



Watershed Delineation with ArcGIS 10.3.x

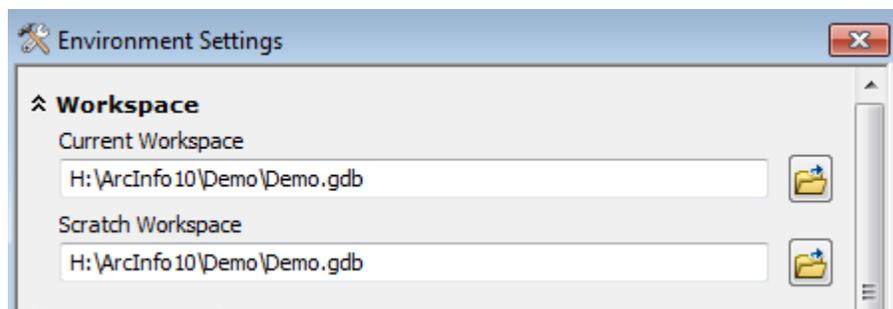
Watersheds, also known as basins or catchments, are physically delineated by the area upstream from a specified outlet point. Watersheds can be delineated manually using paper maps, or digitally in a GIS environment. The process outlined in this document includes steps for delineating watersheds in ESRI's ArcGIS Desktop 10.3.1 software.

This guide assumes that you have obtained the required data, which includes a digital elevation model (DEM) and stream network file for your area of interest. Note that the Ontario Ministry of Natural Resources and Forestry (OMNRF) have released many of the data outputs that are created in this process as a packaged product known as **Ontario Integrated Hydrology (OIH)** data. Obtaining the OIH data set will allow users to skip many of the time-consuming and resource-intensive steps in the process, as noted throughout this guide. Should you have any questions regarding how to access the OIH or other government data sets, please contact us for assistance at madgichelp@trentu.ca

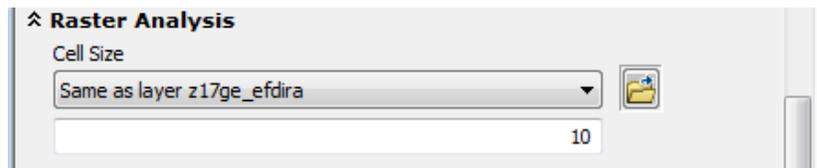
Step 1 Set up your work environment

Use the steps below to set up your map document and establish the working directory you will be using throughout the watershed delineation process.

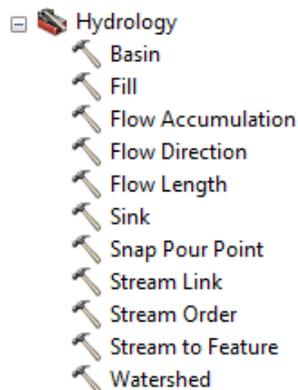
1. Open ArcMap and create a new, blank map document. Use the *Add Data* button  to add the DEM for your area of interest to the map.
2. Browse to *Geoprocessing > Environments*. Under *Workspace*, set the variables for *Current Workspace* and *Scratch Workspace* to the directory where you wish to save your results. It is a good idea to create an empty file geodatabase for this purpose. Further information about the file geodatabase format can be found [here](#).



3. Browse to *Environment Settings > Raster Analysis* and use the drop down arrow to set the *Cell Size* property to be the same as the DEM layer. Click *OK* to accept the changes.



4. If necessary, enable the Spatial Analyst extension (*Customize > Extensions > Spatial Analyst*).
5. Open *ArcToolbox*  from the main menu and expand the *Spatial Analysis Tools > Hydrology* toolbox to view its contents.



6. Save your map document (*File > Save*).

Step 2 Create a depressionless DEM

Note: This step is not necessary when using OIH data from the OMNRF.

The *Fill* tool in the *Hydrology* toolbox is used to remove any imperfections (sinks) in the digital elevation model. A **sink** is a cell that does not have an associated drainage value. Drainage values indicate the direction that water will flow out of the cell, and are assigned during the process of creating a flow direction grid for the landscape. The resulting drainage network depends on finding the 'flow path' of every cell in the grid, so it is important that the fill step is performed prior to creating a flow direction grid.

Double click the *Fill* tool to open its dialog and enter the following parameters.

