CENTER for DIGITAL SCHOLARSHIP

# GIS: Geographic Information Systems

# Module 12: Hydrological modelling

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Hesburgh Library, University of Notre Dame

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# Hydrology

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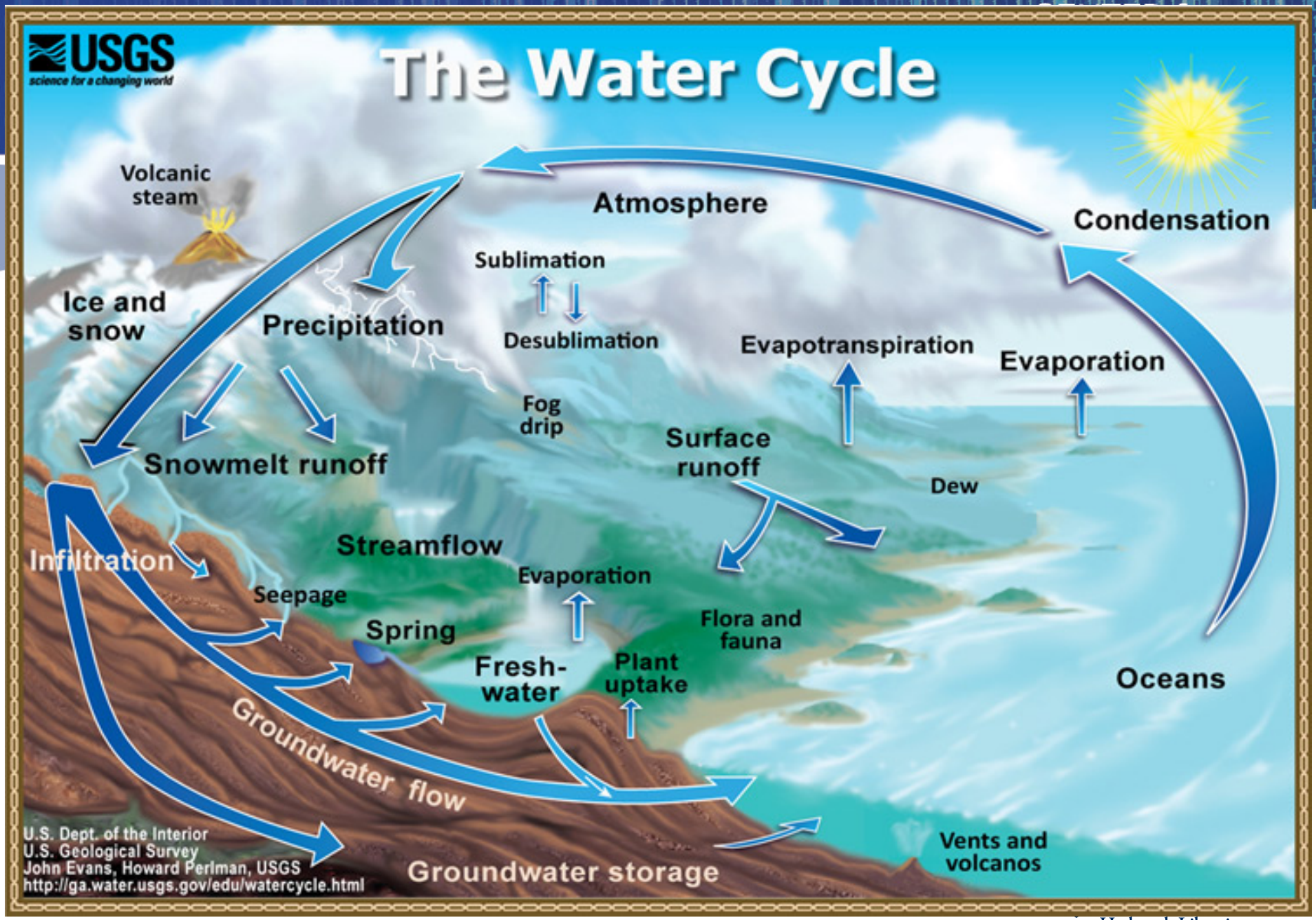
- The study of the movement, distribution, and quality of water on Earth, including the hydrologic cycle, water resources and environmental watershed sustainability
  - Divided into surface hydrology and marine hydrology.
  - Domains include hydrometeorology, surface hydrology, hydrogeology, drainage basin management and water quality, where water plays the central role


USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Infiltration
Evaporation
Seepage
Spring
Flora and fauna
Fresh-water
Plant uptake
Oceans
Groundwater flow
Vents and volcanos
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html

# Watershed

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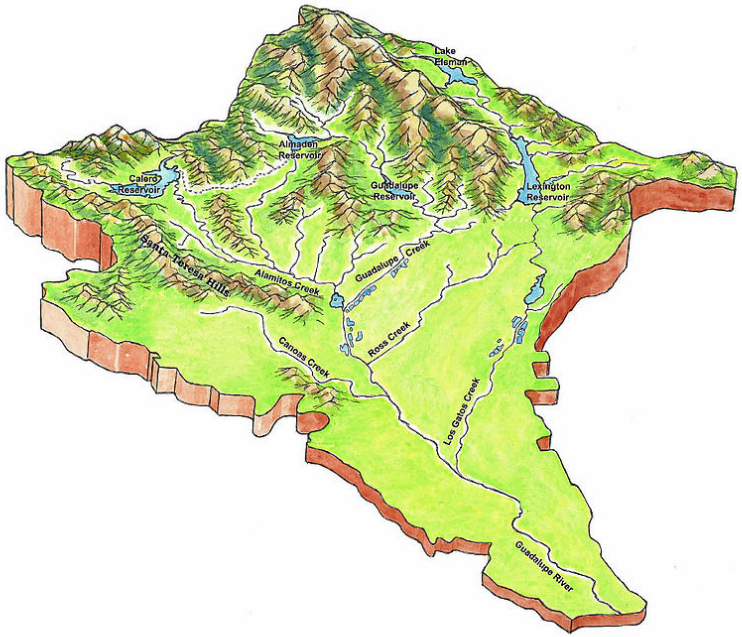
- The area that contributes water to a feature on a landscape
  - Usually represented as a physical area
  - Also called basins, catchments or contributing areas



# Hydrologic modeling

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- Frequent types of questions
  - How much water flows across a point on the landscape?
  - How is rain water likely to flow?
  - What areas are more likely to have water-based erosion
  - What bodies of water would be impacted by a spill at a given location

# Hydrology toolset

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- A series of tools for modeling how water flows across a landscape
- Elevation, in the form of a DEM, is usually the base data
- Important for understanding erosion, rainfall or the spread of pollutants.

# Hydrology flowchart

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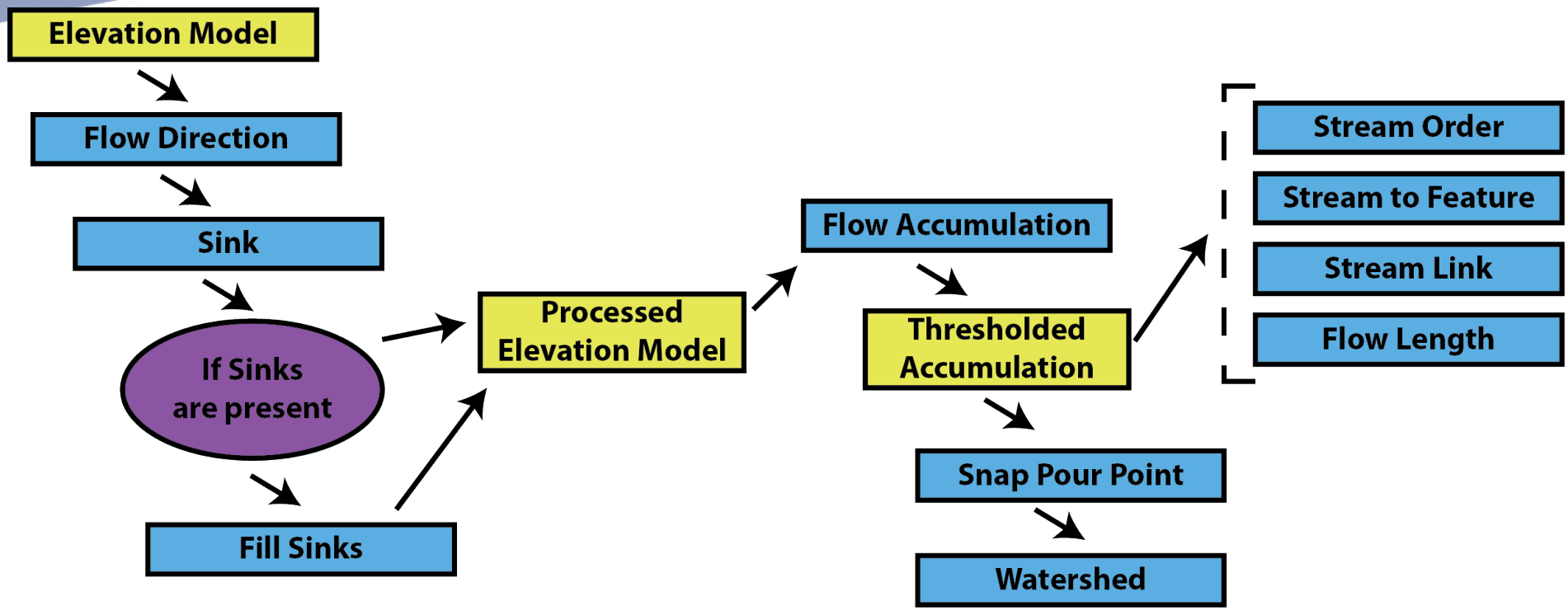


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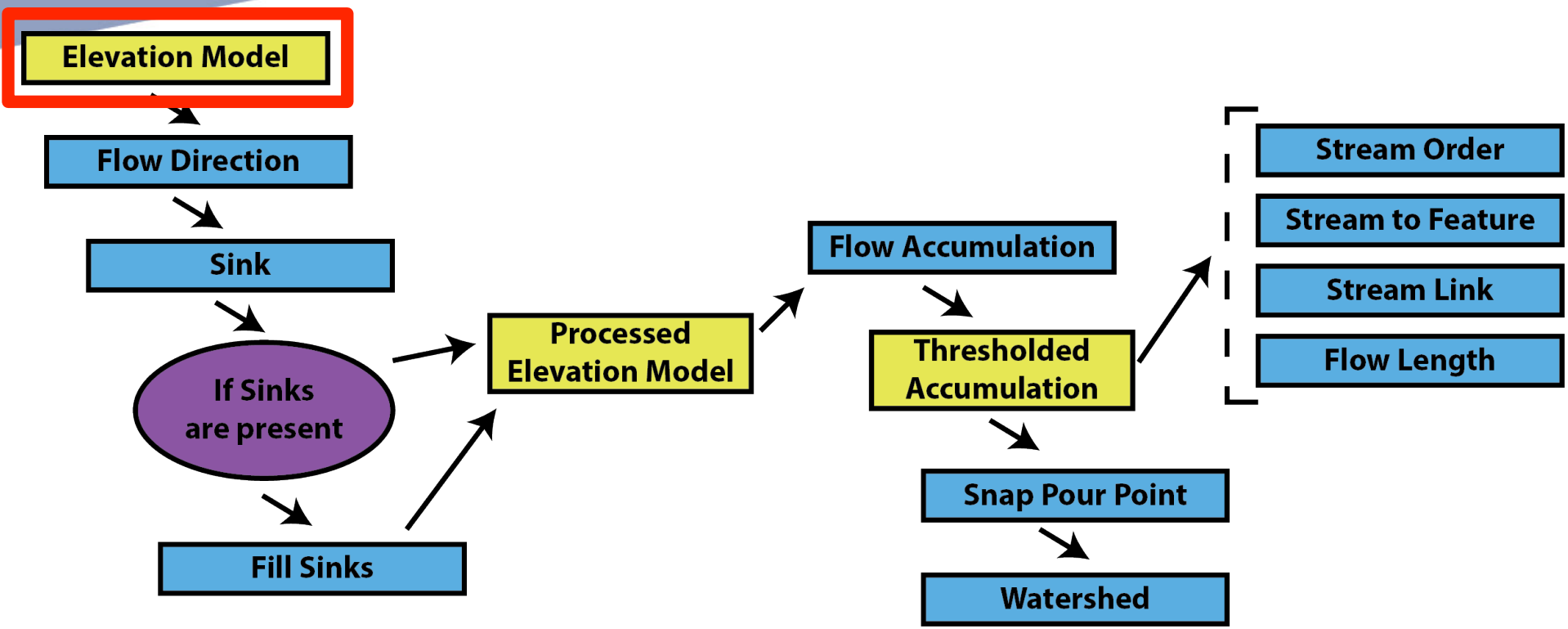
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

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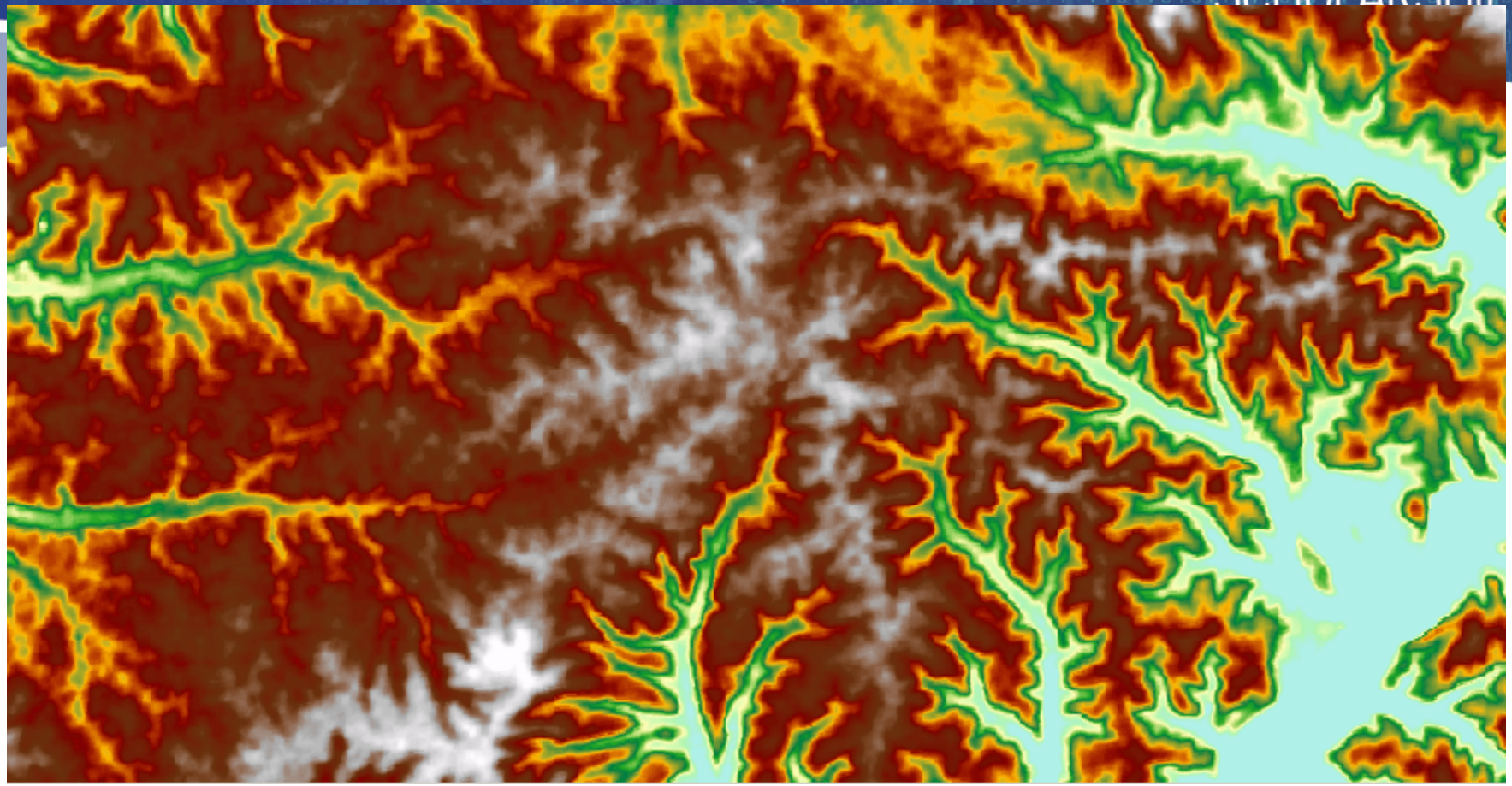
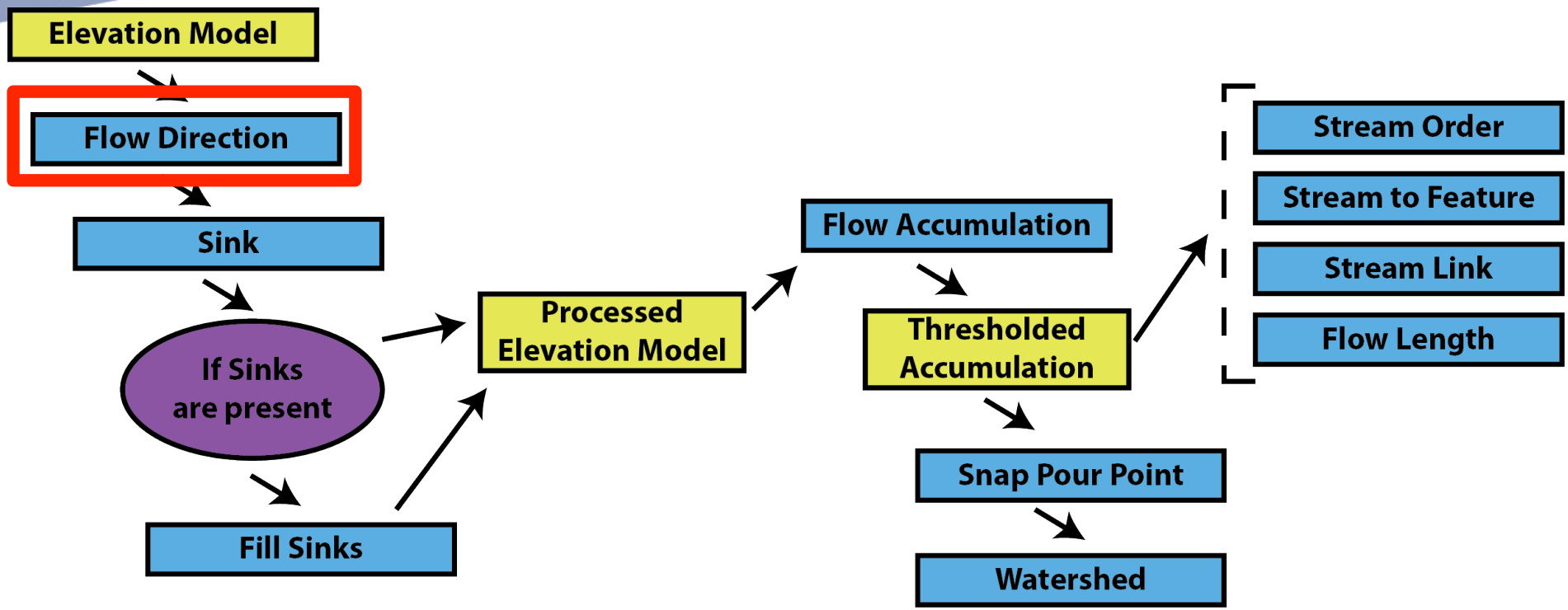
# Example: Raw DEM



