ABE 32500

SOIL AND WATER RESOURCE ENGINEERING

Watershed and Stream Network Delineation using ArcHydro Tools

Introduction

A *watershed* is the area of land where all of the water that drains off of it goes into the same place. Decide the watershed boundary and stream network is the first step before any hydrological modelling. Traditionally, watershed boundary can be manually delineated using a topographic/contour map, which is quite time consuming. Nowadays, as the development of GIS technology, watershed properties can be extracted by using automated procedures. In this lab, we will use Arc Hydro tools to process a digital elevation models (DEM), which is a digital model or 3D representation of a terrain's surface elevation to delineate watershed, sub-watersheds, stream network and some other watershed characteristics that collectively describe the drainage patterns of a basin.

Computer Requirements

You must have a computer with windows operating system, and the following programs installed:

1. ArcGIS 10
2. Arc Hydro tools (version that works with 10)

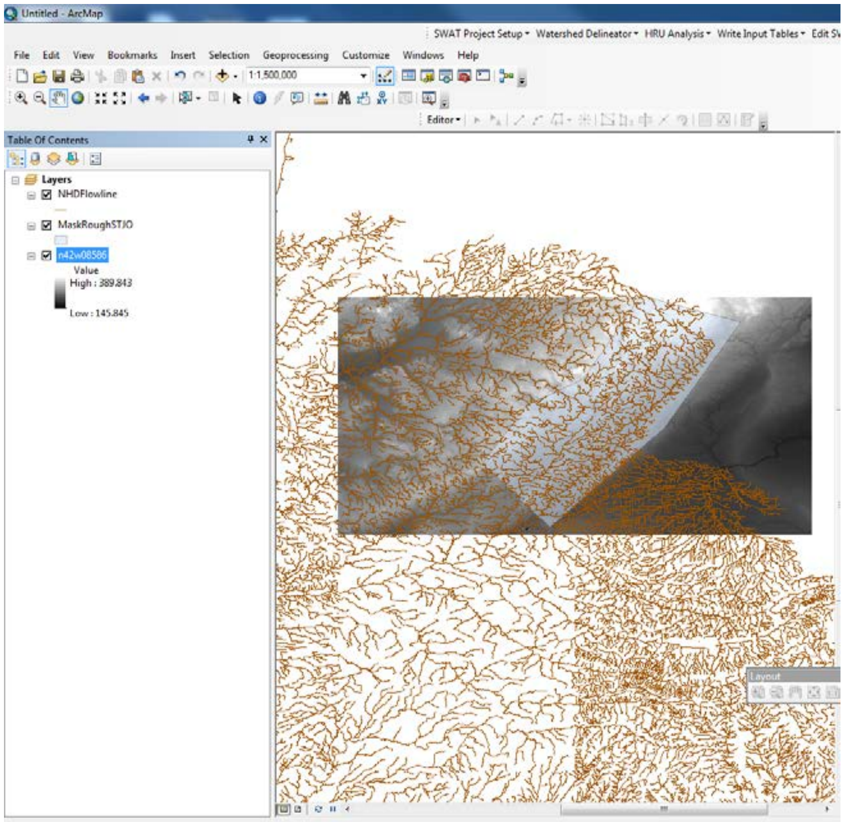
Data Requirements and Description

The data files used in the exercise consist 1) A DEM grid covering St. Joseph River watershed in northeast Indiana, northwestern Ohio and southeastern Michigan and 2) the hydrography data (mainly stream network) of Indiana. Although the data are provided with this exercise, the steps involved in downloading DEM and Hydrography (NHD) are provided at http://viewer.nationalmap.gov/help/The%20National%20Map%20Viewer%20Quick%20Start%20Guide.htm

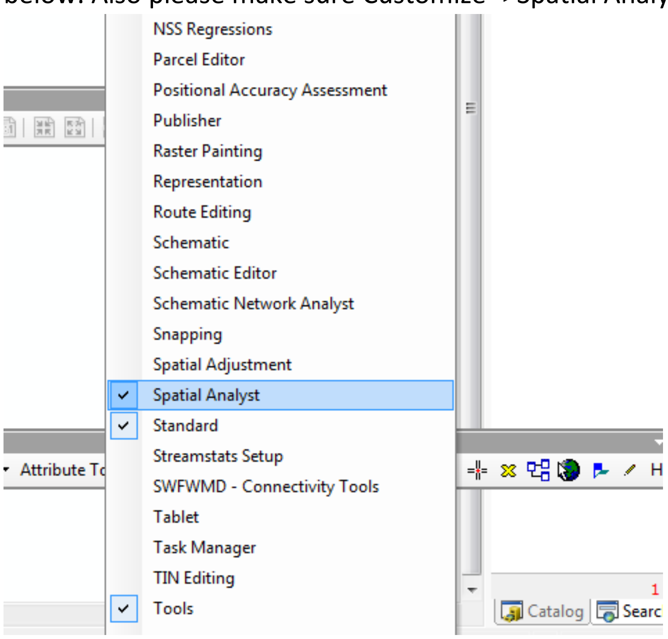
Processing Steps

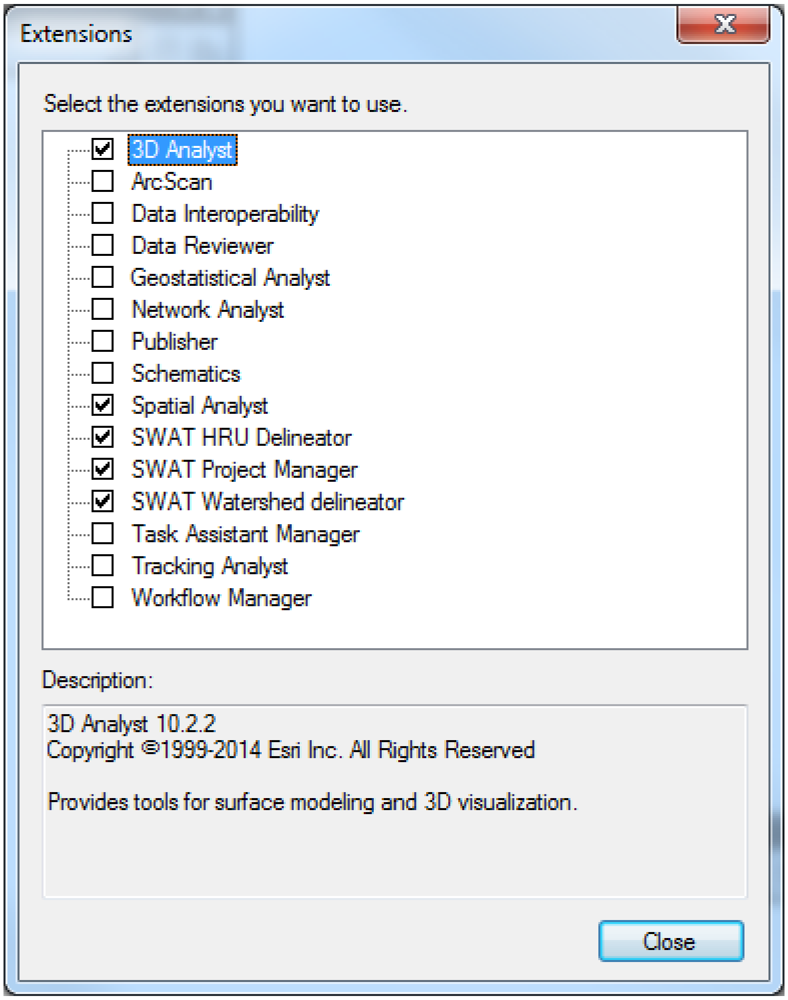
Step 1: Download raw data and data pre-process

1. Download "Workspace" from blackboard, this workspace should include 1) one ArcHydroProj.mxd file; 2) one folders "n42w08586" which contains two merged arc-second (approximately 30 m) level DEM covering the northeast Indiana, northwestern Ohio and southeastern. 3) one folder "StateNHD", which contains streamflow line for the whole Indiana. 4) Mask.gdb which contains a mask file, which is used to extract DEM and hydrograph roughly to St. Joseph River watershed.
2. Open ArcHydroProj.mxd. You should get interface looks like the figure below. Check table of content, make sure you got flowline, DEM and mask.