1. Set the DEM grid as the *Input surface raster*. [screen shot]
2. If necessary, set the *Output surface raster* to your working directory and provide a descriptive name for the output.
3. Accept all other defaults and click *OK* to run the tool. This process can be resource-intensive, and may take some time to complete depending on the processing power available to the software.

Note: The *Show Help* option at the bottom of the tool dialog provides help documentation for each parameter. In this case, the optional input of *Z limit* has been left blank; but it is important that you make your own decisions regarding optional parameters, as every analysis is different and dependent on the data that is being used.

When the fill process is complete, a new grid will be added to the data frame of your map document. There should be a difference in the lowest elevation value between the original DEM and the filled DEM.

You can now remove the original DEM layer from the map view (right-click > *Remove*) and save your map document.

Step 3 Create a flow direction grid

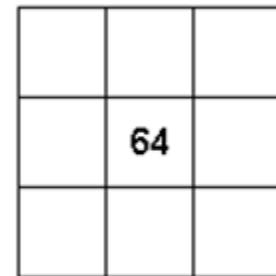
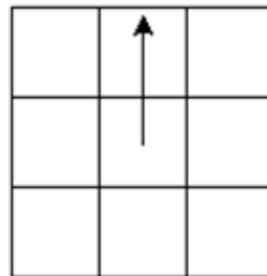
Note: This step is not necessary when using the *OIH* data from the *OMNRF*.

A flow direction grid assigns a value to each cell to indicate the direction of flow – that is, the direction that water will flow from that particular cell based on the underlying topography of the landscape. This is a crucial step in hydrological modeling, as the direction of flow will determine the ultimate destination of the water flowing across the surface of the land.

Flow direction grids are created using the *Flow Direction* tool. For every 3x3 cell neighbourhood, the grid processor finds the lowest neighbouring cell from the centre. Each number in the matrix below corresponds to a flow direction – that is, if the centre cell flows due north, its value will be 64; if it flows northeast, its value will be 128, etc. These numbers have no numeric meaning – they are simply codes that define a specific directional value, and are determined using the elevation values from the underlying DEM.

			32	64	128
			16		1
			8	4	2

Flow direction matrix



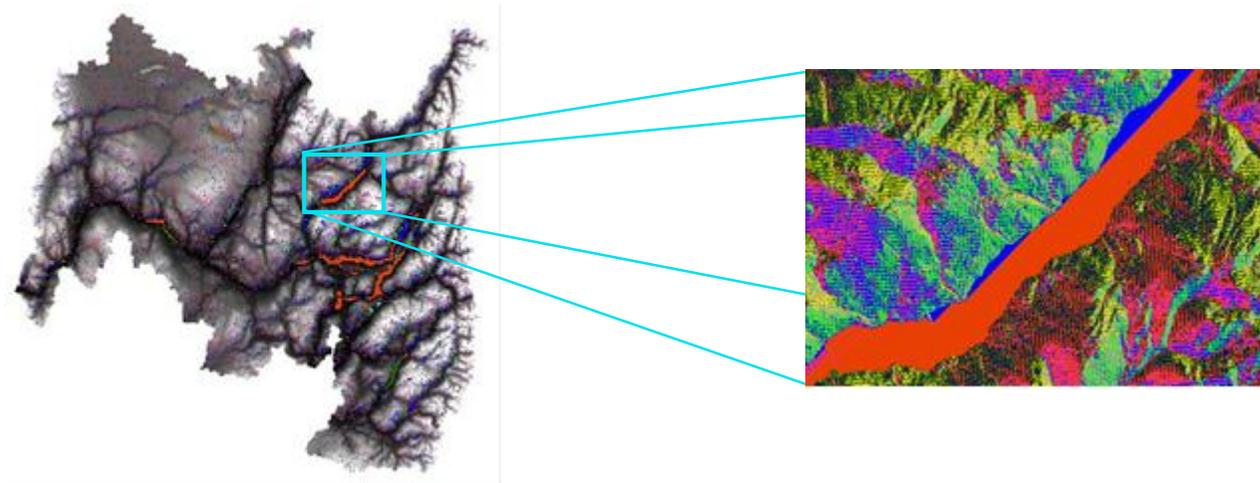
Flow direction is north, cell is coded 64

Double-click the *Flow Direction* tool to open the tool dialog and input the following parameters.