Untreated ASTER gDEM of SW France (30 m resolution)

# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

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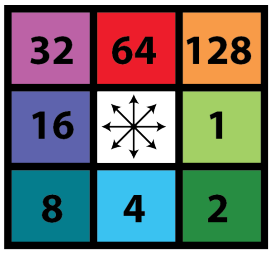
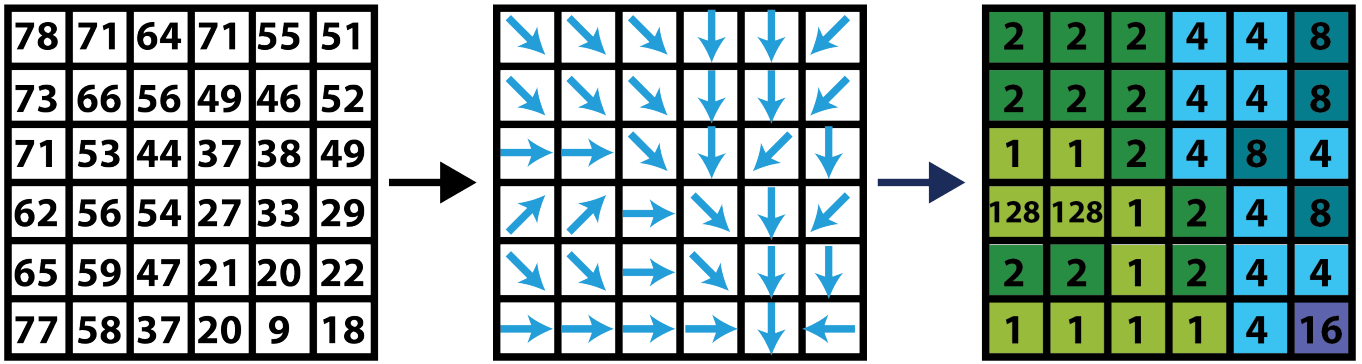
# Flow Direction

CENTER for DIGITAL SCHOLARSHIP

- A raster image where the only value is the direction water is likely to flow
  - Calculated by looking at surrounding pixels




**Digital Elevation Model** **Flow Direction** **Flow Direction**

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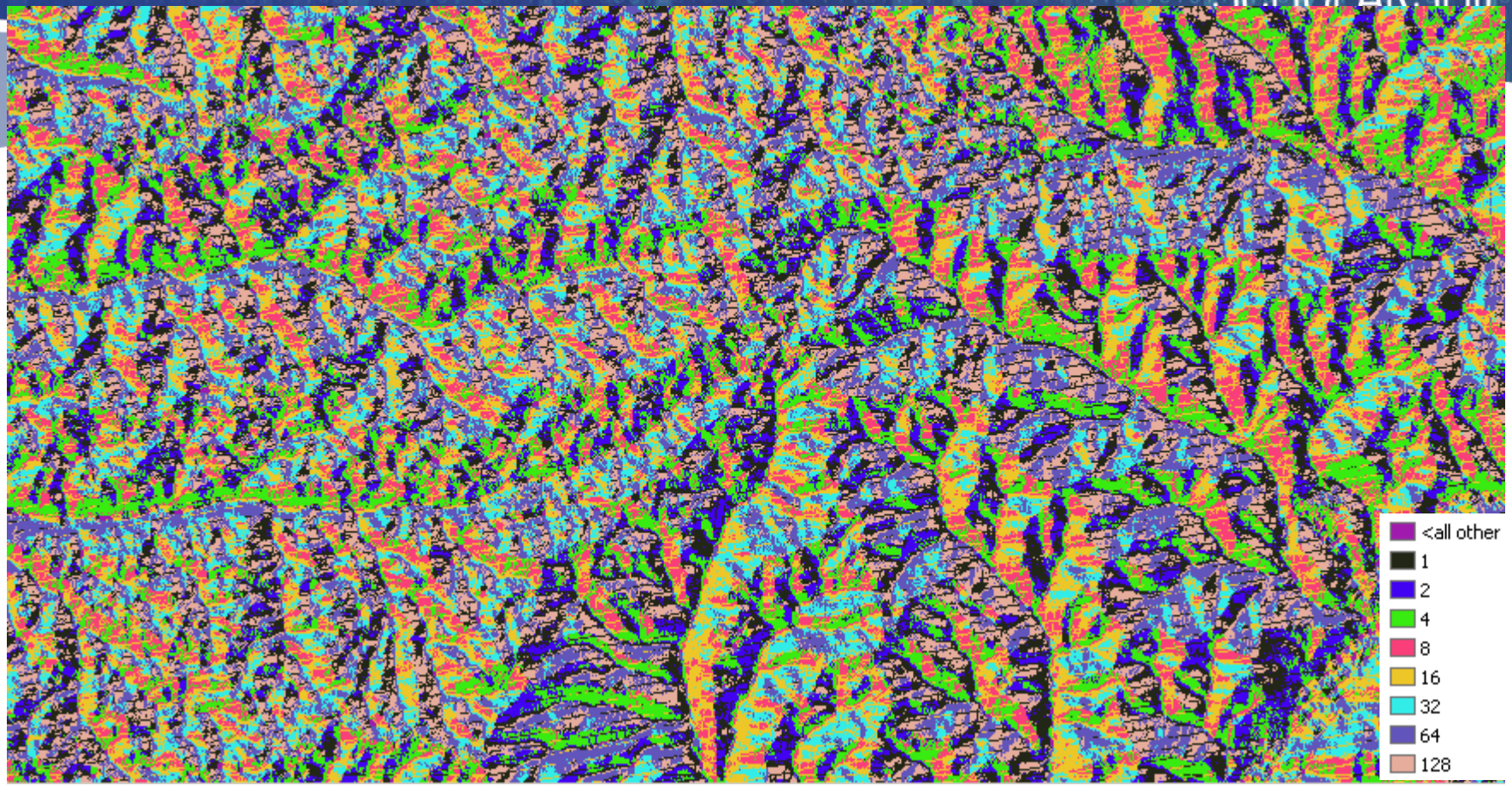
# Example: Flow Direction

CENTER for DIGITAL SCHOLARSHIP




Each cell contains the direction that water would flow

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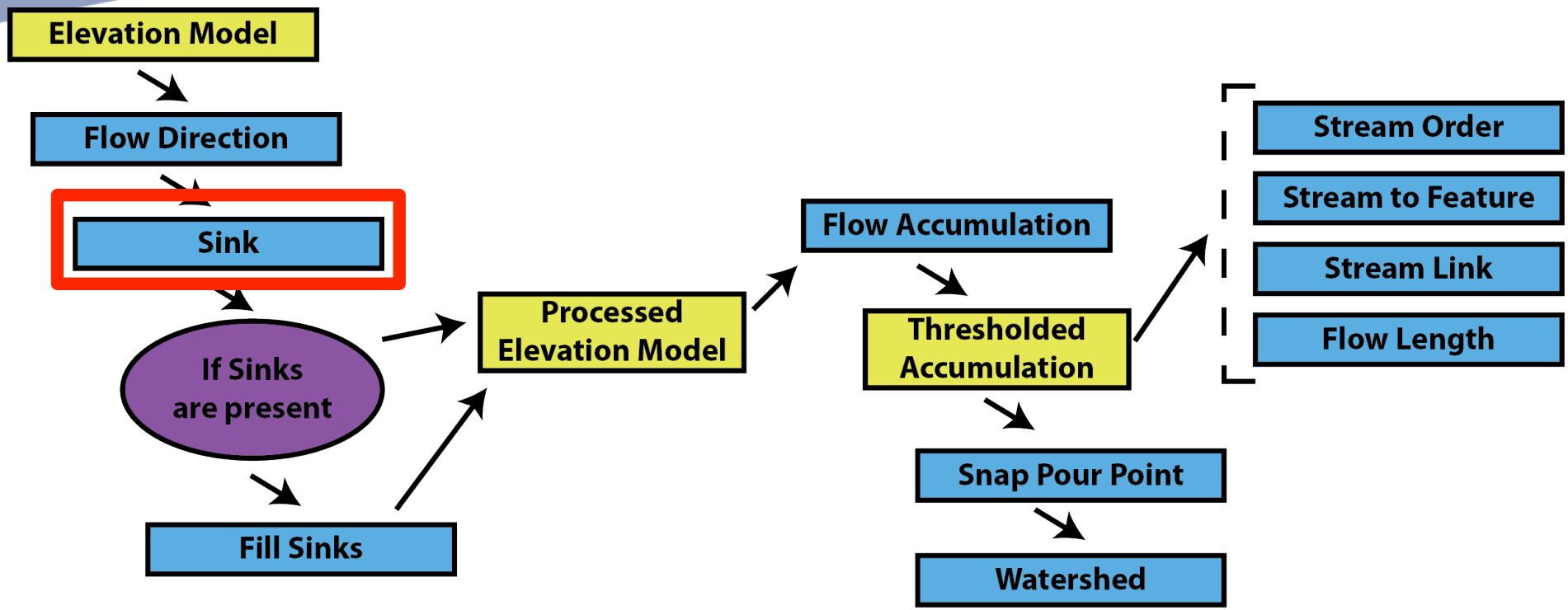
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP



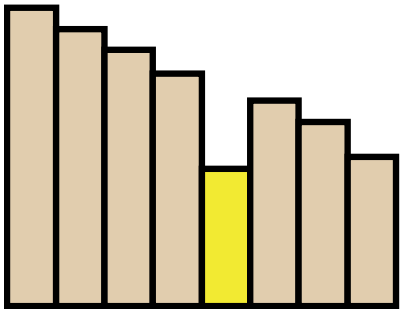
# Sinks

CENTER for DIGITAL SCHOLARSHIP

- A sink is a set of one or more cells which has no downstream cells around it
- DEM creation results in artificial sinks in the landscape
  - Some sinks are natural lakes or ditches, the majority are not
- Unless these sinks are filled they will isolate portions of the watershed
- Filling sinks is the first step for processing a DEM for surface water systems

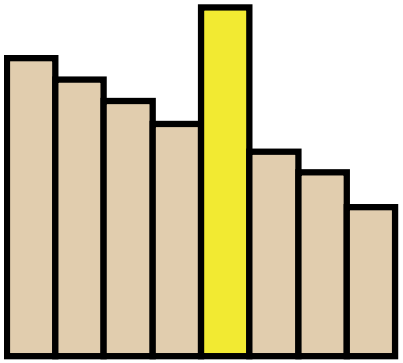
# Sinks and Peaks





## Sink

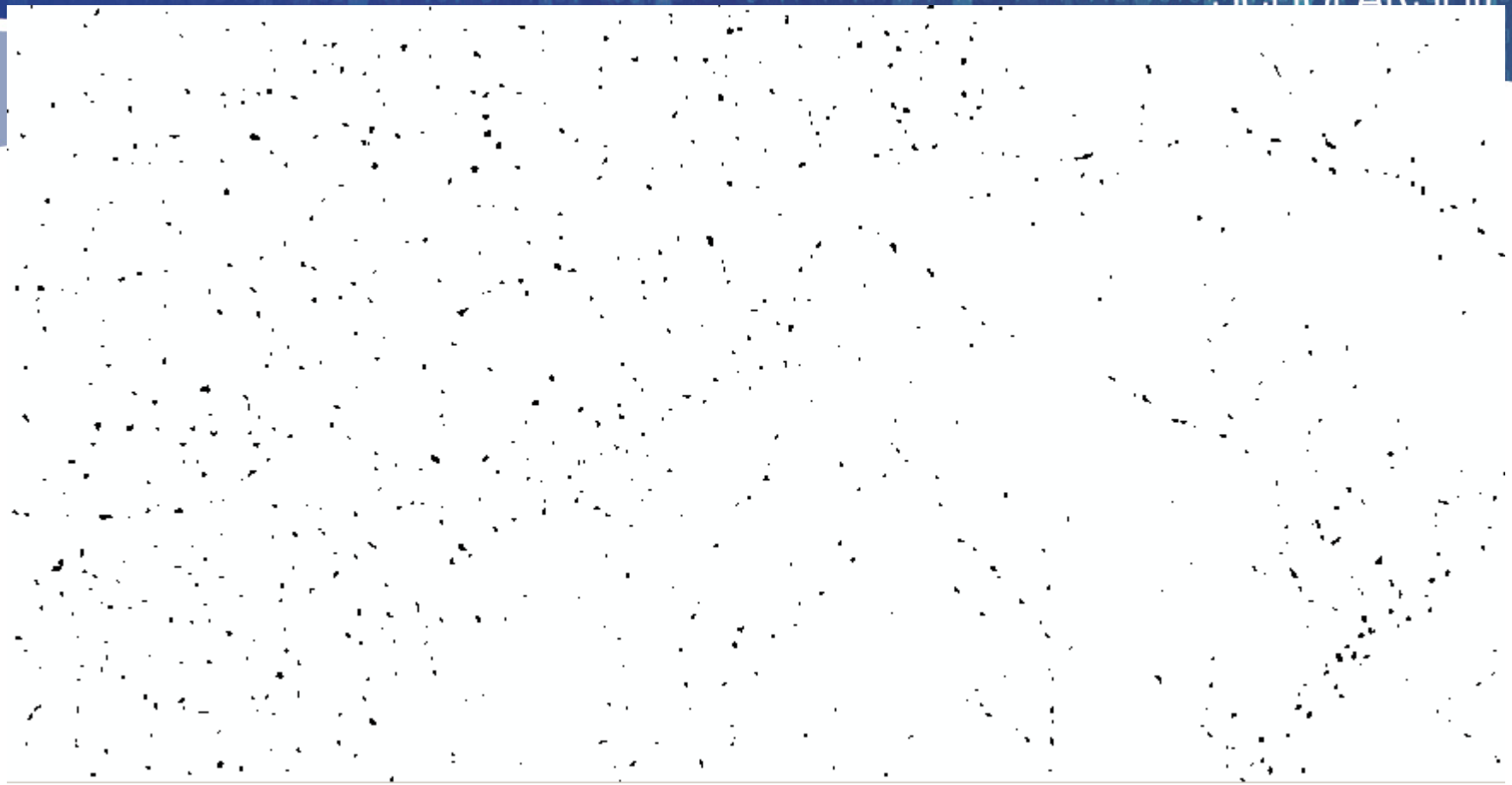
- Sinks are areas that water can flow into, but not back out
- Thus, they have an undefined flow direction
- ArcGIS gives them the sum of possible directions
- Usually the result of errors in the DEM
- Sinks are more common at lower resolution
- Can be real features where water collects



## Peak

- Peaks are areas that are higher than all surrounding pixels
- Less likely to cause problems, but may still be errors in the DEM

