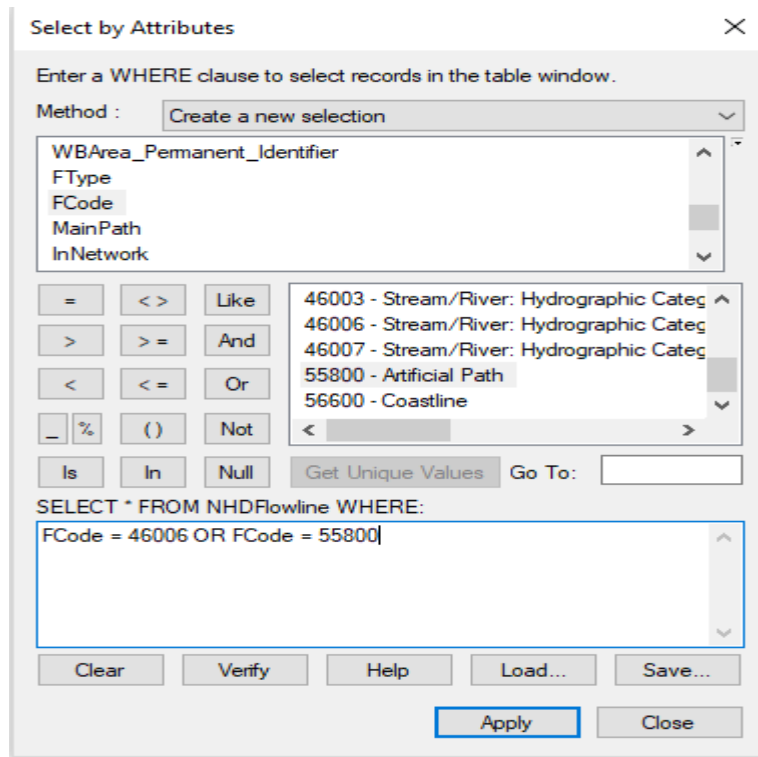

Figure 1: Selecting the perennial rivers using the Select by Attributes tool in the attribute table of the NHDFlowline layer. This tool was used for both NHDFlowline layers for the 207 and 208 subregions of the HU-4 Basin.
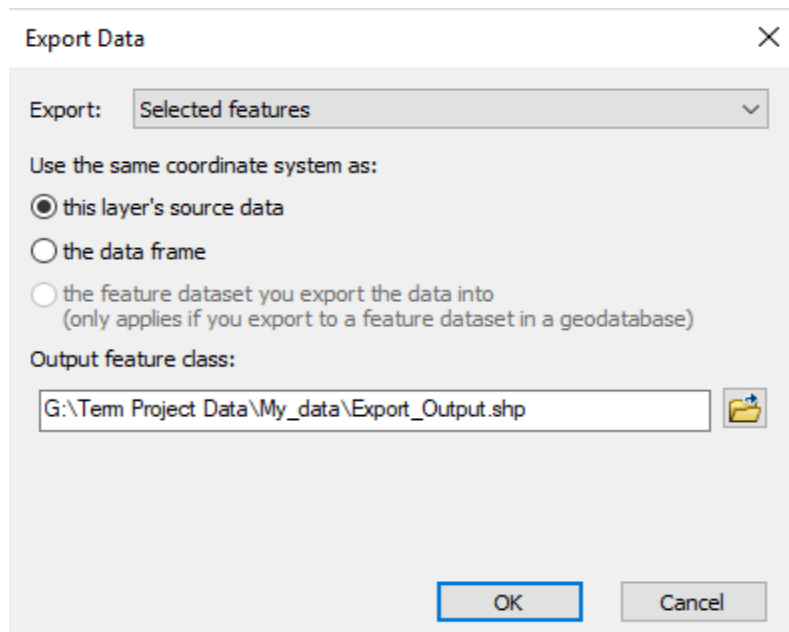
Figure 2: Exporting the selected perennial rivers as its own layer in ArcMap. This was done for both NHDFlowline layers for the 207 and 208 subregions of the HU-4 Basin.

The National Boundary Dataset information came in the form of geodatabases. However, the polygon for the states loaded into the map with the 5 bordering states around it. For example, the Virginia state polygon provided loaded into the map with West Virginia, the District of Columbia, Maryland, Kentucky, and Tennessee loaded in. Since I am only working in the state of Virginia, I needed to cut it down to only the state of Virginia. The process to fix this is similar to getting the major rivers from the NHD dataset. To do this, I went to the attribute table for the National Boundary Dataset for Virginia, selected the row that contained the information for Virginia, and selected Data → Export Data. Similar to before, I chose to export the selected features and to create a new shapefile for the output feature class. Finally, I then chose to export the data as a new layer to the map.

The feature classes and shapefiles added from the downloaded geodatabase were not all consistent with the same coordinate system. To fix, this, the coordinate system of the Data Frame was changed to NAD 1983 UTM Zone 17N. This allows for consistency with the layers and allow for work to be done. For example, this allowed for the creation of the Area of Interest.

