

Lab 11: Terrain Analyses

What You'll Learn: Basic terrain analysis functions, including watershed, viewshed, and profile processing.

There is a mix of old and new functions used in this lab. We'll explain the new, but you are expected to review old labs if needed.

You should read chapter 11 in the GIS Fundamentals textbook before this lab.

Data is in the \Lab11 subdirectory, all in NAD83 UTM zone 15 coordinates, meters, including *driftless*, a raster elevation grid, 3m cell size, Z units in meters, and *driftless30*, a raster elevation grid, 30m cell size, Z units in meters. A shape file called *viewspot.shp* is also used in this lab.

What You'll Produce: Various hydrologic surfaces, a watershed map, a viewshed map, and profiles.

Background

Elevation data, also known as terrain data, are important for many kinds of analysis, and are available in many forms, from many sources and resolutions.

Although the most common use of DEMs is as shaded relief background for maps, we often are interested in working with terrain data – calculating slopes, aspects, steepness or slope along profiles, viewsheds, as well as watershed and other hydrologic functions. The readings and lectures describe some of these applications, and this set of exercises introduces them.

We will complete two projects here, using the same basic data. The first project has two parts, first comparing DEM raster data sets from 2 time periods; a 30 meter data set from the USGS and produced in the late 1980s, and a 3 meter data set from LiDAR data collected about 2006. We then use the LiDAR DEM to explore profile and viewshed tools.

Our second project focuses on watershed processing, using the ArcGIS Hydrology tools.

Project 1: Raster Surfaces, Profiles, and Viewsheds

Start ArcGIS Pro, create a new project, add a Map, add the raster *driftless* to the view, and inspect it. Right click on the layer in the TOC and then **Properties – Source** tab to inspect the layer properties. What is the cell resolution? What are the highest and lowest elevation values?

Now add the raster *driftless30*, and inspect it for resolution, cell size, and values.

Use the **Raster Calculator** to subtract *driftless* from *driftless30*. Inspect the range of differences in elevation and note where they largest differences tend to occur.

This illustrates the differences you can encounter with data from the same area. The *driftless* layer is a newer version developed from LiDAR data at a higher vertical and horizontal resolution, while *driftless30* is an example of the highest resolution data available in most areas until the early 2000's.

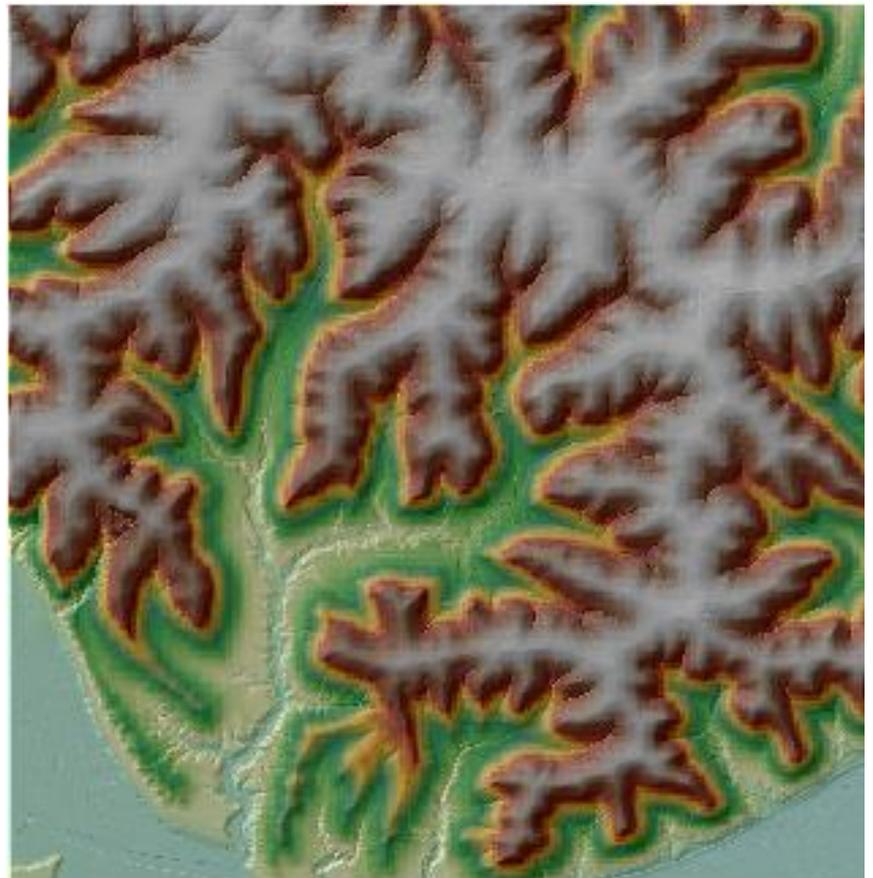
Declutter the view by removing the *driftless30* DEM and the difference layers from the map.