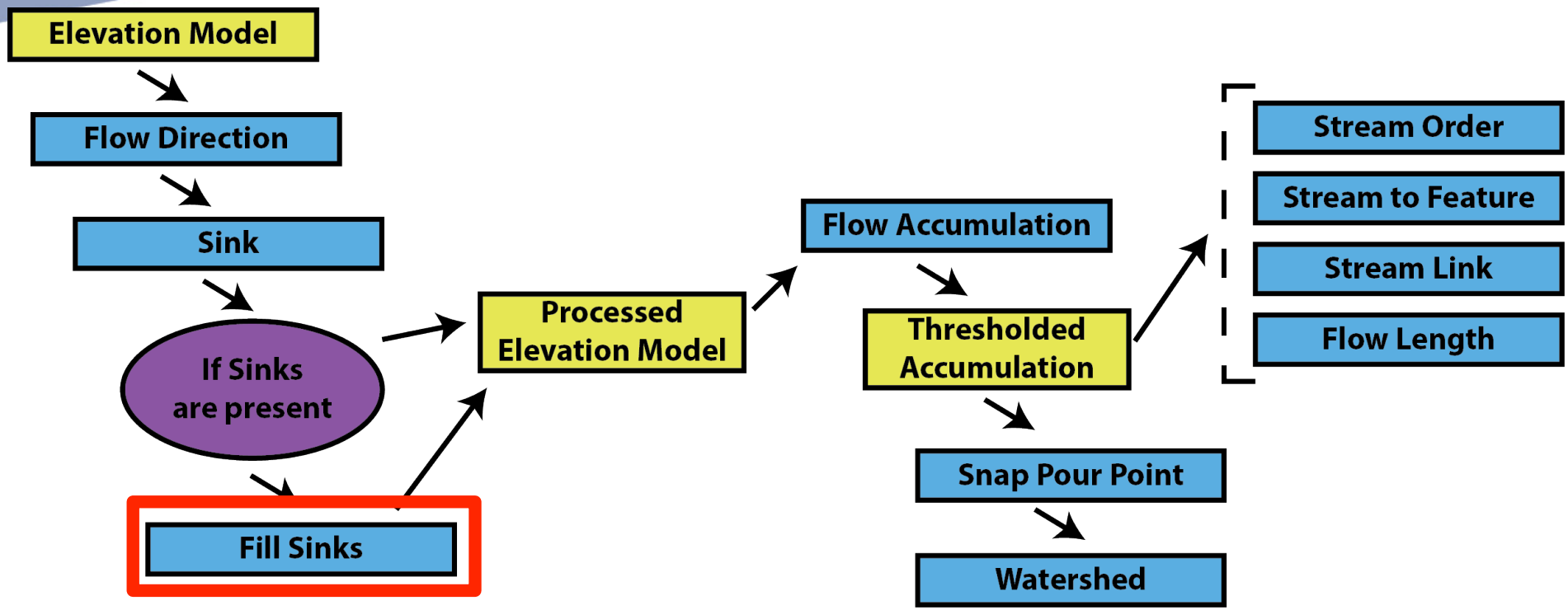
# Example: Sinks



Each black dot is a location where water would collect

# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

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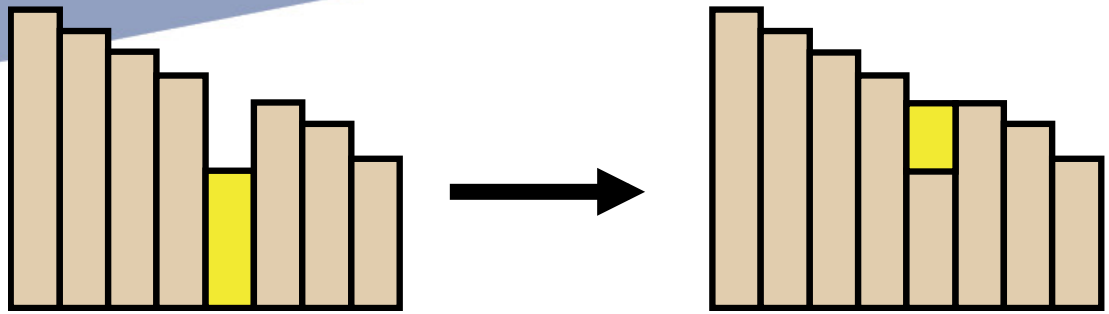
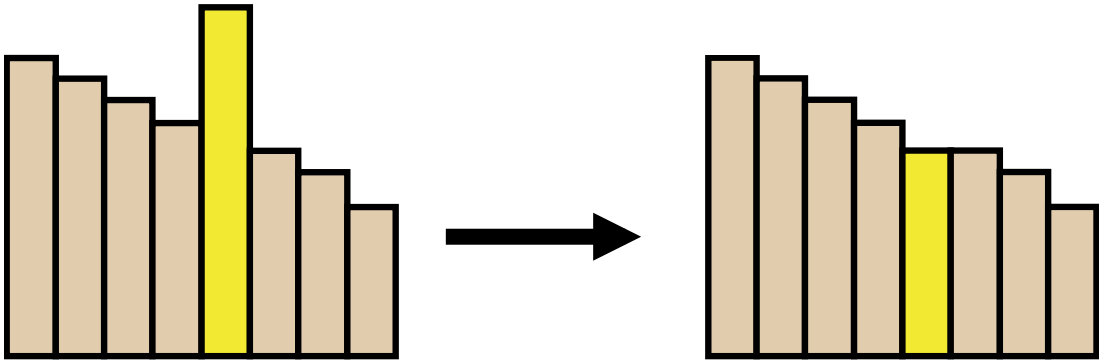
# Fill: Sinks and Peaks

CENTER for DIGITAL SCHOLARSHIP



**Sink**



**Peak**

Inputs the original DEM and outputs a new DEM with peaks and sinks removed

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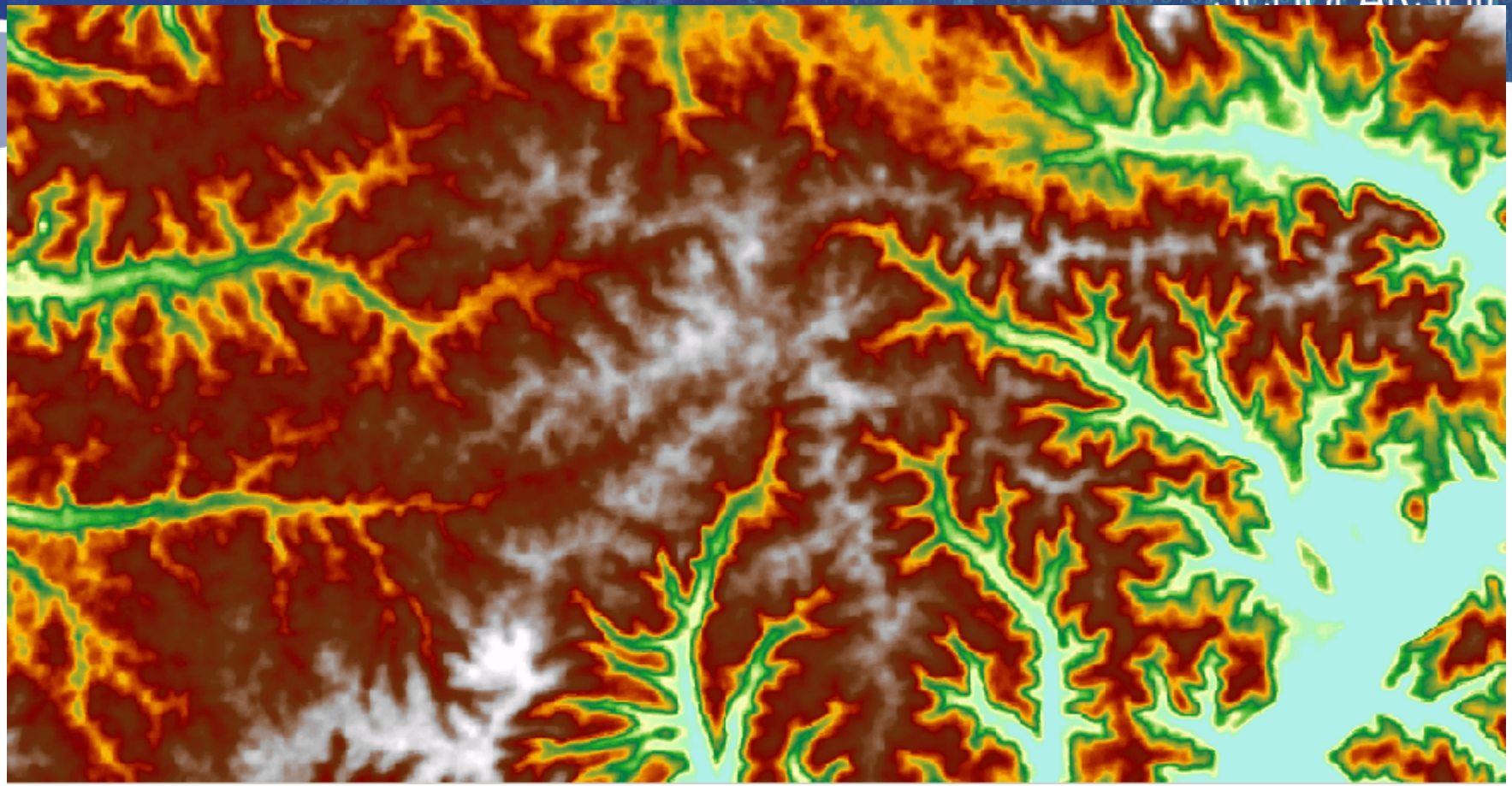
# Example: Raw DEM

CENTER for DIGITAL SCHOLARSHIP



Untreated ASTER gDEM of SW France (30 m resolution)

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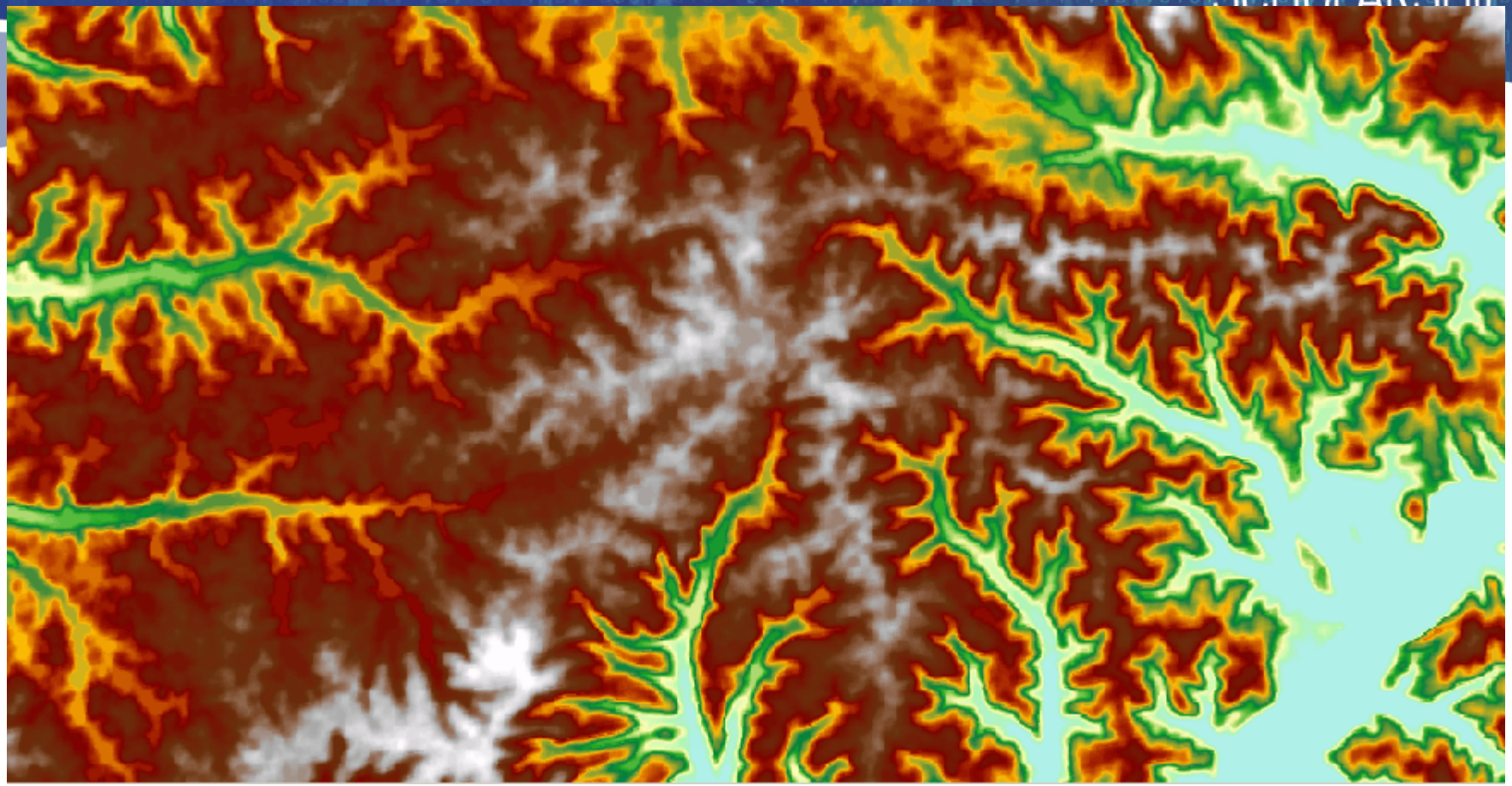
# Example: Filled DEM

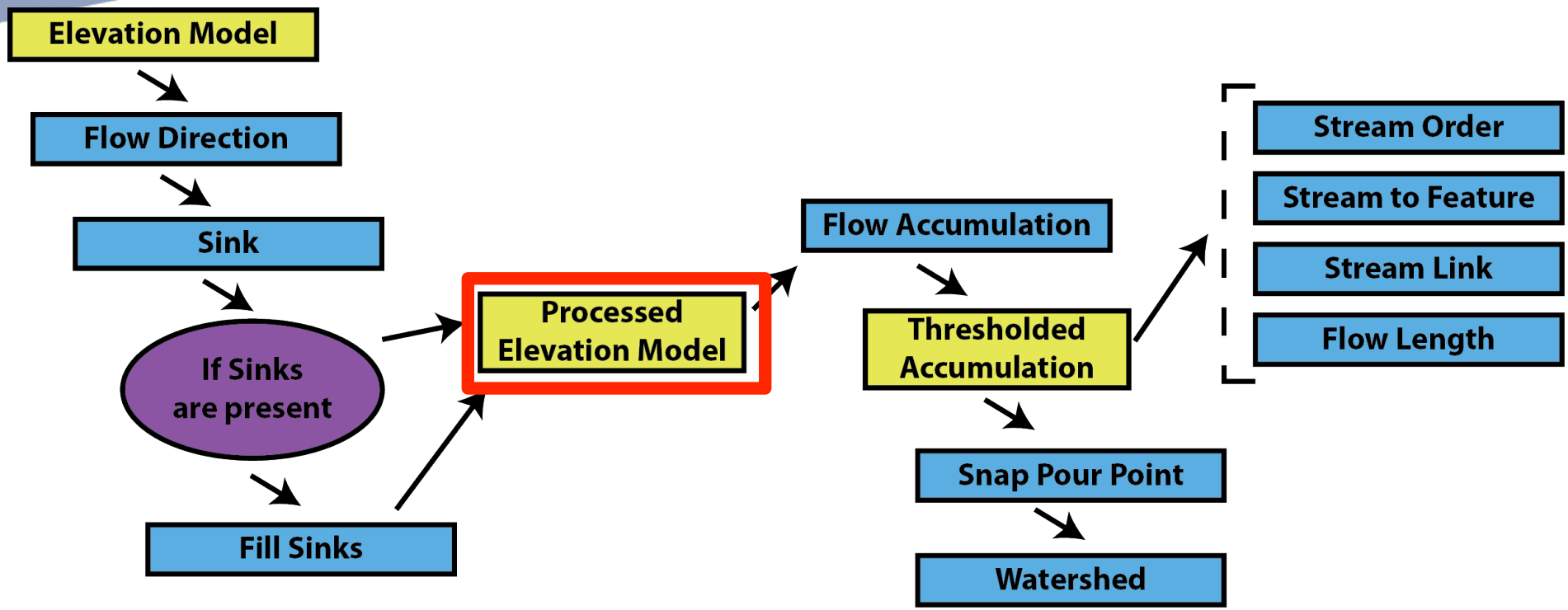




DEM with each of the sinks filled to be level

# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

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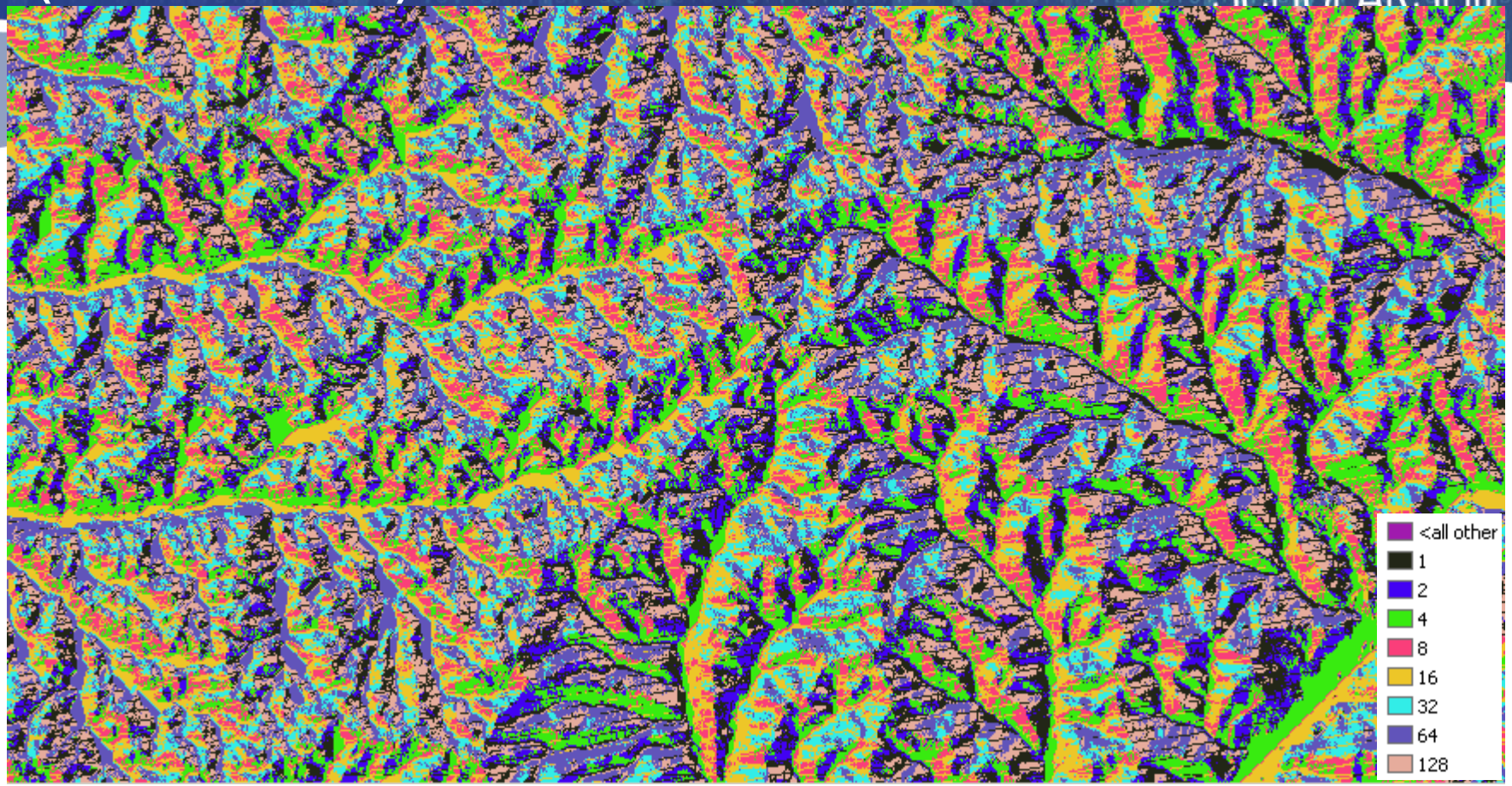
# Example: Flow Direction (filled DEM)

