TERRAIN ANALYSIS

Su Zhang, Ph.D., GISP

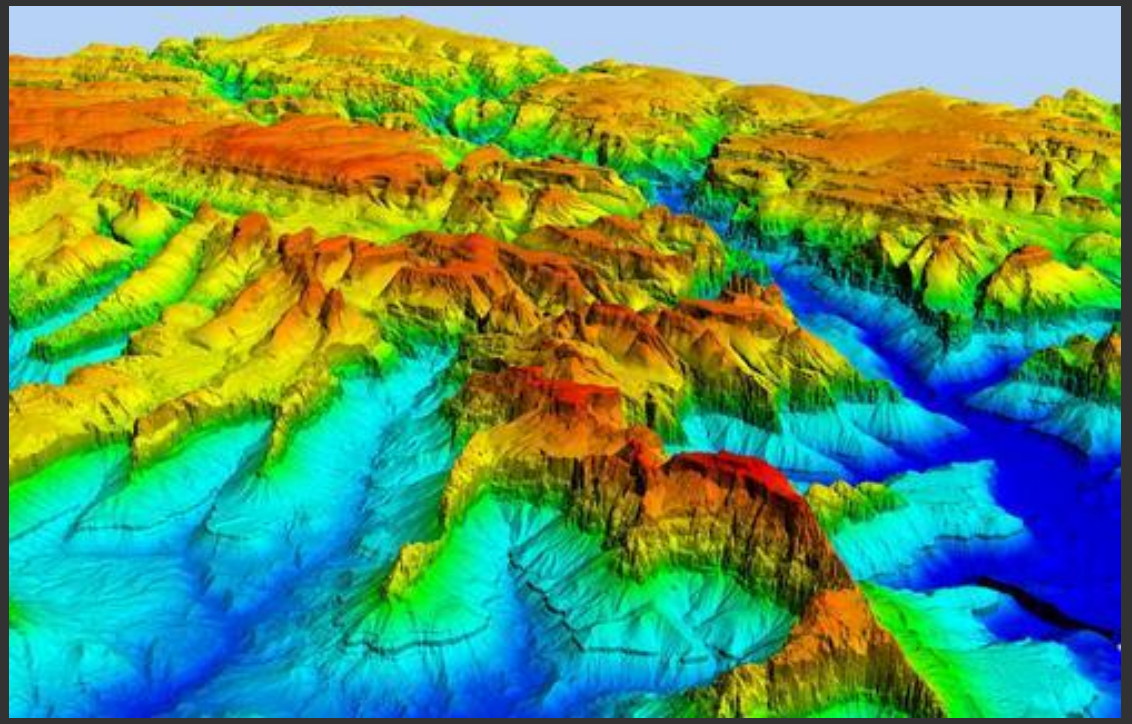
TERRAIN

- What is terrain
  - Also known as relief
  - It refers to the vertical and horizontal dimensions of land surface
  - To describe the terrain of the land, factors such as the slope, elevation, and orientation of the land are used
- Terrain matters
  - Terrain determines the natural availability and location of surface water and therefore soil moisture and drainage
  - Terrain influences the location and nature of transportation networks
  - Terrain determines its suitability for human settlement and the cost and methods of construction

worldatlas.com

TERRAIN ANALYSIS

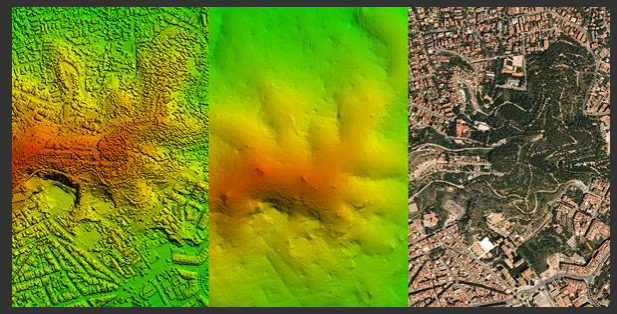
- Terrain analysis can be defined as the analysis and interpretation of topographic features (e.g., elevation, contour, slope, aspect, flow direction) through geographic information systems (GIS)
- Terrain analysis employs elevation data, usually in conjunction with other geospatial information, to describe the landscape, for basic visualization, modeling, or to support decision making
- Terrain analysis ranges from largely qualitative, typified by military terrain analysis, to sophisticated numerical computations in geomorphology
- Example Applications
  - Soil Mapping
  - Hydrologic Mapping
  - Wildlife/Habitat Modeling



usgs.com

ELEVATION DATA

- Provide height information above mean sea level (MSL) for every place in the world
  - An MSL measurement refers to the altitude or height above the average height of the oceans and seas
  - Positive values indicate above mean sea level and negative indicate below mean sea level
  - Above ground level (AGL) – aviation
- Types of elevation data
  - Rectangular raster grid – DEM, DSM, DTM
  - Triangulated Irregular Network (TIN)
  - Contours



