Stream network delineation and scaling issues with high resolution data

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Abstract:
In this tutorial, we will go through the process of extracting a stream network from a high-resolution (1m) digital elevation model derived from ALSM data, resample the original elevation data to 10m, re-extract the stream network, and compare the two, exploring this critical jump in scale.

Note:
We will be using the Spatial Analyst extension in ArcMap, accessed using the Arc ToolBox GUI. Much of this work can be streamlined by writing simple Python scripts, or by using the command line window in ArcMap. For more information on this, I suggest reading through the ESRI online help guide, it is extremely useful.

http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_writing_geoprocessing_scripts

1. Creating the hillshade and slope grids

First, let's make a hillshade and slope map. This is helpful for visualization purposes; you can overlay the DEM or slope map on the hillshade by adjusting the display and symbology. Using the hillshade function (ArcToolbox/Spatial Analyst Tools/Surface/Hillshade), input your base DEM as the input raster, and name the output raster something logical like "project_name_shd." It is helpful to practice good bookkeeping in ArcMap, as it can be extremely difficult to find, move, and rename poorly saved files.
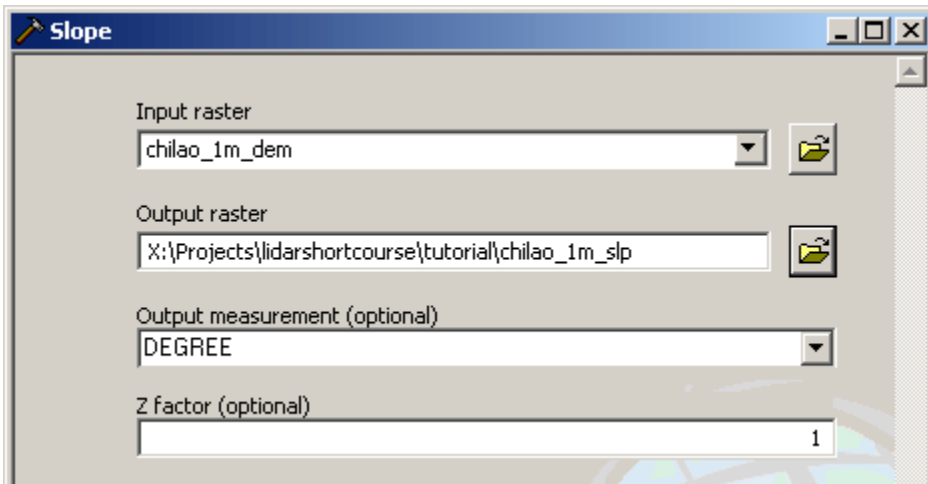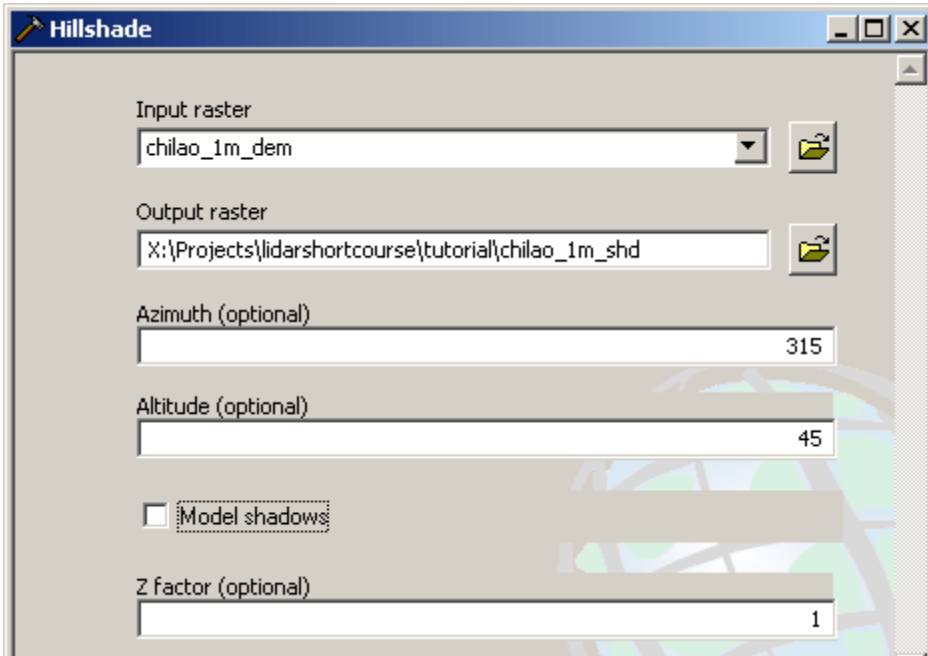

