Watershed Modelling

Watersheds are an integral part the natural landscape. These are areas of drainage where surface water from rain and melting snow converges to a single point to join another water body, such as a river, lake, wetland or ocean. Delineating watersheds contributes to the understanding of contingent fields of study and research, including ecology, resource management and geomorphology.

In this grid modeling exercise watersheds are created with some of the tools available through ESRI ArcDesktop. The general process is outlined to derive the information needed for the final calculations, with four possible watershed outcomes provided, with a comparison to the established delineations used by the province.

The study area for this model resides on the border of Annapolis and Kings Counties, Nova Scotia, Canada (dark blue outline seen at left figure). This is represented in the Canadian Digital Elevation data (CDED) as GASPEREAU LAKE, 21A15 west NTS 1:50000 Map Sheet.

Data Preparation

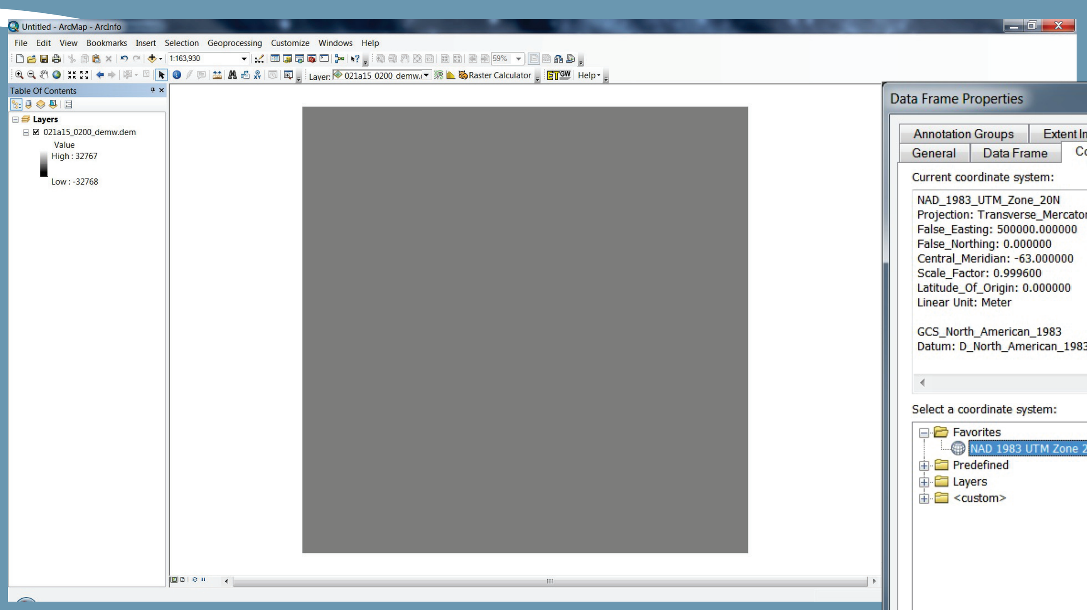


Figure 1

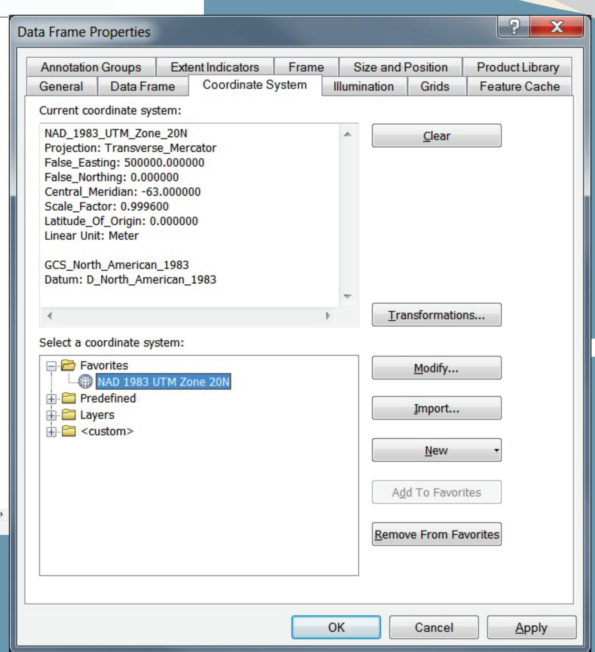


Figure 2

The source data for this project was provided in a DEM format with a horizontal coordinate system of North American Datum 1983 in decimal seconds. This needed to be converted to a grid and adjusted to UTM coordinates. This was accomplished by first setting the data frame coordinate system to NAD83 UTM Zone 20N. The DEM was brought into this workspace and exported out with a 20 by 20 cell size as an Erdas Image file format (extension .img). The data frame was the source of this new raster's spatial reference.