In order to get labels added onto the map, the Label Manager in the Labeling toolbar was used, and the labels for the quadrangles and the state of Virginia shapefile were turned on. Since the Virginia label needed to be a higher weight than the quadrangle labels, the Label Weight Ranking tool was used; the Virginia state shapefile was set to high and the rest of the labels to medium so that the Virginia label is more noticeable and does not get lost (see figure 3).
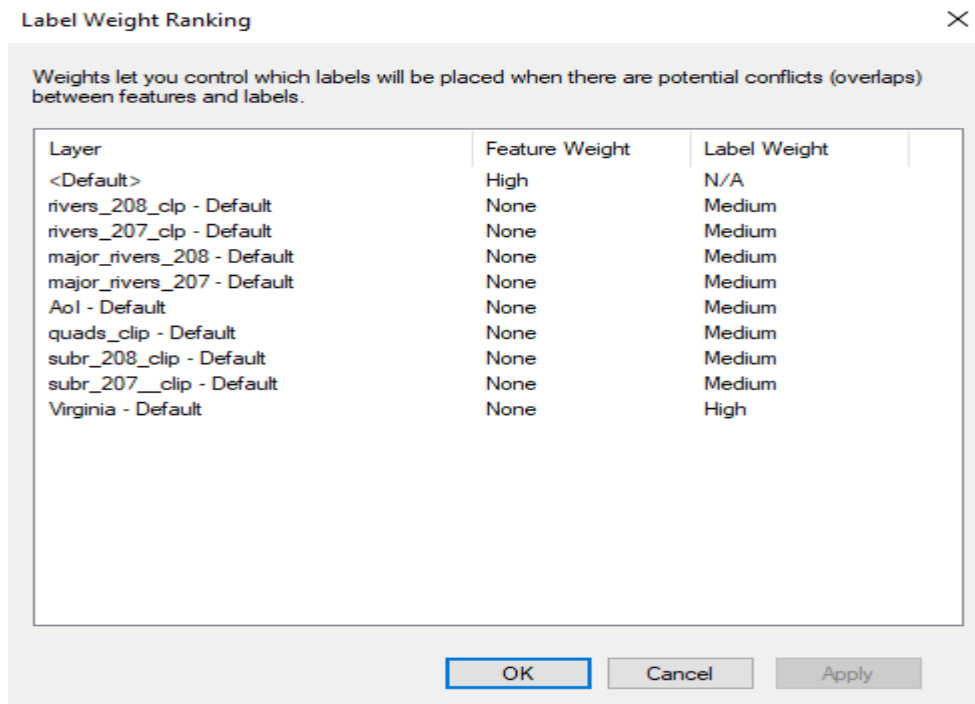
Figure 3: Weighting the labels used on the map so that the Virginia Label has the highest rank.

In order to help determine flow and establish pour points, USGS gauge data was added as NHDPoint to the map. This feature class contained extraneous data, so in the attribute table I used Select by Attribute to select only the gauge station points and exported the data as a layer in the map. This was done for both subregions 207 and 208. Then, by the Select by Location tool, the points inside of the area of interest were selected and exported to the map as a layer. Under Data Management toolbox under General, the Merge tool was used to make these two gauge layers into one layer.

Finally, a hillshade was created in order to see the terrain and for aesthetic purposes for the hillshades. This was created using the Spatial Analyst toolbox under Surface → Hillshade. The input raster for this was the clipped DEM with the output raster being the hillshade.

ArcGIS Processing:

To pinpoint the area of study, an *Area of Interest* was created in ArcMap. First, in ArcCatalog in the My_data folder, a new shapefile for the area of interest was created using a polygon (see Figure 4). Using this shapefile and the editor tool, a rectangular polygon for the Area of Interest was created. After Start Editing was chosen next under the Editing toolbar under Editing Windows, the Create Features option was chosen. Then, the Area of Interest shapefile was chosen along with the Rectangle option under Construction Tools, and the area of interest was created by choosing the vertices in ArcMap. Finally, the Area of Interest was symbolized to have a blank fill color and a red outline, as seen in Figure 5 below.
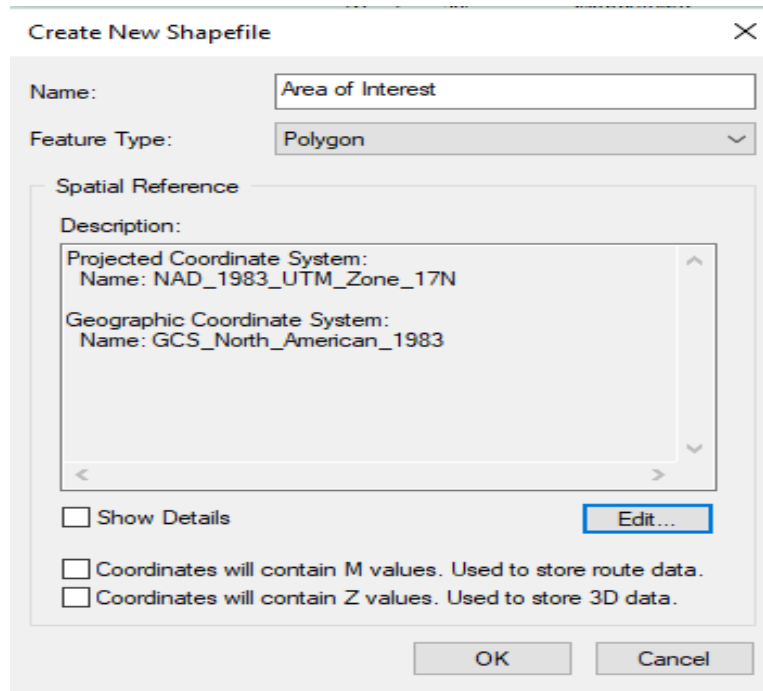
Figure 4: Creating a new shapefile for the area of interest. This tool allows for the shapefile to be a polygon and helped set the coordinate system of the Area of Interest.

Figure 5: The Area of Interest created from the Create Features tool. The light green polygon is the 207 subregion of the HU-4 Basin for the NHD Hydrography dataset. The light purple polygon is the 208 subregion of the HU-4 Basin for the NHD Hydrography dataset. The "*major_rivers*" shapefiles for these subregions were turned off for this screen capture to reduce clutter and to make the Area of Interest more visible.