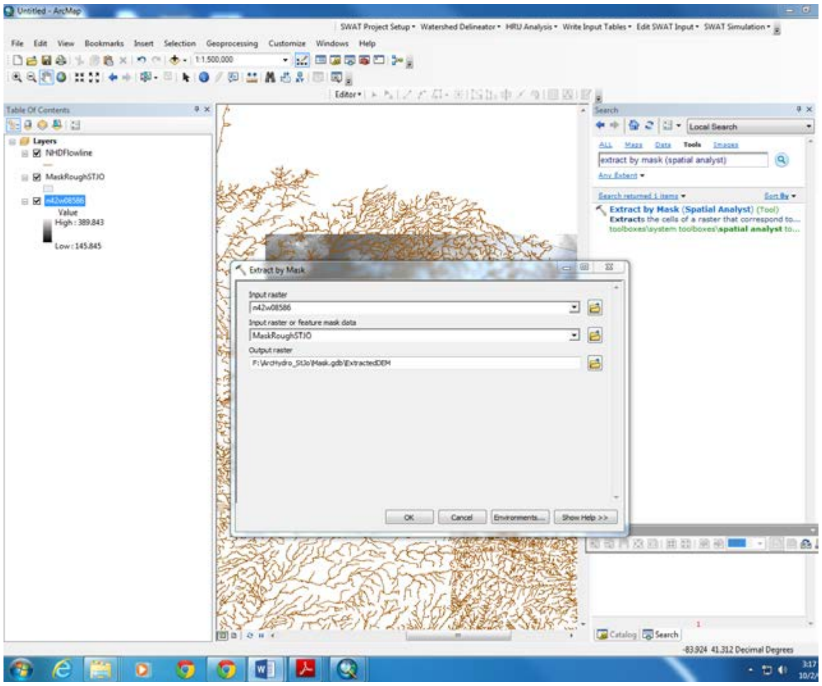


3. **Right click** on the menu bar to pop up the context menu showing available tools as shown below. Also please make sure Customize ->Spatial Analyst is chosen.

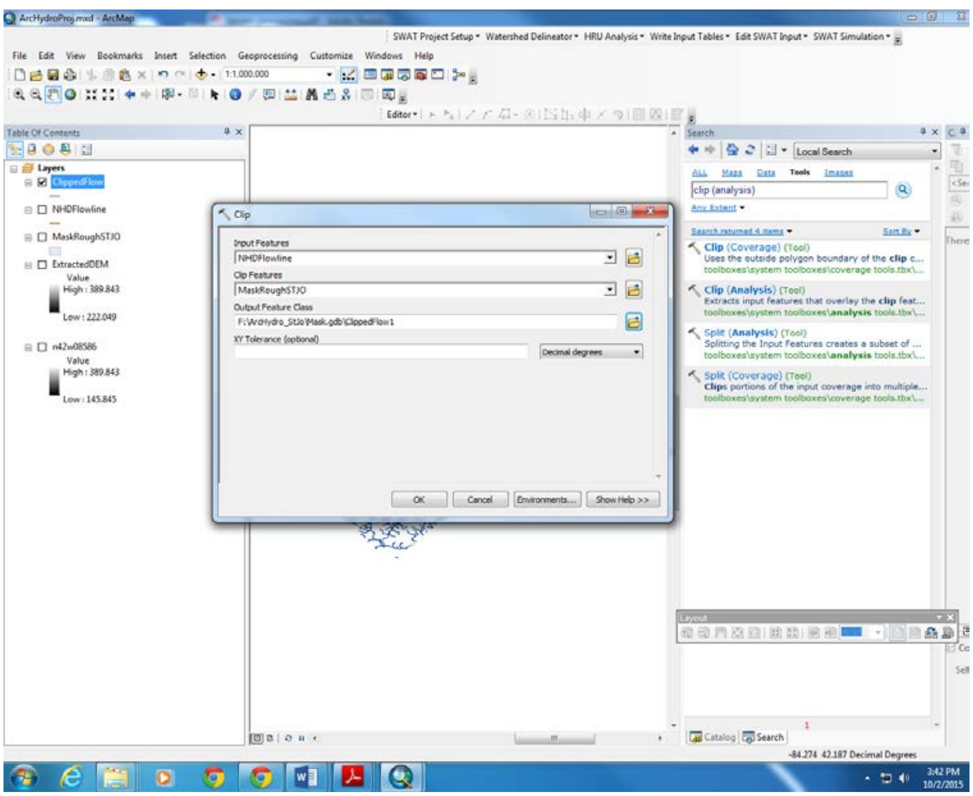




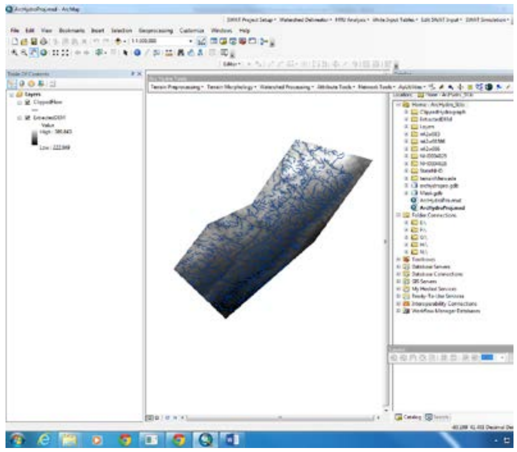
4. Extract DEM, clip hydrograph by mask. Use “Extract by Mask(Spatial Analyst)” to extract DEM file. Store your Extracted DEM to your Mask.gdb
5. Extract DEM, clip hydrograph by mask. Use “Extract by Mask(Spatial Analyst)” to extract DEM file. Store your Extracted DEM to your Mask.gdb



Use "Clip (Analysis)" to clip NHD flowline. Store your clipped flowline at Mask.gdb

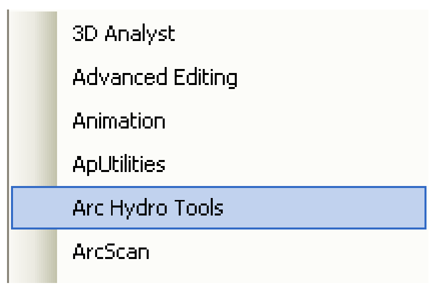


6. Remove original data, keep clipped flow and extracted DEM. Your ArcMap interface should looks like the figure below. Save your ArcMap File using a new map, for example, "ArcHydroProj.mxd".

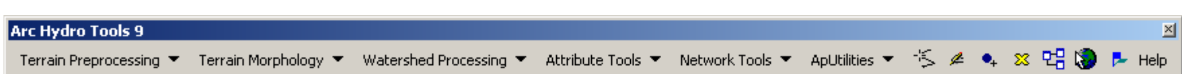


7. Load ArcHydro Extension to ArcMap.

   Start ArcHydro. **Right click** on the menu bar to pop up the context menu showing available tools as shown below.



   Check the Arc Hydro Tools to add the toolbar to the map document. You should now see the Arc Hydro tools added to ArcMap as shown below. You can leave it floating or you may dock it in ArcMap.



Step 2: Terrain Preprocessing and watershed delineation.

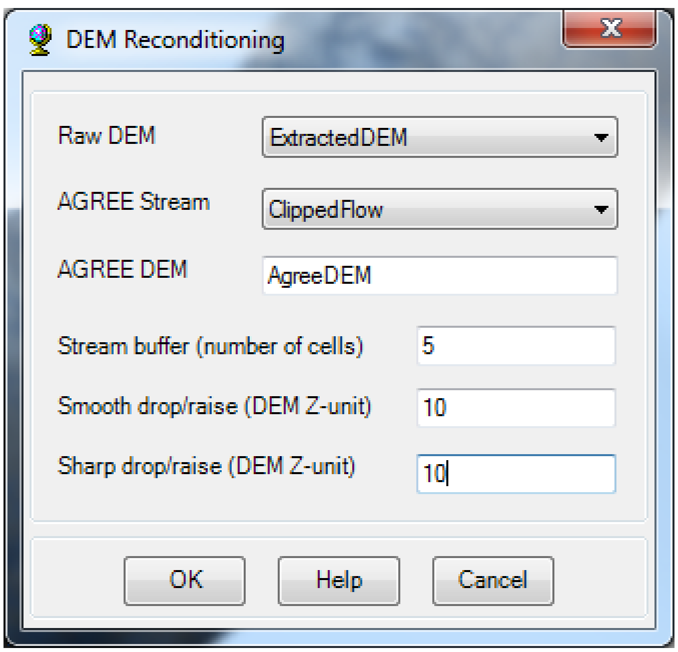
Arc Hydro Terrain Preprocessing should be performed in sequential order. All of the preprocessing must be completed before Watershed Processing functions can be used. DEM reconditioning and filling sinks might not be required depending on the quality of the initial DEM. DEM reconditioning involves modifying the elevation data to be more consistent with the input vector stream network. This implies an assumption that the stream network data are more reliable than the DEM data, so you need to use knowledge of the accuracy and reliability of the data sources when deciding whether to do DEM reconditioning. By doing the DEM reconditioning you can increase the degree of agreement between stream networks delineated from the DEM and the input vector stream networks.