CENTER for DIGITAL SCHOLARSHIP




Each cell contains the direction that water would flow

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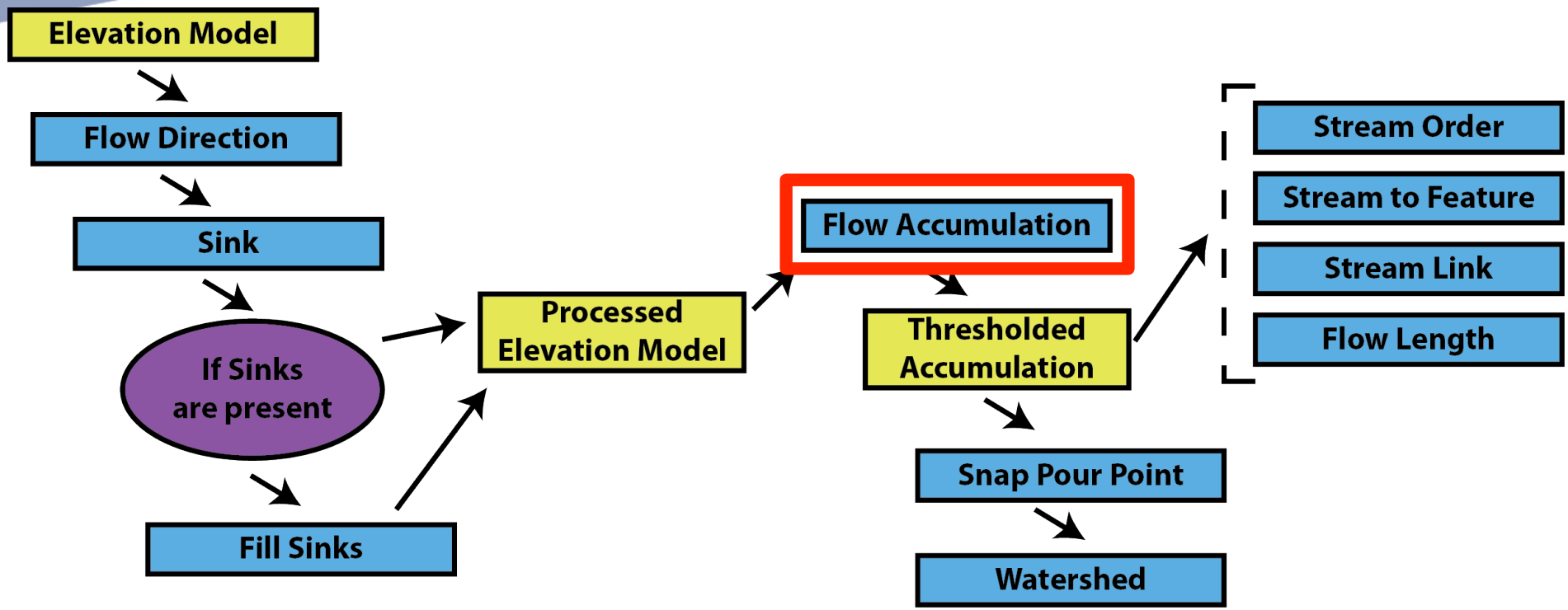
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP



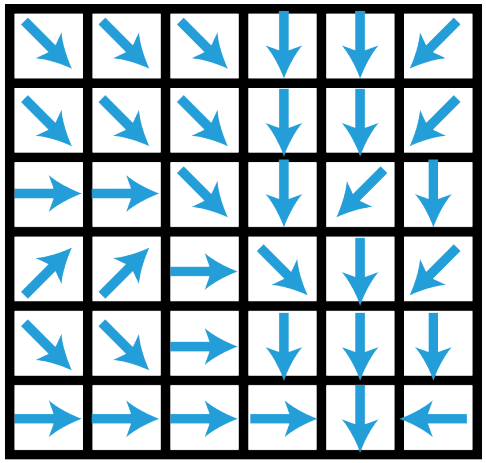
# Flow Accumulation

CENTER for DIGITAL SCHOLARSHIP

- A raster image where the only pixel value is the number of cells flowing into it
- Gives a measure of how much water would flow into a given cell based on what is upstream

| | | | | | |
|---|---|---|---|---|---|
| 78 | 71 | 64 | 71 | 55 | 51 |
| 73 | 66 | 56 | 49 | 46 | 52 |
| 71 | 53 | 44 | 37 | 38 | 49 |
| 62 | 56 | 54 | 27 | 33 | 29 |
| 65 | 59 | 47 | 21 | 20 | 22 |
| 77 | 59 | 37 | 20 | 9 | 18 |

**Digital Elevation Model**



**Flow Direction**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 2 | 2 | 0 |
| 0 | 3 | 7 | 5 | 4 | 0 |
| 0 | 0 | 0 | 20 | 0 | 1 |
| 0 | 0 | 0 | 21 | 20 | 0 |
| 0 | 2 | 4 | 7 | 35 | 2 |

**Flow Accumulation**

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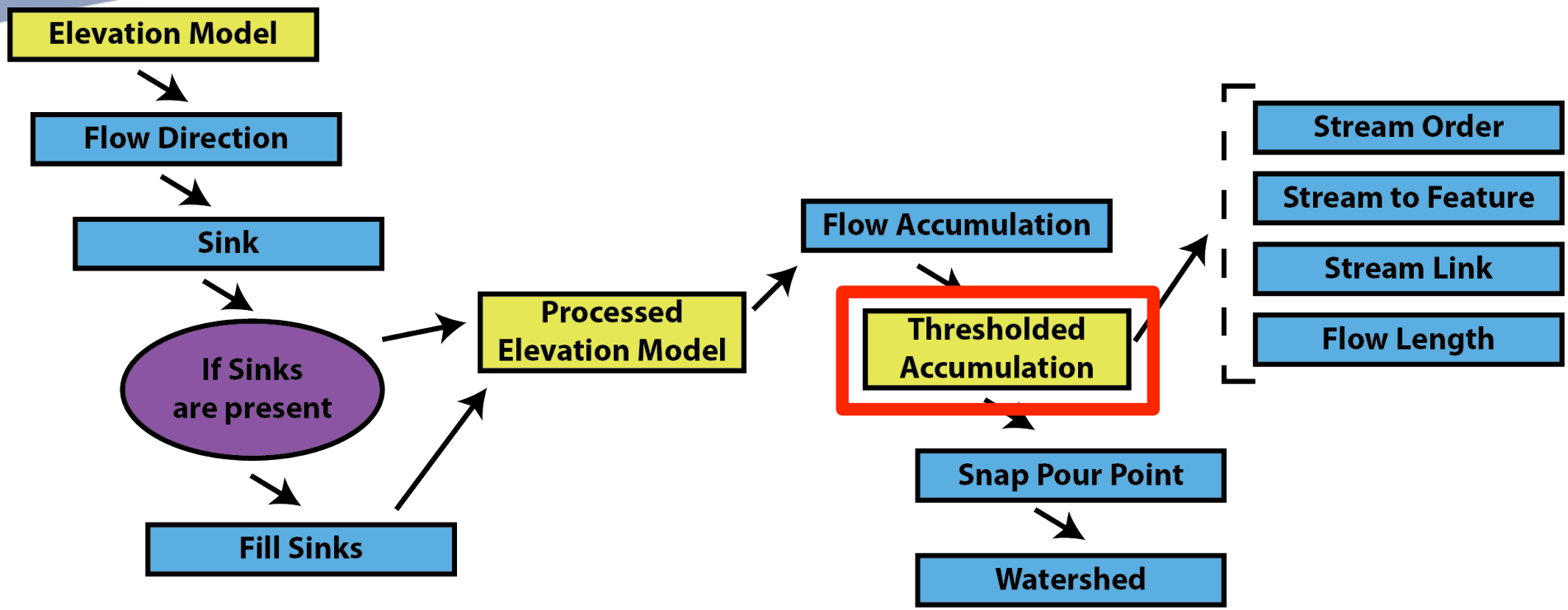
# Example: Flow Accumulation



Each cell contains a count of the number of cells flowing into it (here, 0 – 10,000).

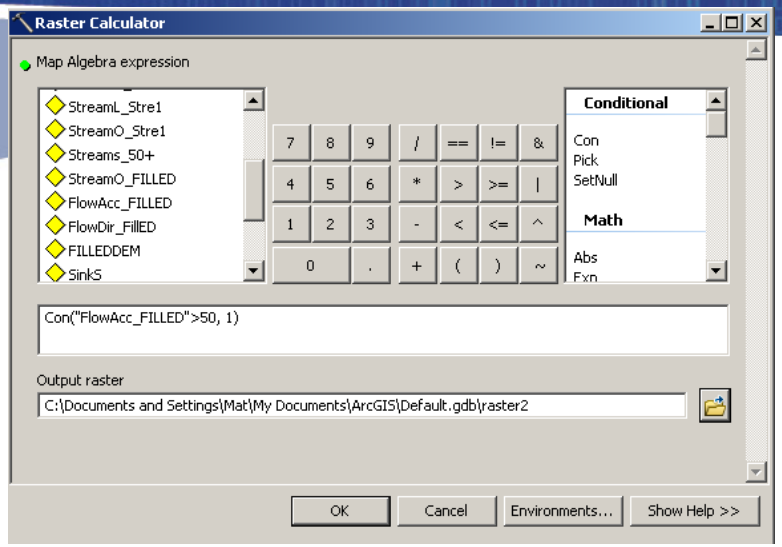
# Hydrology flowchart

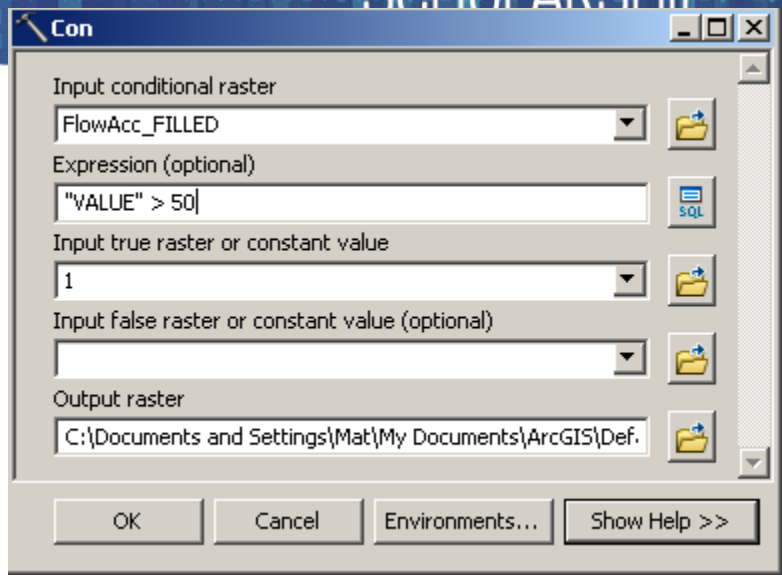
CENTER for DIGITAL SCHOLARSHIP



# Threshold the Flow Accumulation

CENTER for DIGITAL SCHOLARSHIP




- Makes a raster image that only shows the larger water courses
- Not required, but makes processing much easier
- Creates a stream raster

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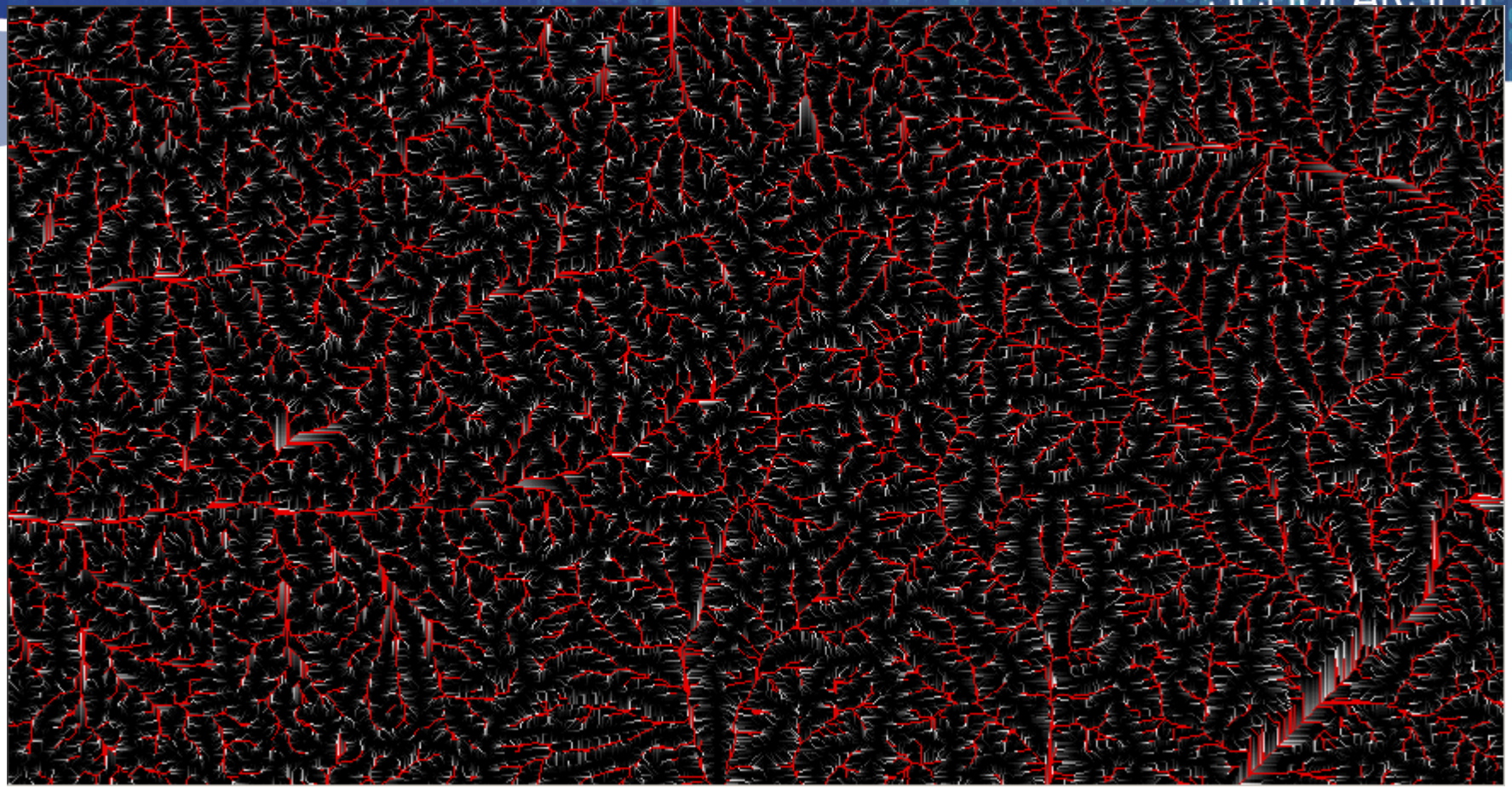
# Example: Flow Accumulation