1. Set the *Input surface raster* to the filled DEM created in the Step 2.
2. If necessary, set the *Output flow direction raster* to your working directory and provide a descriptive name for the output file.
3. An *Output drop raster* is optional for further analysis of slope details, further details are available in the tool's help menu. Click *OK* to run the tool.

4. Browse to *Environment Settings > Raster Analysis* and confirm that the output raster cell size is the same as your filled DEM.

This process may take quite some time to run through to completion. When the tool has finished, the new flow direction grid will be added to the map document.



Step 4 Create a flow accumulation grid

Note: *This step is not necessary when using the OIH data from the OMNRF.*

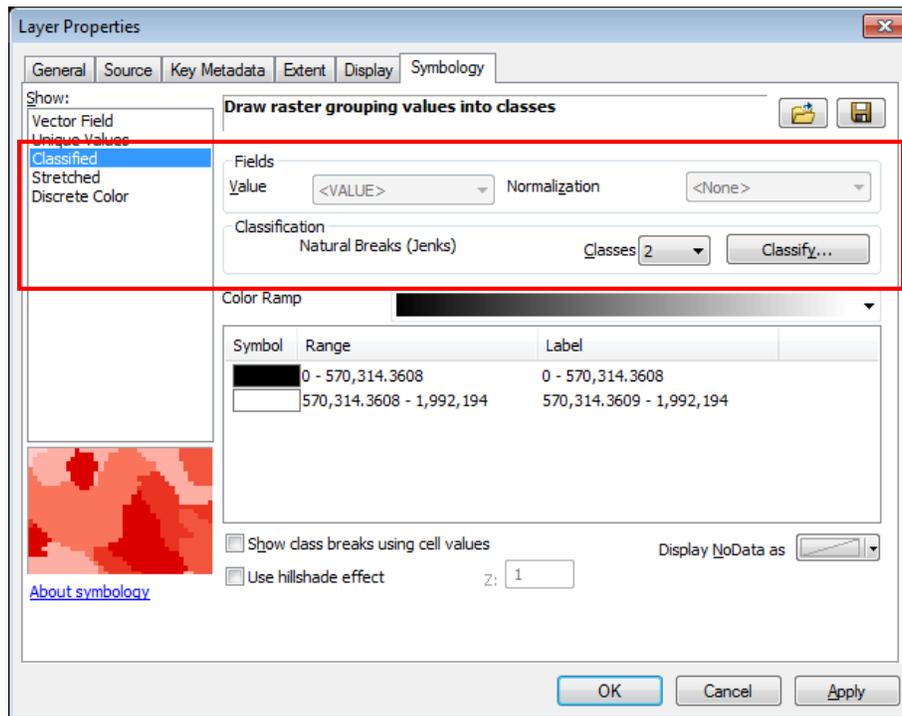
The *Flow Accumulation* tool calculates the flow into each cell by identifying the upstream cells that flow into each downslope cell. In other words, each cell's flow accumulation value is determined by the number of upstream cells flowing into it based on landscape topography.

Double-click the *Flow Accumulation* tool to open the tool dialog and input the following parameters.