Derive the hillshade for *driftless* (see earlier labs, or search in the geoprocessing pane).

Specify 25 for the Altitude and model shadows. Name the output file something like *hs_drift*.

Make the hillshade semi-transparent (**Layer Properties** → **Display**, then set the transparency to something like 50% (**Video: Raster Transparency**). You should get a display that looks approximately like the graphic at right. (*minimum-max, gamma=1*)

We'll look at a few tools that use elevation.



Viewshed

First, we'll identify a viewshed, all the areas that are visible from a given point.

Add the *viewspot* shapefile to your Map. This shapefile displays a single point, in the bottom left portion of the *driftless* DEM.

Open the Viewshed 2 tool, either by searching for it in the geoprocessing pane or from **Tools – Toolboxes – 3D Analyst – Visibility – Viewshed 2**.

Specify the driftless DEM as the input raster, the viewspot and the observer features, and an Observer offset of 2 meters:

Video: Viewshed&LineofSight

Your output should appear as below, with the cells visible from the viewpoint here colored in orange:



Viewshed 2

Parameters | Environments ?

⚠ Input raster
driftless

Input point or polyline observer features
viewspot

⚠ Output raster
Viewshe_drif2

> Viewshed parameters

▼ Observer parameters

Surface offset	Linear Unit
0	Meters
Observer elevation	Linear Unit
	Unknown
Observer offset	Linear Unit
2	Meters
Inner radius	Linear Unit

Visibility on a Line of Sight

Sometimes you wish to know the visibility between two locations, e.g., when placing a repeater for a radio signal, or a Add the shapefile Sightline.shp to your Map.

Specify the Line of Sight tool, either by searching for it in the geoprocessing pane or from **Tools – Toolboxes – 3D Analyst – Visibility – Line of Sight**

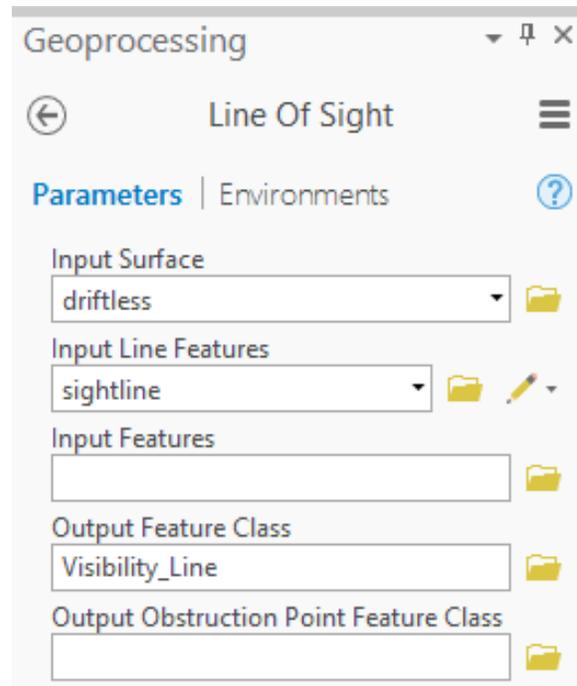
Specify the driftless DEM as the input surface

The sightline polyline as the input line features

and something like VisibilityLine for the output feature class

Leave the other options blank, they are to add or record obstruction locations.

Run, and if it isn't added automatically, add the output feature class to your Map.



This should display a sight line over the DEM, like the one shown on the right. I've increased the line thickness a bit for greater visibility.

The green sections are visible from the starting point on the left, and the red sections are hidden by intervening terrain.



Profile Along a Path

Sometimes you wish to measure or plot the steepness along a path or ski trail, e.g., along a road or potential travel segment.

To do this we must first add the elevation information to the intended path. We can then chart the path.

Add the layer roads.shp to your Map.

Open the tool Interpolate Shape, either by searching for it in the geoprocessing pane or from **Tools – Toolboxes – 3D Analyst – Functional Surface – Interpolate Shape**