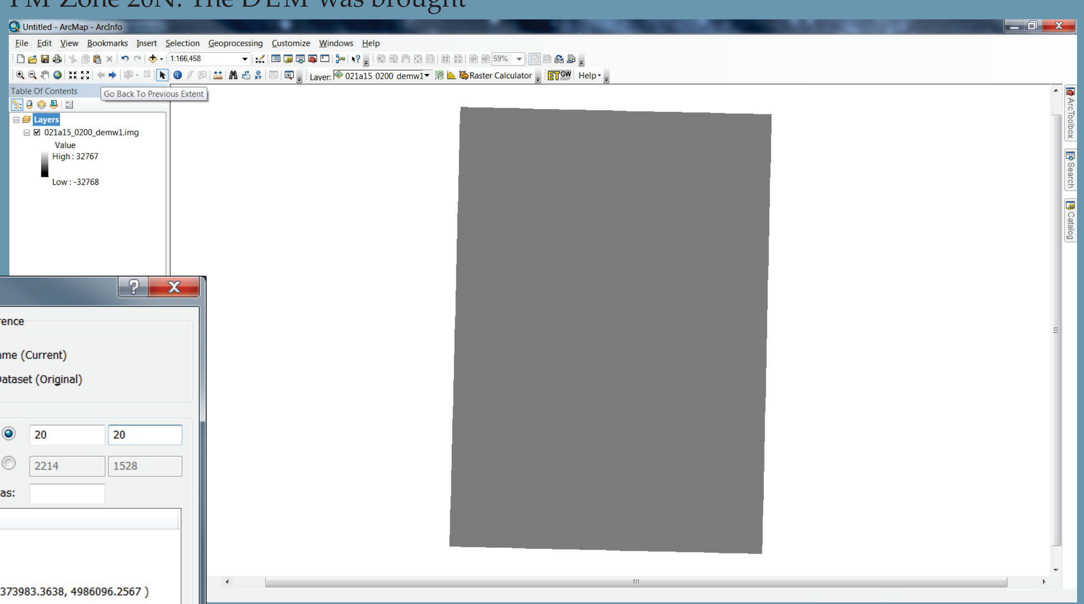


Figure 3

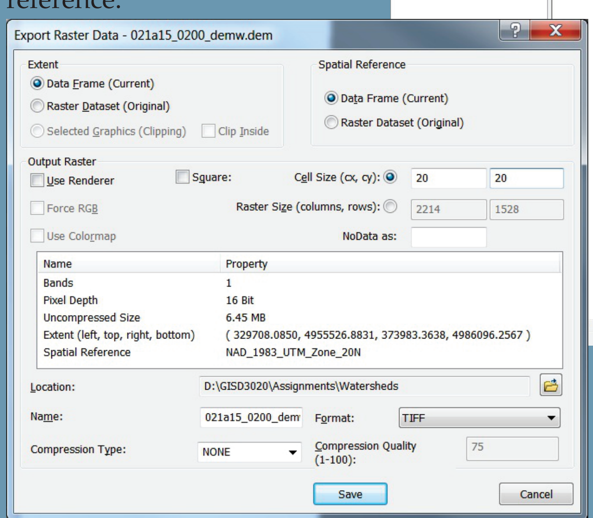


Figure 4

Final Outputs

The final output of this grid modeling has produced four variations of watershed delineation. Each using a different method for its output, whether that be with the final function or the process and treatment of its input data. With these differences a somewhat varying amount of watersheds were produced. In the provincially supplied shapefile 32 watersheds are found in the study area. Some of these are only portions of full drainage basins, as this data is not confined to a particular mapsheet. However in the outputted watersheds these portions are shown as stand alone watersheds, combined with another, or not processed without a part of the stream branch landing in the study area. Therefore watershed 1 has 22 drainage basins, watershed 2 has 17, watershed 3 with 368 and watershed 4 with 25.

There are many similarities between watershed 1 and 2. Both appear to have recognized the same drainage basins. Watershed 1 was created by creating points where the author believed to represent the watershed outlet. However some of these streams that go off the study area are more likely part of a larger system. Therefore many smaller watersheds were created around the edges. However in watershed 2 the process was more automated with the use of the basin function. After this was completed only those basins with a count of 5000 cells or more were converted to polygons, which produced the final result. Watershed is markedly different, with a total of 368 delineations. Since this represents river segments, rather than a stream network, it is at best overcompensation of tertiary watersheds. However when the segments were grouped to represent regions, aggregating based on connectivity, watershed 4 could be produced. This still reflects the same amount of area recognized by watershed 4, but has been grouped to produce larger and more natural delineations. It is perhaps the closest result to the provincially identified drainage basins.

Overall the results from the watershed delineations provide simplified versions of the provincially used set. This is most likely due to stream networks being cut off from the study area extent, making the recognition of larger, neighboring basins non-existent.