*When running the slope command, be aware of the output measurement. DEGREE is constrained between 0 and 90, while PERCENT_RISE can grow quite large. Both have their advantages, but it is usually easier to think in degrees for steep slopes.

2. Creating the flow accumulation grid

Now we will go through how to create a flow accumulation grid, which forms the basis for extracting the stream network. This process has three steps: first, we need to fill in any pits or sinks in the DEM, then we calculate the direction of steepest descent for each cell, and finally, we count up the number of cells that flow into each cell.

2.1 The Fill command

A drop of rain falling anywhere in the DEM must be able to follow a downhill path all the way to the edge of the DEM. In order to do this, the Fill command adds elevation to local lows in the DEM until they 'spill' over. This is an iterative process, and is computationally expensive; some DEMs may take minutes to hours to fill. We can map out the pit depth by subtracting the original DEM from the filled DEM using the raster calculator in the spatial analyst toolbar. This can be helpful for assessing DEM quality.


Profile view of a sink before and after running FILL. □ filled sink
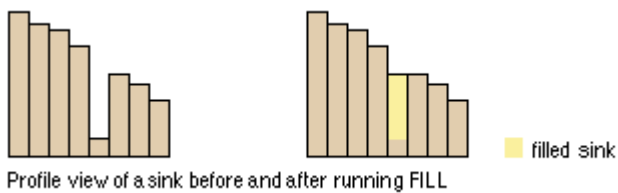
(from ESRI website)
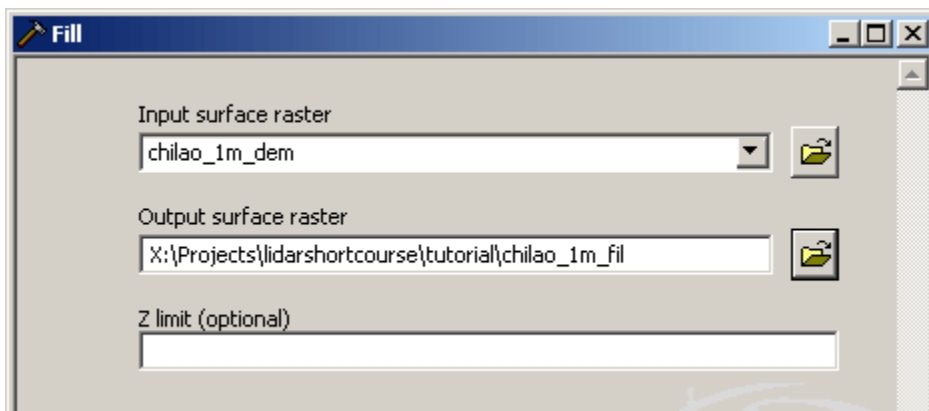
2.2 The Flow Direction command

Now that we have a 'filled' DEM, we can determine a flow direction for each cell. There are many different ways to distribute flow from a cell, but the simplest is the D8 algorithm, which is used by Spatial Analyst. At each cell, a number is assigned based on the direction of the lowest elevation neighbor (steepest descent), as shown below, such that if the elevation is lowest to the left, the output flow direction will be 16.