Specify the driftless DEM as the Input Surface,

Set roads as the Input Features,

Name the Output Feature something appropriate,

Set the sampling distance to between 3 and 6,

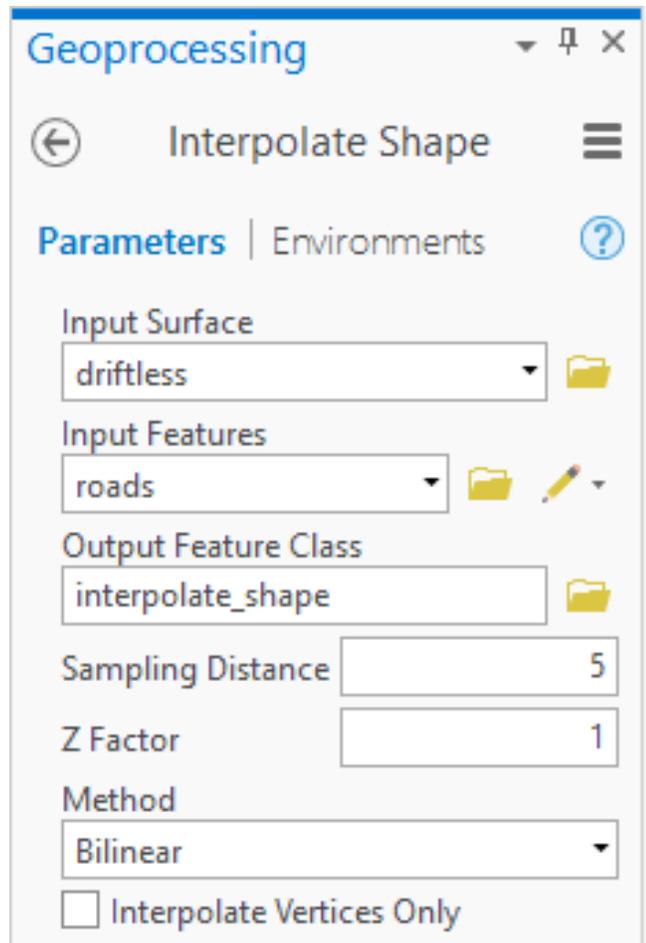
Set Method to Bilinear,

Leave the other features as their defaults, and Run the tool.

On finishing, the tool should add the interpolated shape to your map. It should also have added the elevations to the line data, posting them at the sampling distance you chose.

You can create profile plot from this new output feature you created, which plots the vertical distance you move up or down against the horizontal distance traveled on each segment.

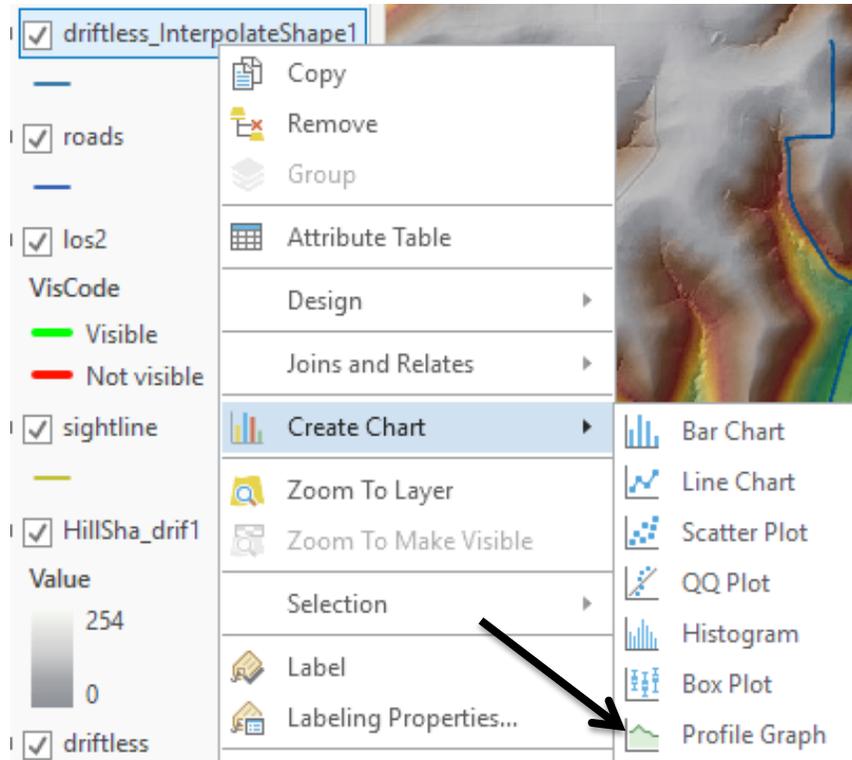
(Video: Profile)