Provincial

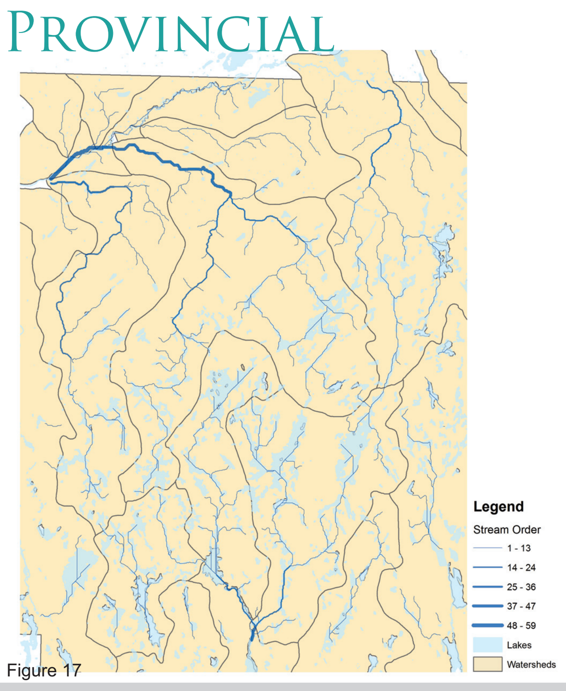


Figure 17

Watershed 1 Precise Point

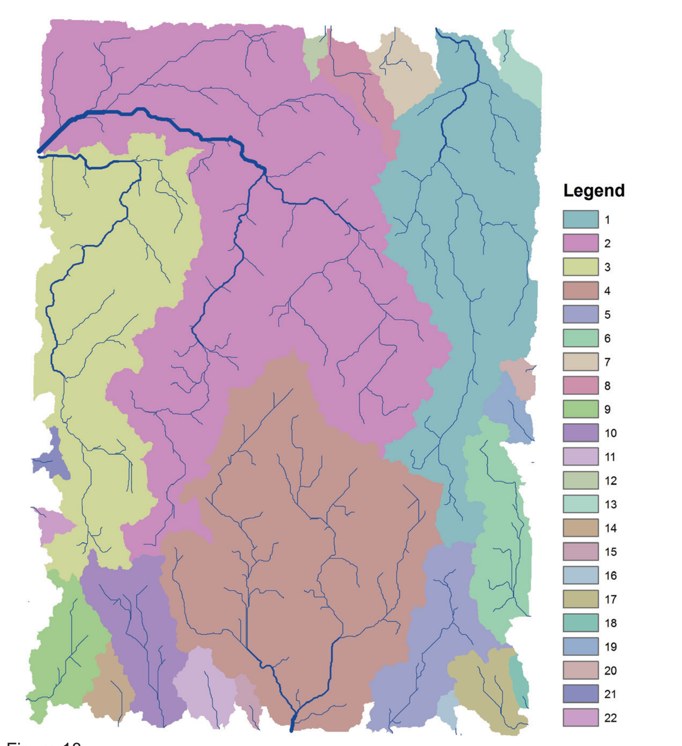


Figure 18

Selected Points convert Feature to Raster (output cell size 20)
Syntax:
SnapPourPoint("Select_pt.img", "demfacc.img", 40) = Gr_Outlet
Watershed ("demfdir.img", "Gr_Outlet.img")

Watershed 2 Basin Function

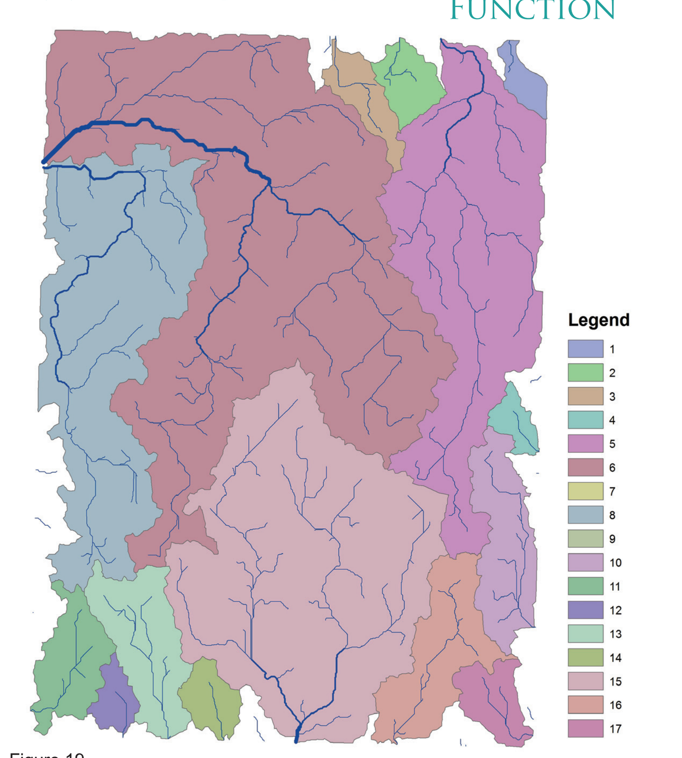


Figure 19

Syntax: Basin ("demfdir.img")
Select by attribute "COUNT" >=5000
Raster to Features