1. DEM reconditioning

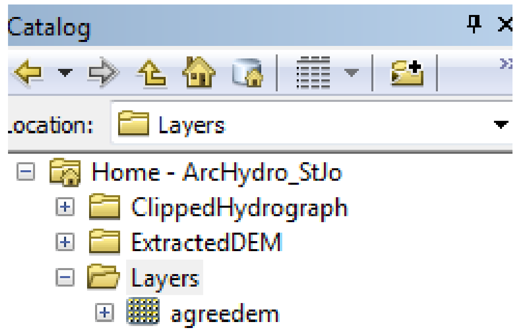
This function modifies a DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed Center for Research in Water Resources at the University of Texas at Austin. For a full reference to the procedure refer to the web link: http://www.ce.utexas.edu/prof/maidment/GISHYDRO/ferdi/research/agree/agree.html. The function needs as input a raw DEM and a linear feature class (like the river network) that both have to be present in the map document.

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->DEM Manipulation->DEM Reconditioning.*

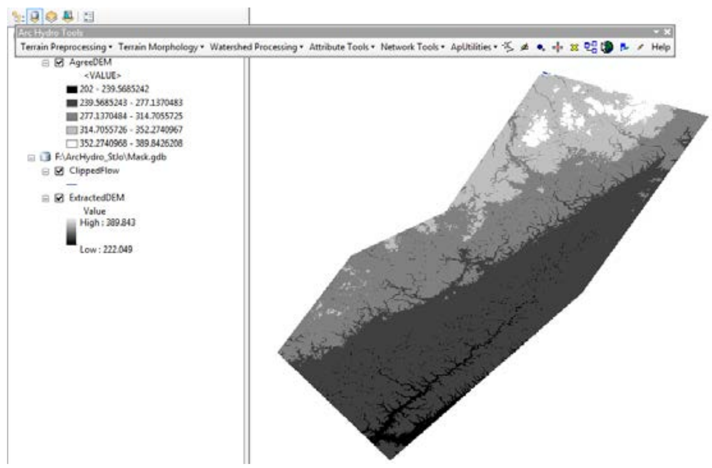
Select the appropriate Raw DEM (ExtractedDEM) and AGREE stream feature (ClippedFlow). **Set** the Agree parameters as shown. You should **reduce** the *Sharp drop/raise* parameter to 10 from its default 1000. The output is a reconditioned Agree DEM (default name AgreeDEM).



A personal geodatabase with the same name as your ArcMap document has also been created as shown in the following ArcCatalog view:



AgreeDEM is also shown in the ArcMap

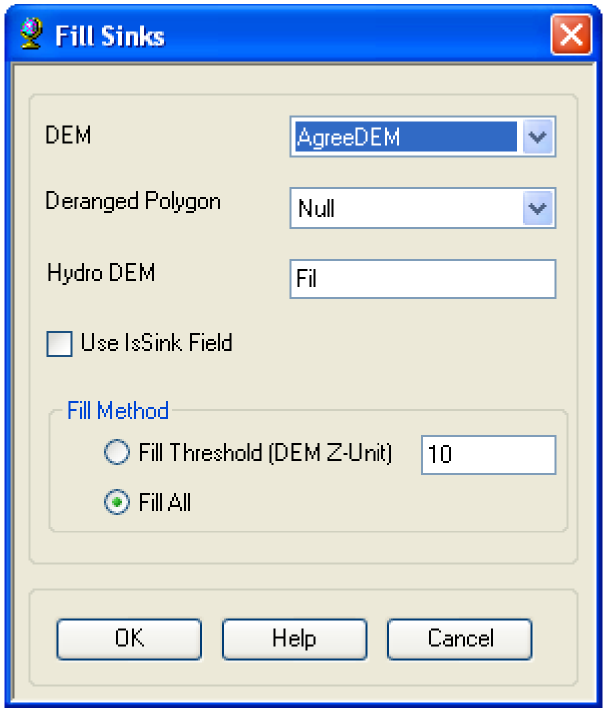


2. Fill Sinks

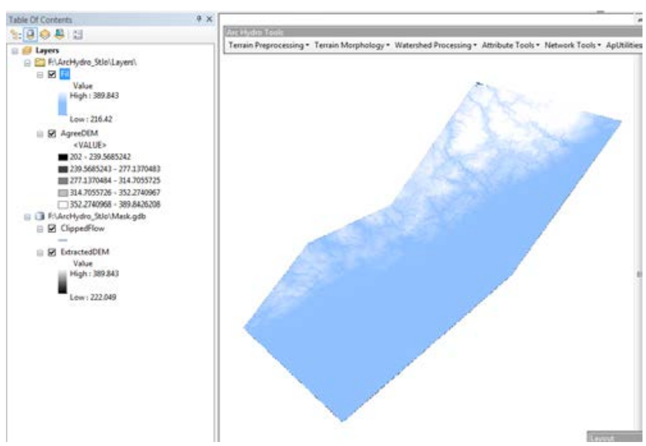
This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

On the ArcHydro Toolbar, ***select*** *Terrain Preprocessing->DEM Manipulation->Fill Sinks.*

Confirm that the input for DEM is *AgreeDEM* (or your original DEM if Reconditioning was not implemented). The output is the Hydro DEM layer, named by default *Fil*. This default name can be overwritten. **Leave** the other options **unchanged**.

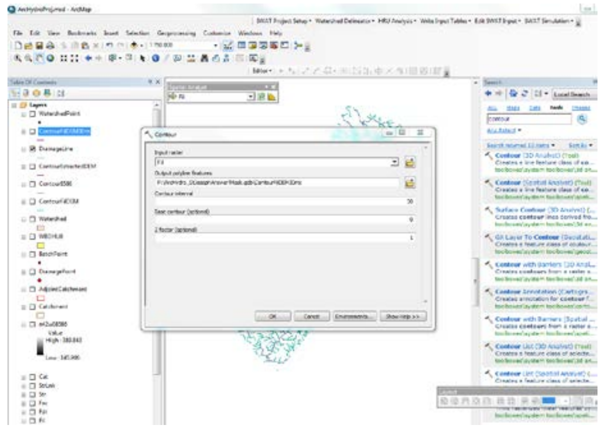


Fil DEM is generated. Notice the lowest elevation of Fil DEM is 216.42, which is higher than Agree DEM.



3. Generate contour map

   Use “Contour (Spatial Analyst)” to start “contour” window. Generate two contour maps using two different contour intervals (For example, 30 m vs 10 m). What is different between your two maps?



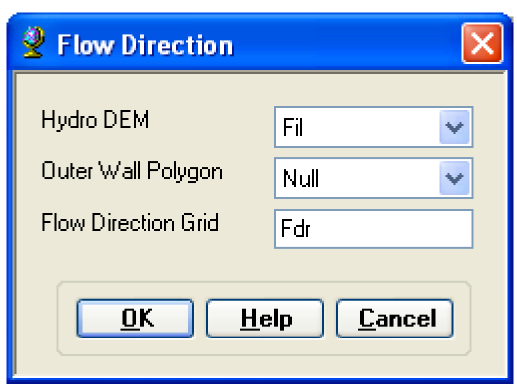
Store your contour maps at Mask.gdb

4. Flow Direction

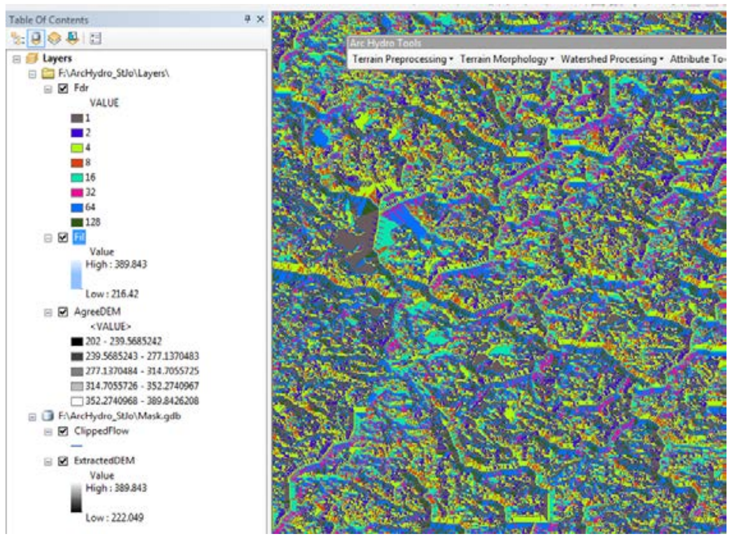
This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->Flow Direction.*

Confirm that the input for Hydro DEM is *Fil*. The output is the Flow Direction Grid, named by default *Fdr*. This default name can be overwritten.