Right click on the Output Features in the TOC, and from the dropdown select

Create Chart, then

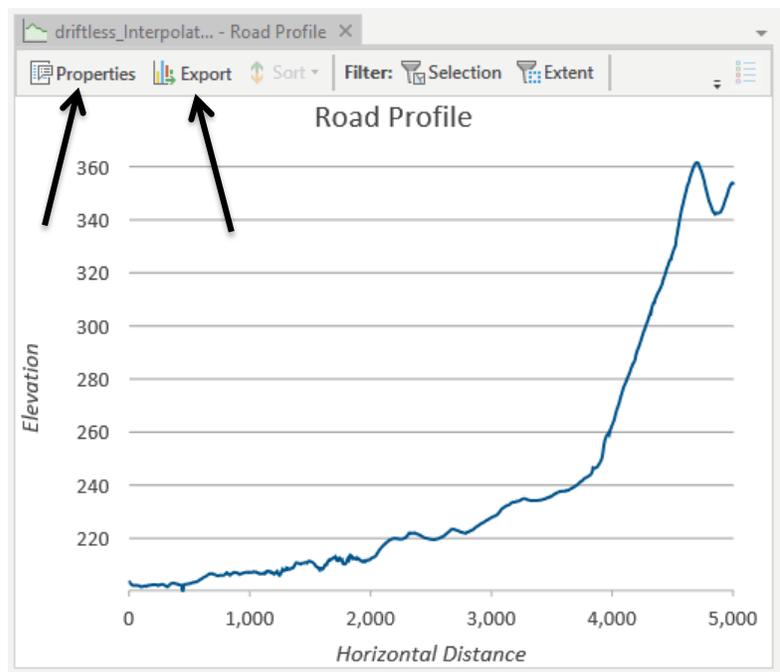
Profile Graph



The profile graph shows the profile line trajectory, but in a side view, with elevations on the vertical axis and horizontal distance on the horizontal axis (see right).

Inspect the profile graph, and then the DEM, and corroborate the changes in steepness along the road path. Note the left-most point on the graph corresponds to the road end at the bottom of the Map.

Also note you can change properties of the graph via a Properties tab (arrow above), including the overall and axis titles, and units.



You may export the graph to an image file, either a jpg or png, using the tab next to the properties tab (right arrow, above). You specify the output by typing the entire name, including the extension, e.g., profile.jpg for a jpeg file.

Create a Layout that includes your Map, legend, north arrow, name, title, and usual other elements.

Make sure you include the following layers in your Layout:

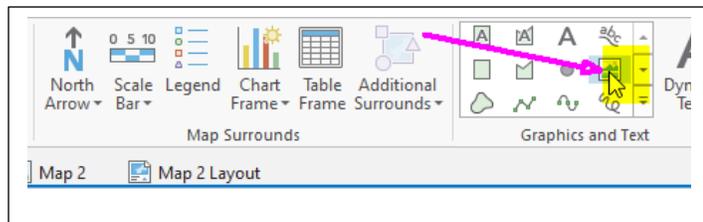
Viewspot and viewshed

Sightline, with visibility/hidden segments shown in different colors

The roads, DEM, and semi-transparent hillshade,

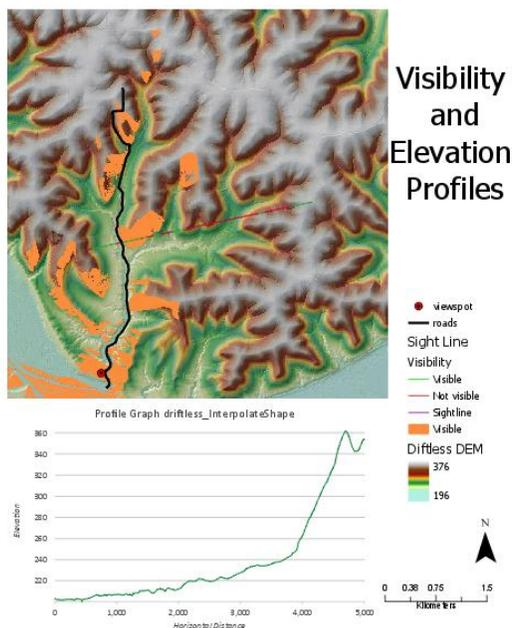
Your profile graph, as a separate element outside of your Map and Legend

You may add the profile plot to your layout by selecting it in the Insert group, next to the scalebar and legend options, then selecting the profile you created and named (see figure).



After adding the profile plot to your layout, double check that it has appeared in the layout view.

Create a layout like that shown below, and export a PDF to turn in.



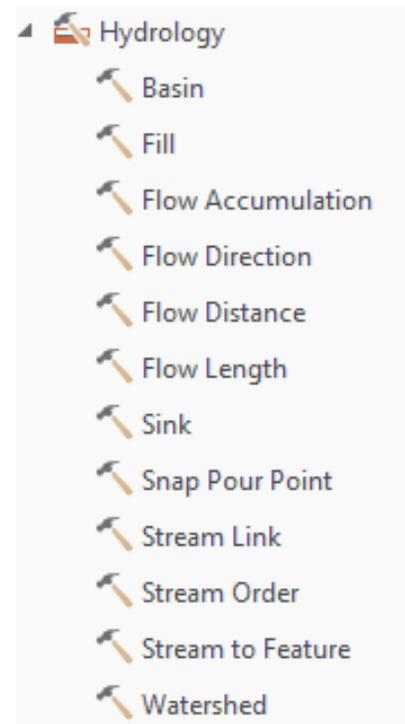
Project 2: Watershed Functions

Save your project, above, if you haven't done so already. Then, open a new Map, either in the same project, or in a new one, and add the *driftless* DEM.