32	64	128
16		1
8	4	2
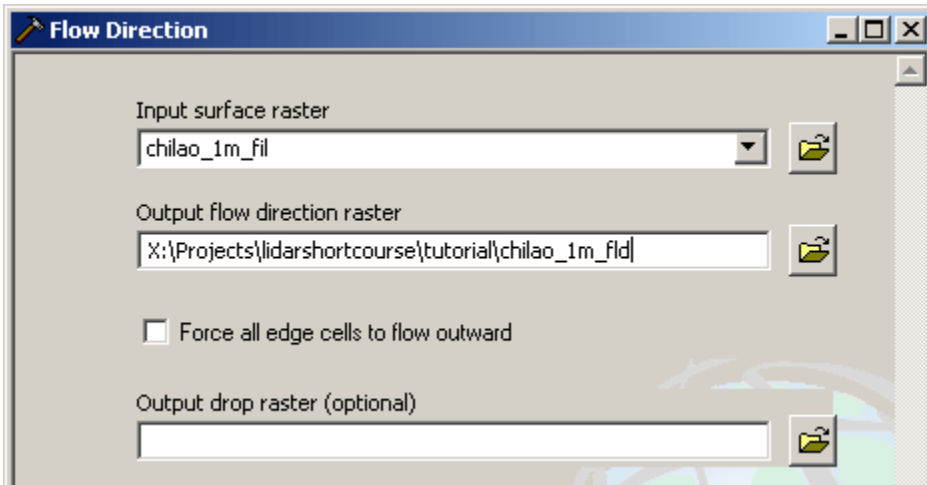
2.3 The Flow Accumulation command

Now we will calculate the flow accumulation for each cell, which tells us how many cells are 'upstream' of a given cell. The output is analogous to the upstream drainage area of each cell, and you can convert from flow accumulation to drainage area by multiplying the accumulation in cells by the square of the cell size. This command, like the fill command, is recursive, and can take a long time to run for large grids. It is helpful to specify the output type as INTEGER in order to save space, as the flow accumulation is simply counting pixels.
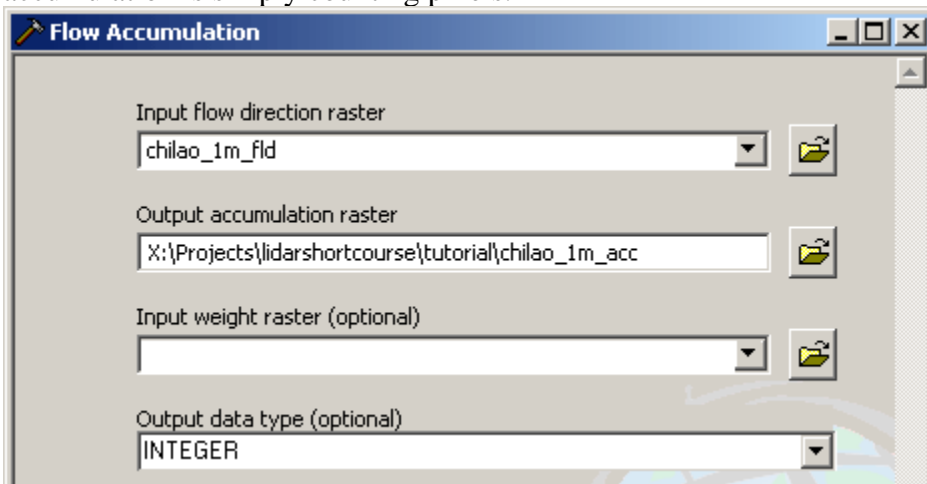

3. Creating a shapefile stream network from the flow accumulation grid

In this exercise, we will select a critical drainage area that defines a channel, reclassify the accumulation array to have values only where this area is exceeded, and convert the grid to a poly-line shapefile for more visualization control