The **zoomed-in** version of the *Fdr* grid should look the map below with each color in the cell having one of the eight numbers shown in the legend representing the flow direction according to the eight-point pour flow direction model

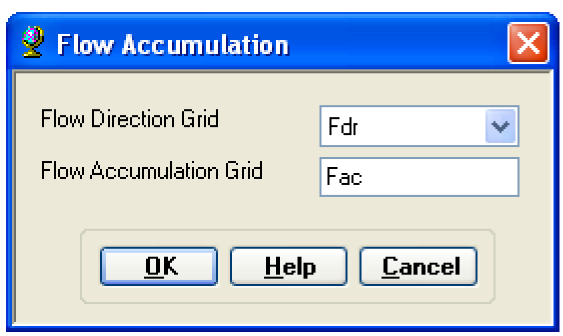


5. Flow Accumulation

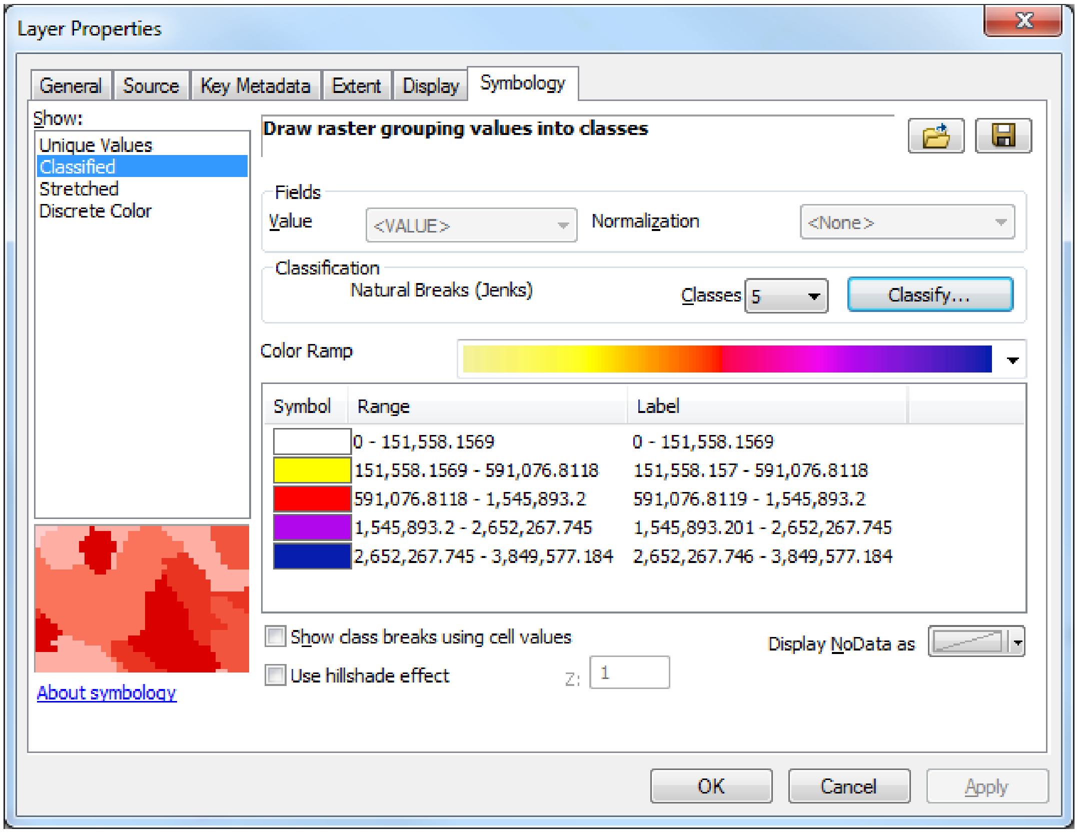
This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->Flow Accumulation.*

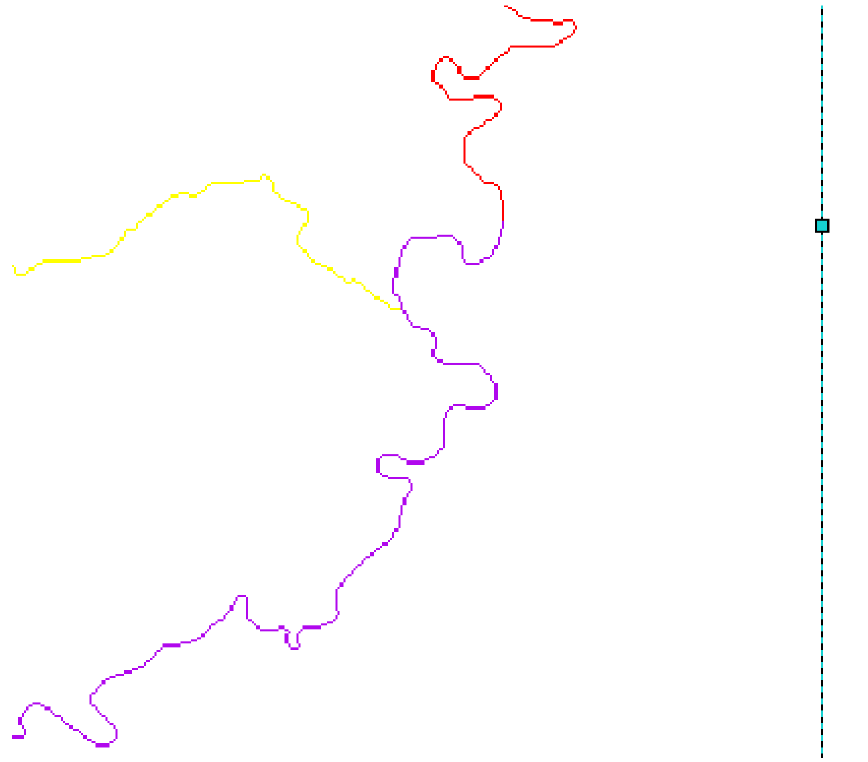
Confirm that the input of the Flow Direction Grid is *Fdr*. The output is the Flow Accumulation Grid having a default name of *Fac* that can be overwritten.



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! **Adjust** the symbology of the Flow Accumulation layer *Fac* to a multiplicatively increasing scale to illustrate the increase of flow accumulation as one descends into the grid flow network.