The next step in this process is to clip the important layers to the Area of Interest in order to do the analysis. ArcToolbox is used to clip the features to the Area of Interest, and this is under Analysis Tools → Extract → Clip. The input features are going to be these important layers (the HU-4 Basins of the two Subregions 207 and 208, the 7.5' quadrangle grid, the two HU-4 Subregions, and the DEM), and the Clip Features is the Area of Interest (see Figure 6 for an example).
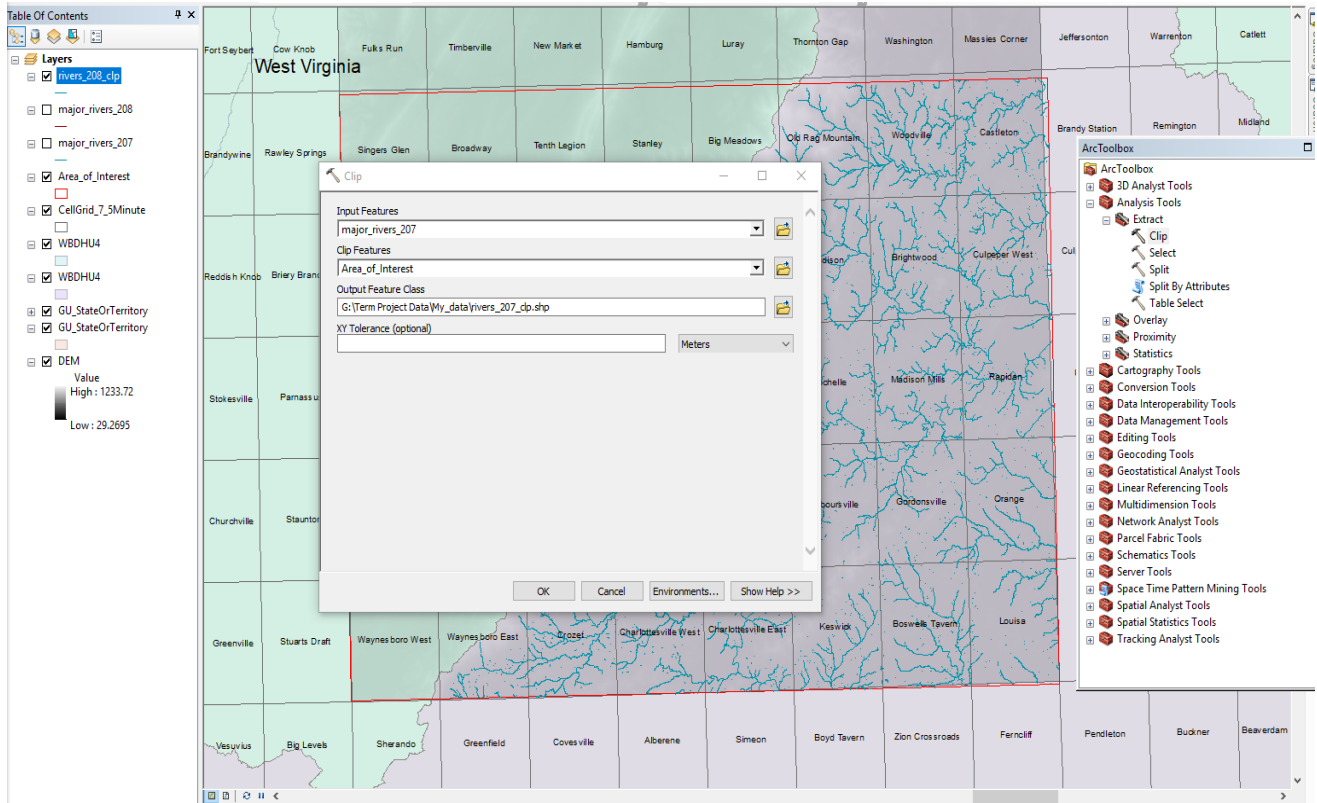
Figure 6: An example of clipping a feature to the Area of Interest. In this case, the *major_rivers_207* layer is getting clipped. In the background, there is an example of how the *major_rivers_208* layer has already been clipped to the Area of Interest, changed to "*rivers_208_clp*".

Since the DEM is a raster, it requires a special tool in ArcToolbox different from the rest of these features. This tool is the Extract by Mask tool under Spatial Analyst → Extraction → Extract by Mask (see Figure 7).
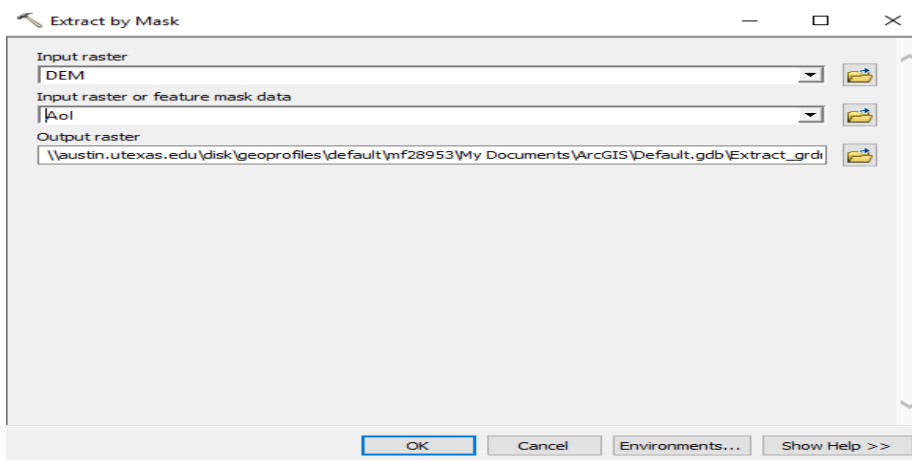

Figure 7: The Extract by Mask tool being used. As stated earlier, the DEM is a raster which is different from the rest of the features.