CENTER for DIGITAL SCHOLARSHIP



The cells in red have more than 50 other cells flowing into them

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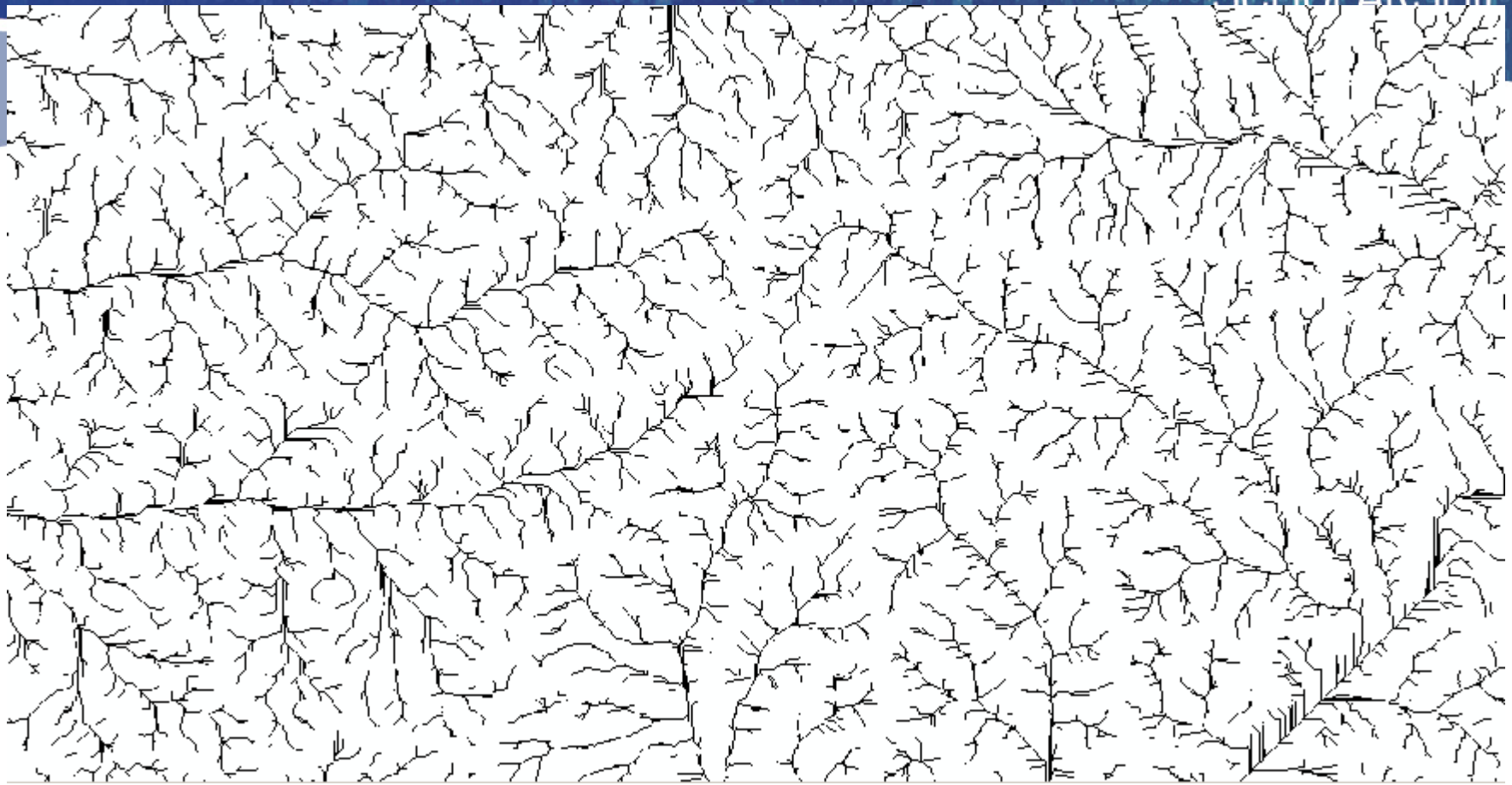
# Example: Thresholded Flow Accumulation

CENTER for DIGITAL SCHOLARSHIP



A binary image where 1 (black) is a stream and NoData (white) is an area contributing to the black areas.

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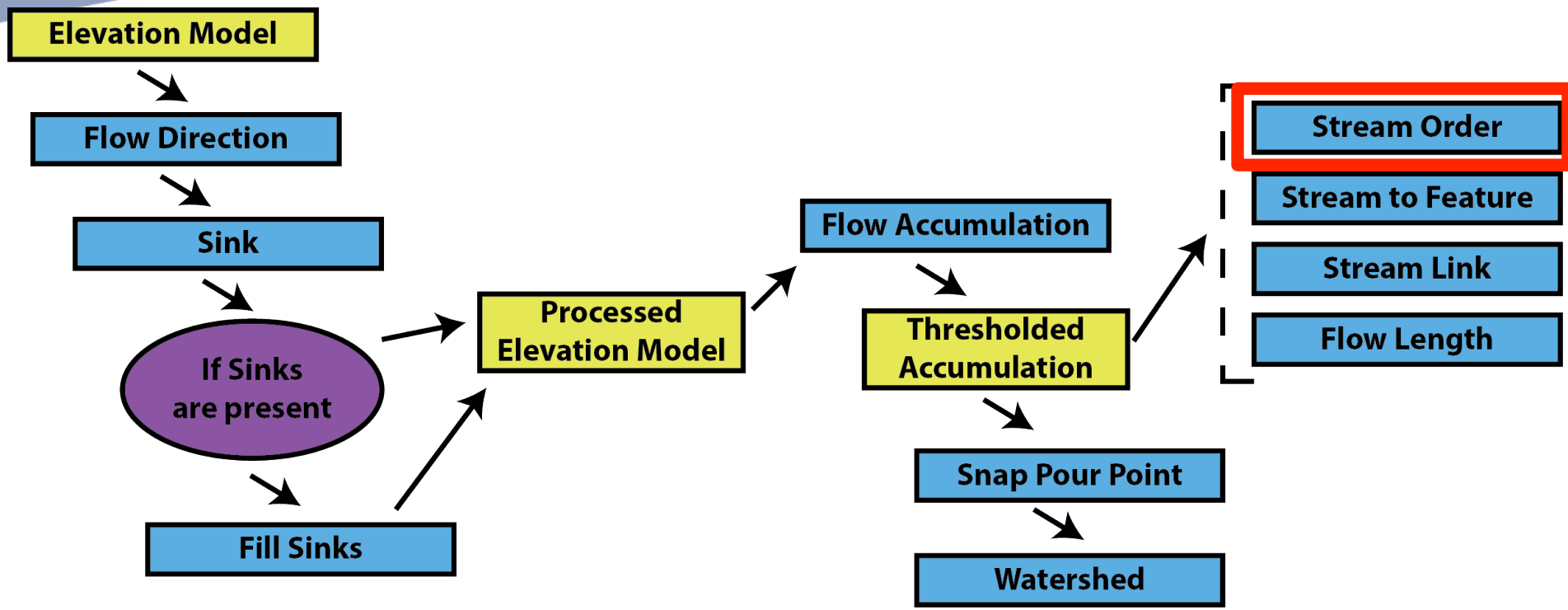
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

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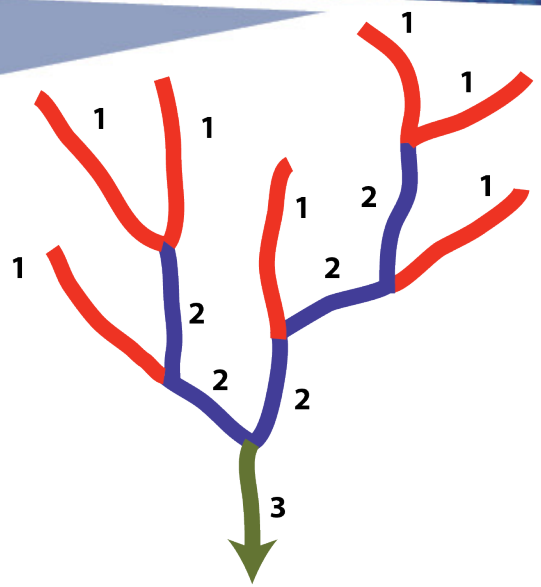
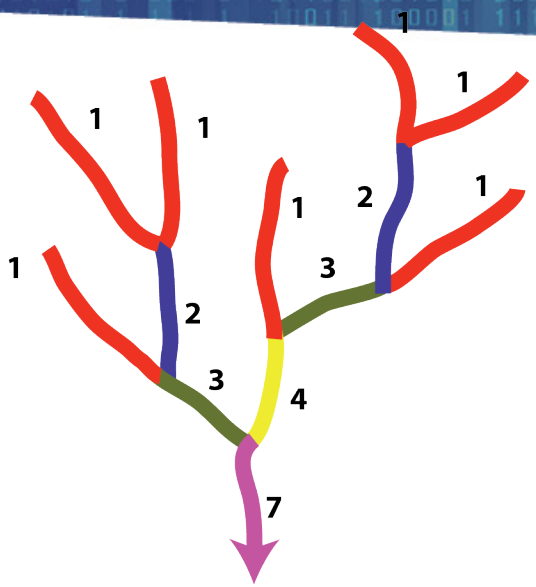
# Stream Order

CENTER for DIGITAL SCHOLARSHIP




**Strahler Method**

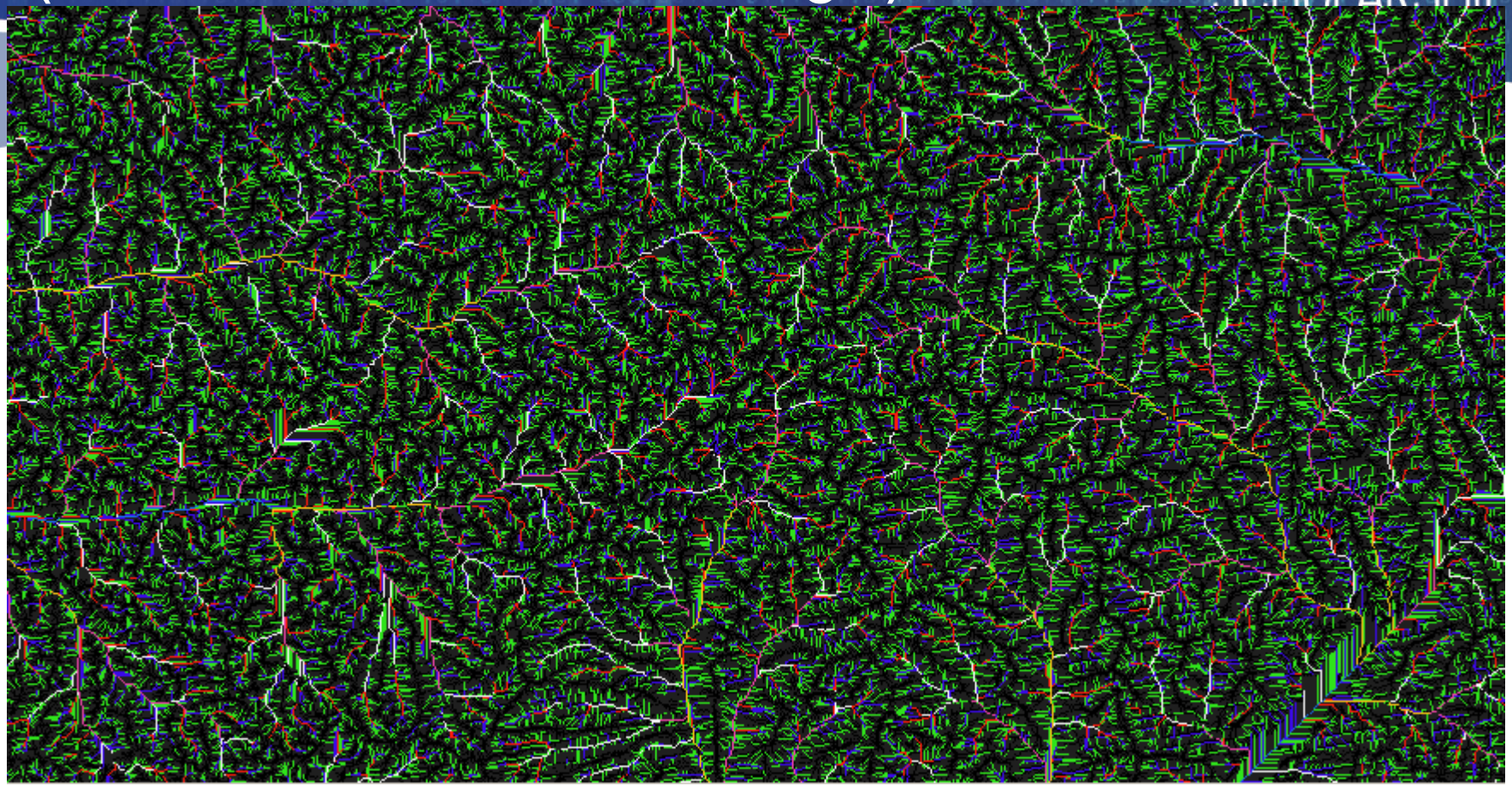



**Shreve Method**

- Two methods. Different rankings, same data
- Each stream feature is ranked by how many other stream contribute to it.

# Example: Stream Order (for un-thresholded image)

CENTER for DIGITAL SCHOLARSHIP



Each stream feature has been ordered based on how many feed into it.

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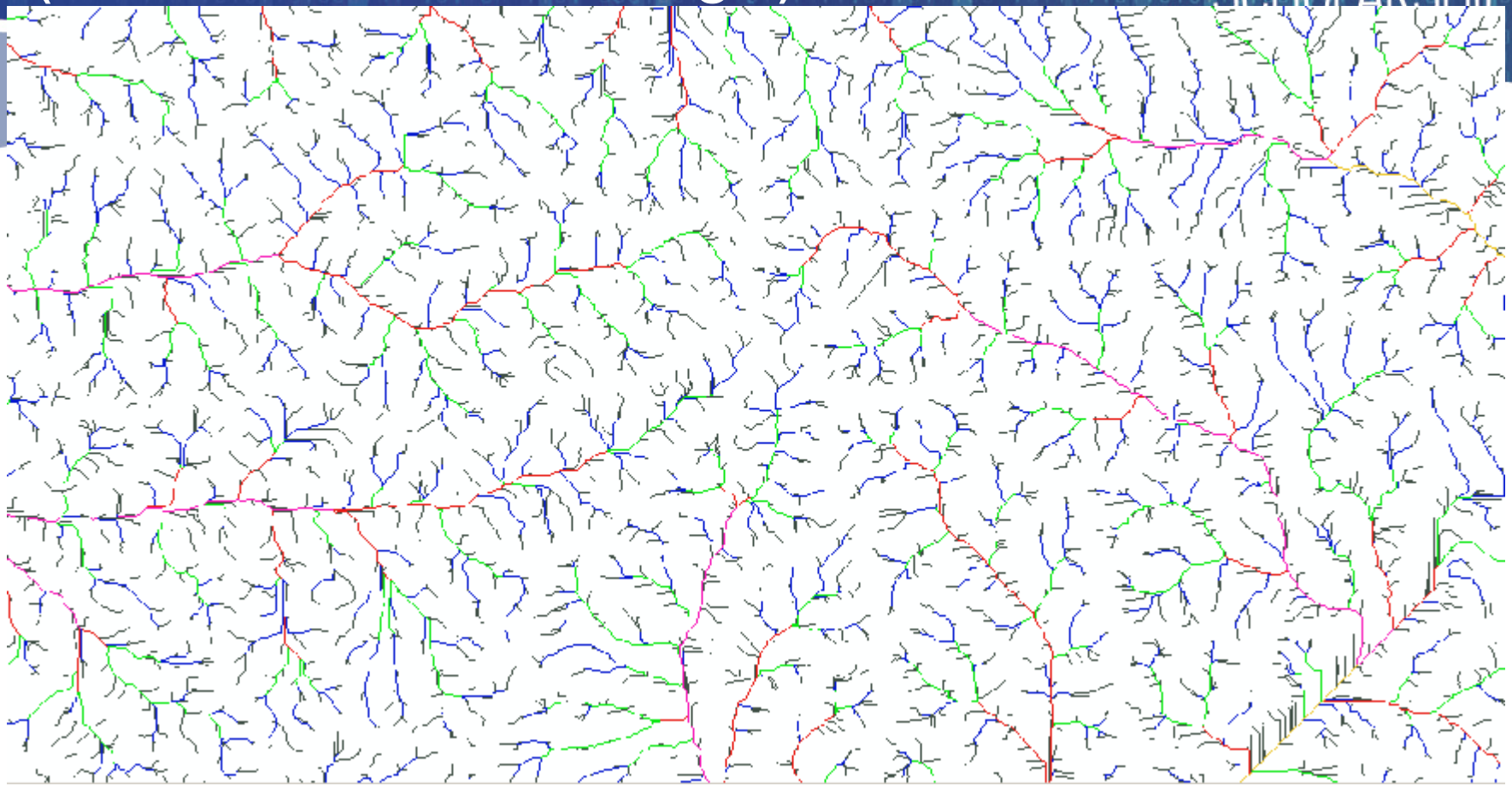
# Example: Stream Order (for thresholded image)

CENTER for DIGITAL SCHOLARSHIP



Each stream feature has been ordered based on how many feed into it.