## 3.1 Pick an appropriate critical drainage area

This step is most likely going to depend on the application, and is an iterative process. We will change the symbology of the accumulation array to see the extent of different accumulation thresholds. First, double click on the accumulation array, or right click and choose properties, and go to the symbology tab. By default the accumulation output is displayed using a stretched (continuos) symbology. For our purposes, we want to display it as a classified (discrete) symbology, with 2 classes. This step may take some time depending on grid size, as Arc needs to build a histogram of the data for picking classification schemes. Click on the break values to edit the critical area (lowest value), click ok, and

then apply to see the extent, and repeat for different areas if necessary. Once you are satisfied, click ok until out of layer properties.
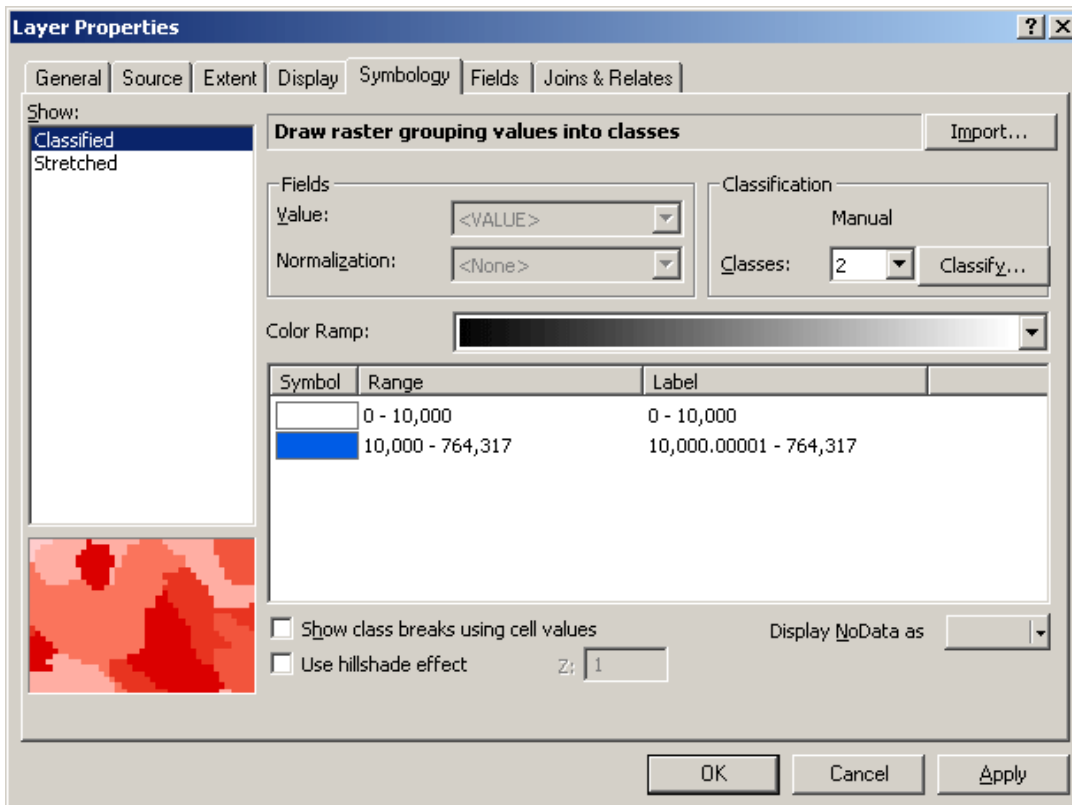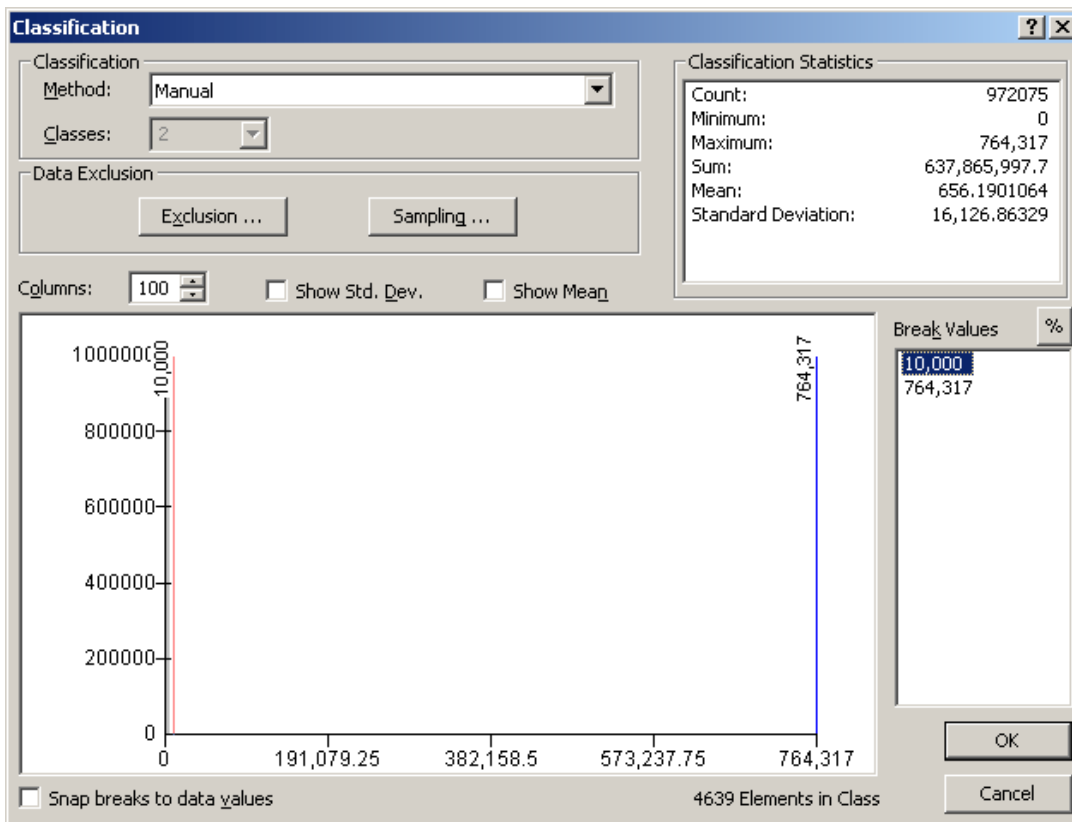
3.2 Reclassify command