Watershed Analysis Using Raster Calculations and ArcToolbox

To start doing the watershed analysis, the area of interest needs to be delineated. To start, there needs to be a flow direction for the area of interest. The first step in delineating watersheds is to create a depressionless DEM. To do that, the Fill tool is used. The Fill tool creates this depressionless DEM by filling in any "sinks" in the original DEM. These sinks are usually No Data for the DEM or either peaks or depressions (areas of internal drainage). Next, the Flow Direction tool is used. The Flow Direction tool uses a DEM to create local flow directions for rivers and streams in the area. The Flow Direction tool is in ArcToolbox under Spatial Analyst Tools → Hydrology → Flow Direction. The input surface raster is the clipped DEM raster created earlier using the Extract by Mask tool (see Figure 8).
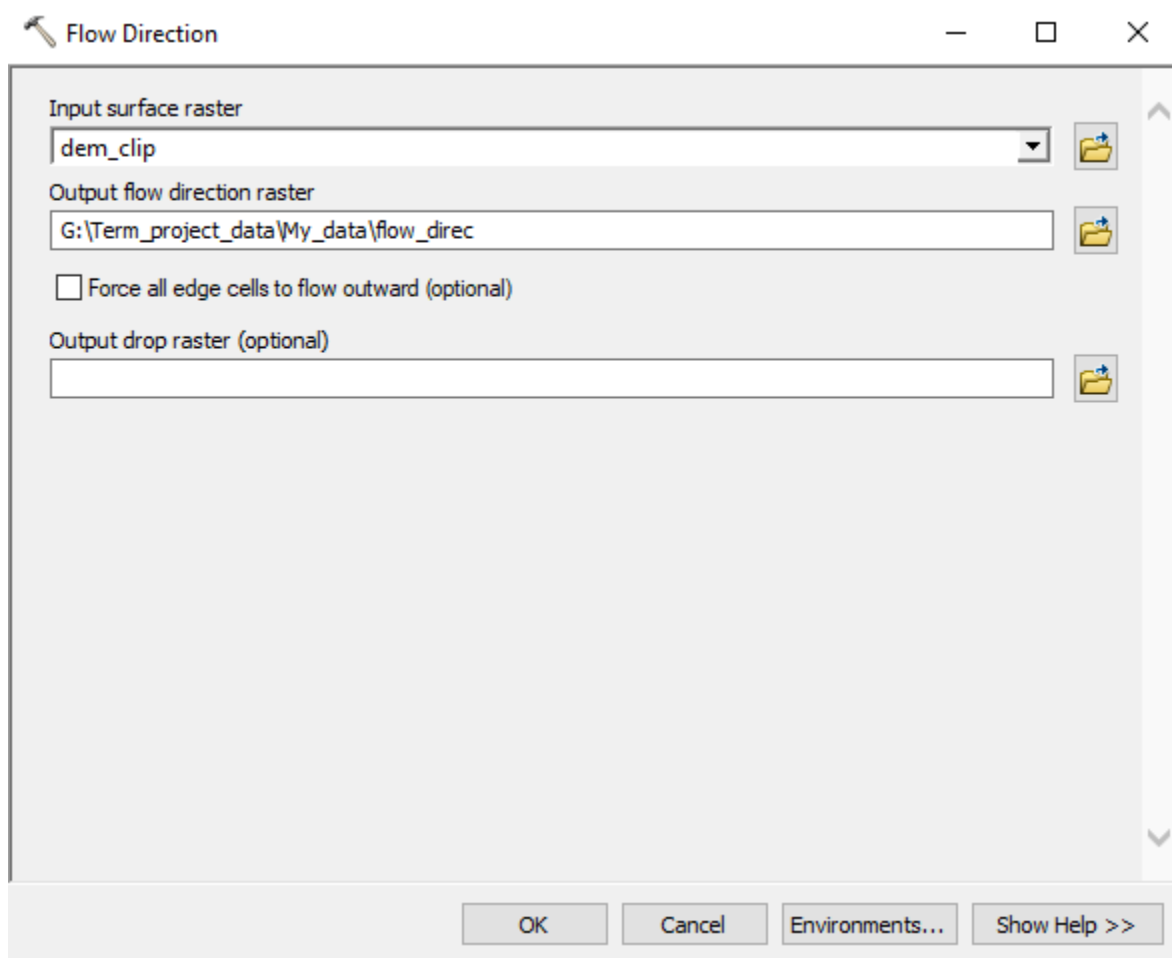

Figure 8: Using the Flow Direction tool to create a flow direction raster for the watershed analysis.

Next, an accumulation raster must be created. This is found under Spatial Analyst → Hydrology → Flow Accumulation. The input flow direction raster is the *flow_direct* raster

created above (see Figure 9). The output raster for this tool is named *accum_1*. This is also a key step for doing the watershed analysis of the area of interest.
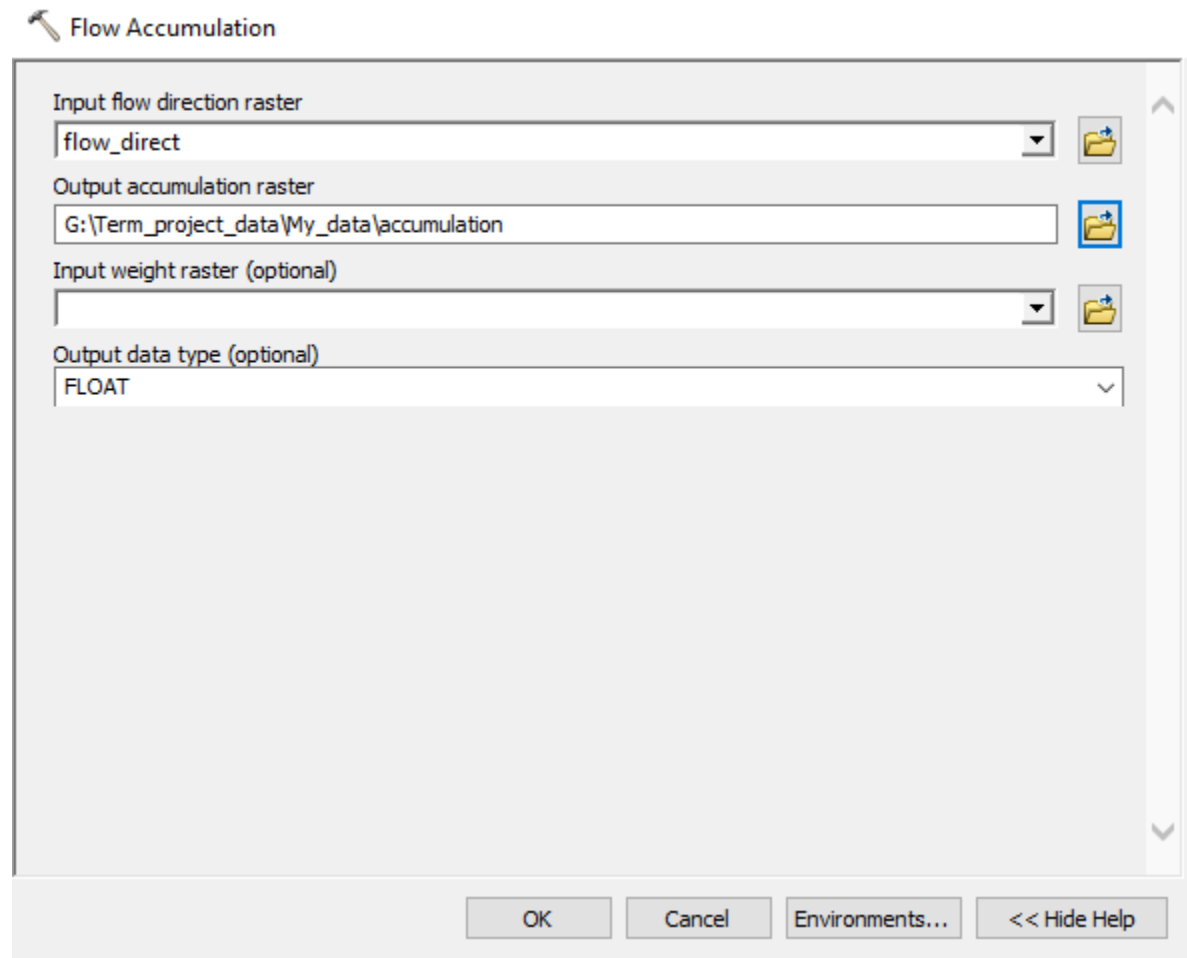