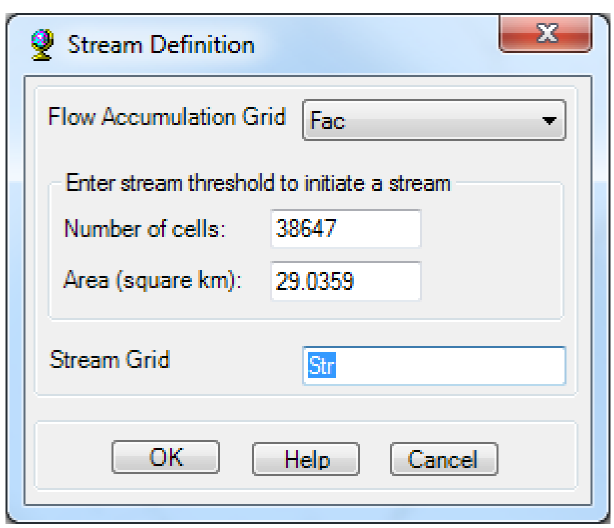
Zoom-in to a stream network junction to see how the symbology changes from light to dark color as the number of upstream cells draining to a stream increase from upstream to downstream as shown below



6. Stream definition

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->Stream Definition.*

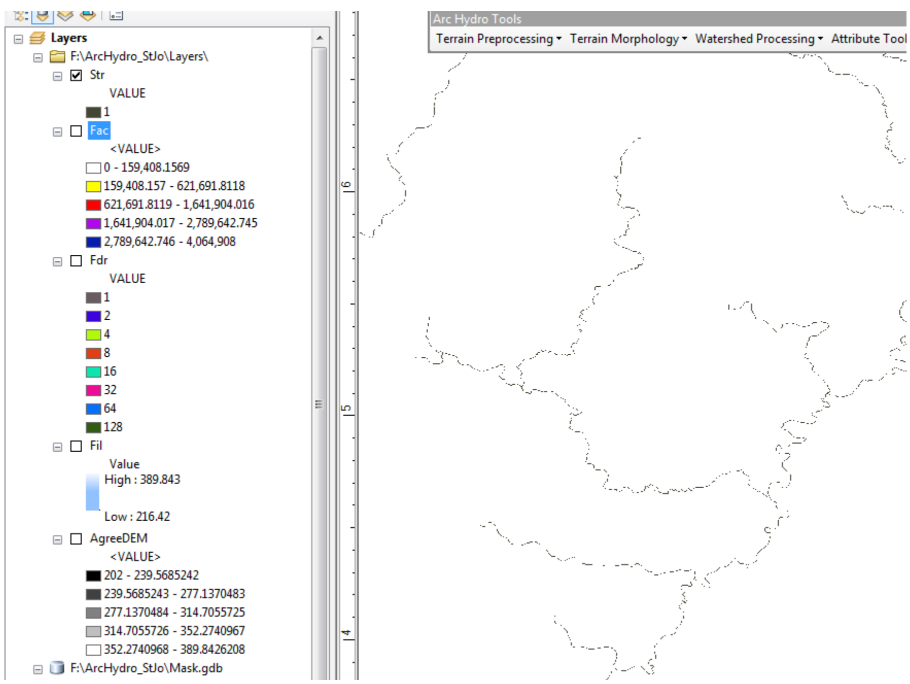
Confirm that the input for the Flow Accumulation Grid is *Fac*. The output is the Stream Grid named *Str*, default name that can be overwritten.



A default value is displayed for the river threshold. This value represents around1% of the maximum flow accumulation: a simple rule of thumb for stream determination threshold. However, any other value of threshold can be selected. A smaller threshold will result in a denser stream network and usually in a greater number of delineated catchments. (Each group should use different "Number of cells" to delineate their watershed, range is from 2000 to 18000)

Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8
2000	4000	6000	8000	10000	12000	16000	18000

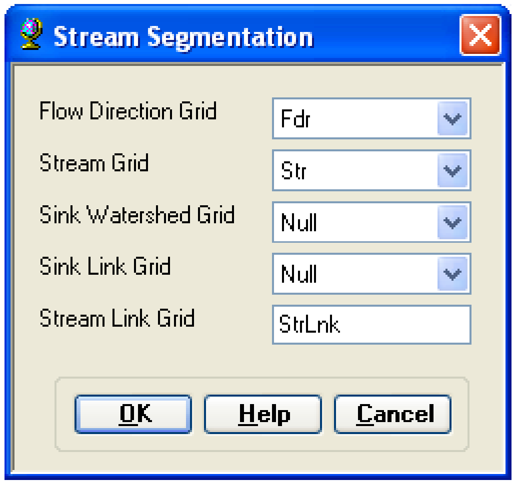
Upon successful completion of the process, the stream grid *Str* is added to the map. This *Str* grid contains a value of "1" for all the cells in the input flow accumulation grid (Fac) that have a value greater than the given threshold (38647 as shown in stream definition). All other cells in the Stream Grid contain no data. The cells in *Str* grid with a value of 1 are symbolized with black color to get a stream network as shown below:



7. Stream Segmentation

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

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->Stream Segmentation.*



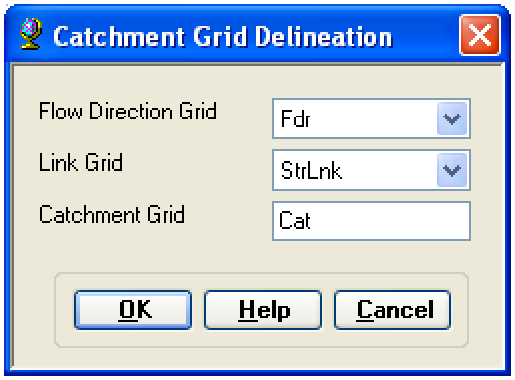
Confirm that *Fdr* and *Str* are the inputs for the Flow Direction Grid and the Stream Grid respectively. Unless you are using your sinks for inclusion in the stream network delineation, the sink watershed grid and sink link grid inputs are Null. The output is the stream link grid, with the default name *StrLnk* that can be overwritten. **Press** *OK*. Upon successful completion of the process, the link grid *StrLnk* is added to the map.

8. Catchment Grid Delineation

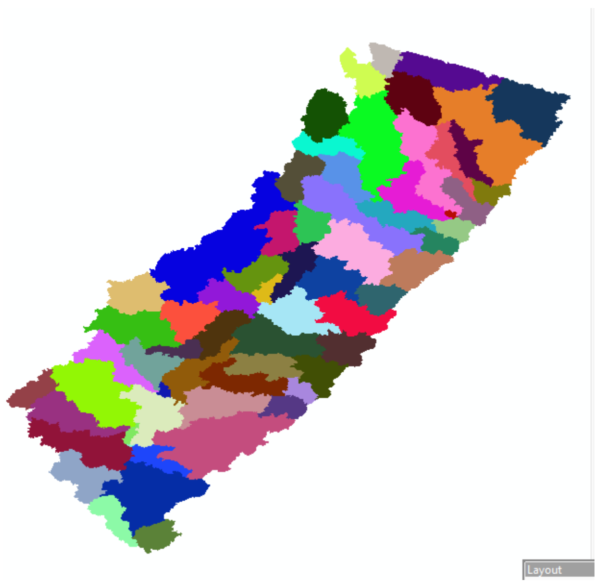
This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid

*On the ArcHydro toolbar, **select** Terrain Preprocessing ->Catchment Grid Delineation.*

Confirm that the input to the Flow Direction Grid and Link Grid are *Fdr* and *Lnk* respectively. The output is the Catchment Grid layer. *Cat* is its default name that can be overwritten by the user.



Press *OK*. Upon successful completion of the process, the Catchment grid *Cat* is added to the map. If you want, you can recolor the grid with unique values to get a nice display (**use** *properties -> symbology*).



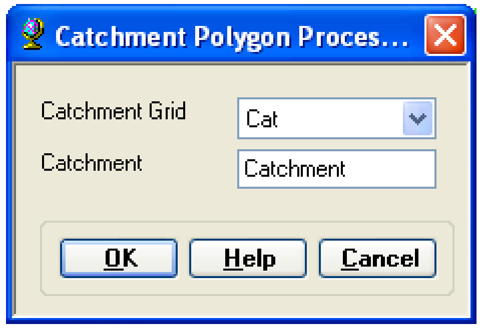
9. Catchment Polygon Processing

The three functions Catchment Polygon Processing, Drainage Line Processing and Adjoint Catchment Processing convert the raster data developed so far to vector format. The rasters created up to now have all been stored in a folder named *Layers*. The vector data will be stored in a feature dataset also named *Layers* within the geodatabase associated with the map document.

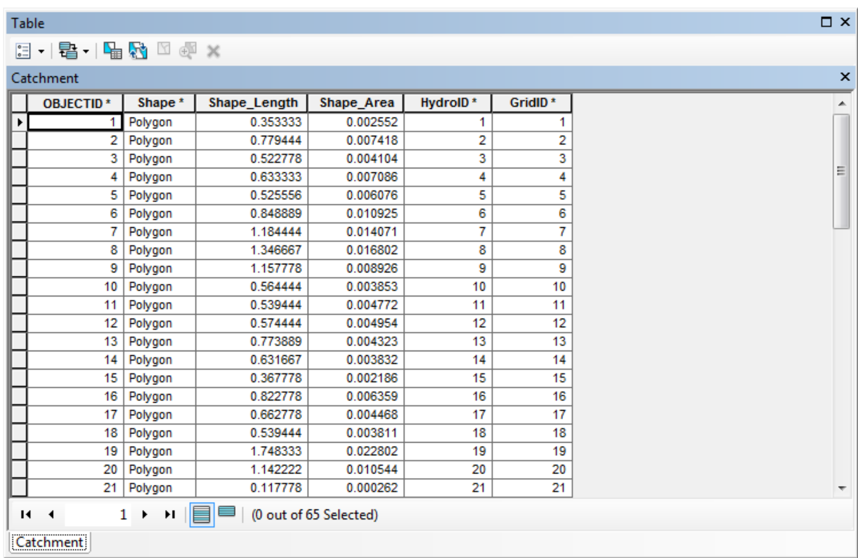
On the ArcHydro toolbar, select Terrain Preprocessing ->Catchment Polygon Processing.