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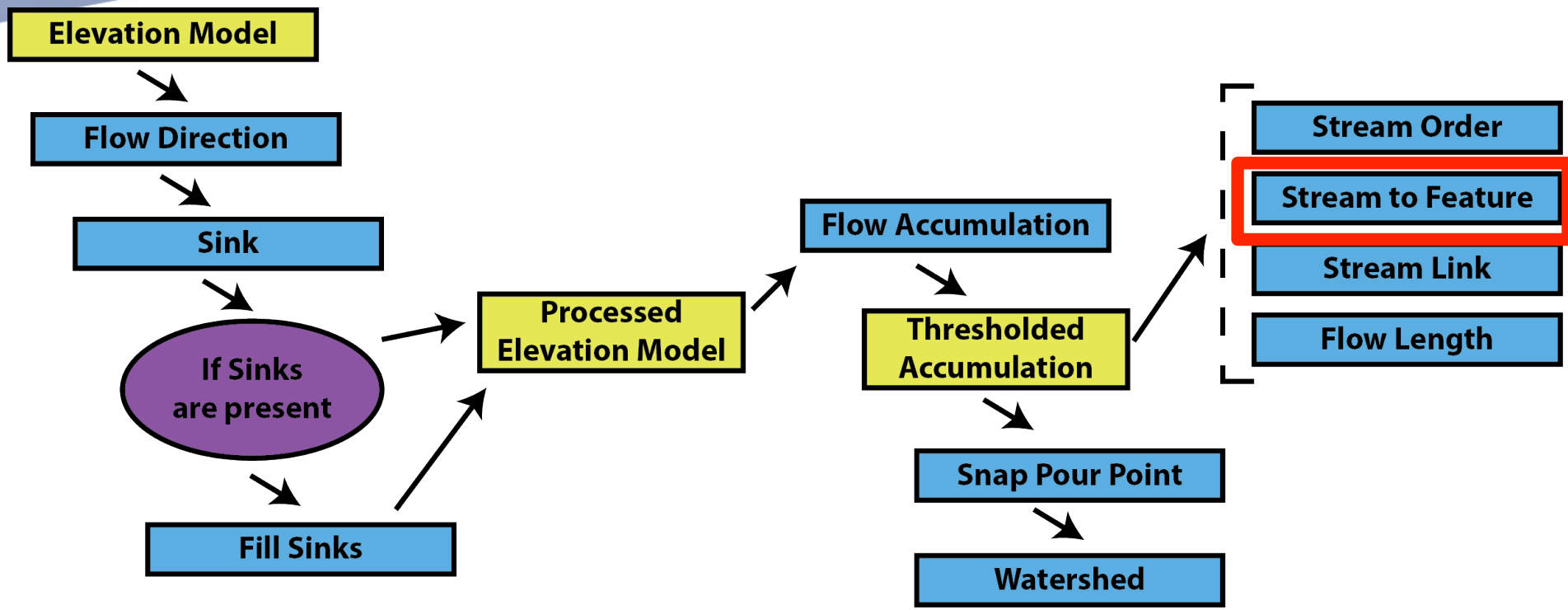
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP



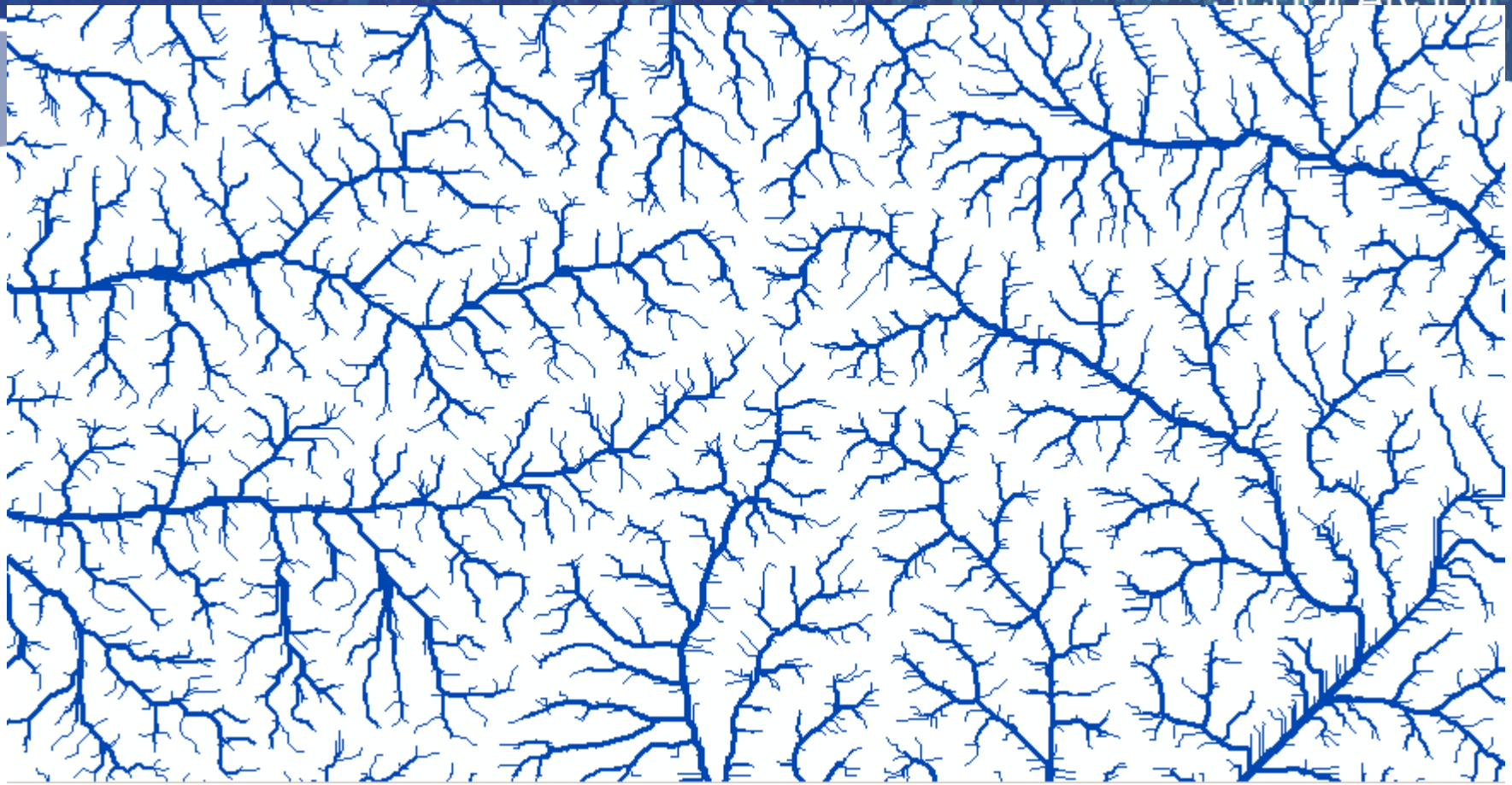
# Stream to Feature

CENTER for DIGITAL SCHOLARSHIP

- Converts a raster stream image into a polyline shapefile
- More effective than simply converting a raster to a polyline
- Retains the stream rank.

# Example: Stream to Feature

CENTER for DIGITAL SCHOLARSHIP



A series of polyline shapefiles tracing the stream paths

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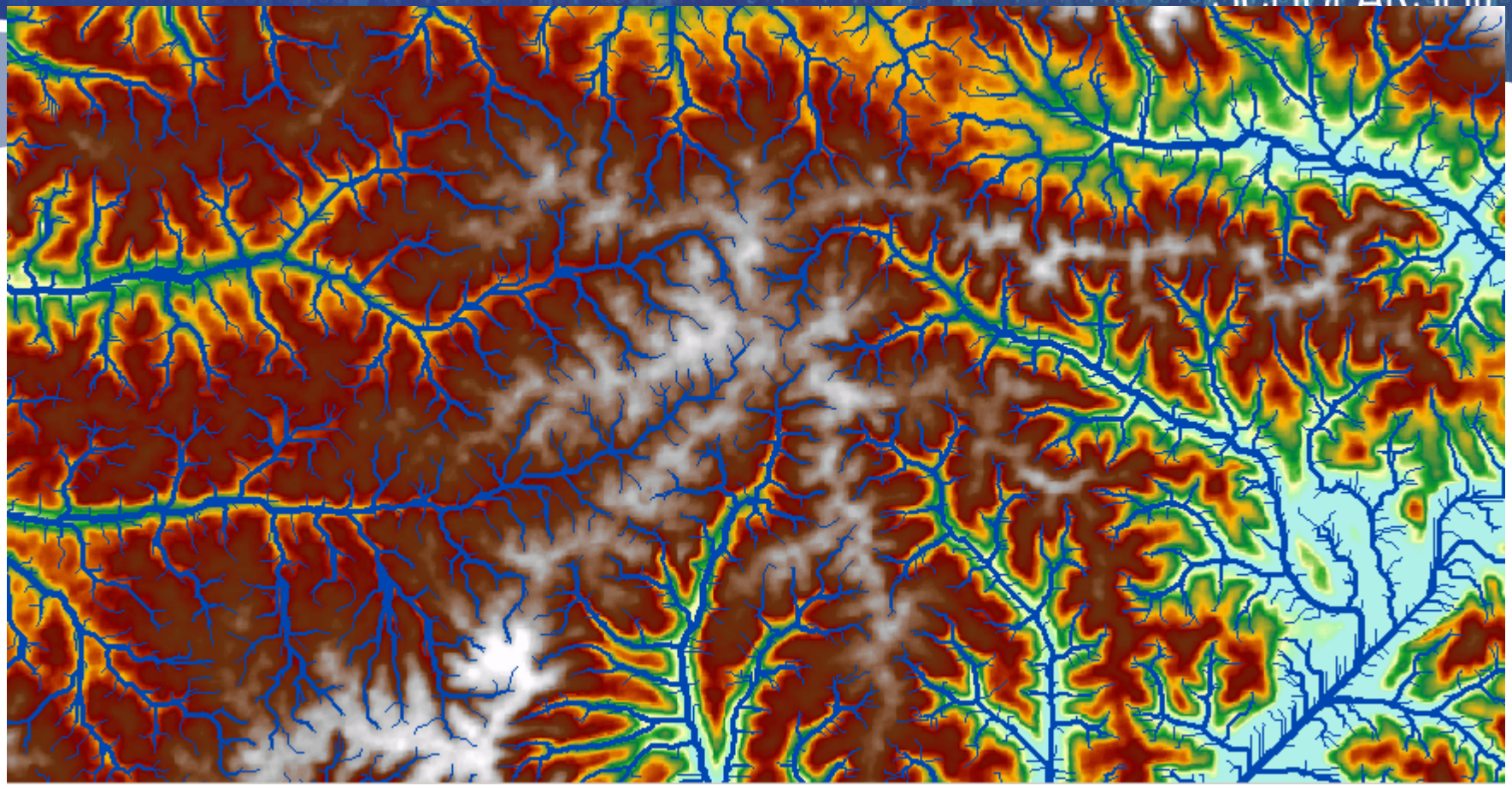
# Example: Stream to Feature

CENTER for DIGITAL SCHOLARSHIP



A series of polyline shapefiles tracing the stream paths

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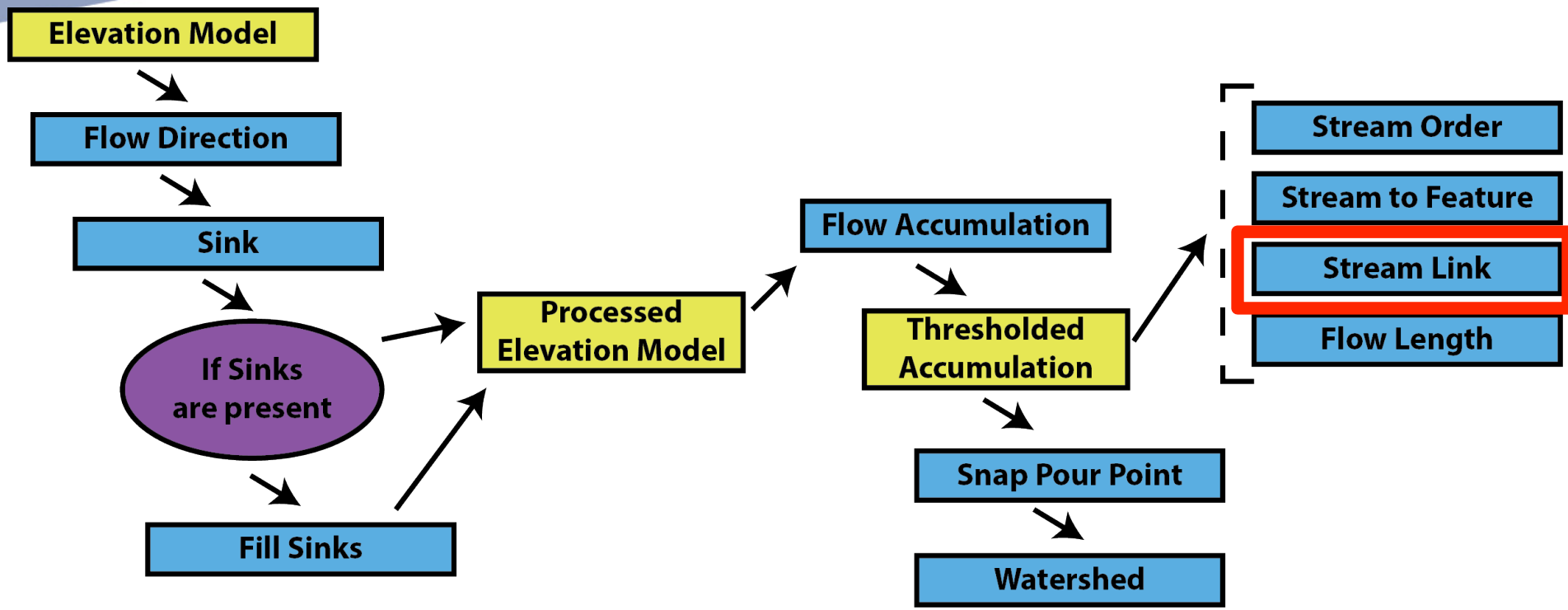
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP

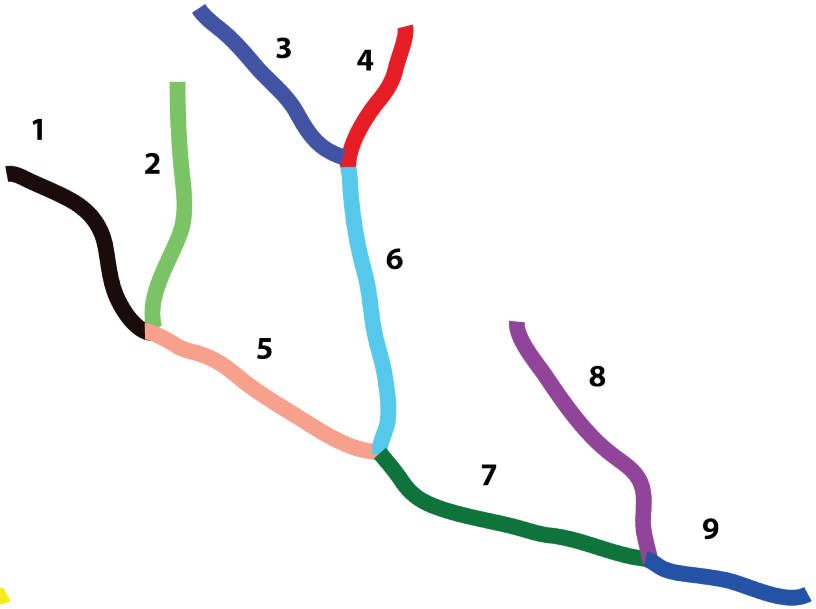


# Stream Link

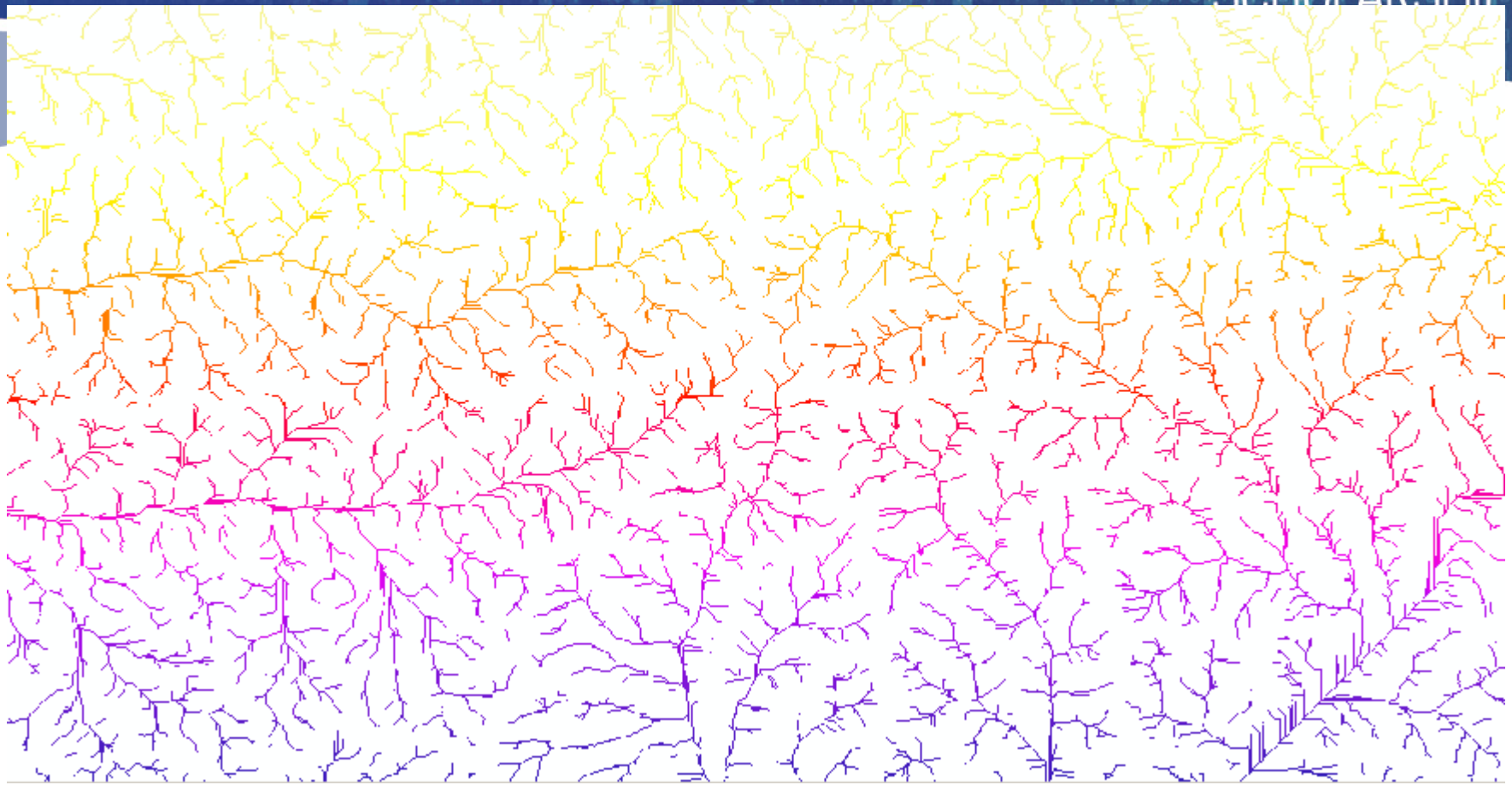
CENTER for DIGITAL SCHOLARSHIP

- Assign a unique value to each stream segment.
  - Can be used as input to Watershed





