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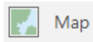
GIS Services Workshops
Introduction to Hydrologic Modeling

INTRODUCTION: This workshop will introduce you to hydrologic modeling; how to model some basic drainage characteristics such as stream networks and watersheds based on the ArcGIS software.

<u>Task 0. Start up, Environment Setup and Other Settings</u>

- Follow the instructor's directions to obtain your datasets. Unzip and save them to your storage device.
- Open ArcGIS Pro and click 

, name your project: **Hydro_Model** and navigate and save it in your unzipped folder in step 1 above**.** Uncheck the box for "Create a new folder for this project", then click **OK**.
- In the loaded map window, click the Insert tab → "New Map" to add a new base map to your project.
- Using the **Add Data** tool under the Map tab, add the following datasets in your saved *Hydro_Modeling* folder to your map; they will appear in the data frame named Map1.
    - DEM.img – a Digital Elevation Model that represents the surface elevation of your study area.
    - GD_gauge.shp – A hypothetical gauge station on the Guadelupe river in TX.
- Activate the **Spatial Analyst Extension.** Go to Project > Licensing> Under Esri Extensions make sure Spatial Analyst says yes > if no, then go to "Configure your licensing options" and check the box for Spatial Analyst in the Licensed column.
- Go into Catalog and check if it contains a file geodatabase **Hydro_Model**. If not, you may create one in your directory: Hydro_Modeling (right click **Hydro_Modeling → New → New File Geodatabase**. Name it **Hydro_Model**).
- Setup the output environment: Click Analysis tab >> Environments
    - Under Workspace, set both *Current Workspace* and *Scratch Workspace* to your file geodatabase in the step above ***...\Hydro_Model.gdb***
    - Output Coordinate System: **NAD_1983_UTM_Zone_14N**
    - Click **OK**

<u>Task 1. Pre-process your Elevation Surface</u>

To achieve accurate results and avoid later hassles, we need to pre-process our DEM before using it. This include:

- Fill Sinks.

Although government source DEMs are generally accurate for GIS analysis, they may still contain some "anomalies in the surface that can interrupt the downhill flow, which causes errors" in an eventual flow direction surface that will be created. These errors are in the form of **sinks**— a cell (or group of cells) surrounded by cells of higher elevation. The presence of sinks in a stream channel often cause the flow to travel into the sink cell(s), thus, creating a break in the stream. Sinks need to be identified and "filled" first before proceeding. When filled, a sink "cell value is changed to be equal to the value of the surrounding cell with the lowest elevation value, so water no longer accumulates in the cell, but rather flows across it as it's supposed to". (Mitchell, 2012, pp. 274-5). To fill all potential sinks in the DEM, search for and use the **Fill** tool in **Geoprocessing** pane.

- Specify **DEM** *as your input raster.*
- Name *your output raster* **fill_DEM***.*
- Then press **Run**

<u>Task 2. Identify Sinks</u>

To identify where sinks exist in your study area, you will use the **Raster Calculator**. Search **Raster Calculator** in **Geoprocessing** pane

- Using Raster Calculator, compute the difference between the original DEM and the filled DEM using this formula: **Int ("Fill_Dem" - "DEM")**. The function ***Int*** converts each cell value in a raster to an integer by truncation. Name the output grid to **sinks_DEM*.***
- Open the attribute table of the output grid sinks_DEM.
    - What does the field "**Value**" mean? What is the maximum depth among the sink(s)?

Task 3: Compute Flow Direction

"The flow direction surface identifies, for each cell— the ***From cell***— the adjacent cell that water would flow to (that is, the adjacent cell that constitutes the steepest downslope)—the ***To cell***. Each cell in the flow direction raster is assigned the direction of the ***To cell***— so if the To cell is directly to the east, the From cell is assigned a value of "east." There are eight possible directions, corresponding to the eight cells surrounding each cell. In the GIS, the directions are actually stored as numeric codes to allow for calculations— **East** is 1, **Southeast** is 2, **South** is 4, **Southwest** is 8, and so on, up to a value of 128 for **Northeast**)". (Mitchell, 2012, pp. 278).
Search for and use the **Flow Direction** tool in **Geoprocessing** pane.