We'll be using ArcToolbox for this new project but **be forewarned** – these tools are buggy. Your best bet is to start early, follow the instructions carefully, save often, and if it doesn't work, close ArcGIS and restart from the beginning (meaning create a new project, and repeat the steps). If this doesn't work, please contact one of the instructors for help – no sense in banging your head against a wall. (see **Video: Watershed**).

In the Analysis tab open

Tools→Toolboxes→Spatial Analyst Tools – Hydrology. This should display the tools shown at the right:



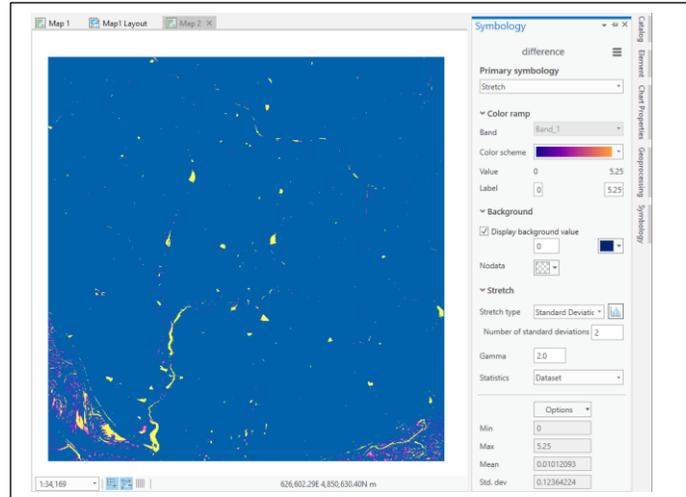
We'll be applying them in the following order:
(The order is important.)

Fill
Flow Direction
Flow Accumulation
Snap Pour Point (on a point feature we'll create)
Watershed

Let's get started, we use the Fill command to fill in pits in the DEM. As described in chapter 11 of GIS Fundamentals, pits are local depressions along which a stream would be expected to flow. These depressions may be real, or they may be due to errors in the data. However, a DEM is a representation of a waterless terrain surface, (the flow algorithms used here are programmed on this basis). So, local pits or flat areas may "trap" our route-finding when we are trying to identify downhill directions. The simplest of watershed processing routines begins by simply filling the pits. More sophisticated ones may fill the pits, and "burn in" a stream line, along which the DEM is lowered after filling to maintain a downstream flow. We will use the simplest Fill approach.

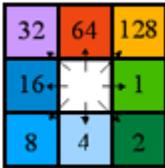
Apply the **Fill** tool from the **Hydrology** toolbox. Specify the driftless DEM as input, and something like *filled_dem* for the output name. Don't bother with the Z limit, here and in the subsequent tasks, and Run the tool. In more a sophisticated analysis, you would specify a small Z limit, with a value that depends on your analytical needs. If this doesn't fill your DEM pits, then you must re-evaluate your goals, processing flow, and data sources. In this instance, we're providing a well-behaved DEM, so you can fill all of them.

After a minute, the filled data set should be automatically added to your view. Subtract, via the Raster Calculator, the *driftless* DEM from your *filled_dem*, and display the calculation. Change the color display and Display Background Value as dark blue. Notice the location and range of the fills; it should look something like shown on the right.



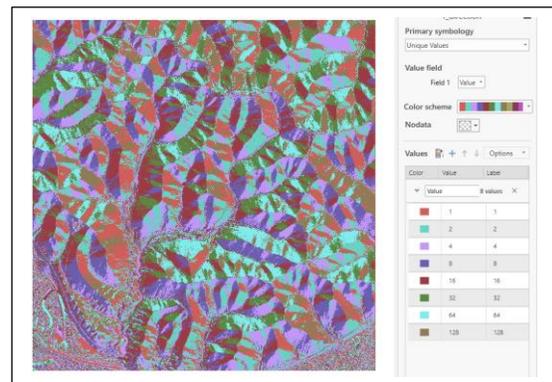
Remove the difference raster to avoid confusion in later steps

Now, apply the **Flow Direction** tool, using the *filled_dem* as your input, and specifying a flow direction output data layer; name the output *f_direction*. Check the box “flow all edge cells to flow outward”, use the D8 method, and don’t specify a drop raster.



As noted in the textbook, this flow direction layer will contain a direction coding, with a set of numbers that define the cardinal and sub-cardinal direction, something like the figure to the right. The number 1 in a cell means water flows due east, 128 indicates northeast, 64 water flows north, and so on. This is a discrete categorization, all the water flows from a cell to an adjacent cell in only one of 8 directions. This method is known as the D8 flow direction, to distinguish it from methods that can send a portion of the water from a cell to multiple neighboring cells.