Watershed 3 From Streamlink

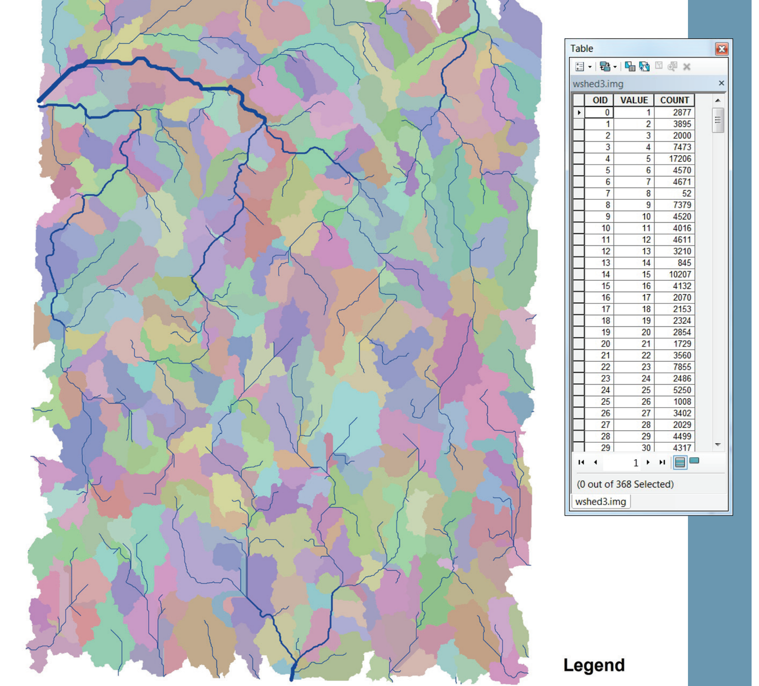


Figure 20

Syntax: Watershed ("demfdir.img", "s_links.img")

Watershed 4 Watershed Function

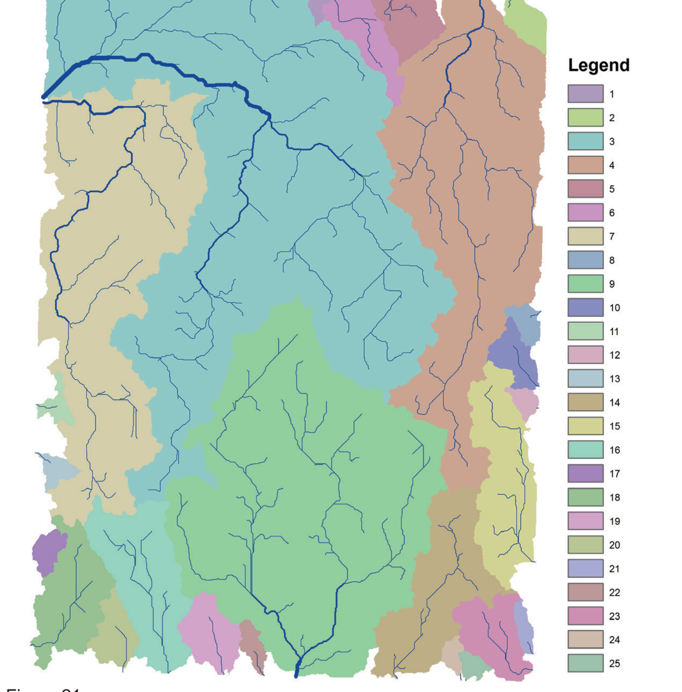
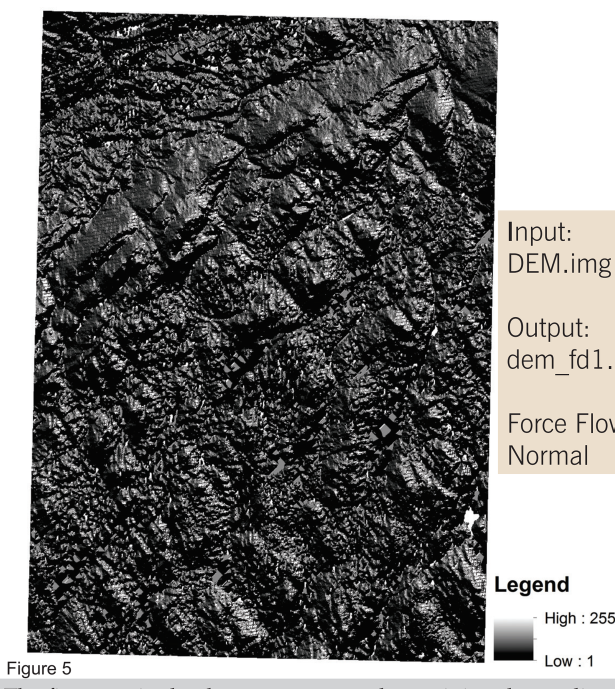


Figure 21

Syntax: Watershed ("demfdir.img, "streams_id.img")

Data Processing

Flow Direction (1)



Input: DEM.img

Output: dem_fd1.img

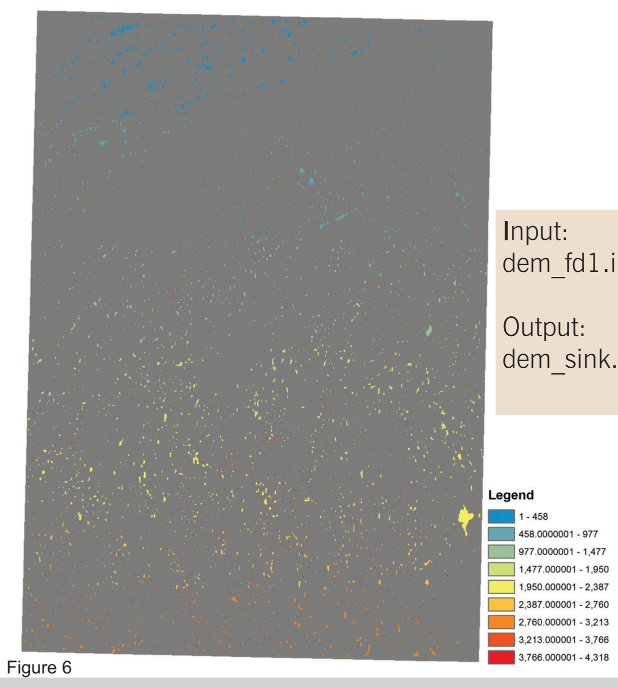
Force Flow: Normal

Figure 5

The first step in the data process was determining the quality of the DEM, that is whether there were any false sinks. If the area was known to be a Karst terrain internal drainage would be legitimate. However the study area is not Karst, so the process of filling in sinks began with finding flow direction. This function took the surface as an input and outputted a raster showing the direction of flow out from each cell.