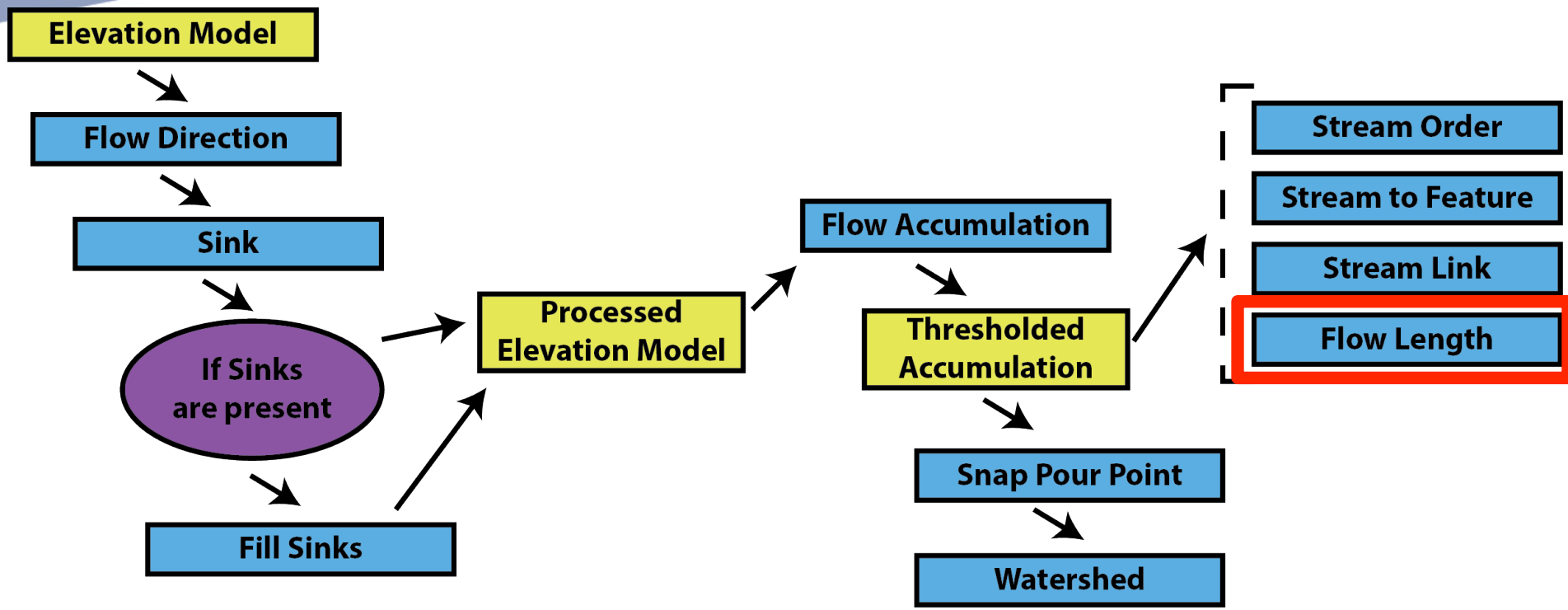
# Example: Stream Link



Each segment of every stream gets a unique identifier

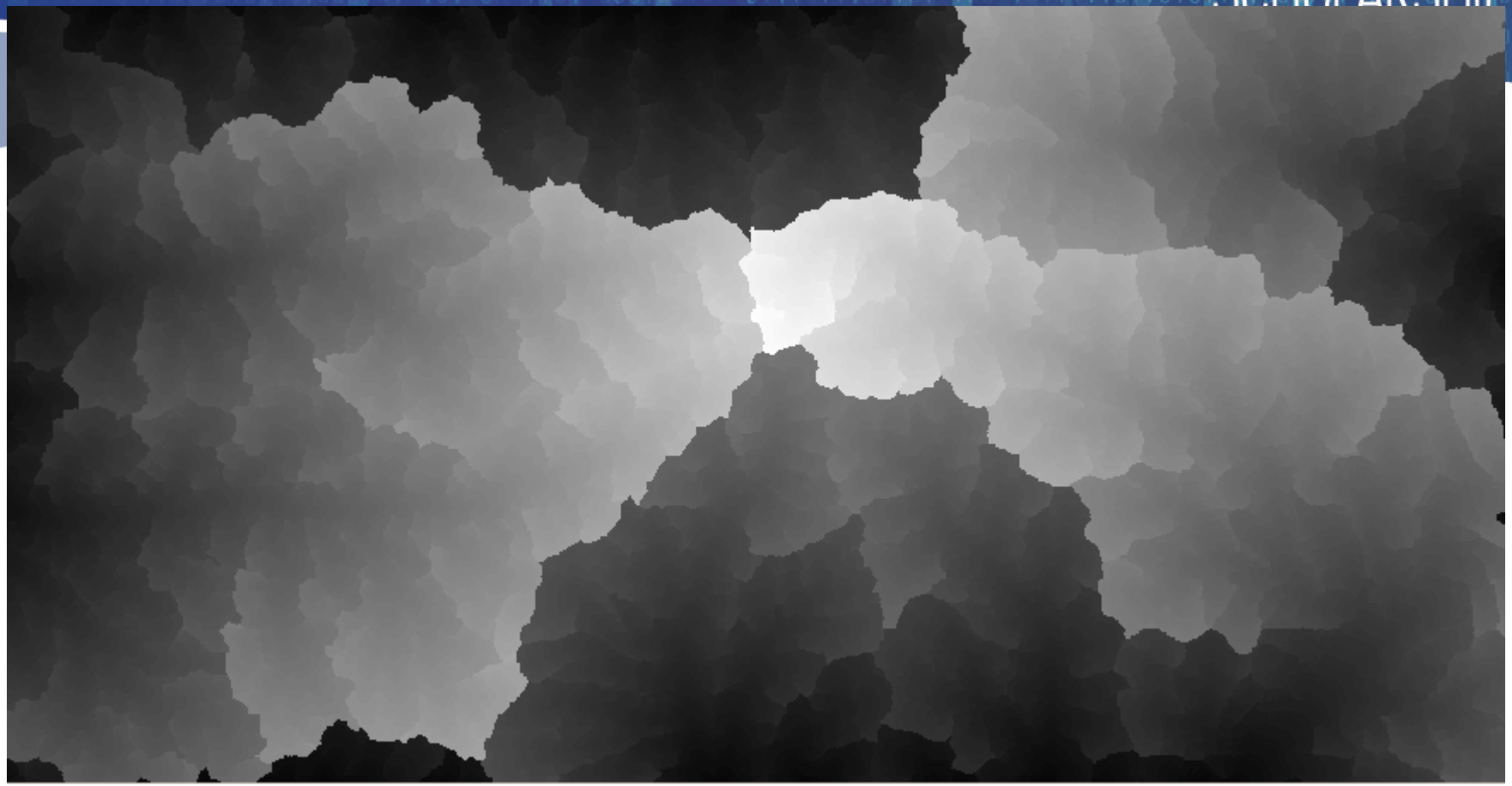
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP



# Example: Flow Length

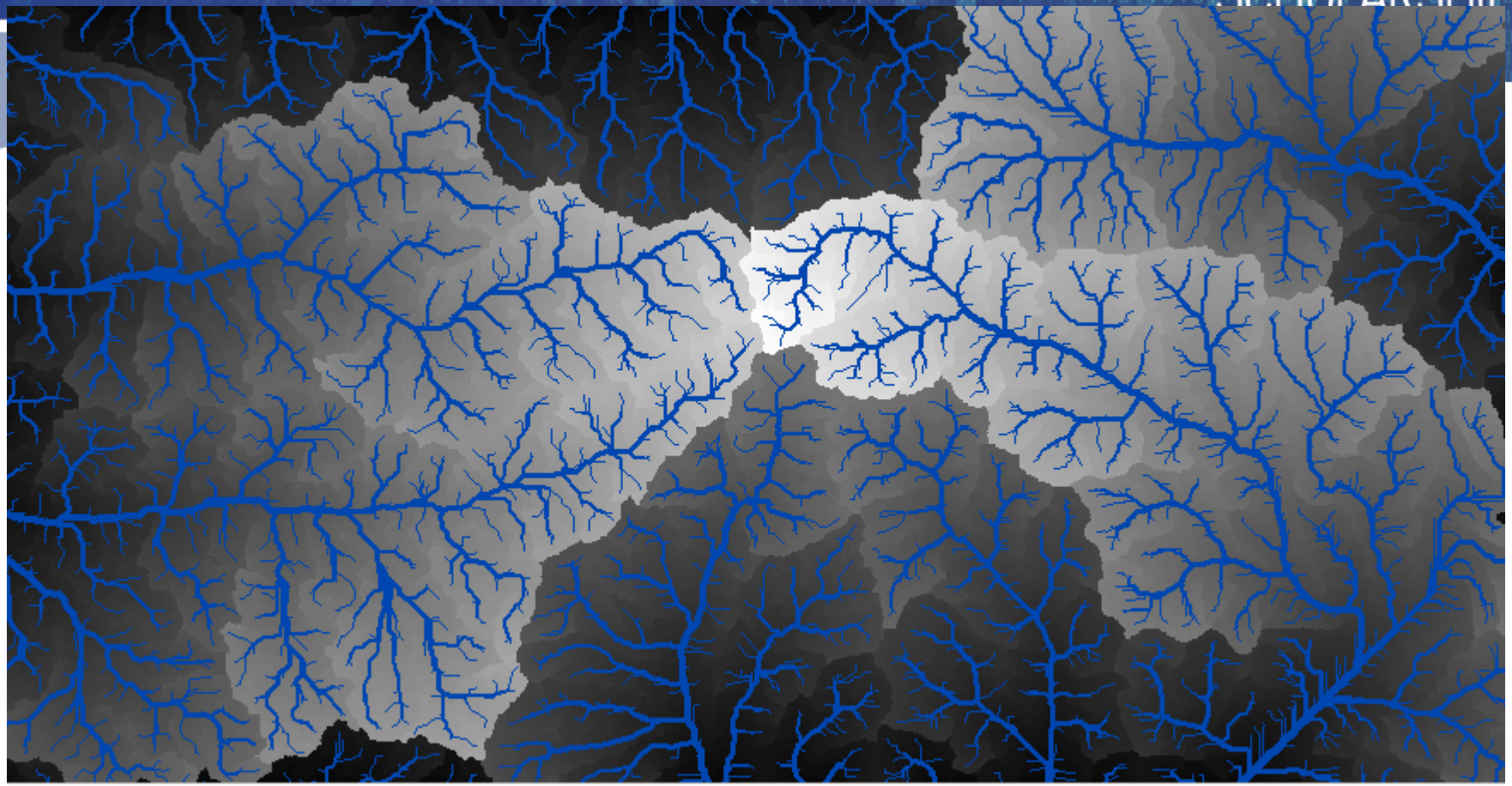
CENTER for DIGITAL SCHOLARSHIP



- Each cell has a value of how far water there would travel before leaving the DEM (can be upstream or downstream)
- Gives an estimate ho long water stays in a particular watershed

# Example: Stream to Feature

CENTER for DIGITAL SCHOLARSHIP



A series of polyline shapefiles tracing the stream paths

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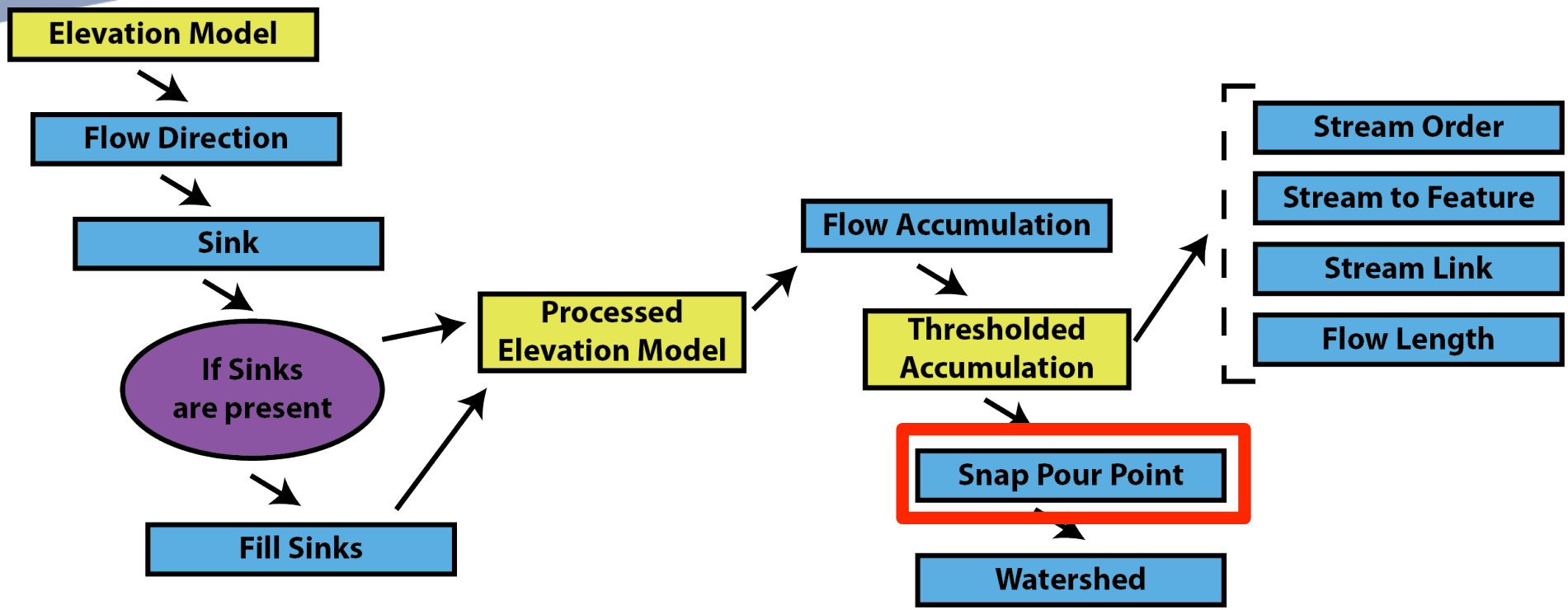
# Hydrology flowchart