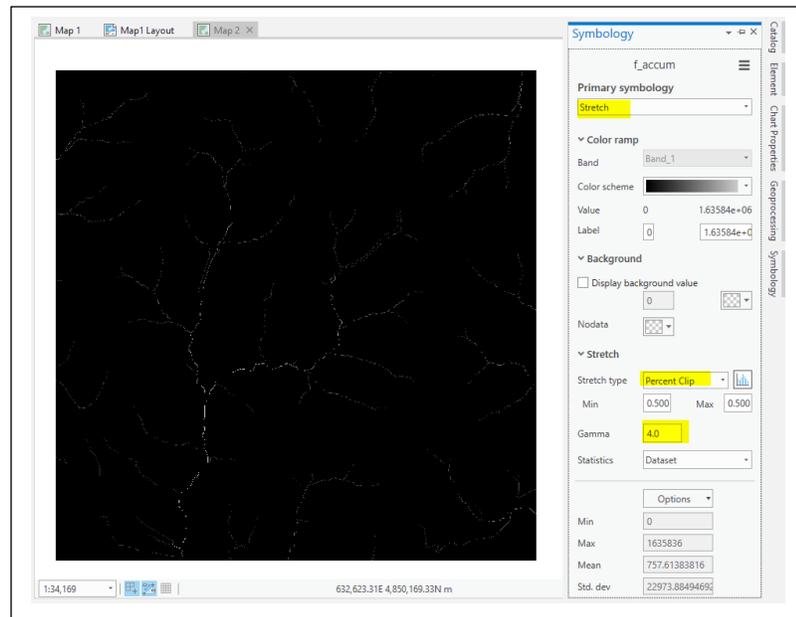
Your output from the flow direction tool should look something like the figure to the right, and the symbols should show 8 values from 1 to 128, corresponding to flow direction.



Now apply the **Flow Accumulation** tool from ArcToolbox. This finds the highest points and accumulates the area (or number of cells) downhill, according to the flow direction.

Specify the input as *f_direction* raster you just created, name the flow accumulation raster something like *f_accum*, ignore the weight raster, and specify an output data type of Float and leave the Input flow direction type as D8.

This should generate a layer that displays like the graphic at right. If you look closely, you will see some narrow, perhaps intermittent white lines in a dark background.



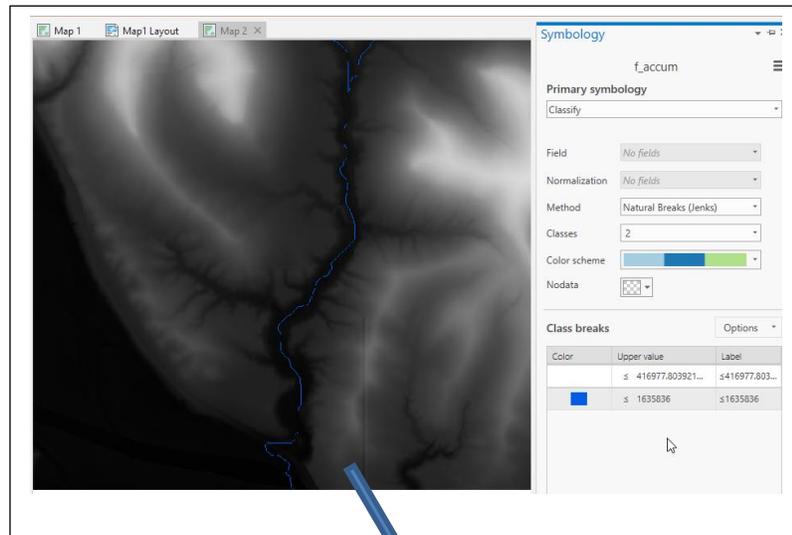
Notice the maximum and minimum value for the data layer, they will be something like 1.63×10^6 and 0.

These numbers are the cells that drain to any given cell. For example, a cell with a value of 12,847 receives water from that many cells. Since these cells are 3 m by 3 m, each cell counts for 9 square meters, and there are about 111,000 cells per square kilometer.

We may use this flow accumulation grid to approximate where streams will be found on the surface, and to determine outlet points for watersheds.