This function converts a catchment grid into a catchment polygon feature.

Confirm that the input to the CatchmentGrid is *Cat*. The output is the Catchment polygon feature class, having the default name *Catchment* that can be overwritten.



Press *OK*. Upon successful completion of the process, the polygon feature class *Catchment* is added to the map. Open the attribute table of *Catchment*. Notice that each catchment has a *HydroID* assigned that is the unique identifier of each catchment within *Arc Hydro*. Each catchment also has its Length and Area attributes. These quantities are automatically computed when a feature class becomes part of a geodatabase.



Table

Catchment

OBJECTID *	Shape *	Shape_Length	Shape_Area	HydroID *	GridID *
1	Polygon	0.353333	0.002552	1	1
2	Polygon	0.779444	0.007418	2	2
3	Polygon	0.522778	0.004104	3	3
4	Polygon	0.633333	0.007086	4	4
5	Polygon	0.525556	0.006076	5	5
6	Polygon	0.848889	0.010925	6	6
7	Polygon	1.184444	0.014071	7	7
8	Polygon	1.346667	0.016802	8	8
9	Polygon	1.157778	0.008926	9	9
10	Polygon	0.564444	0.003853	10	10
11	Polygon	0.539444	0.004772	11	11
12	Polygon	0.574444	0.004954	12	12
13	Polygon	0.773889	0.004323	13	13
14	Polygon	0.631667	0.003832	14	14
15	Polygon	0.367778	0.002186	15	15
16	Polygon	0.822778	0.006359	16	16
17	Polygon	0.662778	0.004468	17	17
18	Polygon	0.539444	0.003811	18	18
19	Polygon	1.748333	0.022802	19	19
20	Polygon	1.142222	0.010544	20	20
21	Polygon	0.117778	0.000262	21	21

1 (0 out of 65 Selected)

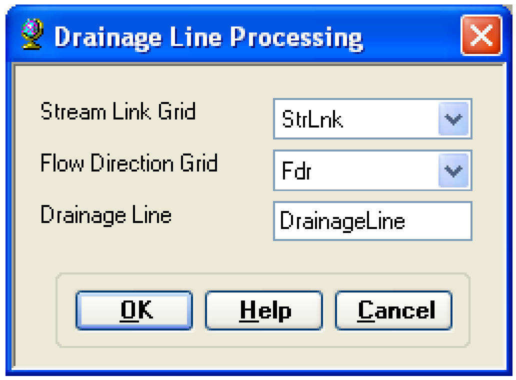
Catchment

10. Drainage Line Processing

This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

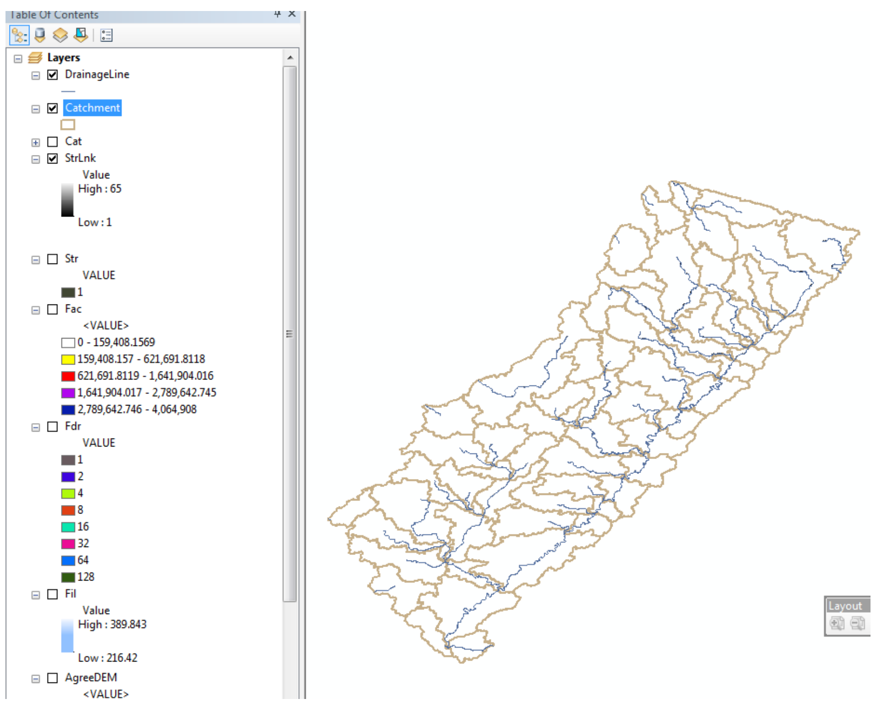
On the ArcHydro toolbar, select Terrain Preprocessing ->Drainage Line Processing.

Confirm that the input to Link Grid is *Lnk* and to Flow Direction Grid *Fdr*. The output Drainage Line has the default name *DrainageLine* that can be overwritten.



Press *OK*. Upon successful completion of the process, the linear feature class *DrainageLine* is added to the map.

The drainage lines and subbasins are shown below.

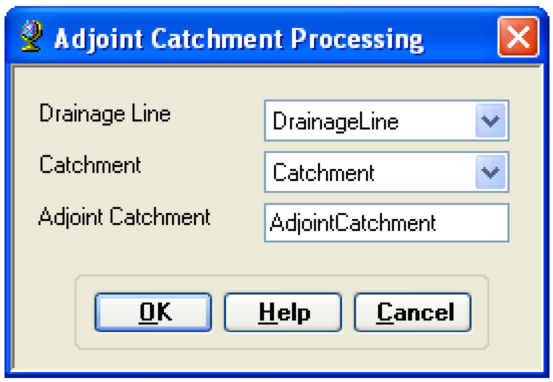


11. Adjoint catchment processing

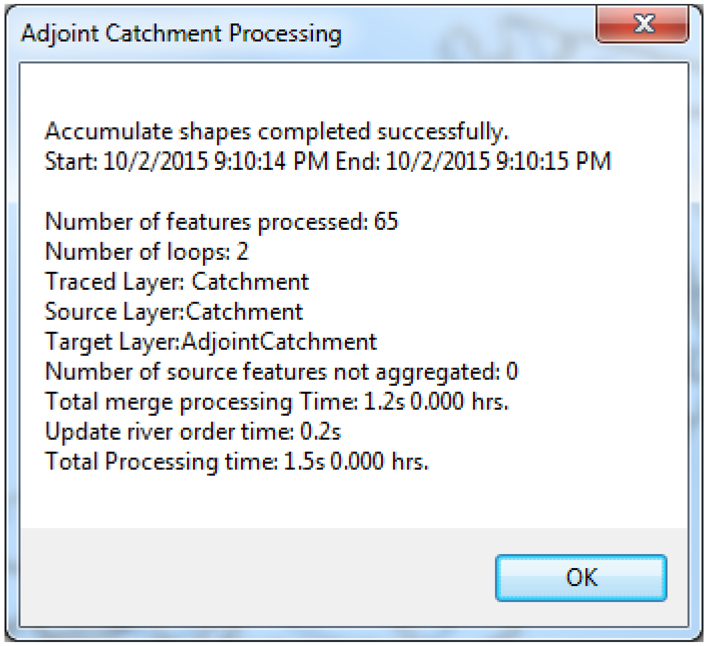
This function generates the aggregated upstream catchments from the *Catchment* feature class. For each catchment that is not a head catchment, a polygon representing the whole upstream area draining to its inlet point is constructed and stored in a feature class that has an *Adjoint Catchment* tag. This feature class is used to speed up the point delineation process.

On the ArcHydro toolbar, select Terrain Preprocessing -> Adjoint Catchment Processing.