Figure 9: Creating the accumulation raster for the watershed analysis.

A threshold for this accumulation raster needs to be specified. This can be done with using Map Algebra using the Con tool. The syntax of this algebra is accum100 = con(accum > 100, 1). This would make all cells with more than 100 cells flowing into them part of the stream network. This creates a layer on the map pinpointing every cell with greater than 100 cells flowing into it. Figure 10 is the outcome of this map algebra (see below).

The Stream Link tool is then used to create a linear network using this threshold. This means that all of the rivers with over 100 cells flowing into them are linked into a linear network.
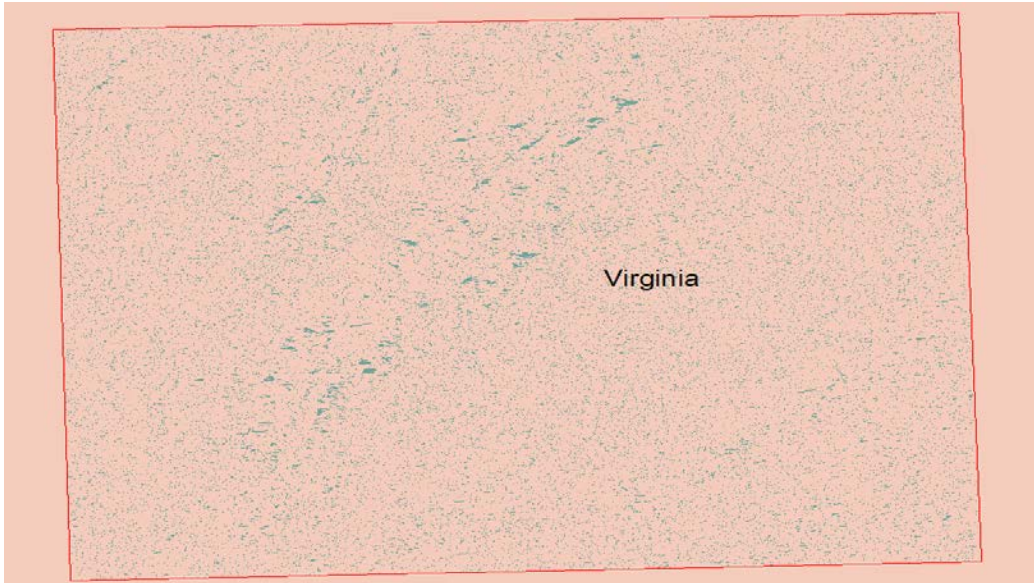
Figure 10: The product of the map algebra. All of the green dots display cells with more than 100 cells flowing into it.

Next, the Flow Length tool is used to calculate the downslope distance along the flow paths within the basins of the area of interest. The input for this tool was the Flow Direction layer *flow_direct_3* and this is a downstream measurement of the flow length. Figure 12 is the output raster for the Flow Length tool (see below).
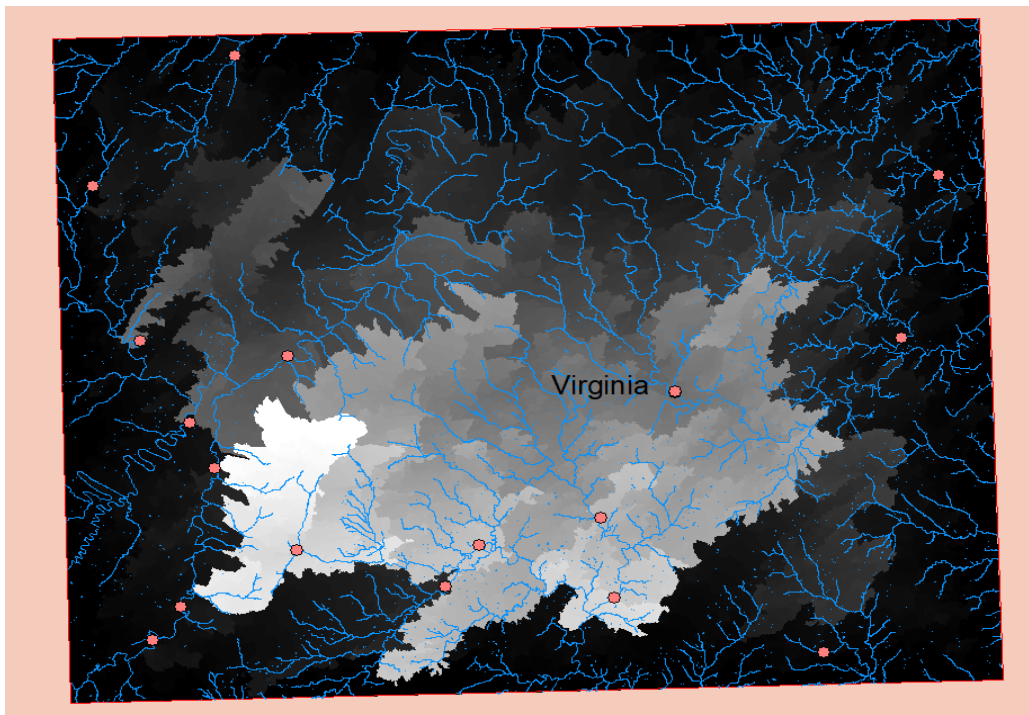

Figure 12: The output of the Flow Length tool. The white areas are basins that are closest to the stream outlet, with the darker areas being farther away.