Syntax: FlowDirection (in_surface_raster, {force_flow}, {out_drop_raster})

Identify Sinks



Input: dem_fd1.img

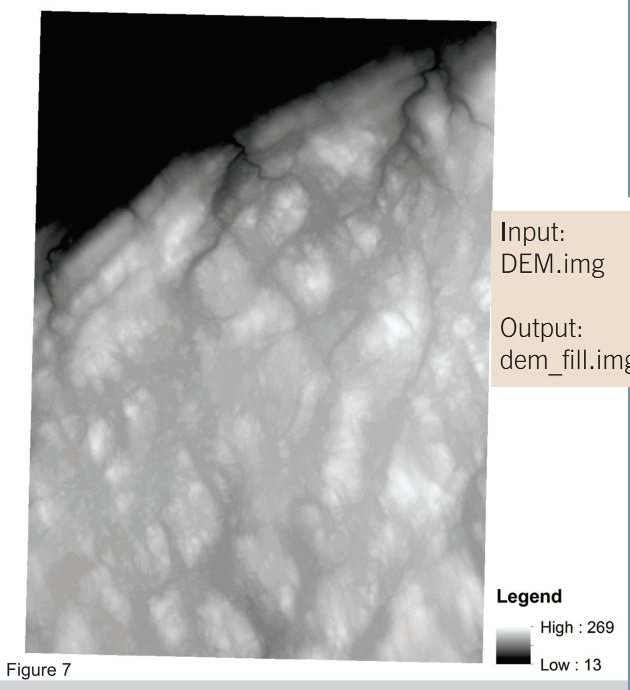
Output: dem_sink.img

Figure 6

From the flow direction, if all neighbors of the processing cell were higher, the processing cell was considered a sink. That is, the sink has an undefined flow direction. These occurrences were flagged with the use of the Sink function which attributed those cells with a code of 255.

Syntax: Sink (in_flow_direction_raster)

Fill Sinks



Input: DEM.img

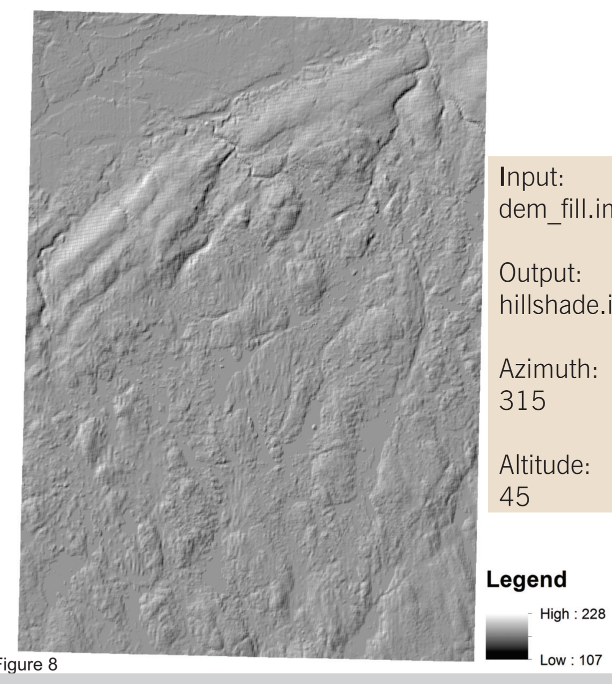
Output: dem_fill.img

Figure 7

Once sinks had been identified in the surface raster, the DEM was run through the Fill function. This tool fills in the imperfections within the data, running an iteration. The output of this process represents a corrected version of the original data that is suitable for the next stages of the watershed modeling procedure.

Syntax: Fill (in_surface_raster, {z_limit})