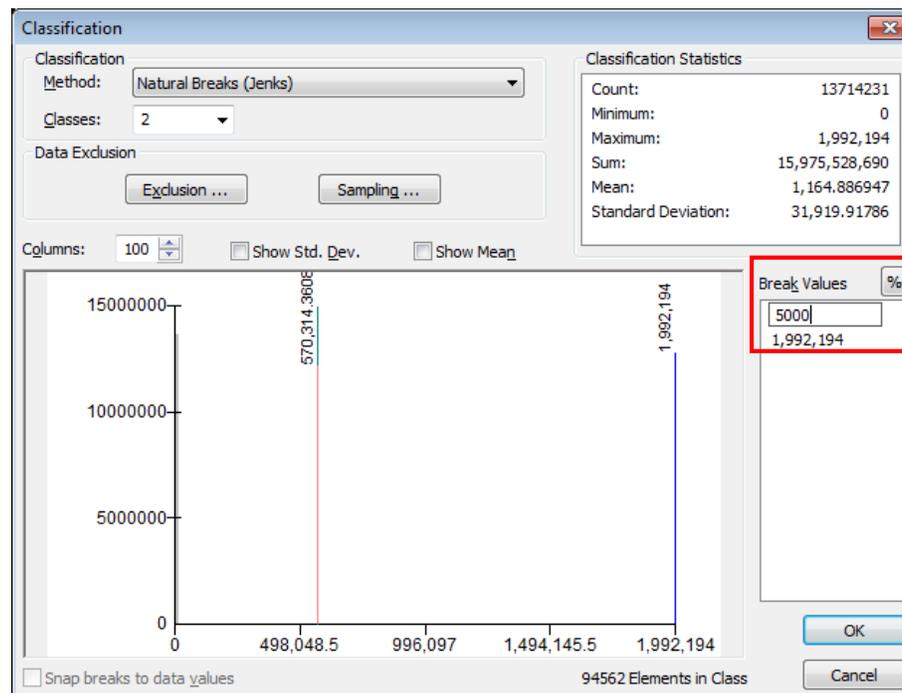
1. Set the *Input flow direction raster* to the flow direction grid created in Step 3.
2. If necessary, set the *Output accumulation raster* to your working directory and provide a descriptive name for the output.
3. The *Input weight raster* option will apply if a weighted factor is to be applied to the flow accumulation.
4. The *Output data type* is a FLOAT by default and will typically remain as a FLOAT for more precise results. Click *OK* to run the tool.
5. Browse to *Environment Settings > Raster Analysis* and confirm that the output raster cell size is the same as your filled DEM.

The new flow accumulation raster will be added to your map document. Each cell in the grid contains a value that represents the number of cells upstream from that particular cell. Cells with higher flow accumulation values should be located in areas of lower elevation, such as valleys or drainage channels where water flows naturally while it is following the landscape.

If the flow accumulation raster appears dark and the cell values are difficult to visualize then it will be necessary to alter the layer symbology.



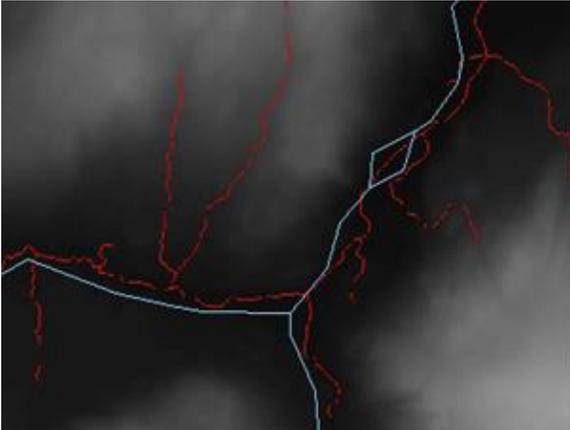
Right-click the layer name in the table of contents and select *Properties > Symbology*. In the left pane, highlight *Classified*. Set the number of classes to 2 and click *Classify*.



Set the first break value to a threshold number that will assist with delineating channels. This value will be based on your data, and is really up to the analyst. For this example we have used 5000 as a threshold, which means that cells that have less than 5000 upstream cells will be symbolized differently than cells with more than 5000 upstream cells. Leave the second value as the maximum value in the grid.

Click *OK* to return to the *Symbology Properties* dialog. Change the symbology by double-clicking the colour swatches under *Symbol*. Select *No color* for the first class (0-5000) and a bright red colour for the second class (5000+). Click *OK* to apply the changes and close the dialog.

The flow accumulation layer is now symbolized so that you are better able to visually pinpoint areas of high flow accumulation. As mentioned, the cells displayed in red have at least 5000 upstream cells flowing through them. Add your stream network layer to visually compare the flow accumulation data with the actual stream network. Note that the two data sets will not line up perfectly, but the flow accumulation grid should correspond closely with the watercourse data as shown below.



Flow accumulations are important because they allow us to locate cells with high flow where streams and channels are to be expected. Each cell has an outlet point called a *pour point* that indicates the location where water would naturally flow out of the cell. Pour points must be located in cells with high cumulative flow or the delineated watersheds will cover very small areas.