Finally, using the output of the Flow Length tool, the watersheds are created. This is done by using the Watershed tool (see Figure 13). As seen in Figure 14, the Flow Direction raster is used along with the input raster being the *flow_length* raster. This has created the watershed areas which will allow for the analysis.
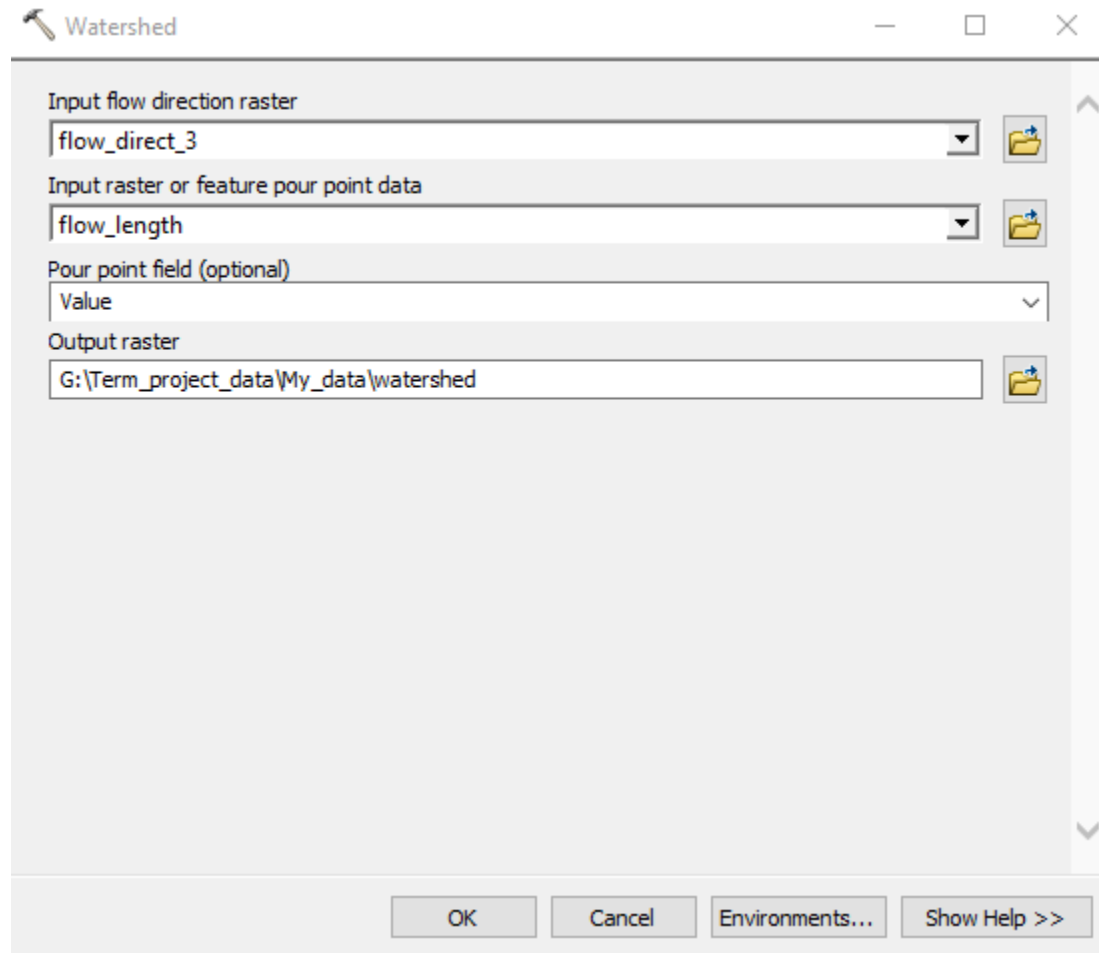

Figure 13: Image showing the data window for the Watershed tool.