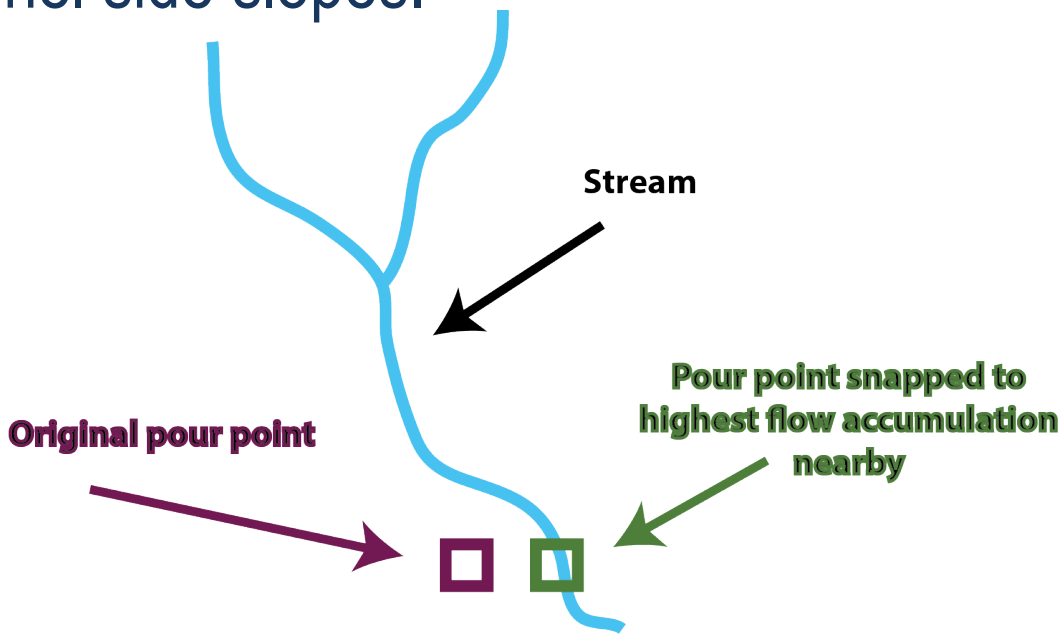
CENTER for DIGITAL SCHOLARSHIP



# Snap Pour Points

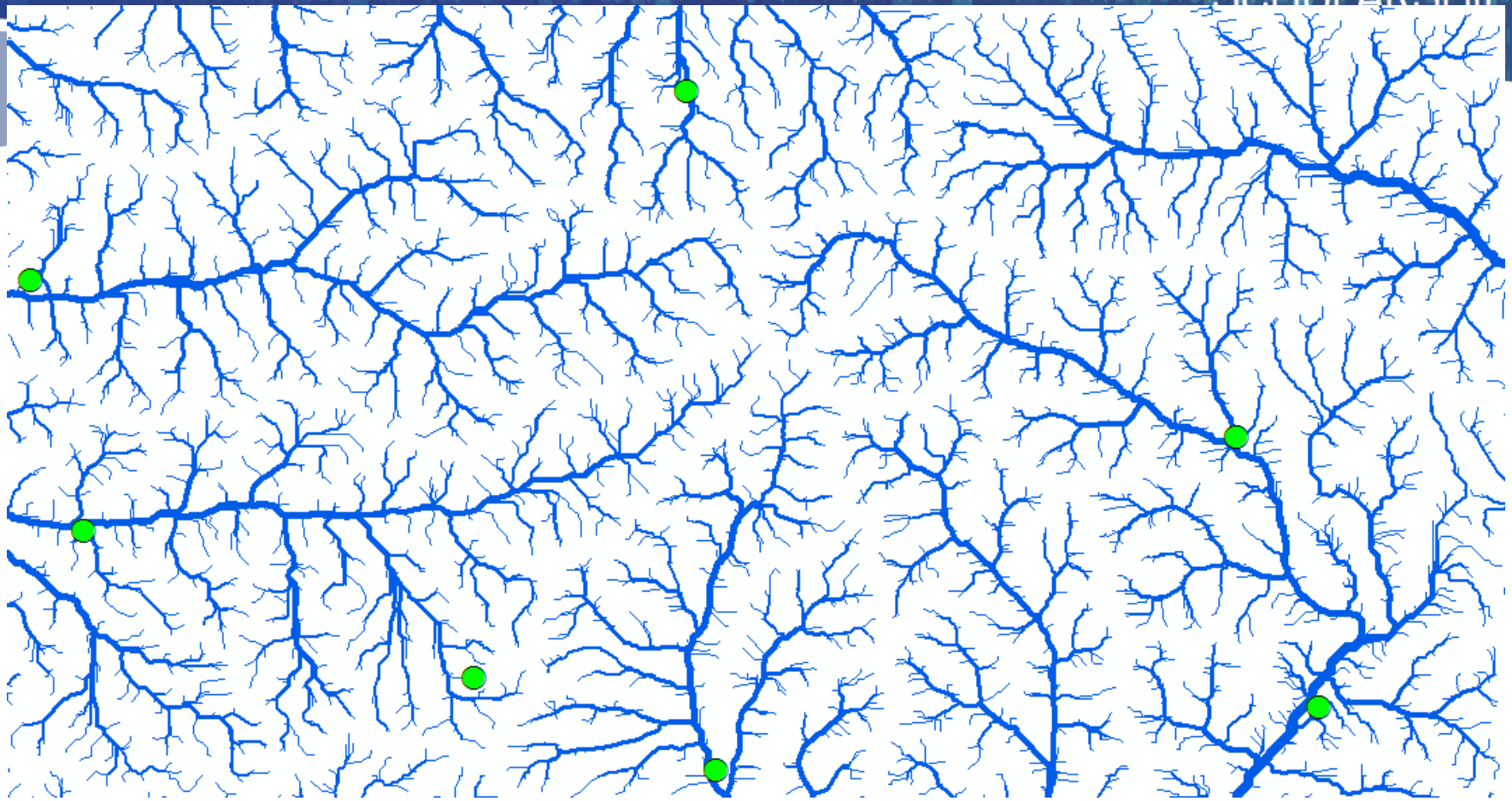
CENTER for DIGITAL SCHOLARSHIP

- Snap the pour point of a watershed to the cell of highest flow accumulation within a neighborhood.
  - Prevents accidental creation of tiny watersheds on channel side slopes.



# Example: Snap Pour Points

CENTER for DIGITAL SCHOLARSHIP



Moves point features to the nearby location with the highest flow accumulation

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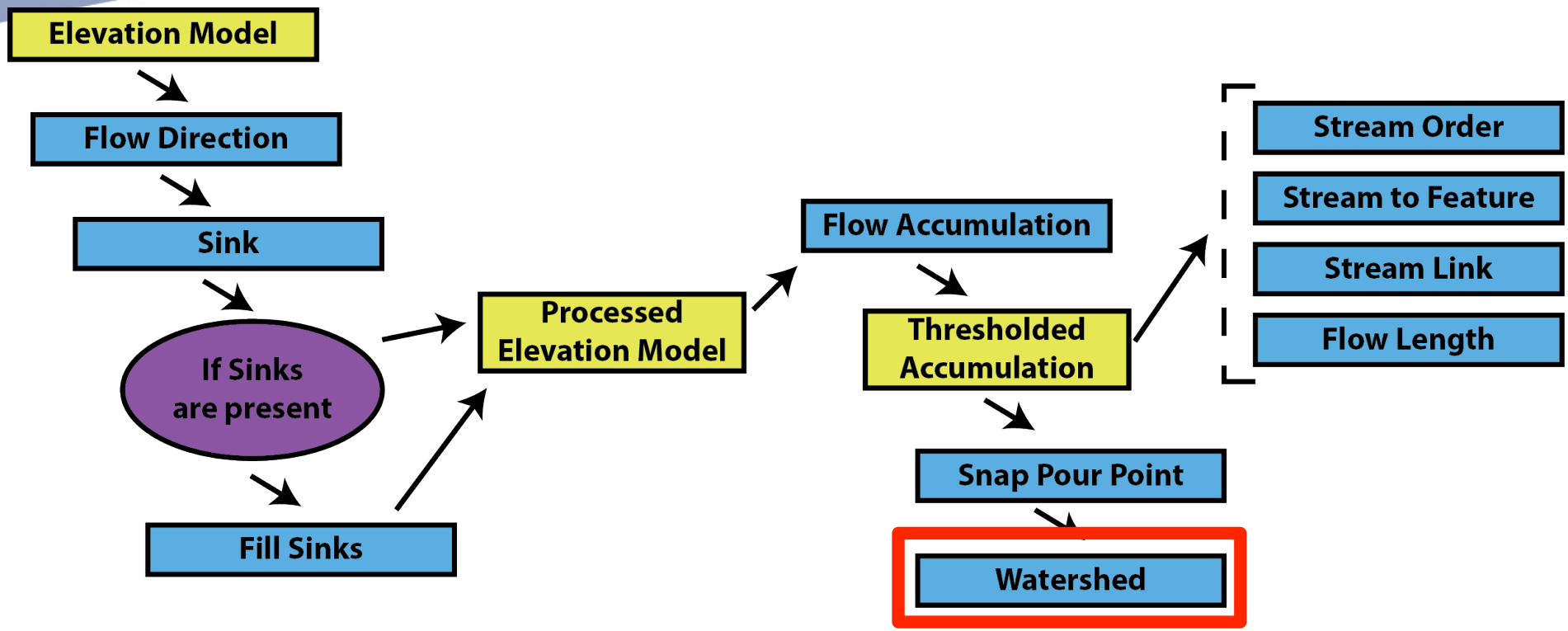
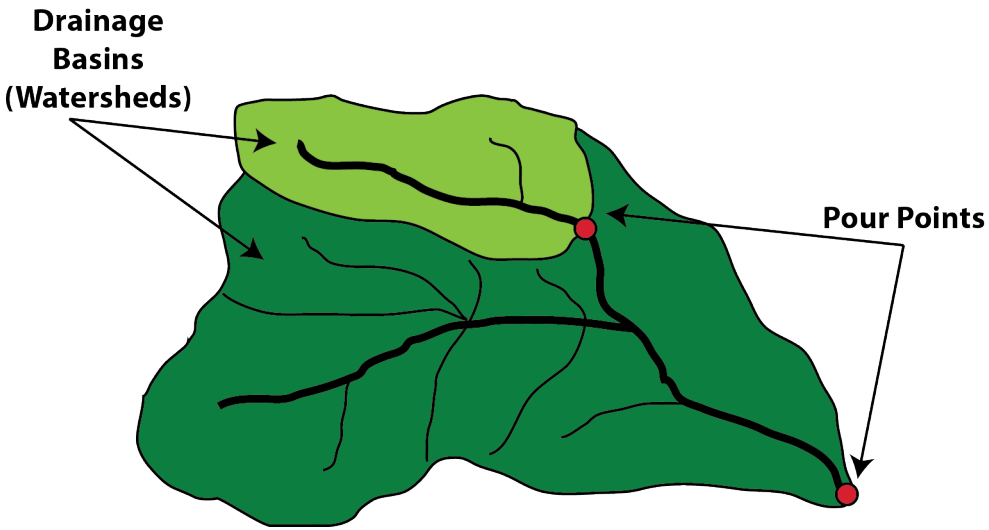
# Hydrology flowchart

CENTER for DIGITAL SCHOLARSHIP



# Watersheds

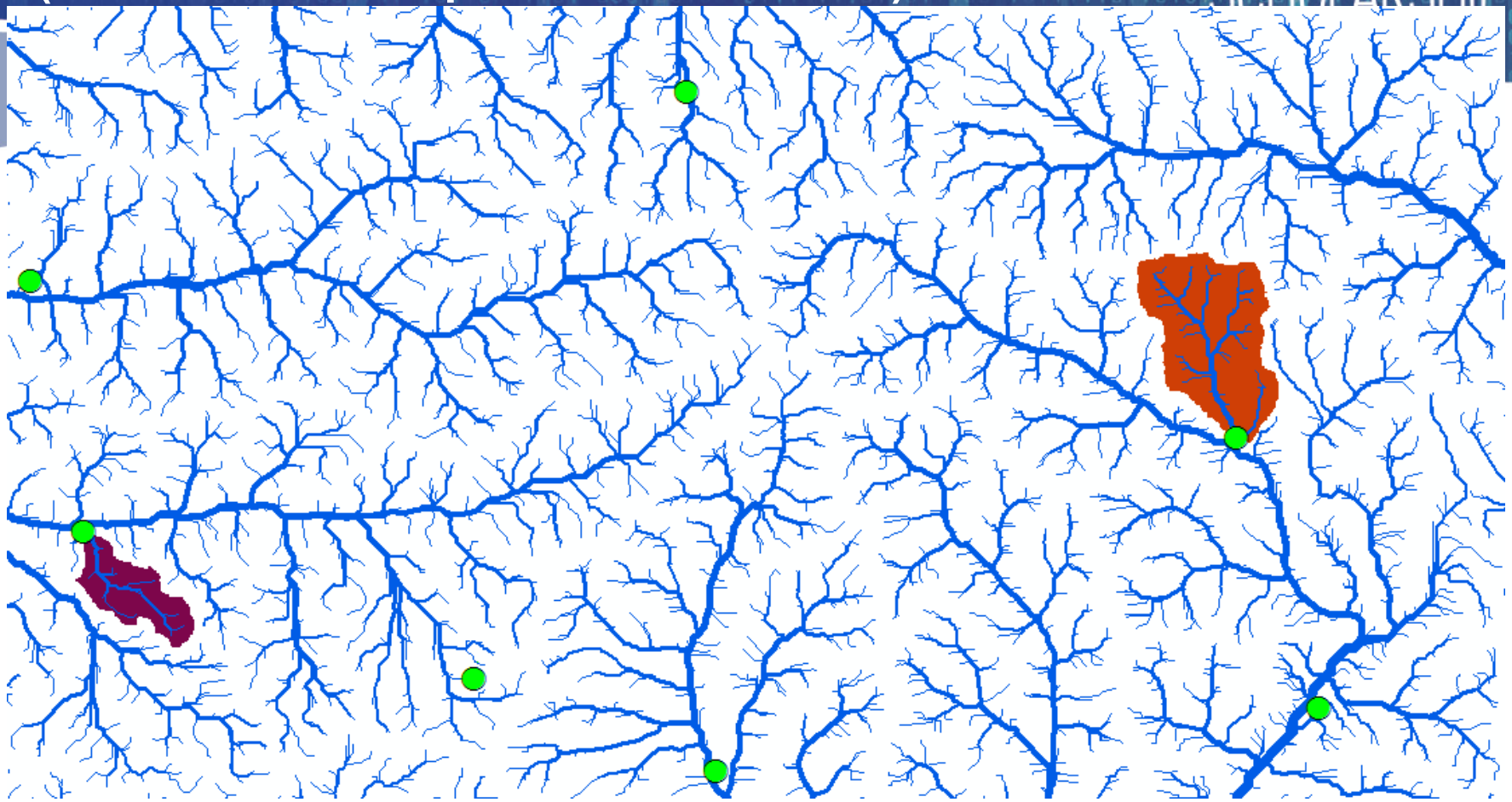





- **Drainage basins** are areas that drain water to a common outlet.
- **Pour point** are where water flows out of an area. Usually the lowest point along the boundary of a drainage basin.

# Example: Watershed (without Snap Pour Points)

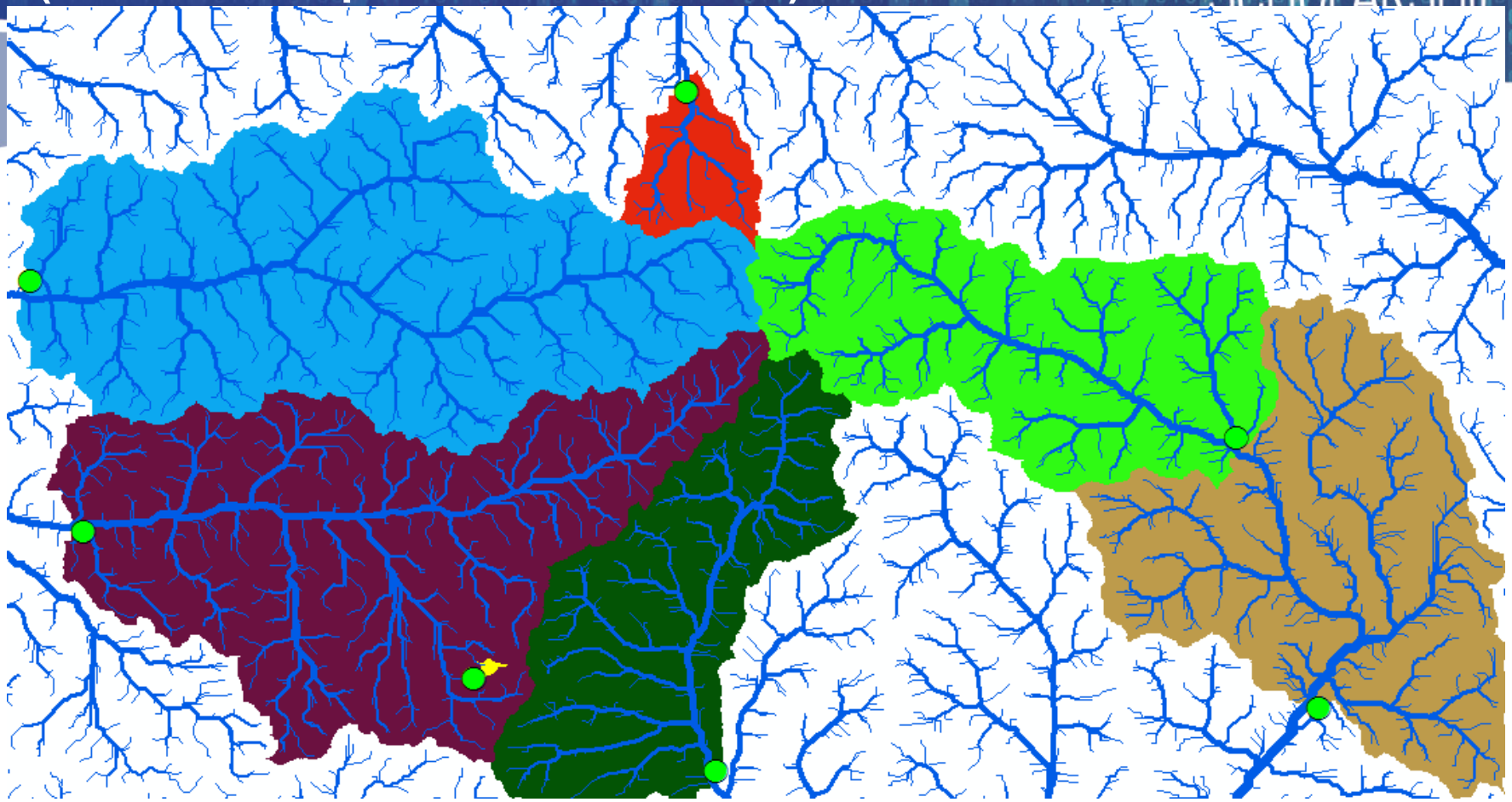




For each location, shows the area that drains into it.

# Example: Watershed (with Snap Pour Points)

CENTER for DIGITAL SCHOLARSHIP



For each location, shows the area that drains into it.

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