In any given small region and geology, there is usually a rough correspondence between drainage area, here measured with flow accumulation, and stream initiation. For example, once a drainage area of 0.45 square kilometers is reached, a stream may form. This would be $0.45 \text{ km}^2 \times 1,000,000 \text{ m}^2/\text{km}^2 / 9 \text{ m}^2/\text{cell}$, or about 50,000 cells. So, if we symbolize the flow accumulation layer so all cells above 50,000 are blue, and all equal or below is no color, we will get an approximate idea of where the streams will be found (this threshold is made for this exercise but is probably not too far off). **(video: FAC2Streams; note: two different approaches are described in this video. You only need to do the first approach, the reclassification of the symbology now, but at the end of this lab you will do the second approach, reclassification of the raster layer to a new raster layer and then exporting that new raster layer to a polygon.)**

You may apply the symbolization by reclassifying the flow accumulation layer into two classes, and setting the lower threshold to 50,000, the upper threshold to the maximum value, as described in previous labs.



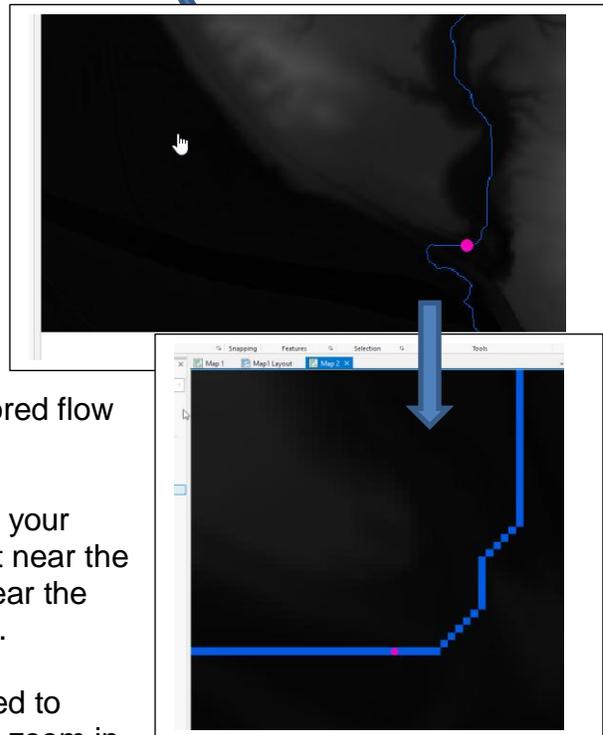
We must apply a couple of more steps to define our watersheds. First you must **create** an empty point layer in the same coordinate system as the driftless DEM, named something like *outlet*. Refer to previous labs if you're unclear how to do this; Lab 3;).

Then we must digitize a watershed outlet point. Add the new empty *outlet* data class to the make it the active editing target and display the DEM with the recolored flow accumulation grid over it.

Zoom into the southwest quadrant, so that your view looks like that at right. Digitize a point near the location shown below, along the stream near the outlet to the largest watershed in the DEM.

Remember, the figure at the right is zoomed to about $\frac{1}{4}$ of the DEM extent. You'll want to zoom in much closer to digitize the point, so you can place it near the center of one of the stream cells.

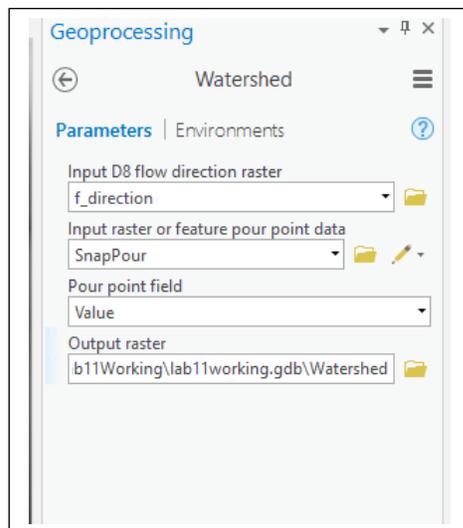
A zoom something like that shown in the bottom image is more appropriate: Start Editing, add your point, then save your edits and stop editing. Zooming in as far as you can helps you make sure your digitized outlet point is exactly on a stream cell.



Now apply the **Tools**→**Toolboxes**→**Spatial Analyst Tools Hydrology**→**Snap Pour Point** tool.

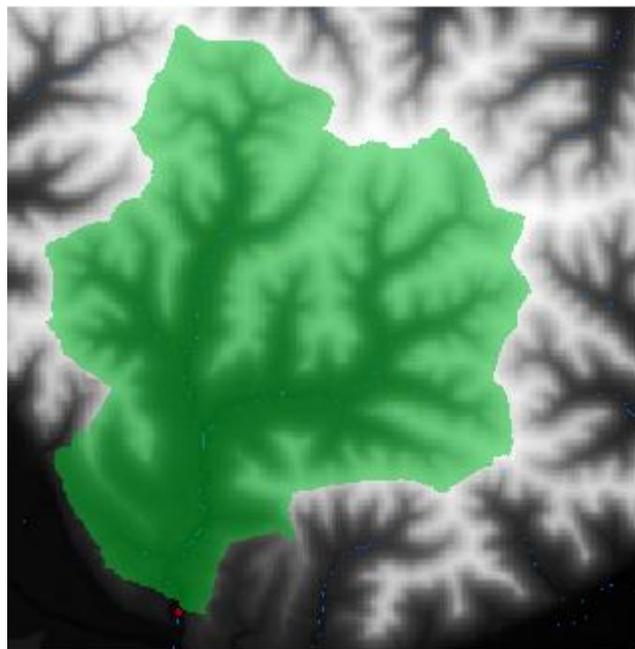
- Specify *Outlet* as your input raster or feature pour point dataset,
- any pour point field, (OBJECTID is fine)
- the flow accumulation raster you created earlier
- a new output raster to contain your raster pour point, name it something SnapPour
- an appropriate snap distance, something like 3 to 9 (about 1 to 3 cells).