The Watershed tool created 3 different areas for the watershed analysis (see Figure 14 below. These watersheds have been placed on top of the hillshade in order to get a better understanding of the downstream environments for the area of interest.
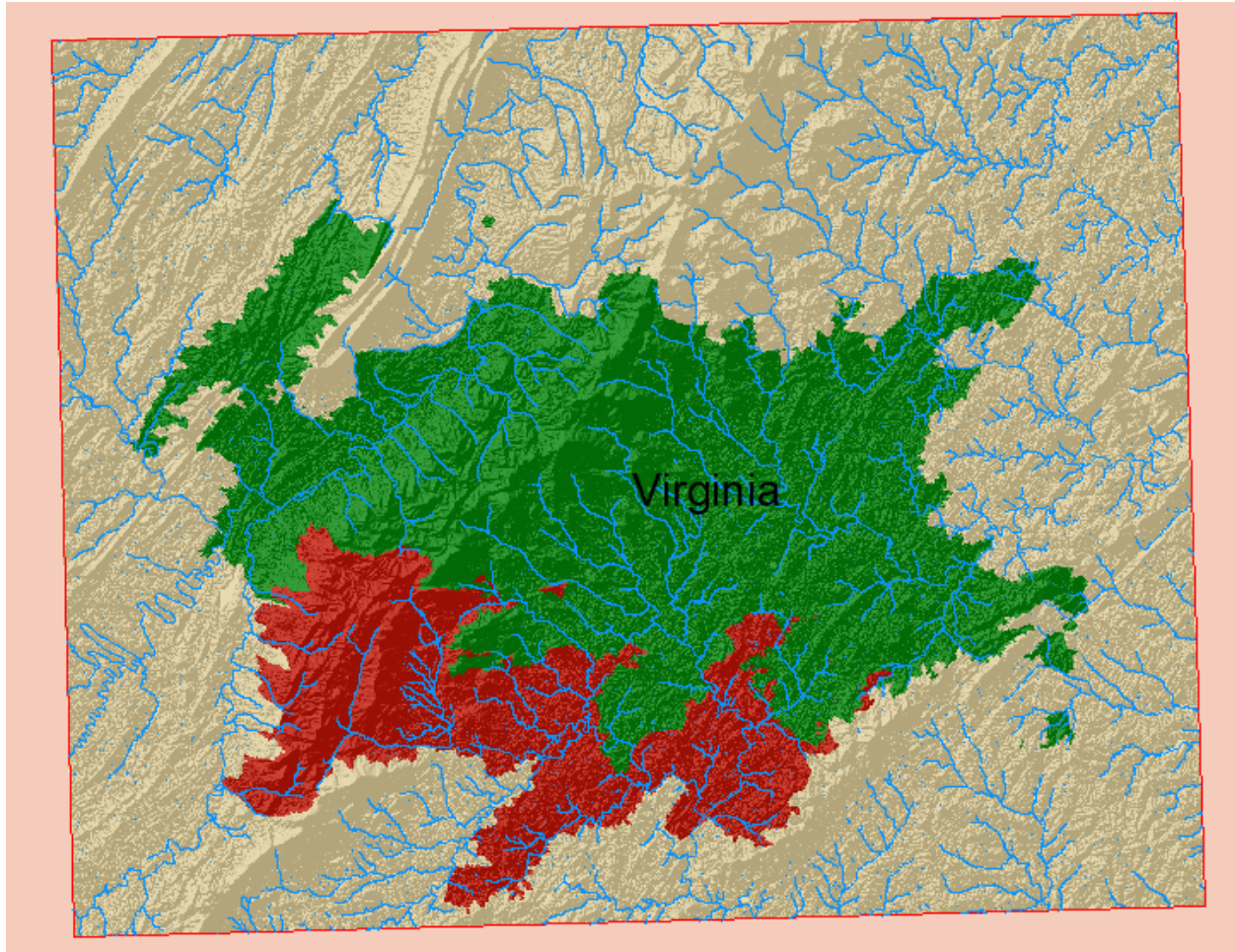
Figure 14: The product of the Watershed tool. With the Rivers feature class, the downstream environments of this region are better understood.

The final step is to calculate the area of the watersheds. This area calculation will allow for discharge and possibly annual precipitation as well. Before doing the area calculation, the watershed raster needs to be converted to a polygon. In ArcToolbox under Conversion and From Raster, the Raster to Polygon tool is selected. This creates one individual polygon for the whole raster, so in the attribute table of the polygon and the Select by Features tool, the gridid of each watershed is selected and is exported as a layer. This process is similar to earlier with the rivers and isolating the Virginia shapefile. This area calculation can then be done by going to the attribute table for each watershed layer and creating a new field through "Add Field…" called "Area". Next, "Field Calculator" is chosen and "Area" is selected, with the units being square kilometers (see Figure 15). This calculates area for each polygon within that watershed layer's total polygon, which needs to be added up to get the area for the total polygon. The perimeter also needs to be calculated, which is the same process as calculating area, but using Perimeter as the property in the Calculate Geometry tool.
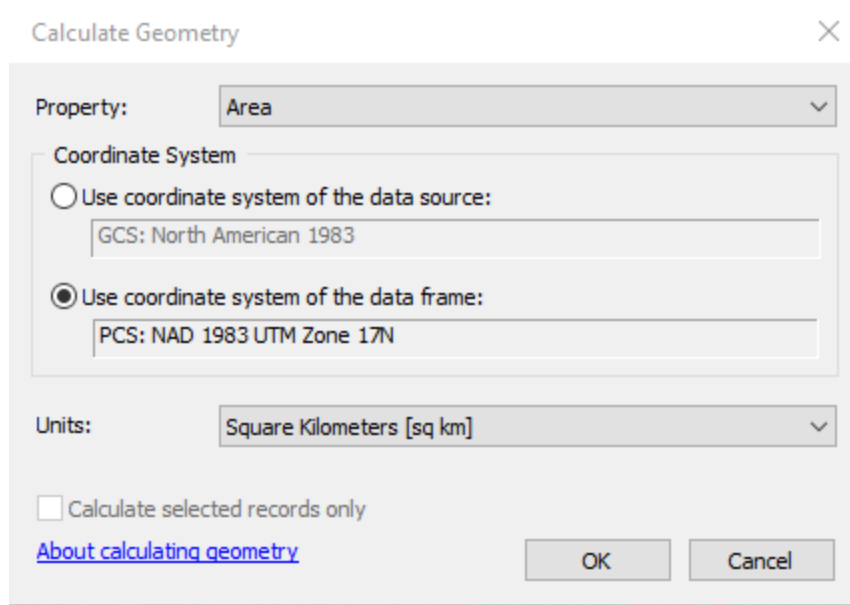
Figure 15: Calculating the area of the watershed polygons.

A table containing the areas and perimeters of the three watersheds is seen below in Table 1. This information is helpful for calculating amount of downstream discharge and annual precipitation, among other things.

WATERSHED ID	AREA (KM^2)	PERIMETER (KM)
0	3933.905944	1305.924613
1	1561.827013	1025.72524
2	565.317455	605.859346

Table 1: Area and perimeter of the three watersheds for the area of interest.

Interpretation of Watershed Analysis and Conclusion

As seen from the Flow Length raster (Figure 12), the majority of the discharge for the area of interest is coming from the tops of the mountain range. A majority of the lighter gray or white areas are found close to the mountain range, meaning that they are closer to the stream outlets for the area. With overlaying the Flow Length raster and the watersheds on top of one another, it can be determined that watershed area 2 would produce the most discharge, with watershed area 1 with less discharge. The watershed area 0 seems to be areas of little discharge compared to the rest, most likely meaning the area contains small streams that are not affected by the downstream flow of the rivers coming from the Blue Ridge.