Now we will create a raster that only has values where the accumulation grid is greater than the critical area. Go to (Spatial Analyst Tools\Reclass\Reclassify\) and input the accumulation grid. Edit the reclassification table such that it has values of NoData for old values less than the critical area, and 1 for old values greater than the critical area. This raster just needs to be saved temporarily, so any output location will do.
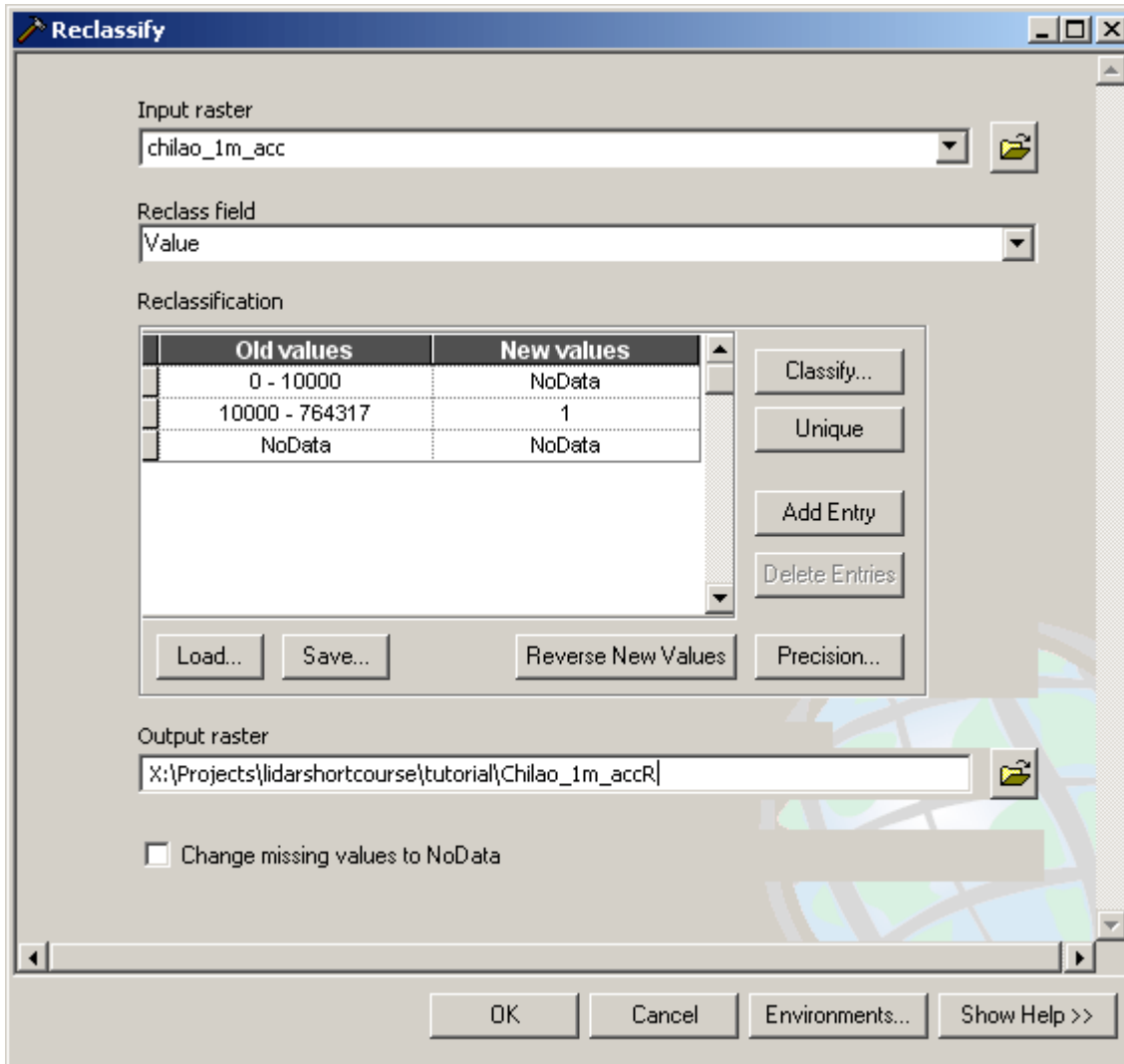