This should create a raster with a single cell for a value, near your digitized outlet.

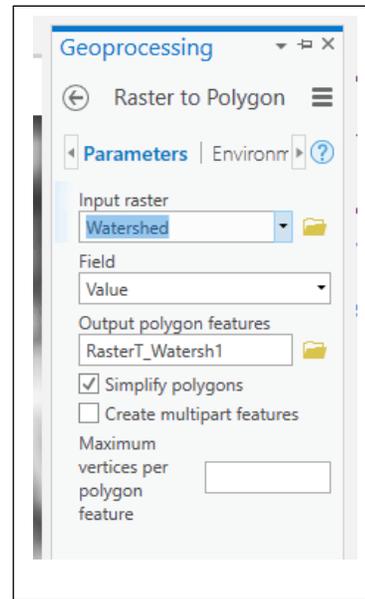


Now, run the **Hydrology**→**Watershed** tool, specifying your flow direction raster, your just created raster pour point layer, leaving the pour point field as “Value”, and specifying an appropriately named output watershed, like *watershed*.

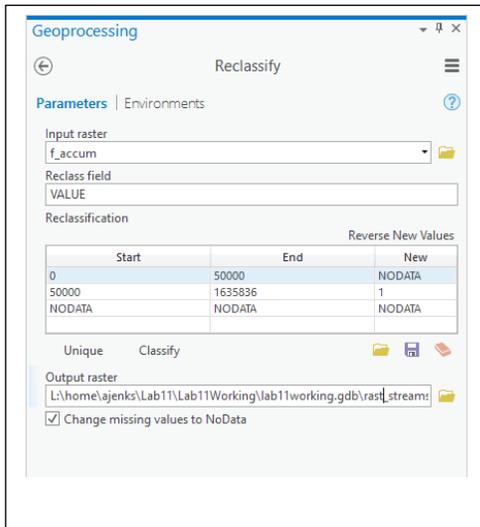
This should create a watershed raster. Use symbology, unique values to add a color and make the watershed raster layer semitransparent (see below)



If you want, you can export it the raster version of the watershed to a polygon by **Tools**→**Toolbox**→**Conversion Tools**→**From Raster**→**Raster to Polygon**. Changed the color and made the watershed polygon 50% transparent.



We want to reclassify and then export the flow accumulation raster, if we don't we will only have

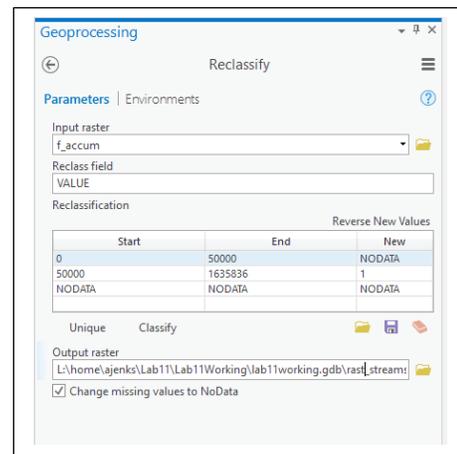


cells that are streams and we can't make the width of the stream larger and more visible on our Layout. We'll use a threshold of 50,000 cells, as described in the section above. In case you've forgotten, a reclassify is most easily done with the Reclassify tool described in an earlier lab, found at **Spatial Analyst Tools**→**Reclass**→**Reclassify**. You'll want to set values at or above 50,000 to 1, and below 50,000 to NoData. Name the output something like *rast_streams*.

Now convert the reclassified streams from a raster to vectors, use **Tools**→**Toolbox**→**Conversion Tools**→**From Raster**→**Raster to Polyline**

Name the output something like *Derived_Streams*.

Select Background value as NODATA and Simplify polylines.



Create a layout displaying the *driftless* DEM, Watershed, *Outlet* and *Derived_Streams* with all the usual elements, export it as a .pdf. Remember to include your name.

Remember to turn in:

- 1) a Visibility & Elevation Profiles map**
- 2) a Watershed map**