Step 5 Create outlet (pour) points

Pour point placement is an important step in the process of watershed delineation. A pour point should exist within an area of high flow accumulation because it is used to calculate the total contributing water flow to that given point. In many cases you will already have a file containing the locations of your pour points, whether they are sampling sites, hydrometric stations, or another data source. However in some cases, it may be necessary or preferable to create pour points manually. Instructions have been provided for both cases below.

a. Loading pour points from an existing file

Add the point file containing pour point locations to your map document along with the flow accumulation grid created in Step 4. Zoom in to each point (or a random sample of points) to determine if they fall on a path of high flow accumulation. As mentioned, if the pour points are not situated in cells of high flow accumulation then the resulting watersheds will be excessively small. Assuming that your pour points are situated correctly, move on to Step 6.

b. Creating pour points through visual inspection

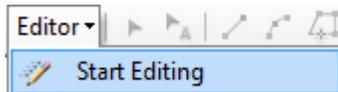
Open the ArcCatalog window  and create a new point file in your working directory (right-click the directory in the Catalog tree and select *New > Feature Class* with the type set to Point Feature if you are working from a geodatabase, or *New > Shapefile* if you are working from a folder). Give the file a

descriptive name and apply the appropriate coordinate system for your data. Click OK to add the new point layer to the map document.

Zoom in to your study area so that you are able to see the individual cells of the flow accumulation grid.

Use the *Identify* tool  to examine the values of the grid. The chosen pour point must be on the high flow accumulation path, and should be a natural outlet for the upstream cells. Your choice essentially determines the 'end' of your catchment area; everything upstream from the point that you create will define a single watershed.

When you are satisfied with your choice, add the point by starting an editing session (*Editor > Start Editing*). If you are asked which layer you would like to edit, select the empty point layer and click *OK*.



If necessary, open the *Create Features* window  and highlight the pour point file in the list. Move your cursor onto the map document and add a pour point by clicking in the centre of the cell you have chosen as the location of your outlet point. Try to place the points directly in the centre of the chosen cells and remember to place the points one or two cells away from stream confluences.

If you are creating a single watershed then save your edits and move on to Step 6.

If you are creating multiple watersheds, complete the process of adding outlet points then save your edits and exit the editing session. Open the point layer's attribute table (right-click > *Open Attribute Table*), click the *Table Options* button and select *Add Field*. Create a field called UNIQUEID of type *Short* (short integer).

Start another editing session and number your pour points sequentially (this can be done programmatically - see <http://support.esri.com/fr/knowledgebase/techarticles/detail/38517>).

Save your edits and stop the editing session. Individual watersheds will be identified and delineated by the software using this UNIQUEID field.

Step 6 Snapping pour points

The *Snap Pour Point* tool accomplishes two things; it snaps the pour point/s created in Step 5 to the closest cell of high flow accumulation to account for any error during placement, and it converts the pour points to raster format for input to the *Watershed* tool.

Double click the *Snap Pour Point* tool to open its dialog and enter the following parameters.

1. Set the *Input raster or feature pour point data* to the pour point layer created or loaded in Step 5.
2. Set the *Pour Point Field* to the UNIQUEID field created in Step 5 (only applicable when delineating multiple watersheds).
3. Set the *Input accumulation raster* to your flow accumulation grid created in Step 4.

4. Set the *Output raster* to your working directory and give the output a descriptive name.
5. The *Snap Distance* is the specified distance (in map units) that the tool will use to search around your pour points for the cell with the highest flow accumulation value. The snap distance should be based on the resolution of your data; it may require some trial and error to determine the best value. If your pour point is not located on a high flow pathway, the tool will move it to the cell within the search radius with the highest accumulation value. If your pour point is already located on the high flow pathway, then the tool will move the point to a downstream cell within the search radius. If it is important that your points remain at the exact cell location of initial placement, then run the tool with a snap distance of 0.
6. Browse to *Environment Settings > Raster Analysis Settings > Cell Size* and ensure that the cell size is set to the same as your flow accumulation layer.