3.3 Stream to Feature command

Now we will convert the reclassified grid into a shapefile, which loads quicker and is easier to display. Go back to the Hydrology tools in Spatial analyst and open Stream to Feature. Input the reclassified accumulation array and the flow direction grid. Do not simplify polylines unless you are seriously concerned about file size (PDA use with ArcPad for example).
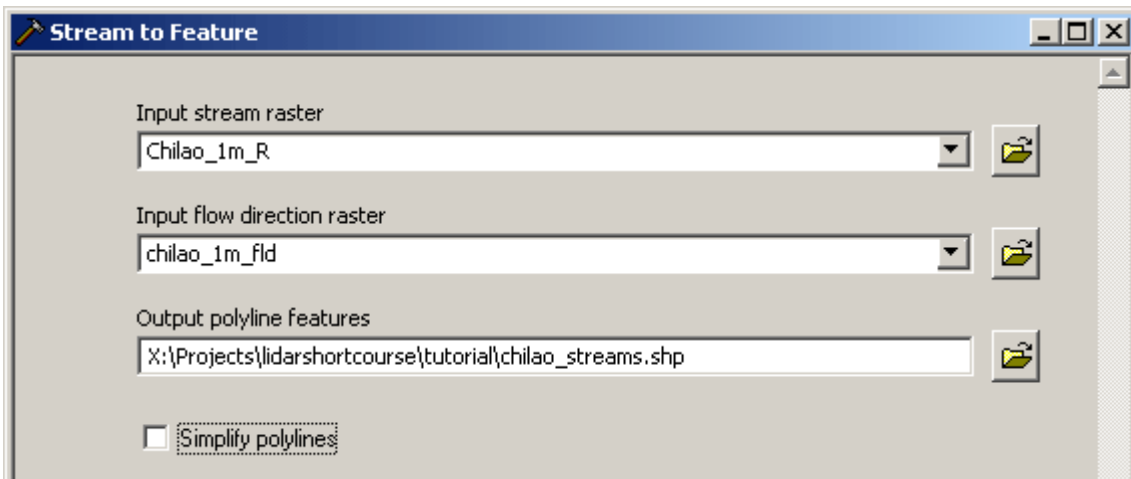
Your final shapefile should look something like below if you edit the symbology a bit and thicken the line.
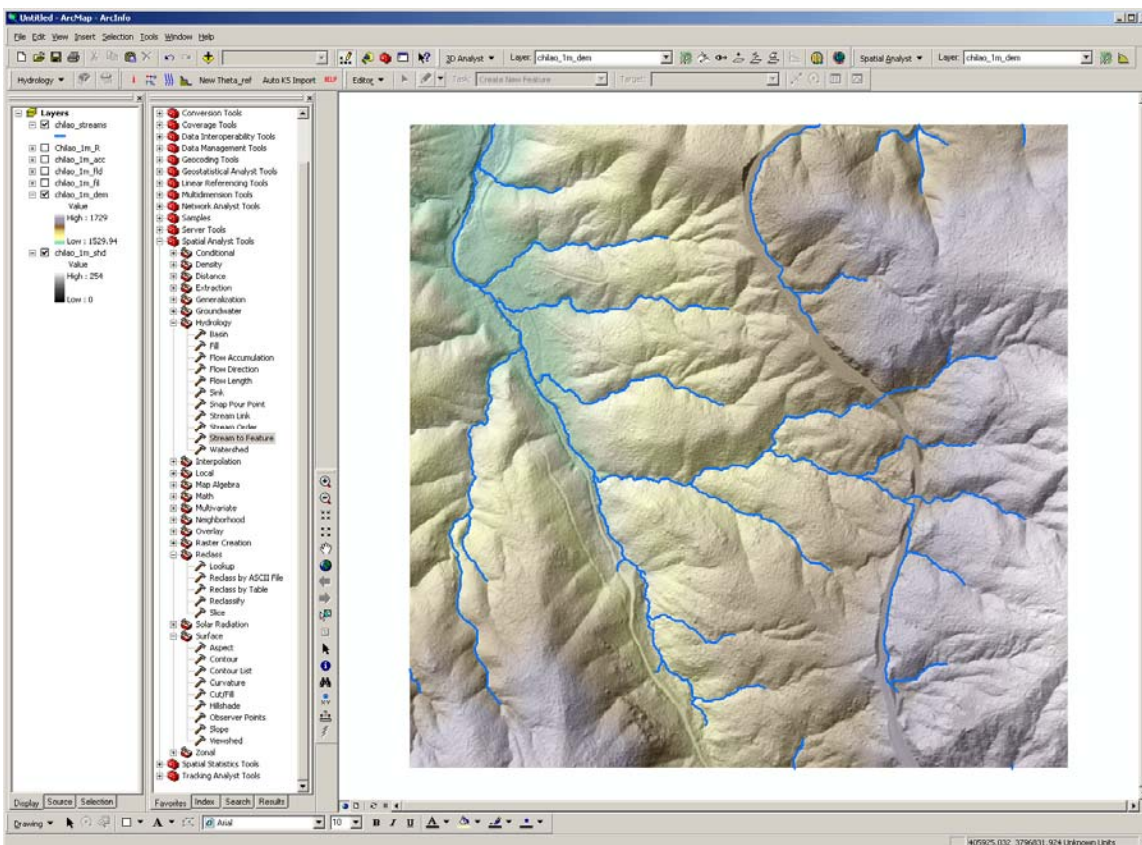
Now let's take a look at the final stream network extracted from chilao_1m_dem. At a resolution of 1m, there are some obvious issues with the flow directions. The road in this clip is creating major problems with flow routing, and connecting two basins that should be separated in the north. Many streams in the southeast of the area are beheaded as well. For most purposes, we want to look at natural flow paths, not recent human alterations. Even if we did want to study modern flow routing, culverts and bridges are not accounted for and must be modeled somehow. To solve this problem, let's resample the 1m DEM to 10m so we can see if there is a difference in flow routing with scale.