Mason Fredericks
12/6/2018

# Watershed Analysis of the Blue Ridge Mountains in Northwestern Virginia

Blue Ridge Mountain Range

Virginia

N
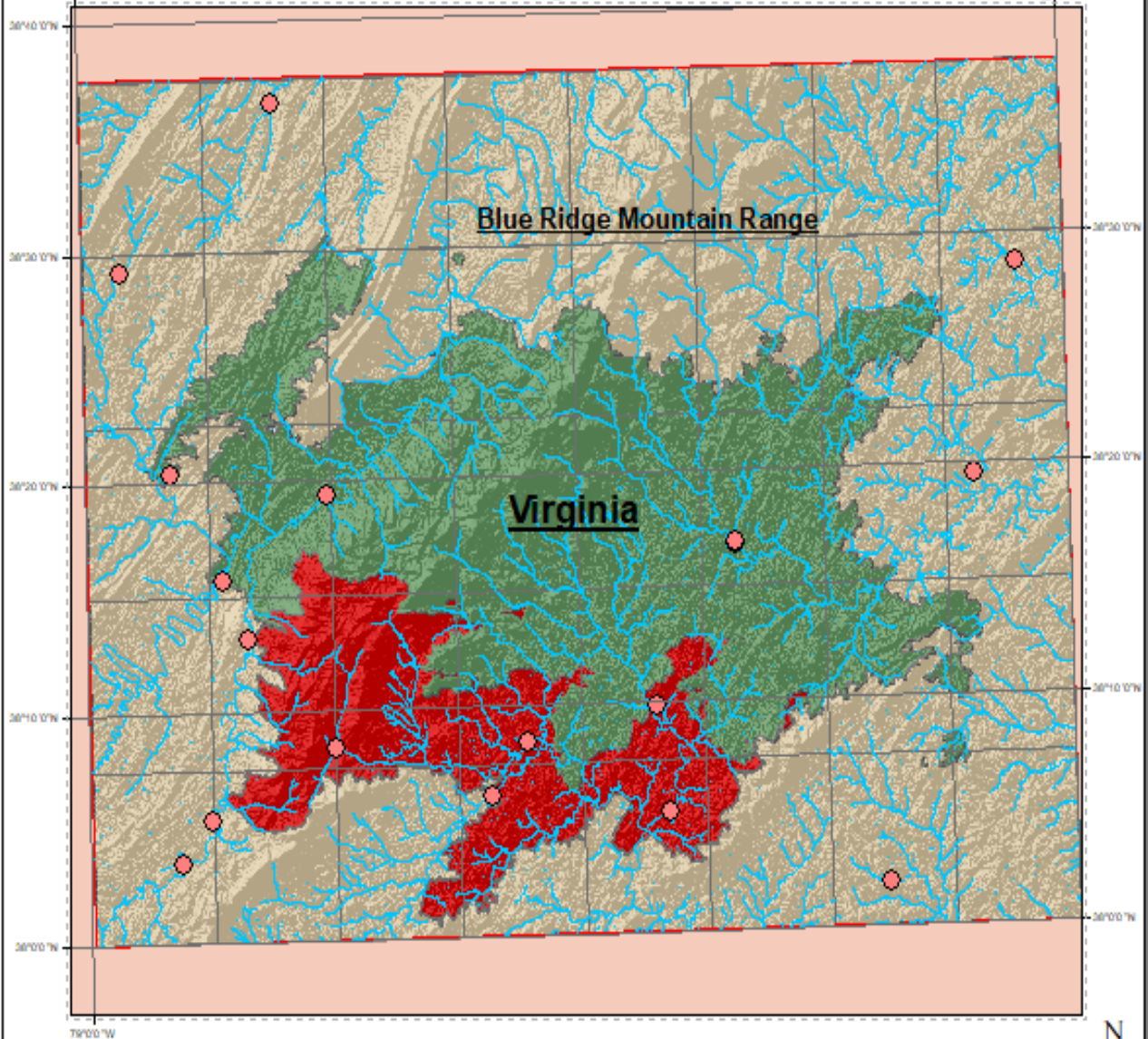
1:470,129

0   5   10   20 Kilometers
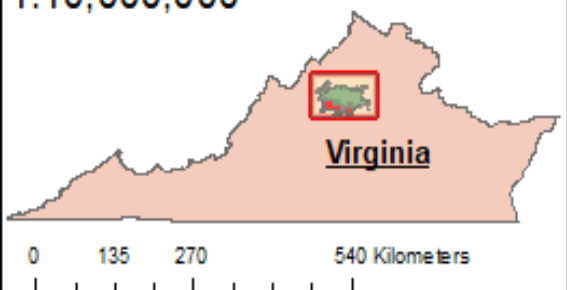
NAD 1983 UTM Zone 17N
Projection: Transverse Mercator
Geographic Coordinate System: GCS North American 1983

Explanation

- ● USGS Gauges
- ── Rivers
- ▭ Area of Interest
- ▭ Quadrangles
- ▭ Watershed Area 0
- ▭ Watershed Area 1
- ▭ Watershed Area 2
- ▭ Virginia

1:10,000,000

Virginia

0   135   270   540 Kilometers

References

 "Deriving Runoff Charcteristics." What Is SQL?-Help | ArcGIS Desktop, ESRI,
         desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/deriving-runoff-
         characteristics.htm.

"How Watershed Works." How Watershed Works -ArcGIS Desktop, ESRI,
         desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-watershed-
         works.htm.

"Hydrologic Analysis Sample Applications." Help |ArcGIS Desktop, ESRI,
         desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/hydrologic-analysis-
         sample-applications.htm.

PowerPoint from Dr. Maidment, 2015. "DEMs, Watershed and Stream Network Delineation"
         24 September, 2015
         http://www.caee.utexas.edu/prof/maidment/giswr2015/Visual/DemWatershedDelinea
         tion.pptx

Powerpoint from Dr. Maidment, 2015. "Exercise 4: Watershed and Stream Network Delineation",
         1 October, 2015,
         http://www.caee.utexas.edu/prof/maidment/giswr2015/Synopsis/SynopsisWatershedDelinExer
         cise.pdf

"Surface Hydrologic Modeling and Watershed Delineation." *Introduction to Geographic
         Information Systems in Forest Resources*, University of Washington, 30 Sept. 2010,
         courses.washington.edu/gis250/lessons/hydrology/index.html.

"The National Map Viewer." *The National Map - Advanced Viewer*, United States Geological
         Survey, viewer.nationalmap.gov/basic/.