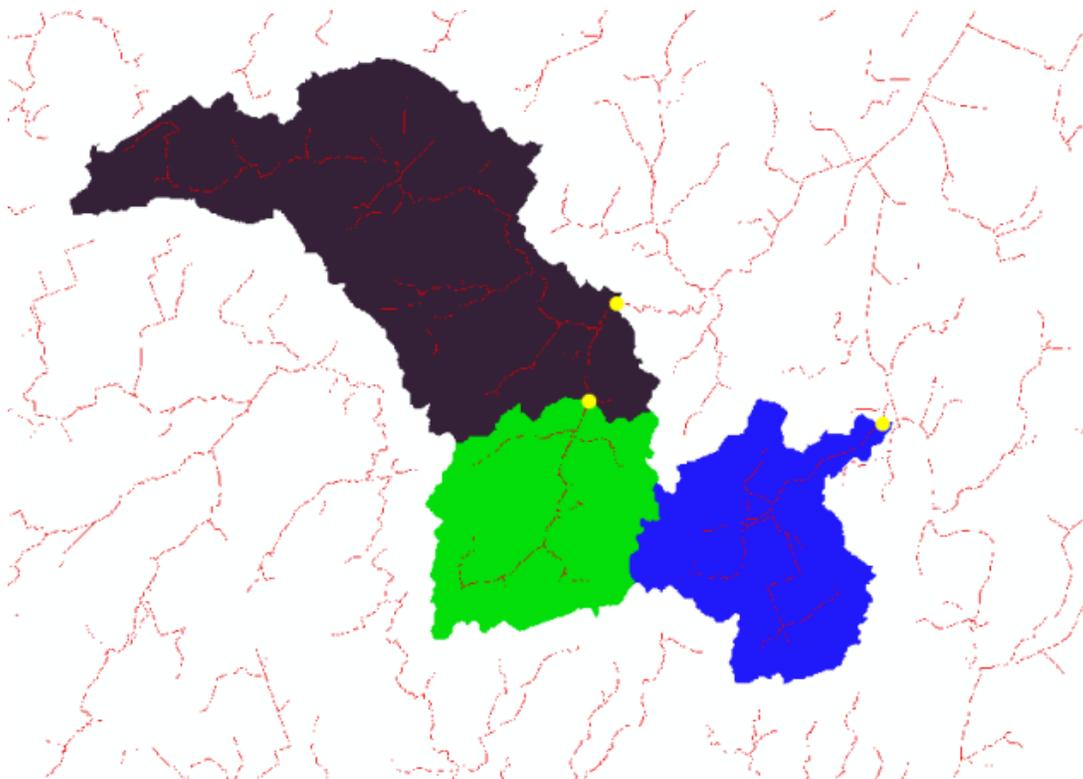
Click OK to run the tool. The output will yield a raster file of pour points that will be added to the map document.

Step 7 Delineate watersheds

Double-click the *Watershed* tool to open the tool dialog and set the parameters as follows.

1. The *Input flow direction raster* is the flow direction raster output in Step 3, or the enhanced flow direction grid provided with the OMNRF data package.
2. The *Input raster or feature pour point data* is the raster pour point file created in Step 6.
3. The *Pour point field* can be left as default, or optionally you may choose to select the UNIQUEID field created in Step 5.
4. If necessary, set the *Output raster* to your working directory and provide a descriptive name for the output file.

Click OK to run the tool. Upon completion, a new watershed raster will be added to your map document.



Step 8 Convert watershed rasters to polygons

Most users will find vector watersheds more useful than raster files in order to run further geoprocessing and analyses. Raster files can be converted to vector format using the *Raster to Polygon* tool (*ArcToolbox > Conversion > From Raster*). Double-click the tool to open its dialog and enter the parameters as follows.

1. Set the *Input raster* to the watershed raster file created in Step 7.
2. If necessary, set the *Output polygon features* to your working directory and give the output a descriptive name.

Leave all other defaults and click *OK* to run the tool. A new polygon file displaying your watersheds will be added to the map document.

This completes the process of watershed delineation in ArcGIS 10.3.x. As mentioned, it is often no longer necessary to perform the majority of these steps if you have taken the steps to acquire hydrology data through MaDGIC. However if your study area falls outside the province of Ontario, or you wish to delineate watersheds independently for comparison purposes, then these steps can be used to guide you through the process. Please keep in mind that this guide is meant to be used as an example only; decisions should be made based upon the data you are using and the type of analysis you wish to perform.

For further assistance with this guide or other topics related to geospatial and/or statistical data and software, please contact us at madgichelp@trentu.ca.