Hill shade



Input: dem_fill.img

Output: hillshade.img

Azimuth: 315

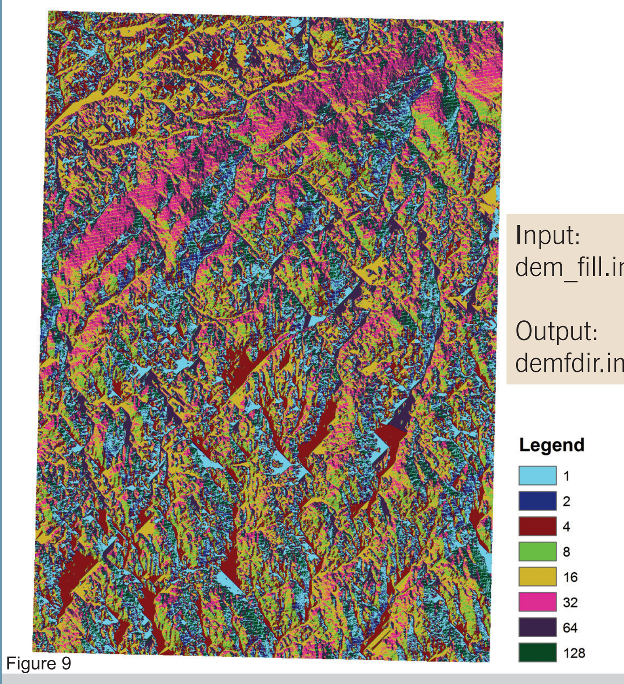
Altitude: 45

Figure 8

A hill shade was derived from the newly corrected DEM. This is a representation of the surface with shaded relief by taking into account the illumination source angle and shadows. In this output the defaults of the azimuth and altitude of the light source were left at the function's defaults.

Syntax: Hillshade (in_raster, {azimuth}, {altitude}, {model_shadows}, {z_factor})

Flow Direction (2)



Input: dem_fill.img

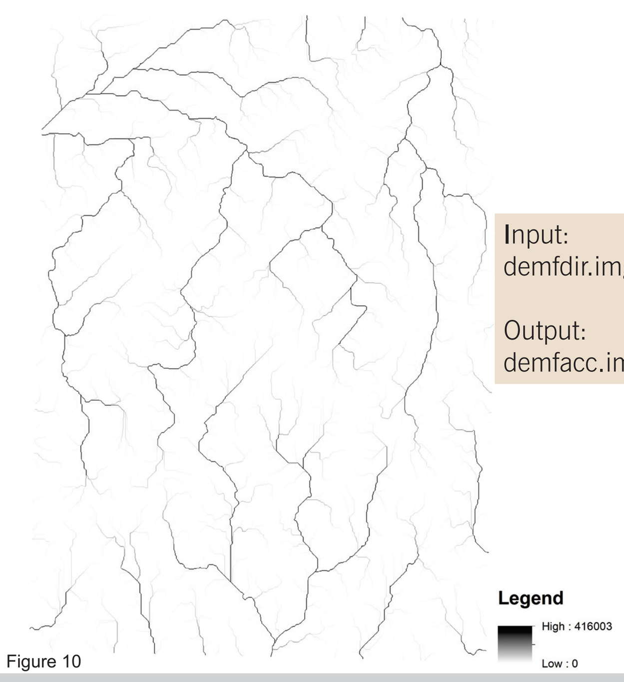
Output: demfdir.img

Figure 9

Woking on the same principles that the first flow direction was created, a second version was made to account for the correction to the DEM raster. In this figure the output has been symbolized to show how flow direction will only move in the eight cardinal direction points.

Syntax: FlowDirection (in_surface_raster, {force_flow}, {out_drop_raster})

Flow Accumulation



Input: demfdir.img

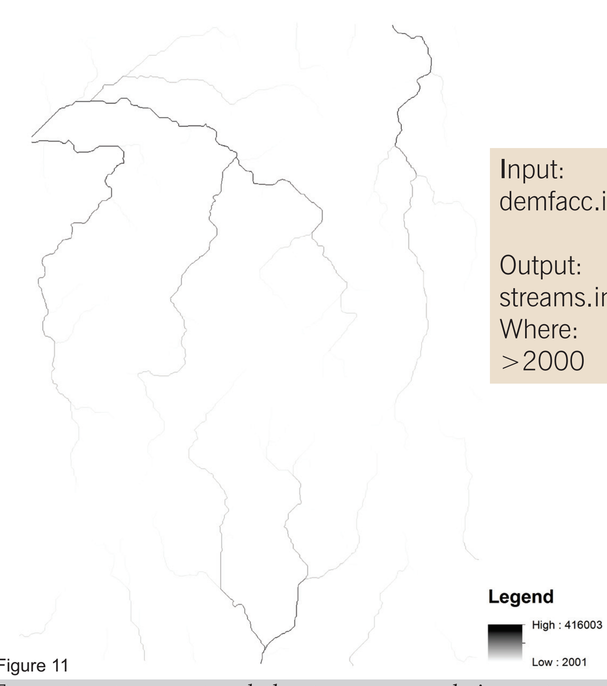
Output: demfacc.img

Figure 10

From the surface's flow direction a flow accumulation function was applied to identify stream channels. This was accomplished by the tool's ability to calculate the accumulated flow by the weight of all cells flowing into each downslope cell.