4. Resample 1m DEM to 10m

The Resample command is under Data Management\Raster\. For the input raster, use the 1m DEM provided. Name the output raster something descriptive, and change the cell size to 10 (or whatever resolution you want to resample to). The resampling technique is very important, and needs to be either BILINEAR or CUBIC for continuous datasets rather than NEAREST, which is the default. Choosing NEAREST will introduce pronounced unwanted artifacts into the new DEM.
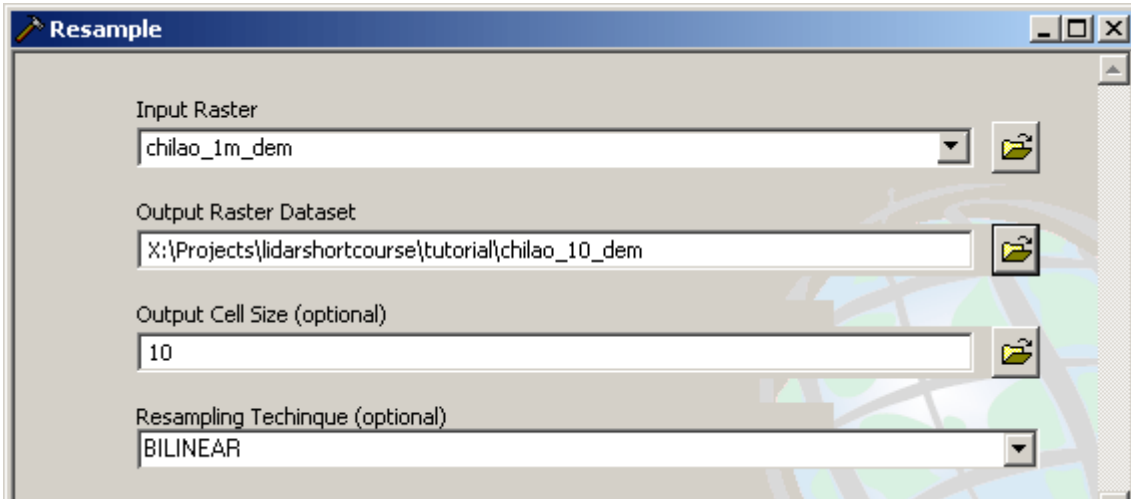
5. Redo steps 1-3

This should go much faster, both because of familiarity, and the fact that the dataset is 100 times smaller in size. Compare the two stream networks. Notice how the 10m DEM begins to smooth out anthropogenic features such as the road in this area. Also look at the stream segment lengths; in general, stream length, and thus slope, depends on the grid resolution. At low resolutions (30-90m), meanders are often short circuited, resulting in channel slopes that appear steeper. At high resolutions (1-5m), the grid size becomes smaller than the channel width for most streams, and flow is unnecessarily routed around boulders and bedforms, resulting in channel slopes that appear more gentle. It is always important to consider heterogeneity scales and find the sweet spot between high frequency noise and overly smoothed data when doing digital topographic analysis.

6. Extract profiles from LiDAR data (if time allows)

Using 3D analyst, we will go over how to extract simple cross sections of raster data, as well as how to convert the stream shapefile into a 3D shapefile for channel profile extraction and viewing in ArcScene.