Confirm that the inputs to Drainage Line and Catchment are respectively *DrainageLine* and *Catchment*. The output is Adjoint Catchment, with a default name *AdjointCatchment* that can be overwritten.



Press *OK*. Upon successful completion of the process, you will see a message box similar to the one below that will give you a summary of the number of catchments that were aggregated to create the adjoint catchments.



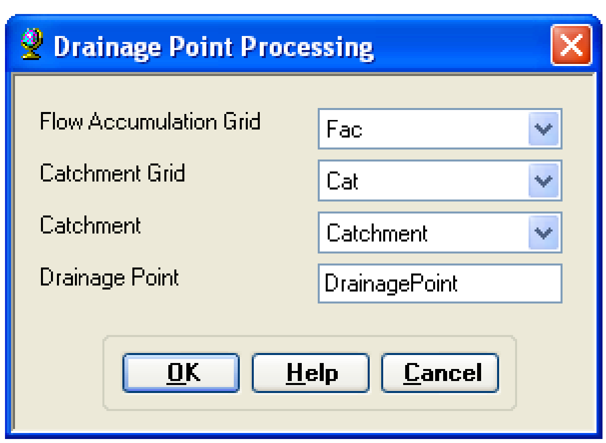
Click OK, and a polygon feature class named *AdjointCatchment* is added to the map.

12. Drainage Point Processing

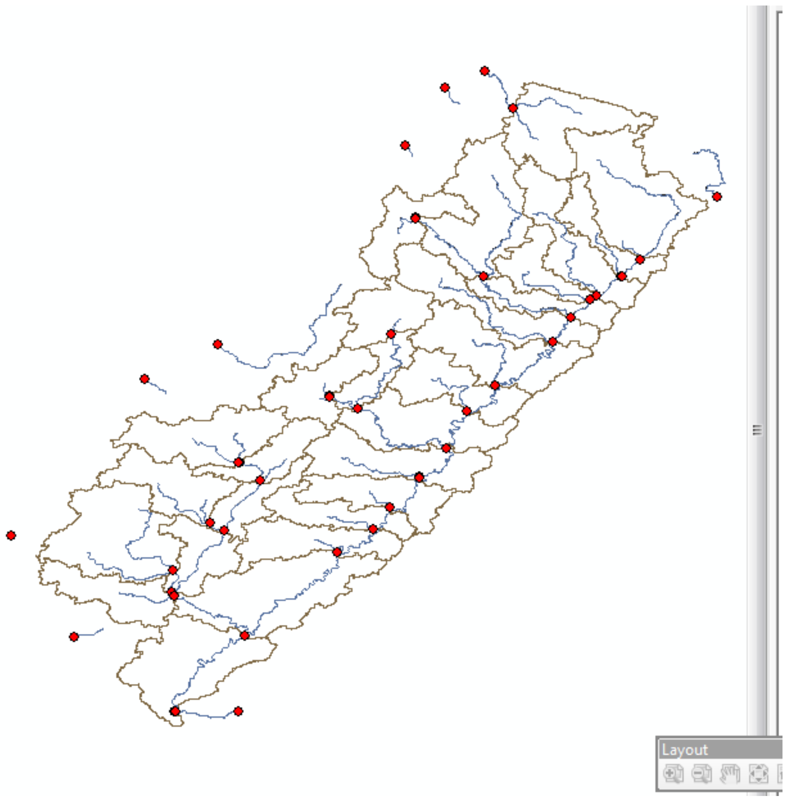
This function allows generating the drainage points associated to the catchments.

On the ArcHydro toolbar, select Terrain Preprocessing -> Drainage Point Processing.

Confirm that the inputs are as below. The output is Drainage Point with the default name DrainagePoint that can be overwritten.



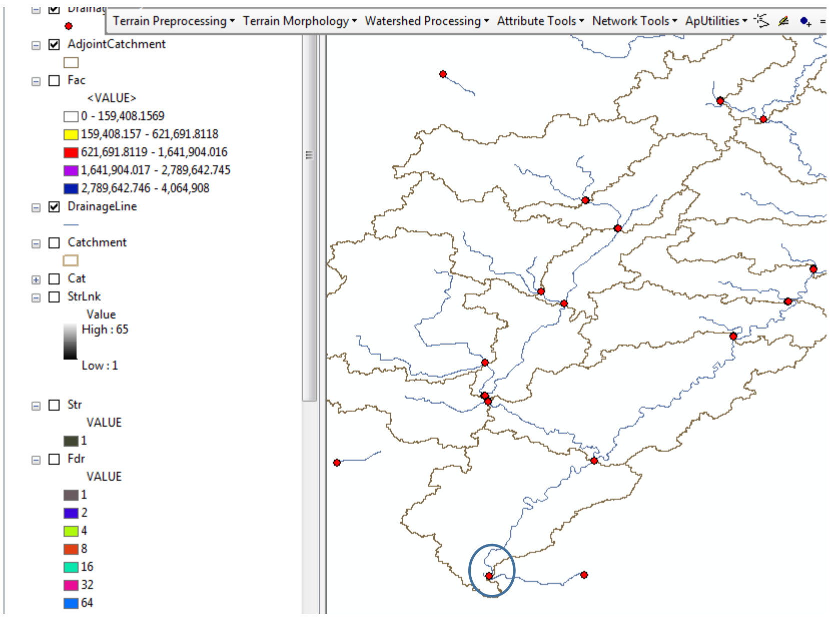
Press *OK*. Upon successful completion of the process, the point feature class “DrainagePoint” is added to the map, which is shown in the figure below



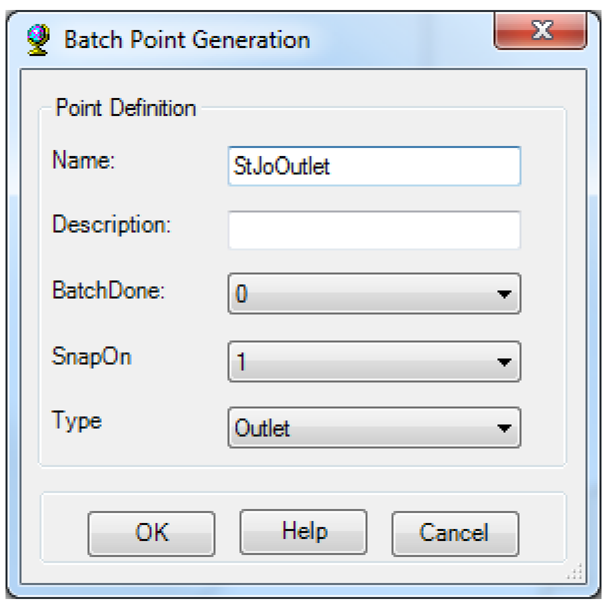
Step 3: Watershed Processing

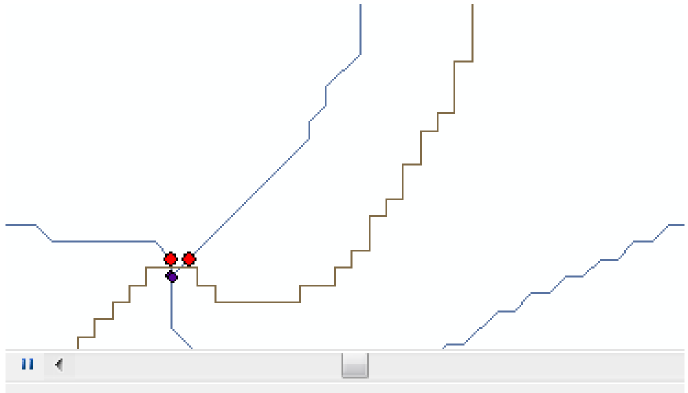
Arc Hydro toolbar also provides an extensive set of tools for delineating watersheds and subwatersheds. These tools rely on the datasets derived during terrain processing. This part of the exercise will expose you to some of the Watershed Processing functionality in Arc Hydro.

The Arc Hydro tools Batch Point Generation  can be used to interactively create the Batch Point feature class. We will use this to locate the outlet of the watershed. Arrange your display so that DrainagePoint, AdjointCatchment and DrainageLine datasets are visible. **Zoom-in** near the outlet of the St. Joseph River basin (bottom). The display should look similar to the figure shown below.