Syntax: FlowAccumulation (in_flow_direction_raster, {in_weight_raster}, {data_type})

Stream Threshold



Input: demfacc.img

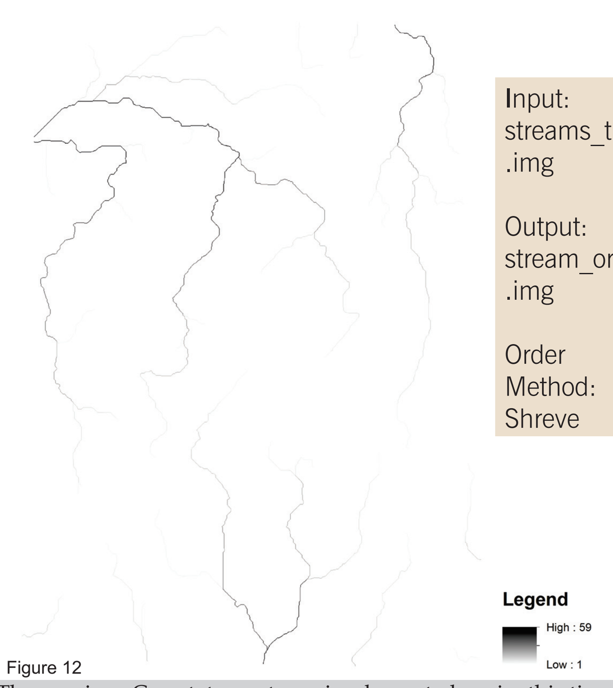
Output: streams.img Where: >2000

Figure 11

To create a stream network the stream accumulation raster was passed through a Con statement. By using this function the cell values could be reassigned and a threshold value selected. Those cells that had a value above 2000 were left, indicating the most likely cells depicting streams, any below this threshold were given a "nodata" value. This stream threshold was then used to select precise points for watershed 1's result (see final product/process at left).

Syntax: Con (in_conditional_raster, in_true_raster_or_constant ,{in_false_raster_or_constant}, {where_clause})

Stream Order



Input: streams_thr .img

Output: stream_ord .img

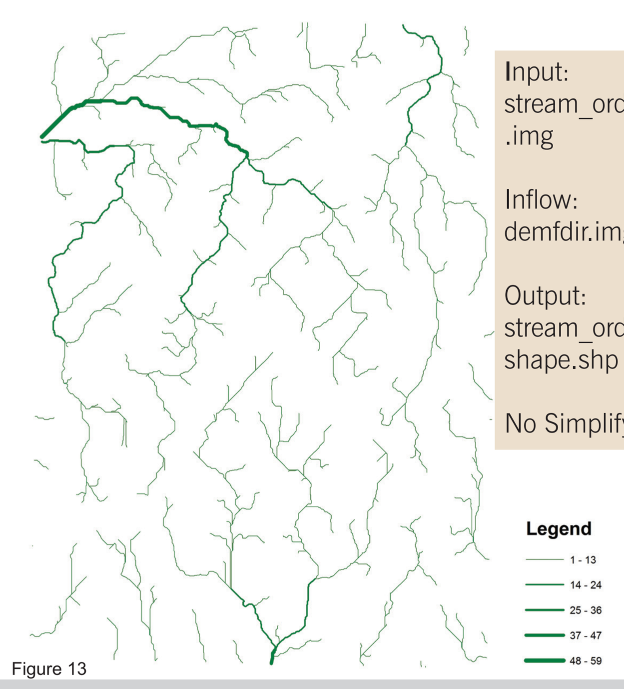
Order Method: Shreve

Figure 12

The previous Con statement was implemented again, this time by replacing those values below the threshold with a value of "1". This way the raster output could be used in further calculations, like stream order. Stream order assigned a numeric order to the cell segments representing the stream network. This method used a Shreve order, in which all exterior links are assigned an order of 1 while interior links are additive. This is also known as magnitudes.

Syntax: StreamOrder (Con("demfacc" > 2000, 1), in_flow_direction_raster, {order_method})

Stream Shape



Input: stream_ord .img

Inflow: demfdir.img

Output: stream_ord_ shape.shp

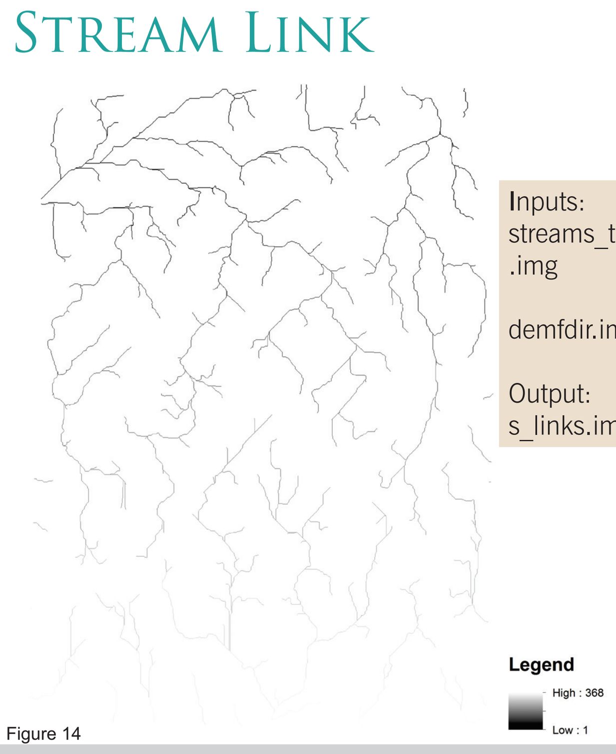
No Simplify

Figure 13

This product is the result of converting the previously created stream order raster to a line shapefile. This allowed for a more properly symbolized stream order system with graduated line weights. The shapefile would also be viewable above any of the final watershed rasters to compare how each method produced drainage basins from this stream network.