- Set the input surface raster as ***fill_DEM.***
- Name the output raster ***flowdir.***
- Then press **Run**

Task 4: Compute Flow Accumulation

This represents "the number of cells upstream of any point— at any location on the surface". The value of each cell in the flow accumulation layer is the number of cells that flow into— or are upstream of— that cell. It is produced flow the flow direction surface. The flow accumulation output can be used to calculate the total area upstream of the location (by multiplying the number of cells by the area of a cell). (Mitchell, 2012, pp. 280).
Search for and use the **Flow Accumulation** tool in **Geoprocessing** pane.

- Set the input surface raster as ***flowdir.***
- Name the output raster ***FlowAcc.***
- Then press **Run**

Task 5: Extract Channels

You can extract channels to reveal the streams in your study area. To do this, one will need to specify a threshold or cutoff value for flow accumulation. This defines which cells constitute a channel, thus cells that are greater than this value will be part of the drainage system and vice versa. (Mitchell, 2012).

- Search **Raster Calculator** in **Geoprocessing** pane. Use Raster Calculator to extract stream channel based on the expression:

  Con("FlowAcc" >= 500, 1)
- Name the output raster ***stream_ras***
- Then press **Run**

*NB: You can execute this process using the **Reclassify** tool as well.*

Task 7: Compute Stream Order

A stream order essentially signifies how many streams flow into each stream. It is useful in determining the hierarchy or importance of a particular stream. "A common way of assigning stream order is the method developed by geographer Alan Strahler, where a first-order stream has no other streams flowing into it, a second-order stream is formed when two first-order streams join, a third-order stream is formed when two second-order streams join, and so on". (Mitchell, 2012, pp. 285). Search for and use the **Stream Order** tool in **Geoprocessing** pane.

- Set the input stream raster as ***stream_ras.***
- Set the input flow direction raster as ***flowdir.***
- Specify the Method of stream ordering as **STRAHLER.**
- Name the output raster ***strmOrd***
- Then press **Run**

Task 8: Convert Stream to Feature

Displaying streams in a raster format is constrained by cell size. Also, one cannot display the streams by any other attribute information except the values. To overcome these challenges, the stream raster layer must be converted to vector line features. Search for and use the **Stream to Feature** tool in **Geoprocessing** pane.

- Set the input stream raster as ***strmOrd***
- Set the input flow direction raster as ***flowdir***
- Name the output raster ***Streams***
- Then press **Run**

*NB: You can execute this process using the **Raster to Polyline** tool as well.*

Task 9: Delineate Watershed

Finally, we will determine drainage basins (the total area comprising a major stream and its tributaries) that are of interest to us within our study area. To determine this, we will have to first specify a point of reference; the gauging station located on the river from where we can delineate the upstream basin. Search the **Snap Pour Point** tool in the **Geoprocessing** pane.

- Set the input raster or feature pour point data as ***GD_gauge*** *(*This is a hypothetical gauge station for this exercise*).*
- Specify the Pour point field as **Id**.
- Set the Input accumulation raster as ***FlowAcc.***
- Name the output raster ***SnapPour_GD***
- Then press **Run**

Now proceed to delineate your watershed. Search for the **Watershed** tool in **Geoprocessing** pane.

- Set the input flow direction raster as ***flowdir.***
- Set the Input raster or feature pour point data as ***SnapPour_GD.***
- Specify the Pour point field as **Value**.
- Name the output raster ***WS_GD***
- Then press **Run**

For display purposes, convert your watershed to vector. Use the **raster to polygon** tool for this step.

Based on the hydrologic modeling you've performed above, answer the following questions:

- What is the total area of your drainage basin in km^2?
- What is the total length of streams in your basin in km? (*hint,* clip the streams with your watershed first, calculate for their geometry and then sum them).

Lastly, create a **map** of your watershed along with your streams. You may display the DEM in the background.

Reference

Mitchell, Andy. Esri Guide to GIS Analysis, Volume 3: Modeling Suitability, Movement, and Interaction, Esri Press, 2012. ProQuest Ebook Central,

E-book link at Texas State:
https://ebookcentral.proquest.com/lib/txstate/reader.action?docID=3238265