RESOURCE NOTES

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Automated Drainage Network and Watershed Delineation from Digital Elevation Data

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Geographic Information Systems (GIS) consist of sets of computerized map analysis methods for doing what we have always done with maps: collect data to organize geographic information about various aspects of our environment that we want to know about. Then, similarly to the map analysis and map overlay methods that have been developed using transparent film map overlays, we relate the geographically distributed data via conceptual models. These models are in turn based on the accumulated knowledge arising from observation of naturally occurring environmental processes. Geographic Information Systems perform various types of routine map analyses more efficiently than human beings, however ultimate judgement as to the accuracy of model results always remains with the scientist. In that way GIS permits us to quickly perform various routine mapping tasks so that we can spend more time on interpretation of results rather than on repetitious data preparation.

One powerful way to utilize GIS as an environmental analytic tool is for drainage pattern and watershed boundary delineation from Digital Elevation Models (DEMs). The 7.5 minute quadrangle DEMs are roughly as accurate as the United States Geological Survey (USGS) 7.5 minute quadrangle topographic sheets. Quadrangle DEMs for most areas in the United States can be downloaded at no cost by simply connecting to the USGS DEM site and using FTP (file transfer protocol) to download the data (WEB address: http://edcwww.cr.usgs.gov/doc/edchome/ndchb.html). Since resource analysis work always contains a component related to streams and watersheds, the standard GIS capabilities to delineate streams and watersheds from Digital Elevation Models (DEMs) provide us with quick automated ways to model surface hydrology of the of the landscape from shape of the terrain.

The methodology was originally developed by S. Jenson and J. Domingue in 1987, and when ESRI, Inc. developed the raster portion of their ARC/INFO GIS the methods were incorporated into the GRID module for analyzing maps in cell data format. DEMs are essentially lattices of points that represent centers of cell. For the USGS 7.5 minute DEMs the standard are grid cells the size of 30 m by 30 m on the surface of the source map that is being used to create them, usually the traditional USGS 7.5 minute quadrangle topo sheets. So each cell, or each point of the lattice, represents an elevation value calculated from topographic contours as representing the center of the cell or that area on the ground. Thirty meter DEMs turn out to be quite accurate for most areas when the results of terrain analysis to derive stream networks are compared to the actual surveyed stream networks available in the Digital Line Graph (DLG) or Spatial Data Transfer Standard (SDTS) format, the latter often being accurate to 2 m on the surface.

Stream network and watershed boundary modeling requires similar steps that results in maps which can be utilized over and over again. These maps are created in the data preprocessing stage of hydrologic terrain modeling. As the first step the users need to calculate flow direction using the GRID FLOWDIRECTION function, but they have an option of applying the function on the original DEM, which contains internal drainages (surface depressions), or on a filled DEM, where all the surface depressions are filled using the GRID FILL function. To most easily trace stream and watershed boundary data from digital terrain data we should fill the DEM. Then by comparing the filled DEM and the original DEM we can discover the location of all the surface depressions. We can calculate flow direction from either the filled terrain map or the original data.

Once this is accomplished we can evaluate, based on flow direction, which cells of the geographic grid flow from or into which other cells. In that way we can build up a flow accumulation count map in which the value of each cell represents the number of other cells flowing into it. Naturally the greatest amount of flow concentrates in the drainages. Therefore by selecting ranges of flow accumulation values it is possible to model drainage patterns. The lower the initial flow accumulation value used to model a drainage network, the further upland can we extend the network. It is a tradition when calculating watershed morphometric parameters that require drainage network information (e.g. drainage density) to delineate the streams and channels all the way to the watershed boundary. This approach includes delineation of the hollows eroded by intermittent streams, or the generally moist concave areas which break the continuity of the hillslope. The filled DEM produces streams that continue throughout the landscape without draining into a depression giving us a better network, while using the original DEMs will result in flow directions pointing toward internal drainages.

By knowing flow direction we can also delineate watersheds, or, more precisely, areas from any point on the map (and, approximately, the ground) up to the nearest divide. For example, if our watershed outlet is placed near the outlet of a hollow, the modeled watershed will include the trough of the hollow and its side slopes. Same is the case with valleys of first order streams, second order streams, and so forth down the network. To obtain best results we need to place the outlet points (or other outlet locations such as areas, e.g. a lake, or linear features such as dams) so that they are registered properly to the flow accumulation data obtained from the elevation grid. Point outlets or watershed pour points need to be located right on the drainage patterns modeled from terrain, otherwise the watershed delineated will outline only a limited area flowing into a point on an adjacent hillslope. The GRID module provides capabilities for moving or snapping selected points to the nearest high flow accumulation value within a user specified distance (GRID function SNAPPOUR).

At the NARSC we have developed several Arc Macro Language (AMLs) programs that can make stream network and a watershed delineation a lot easier. If there is enough interest in making these AMLs into an ARCVIEW extension this is also possible. The completed programs include the following:

1. STREAMNETWORK.AML
Automatically delineates streams and channels from terrain data.

2. REACHSHEDMODEL.AML
Automatically delineates watersheds for each reach (length of stream between two junctions with other streams) of a stream network.

3. INTERACTSHEDS.AML
Interacts with the user to delineate watersheds from point or polygonal outlet locations specified graphically by the user.

4. POLYGONSHEDS.AML
Converts a grid of modeled watersheds into a polygonal watershed coverage eliminating diagonally connected watershed cells since they create additional polygons.

Other AMLs under development include:

1. SEEDSHEDMODEL.AML
Delineates watersheds for each reach of a stream network from input line stream data such as the USGS DLGs.

2. MAKEDAMS.AML
Delineates and analyzes reservoirs for dams or other user specified obstructions delineated in the terrain.

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