Syntax: StreamToFeature (in_stream_raster, in_flow_direction_raster,out_polyline_features, {simplify})

Stream Link



Inputs: streams_thr .img

demfdir.img

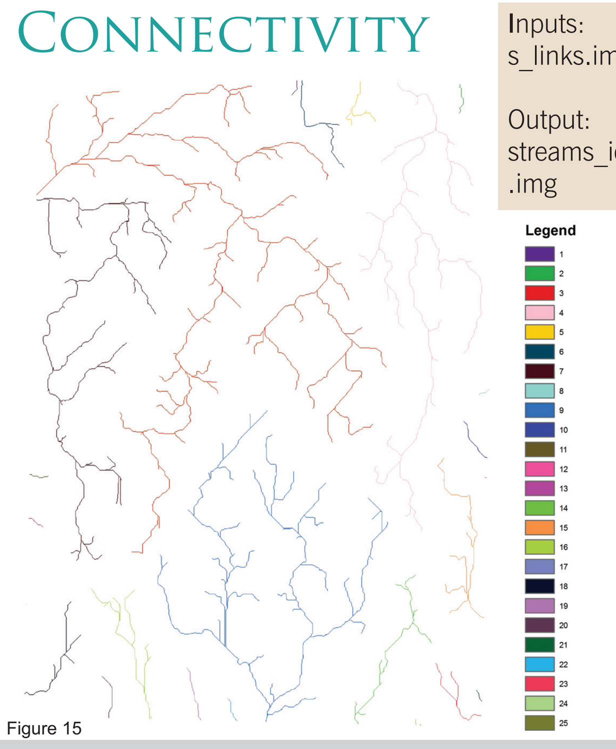
Output: s_links.img

Figure 14

The stream link function was used to find sub basin points in the stream network. The result of this process was 368 unique values to the sections between these sub basin points, or intersections. This would allow for the most detailed watershed delineation, as seen in the watershed 3 final output.

Syntax: StreamLink (in_stream_raster, in_flow_direction_raster)

Connectivity



Inputs: s_links.img

Output: streams_id .img

Figure 15

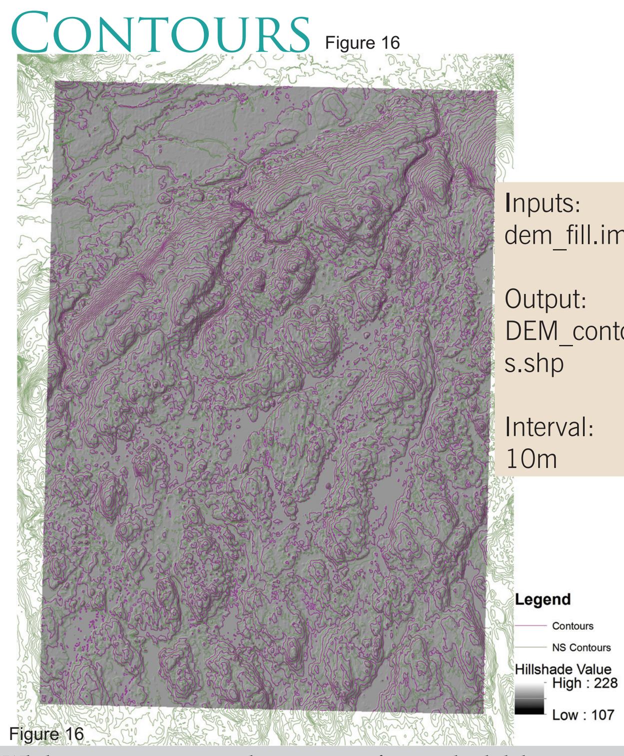
To create watershed 4 a region group function was performed to aggregate the streams by connectivity. This required that the 368 unique streams from s_link.img have the same value. A Con function was nested in the region group to accomplish this value reassign. The outputted raster represents connected basins, with 25 primary basins in all.

Syntax: RegionGroup (in_raster, {number_neighbors}, {zone_connectivity}, {add_link}, {excluded_value})

RegionGroup(Con("s_links" >= 0, 1), "EIGHT")

Contours

Figure 16



Inputs: dem_fill.img

Output: DEM_contour s.shp

Interval: 10m

Figure 16

While not contingent in the creation of watershed delineations; this function was implemented to create contours that match the contour interval of the NTS 1:50 000 map sheet. Above is a comparison of that result, with the generated and smoothed contours in purple and NTS contours in green. These have been displayed over the hill shade generation to compare how each displays the surface of this area. The results show that the computed contours do not cover the same amount of detail, which can be solved by shortening the contour interval.

Syntax: Contour (in_raster, out_polyline_features, contour_interval,{base_contour}, {z_factor})

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Sources:
Map data: Nova Scotia Geomatics Centre, 1:10 000 Nova Scotia Topographic Database, http://www.nsgc.gov.ns.ca/
DEM Data: Canadian Digital Elevation Data, 1:50,000. http://www.geobase.ca

Software:ESRI ArcGIS 10.0 with Spatial Analyst extension., CorelDRAW X6 ver 16.

Images and Poster Produced by Samantha Cyr for GISD 3020 Grid Modeling and Map Algebra, October 24th, 2012.