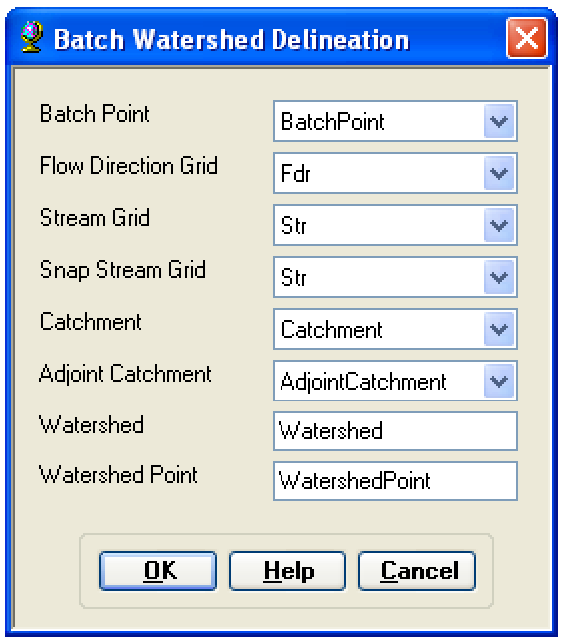


Zoom in to the outlet position sufficiently. **Click** on the icon in the Arc Hydro Tools toolbar. **Click** on the DrainageLine near the outlet position to create the total outlet of the basin.





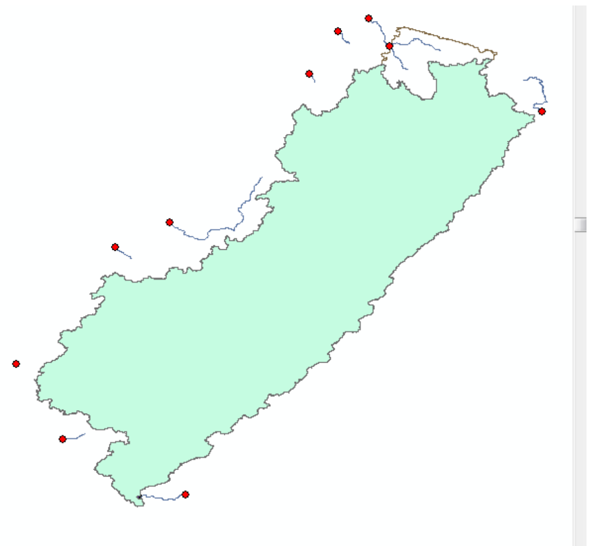
On the Arc Hydro toolbar, **select** Watershed Processing -> Batch Watershed Delineation.



Confirm that *Fdr* is the input to Flow Direction Grid, *Str* to Stream Grid, *Catchment* to Catchment, *AdjointCatchment* to AdjointCatchment, and *BatchPoint* to Batch Point. For output, the Watershed Point is *WatershedPoint*, and Watershed is *Watershed*. *WatershedPoint* and *Watershed* are default names that can be overwritten.

Press *OK*. You will get a message indicating that 1 point has been processed.

The delineated watersheds for the selected point should correspond closely to the outline of the St. Joseph River watershed as shown below. You are done!



What to Turn In

Submit the following as part of your lab report:

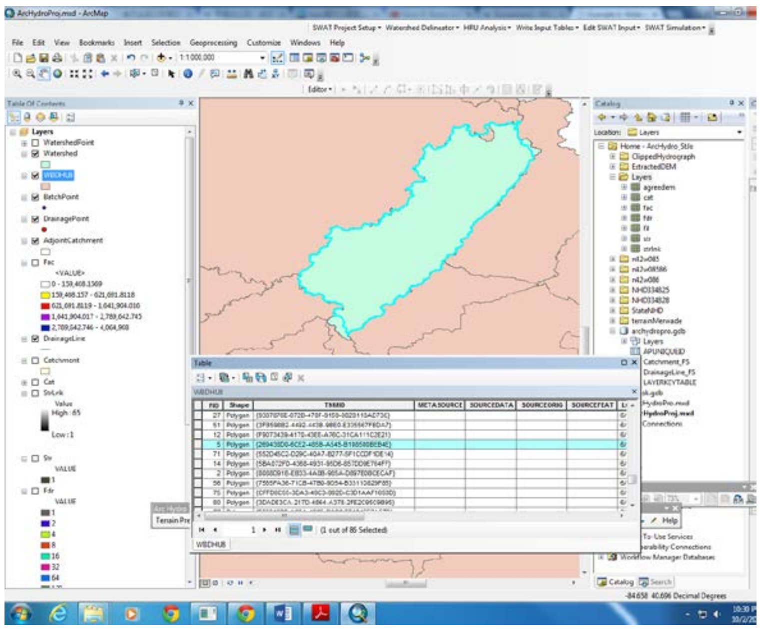
- 1. An introduction to describe what is a watershed, and how people delineate watershed boundary. What is need for manually delineation? What is needed for auto delineation using ArcHydro? What's the same and difference, such like principle, material, etc., between those two methods? List your cited references at the end of the report. 2. Generate a histogram showing the area distribution of catchment inside your watershed boundary. What's the mean and standard deviation of those subbasin areas? For those subbasin inside your watershed boundary, where (headwater/outlet) can you find the max/min river order?
- 3. A figure showing your delineated watershed boundary and HUC8 boundary (WBDHU8) for St. Joseph River watershed. Describe in which part you detect difference between two boundaries. Please also show that part in your figure (You may need to zoom in to see the difference). What could cause the difference?
- 4. A figure showing DrainageLine" and "ClippedFlow". What parameter controls the density of your "DrainageLine"?
- 5. A figure including two subplots containing your 10m and 30m contour map.
- 6. A figure showing your 30m contour map, "DrainageLine" and watershed boundary visible on the screen.

7. A discussion part addressing the following questions in your lab report.Questions:

1. Open the attribute table of the "Catchment" layer by right-clicking on the layer name and selecting "Open Attribute Table". How many catchments are there in the layer? How many of

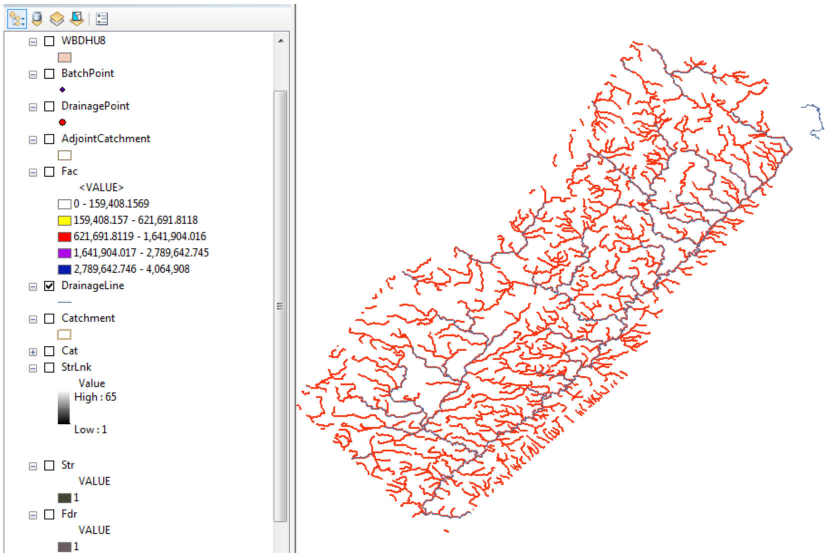
them are inside the boundary of your delineated watershed? Generate a histogram showing the distribution of all catchment areas. (The unit of area in the attribute table is m^2).

2. Overlap WBDHU8 from StateNHD/NHD_M_18_Indianan_ST using ArcMap. Open the attribute table of WBDHU8, and highlight FID=5, HUC8=04100003. You should get a map like below.



3. Compare the shape of the highlighted area and your delineated watershed. Do they match with each other? What's the "shape_area" of your delineated watershed (unit is m^2)? What's the "AREASQKM" for WBDHU8? (unit is km^2)? What causes the difference?

4. Adjust your layers in the table of content, make sure you have "DrainageLine" and "ClippedFlow". You should have a map looks like the figure below



5. Which one has a denser stream network? Which parameter affects the density of "DrainageLine"?

6. Adjust your layers in the table of contents, and overlay the contour map you generated earlier. Make sure you also have the "DrainageLine" and watershed boundary visible on the screen. How does your watershed boundary compare to the changes in elevation visible in your contour map? How is your streamflow (drainage) network related to the contours in the watershed?

Reference

Lab modified from CE 549 Computational Watershed Hydrology Fall 2012 by Dr. Venkatesh Merwade.