Watershed Delineation Method for Rhode Island

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# Summary

This is the method used to delineate sub-watersheds for Watershed Watch sampling locations. Processing of the original DEM (fill through flow accumulation) is very slow and takes up a lot of space. For this process you need a digital elevation model (DEM) and a (point) feature class of the location of the outlet of the watershed that you want to delineate. Having a compatible location for the watershed outlet is critical for the watershed to be delineated accurately. A Python script was developed to automate the delineation process however the outlet point must still be manually created.

# Requirements

1. ArcMap 10.x - though this process is possible within ArcPro, these instructions reference the naming conventions of the ArcMap toolboxes and so will not map one-to-one. Additionally, ArcPro runs on Python 3.x whereas ArcMap runs on Python 2.x - the provided script will be incompatible with the ArcPro versions of arcpy due to the interpreter version change as well as the modifications to the arcpy API (it’s not backwards compatible, some functions were removed).
2. A digital elevation model (DEM) covering the surface of the watershed that you’re delineating.
3. A point feature class containing an outlet point for the watershed that you’re delineating.
4. A polyline feature class containing existing stream & river networks within the watershed of interest - when in doubt, you can fall back to the NHD datasets

# Data

S:\Gold\_Lab\Seaver\Watershed Watch Data

All delineated watersheds and outlet points can be found in the Lake\_Pond\_Res\_WatershedDelineations folder with delineated watersheds in the LakesPondsResWatershedsSPF geodatabase. These watersheds should be checked against contour lines and hydrography before making final maps. I tried to organize everything else needed for putting together the maps very clearly into folders with labels such as “Hydrography”, “Landuse”, “Delineation Files”, “dams”, and “Conserved Land”.

# Manual Procedure

1. *(Optional)* Clip DEM to area of interest. If you’re delineating a subwatershed, such as a URI Watershed Watch sampling point, then you may consider clipping to the HUC10 or HUC12 watershed which contains it, knowing that the subwatershed must necessarily be contained within. The processing time is greatly improved with a smaller DEM.
2. Convert DEM, outlet feature class and stream feature class to the same projection. I chose NAD 83 UTM Zone 19 because it is suggested to match the units of the coordinate system with the units of elevation in the DEM for watershed delineation. The elevation values of the USGS DEM are in meters, and the units for UTM coordinate system are also in meters.
3. Perform a hydrography *burn-in* of the DEM with the stream network. This will lessen the potential for error due to culverts and other under-the-road water connections that will affect the watershed delineation.
   1. Convert the stream network to a raster using the Polyline to Raster tool of the Conversion toolbox. Specify the cell size as being that of the DEM raster; use any field for value as we’ll reclass it shortly.
   2. Reclassify the raster values using the Reclassify tool from the Spatial Analyst toolbox, setting any *actual* value to the same constant number and NoData to 0. Whatever value you choose for a constant is how much the DEM will be lowered by for cells that overlap the stream raster. Think of it as carving a channel into the DEM so that culverts or other features not observed in a DEM are recognized as connections for a watershed. If you’ve followed the steps exactly, a good number is in the range of (5, 10) as the vertical unit is meters.
   3. Using Raster Calculator from the Spatial Analyst toolbox, subtract the stream raster from the DEM. Use the output in the next phase of delineation.
4. Follow the instructions in the Trent University Watershed Delineation tutorial: A quick description of those steps is listed here but see the document for more information. These tools are located in the Spatial Analyst, Hydrology toolbox. Steps A, B, and C only need to be done once and I would just use the existing Flow Accumulation and Direction rasters found in S:\Gold\_Lab\Seaver\Watershed Watch Data\Delineation Files
   1. Fill DEM using the “fill” tool
   2. Calculate Flow Direction with the “flow direction” tool
   3. Calculate Flow Accumulation using the “flow accumulation” tool- the result of this step will likely be all black, and at this point it is necessary to change the symbology as it mentions in the Trent Univ. article. For my purposes, I set the first break value at 2000 but this is really just trial and error to find the right break. As the Trent article says, “This means that cells that have less than 2000 upstream cells flowing into them will be symbolized differently than cells with more than 2000 upstream cells.” Basically, you want to show the cells with more than 2000 upstream cells and hide the cells with less than 2000 (or whatever your break is). The cells with highest accumulation are going to be the wet areas of the landscape (streams and rivers) and the goal is to find a break value that approximately replicates the stream network of the region. It is not going to be exact so don’t drive yourself crazy- just try to find the break value that will show most of the major streams and rivers as flow accumulation lines.
   4. Make sure that the outlet point is directly on top of the closest high flow accumulation line. It may not be exactly on top of a high flow accumulation line because usually the flow accumulation lines do not exactly match the stream network, and this is fine. Just move the location of the outlet to the closest high flow accumulation line.
   5. “Snap Pour Point”- this serves two purposes- it basically replicates the previous step by moving the outlet location to the closest high flow accumulation cell within whatever radius you specify (I used a radius of 10 meters). It also converts the outlet to a raster, which is required for watershed delineation. I do suggest doing the manual move of the outlet to a high flow accumulation cell in addition to the snap pour point because I think it gives you some control over where the outlet is moved to.
   6. Create watershed using the “watershed” tool
   7. Convert watershed from raster to vector
   8. Convert watershed to final desired projection
5. Do a final review of the watershed and fix any big errors- this is critical! The delineation process is not perfect and there is almost always something not right in the delineated boundary. Because it is based on the DEM, it does not account for large amounts of impervious cover or hydrography. Display the stream network and contour lines on top of the watershed at the end to make sure that it makes sense. If a stream is cut in half, you should just manually move the boundary of the watershed to encompass the entire stream by following the contour lines.

# Scripts & Tools

The above process has been scripted and can be run directly from the command line (using the python 2.7 binary provided with ArcMap) or an IDE such as PyCharm, Spyder or VS Code.

The delineation process can be automated for many given points at one time using the script I wrote in Python located in Seaver’s folder, S:\Gold\_Lab\Seaver\Watershed Watch Data\Delineation Files\Python Scripts. The process of snapping the outlet point to a flow accumulation must still be done manually. This script can delineate many watersheds at once and convert them to shapefiles in a matter of minutes rather than going through the whole process in ArcGIS. The script has instructions on lines that need to be changed and is quite simple. Make sure the Project Interpreter is set to Python 2.7 before running the code.

Alternatively, a tool was created to do exactly the above with an optional burn-in network. You provide the DEM and the point feature class and stream network and the resulting watershed is saved as a feature class. To load this tool:

# Additional References

* <http://sites.tufts.edu/gis/files/2013/11/Watershed-and-Drainage-Delineation-by-Pour-Point.pdf>
* <http://www.ce.utexas.edu/prof/maidment/giswr2012/Ex4/Ex42012.pdf>