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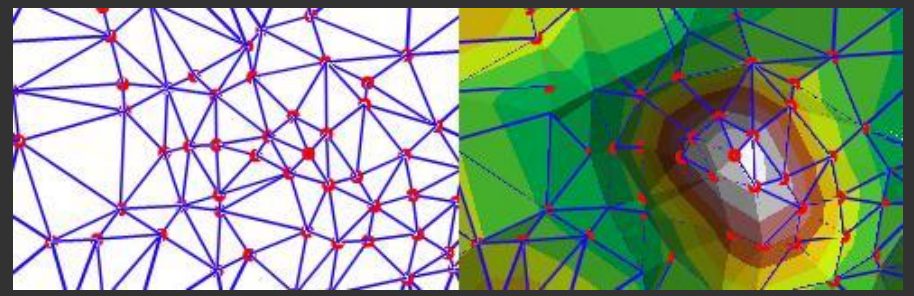

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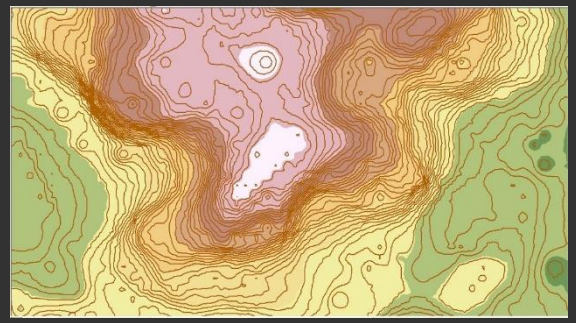

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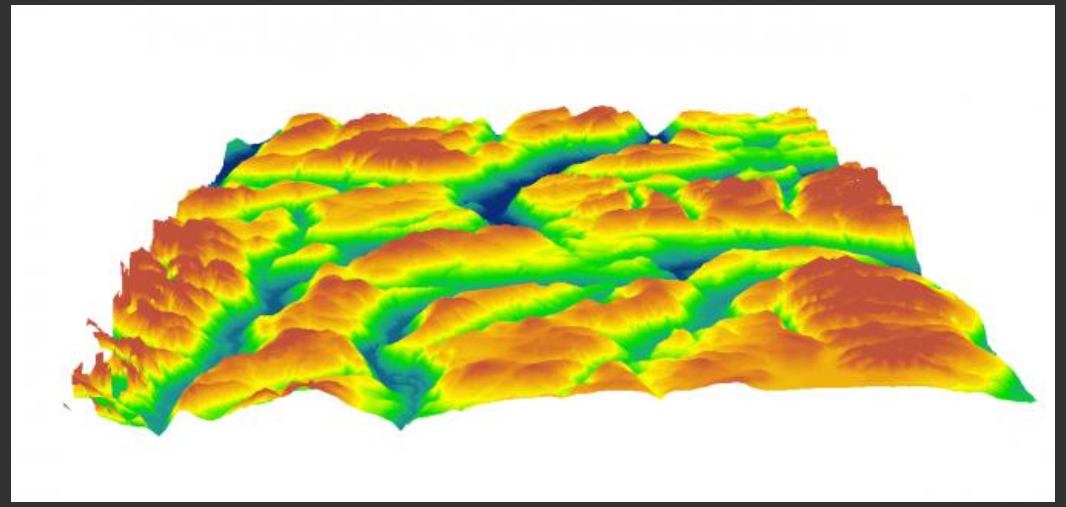
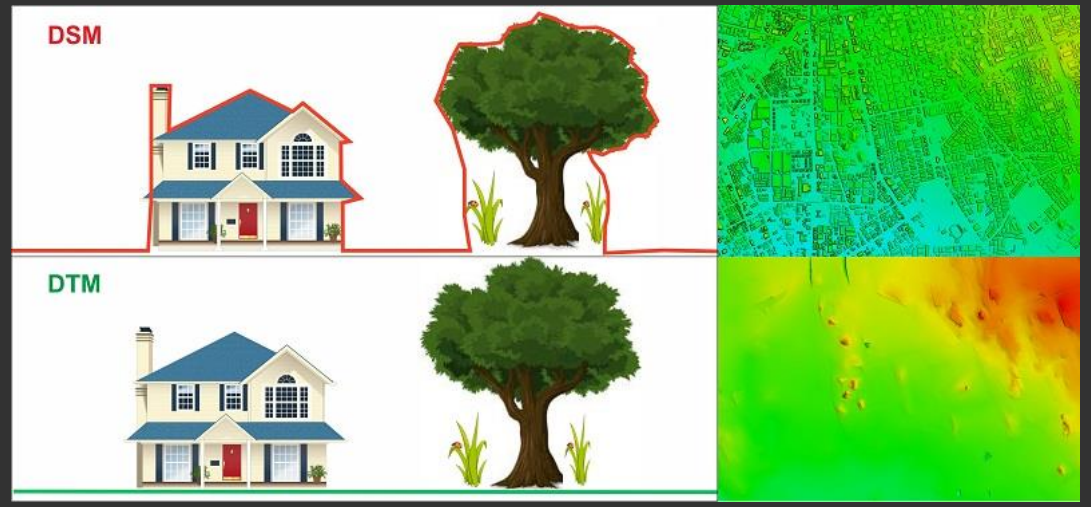
ELEVATION DATA

- DEM – General term for digital topographic data in various formats
- DTM – bare-earth DEM
- DSM – captures the natural and built features on the Earth's surface



gisgeography.com



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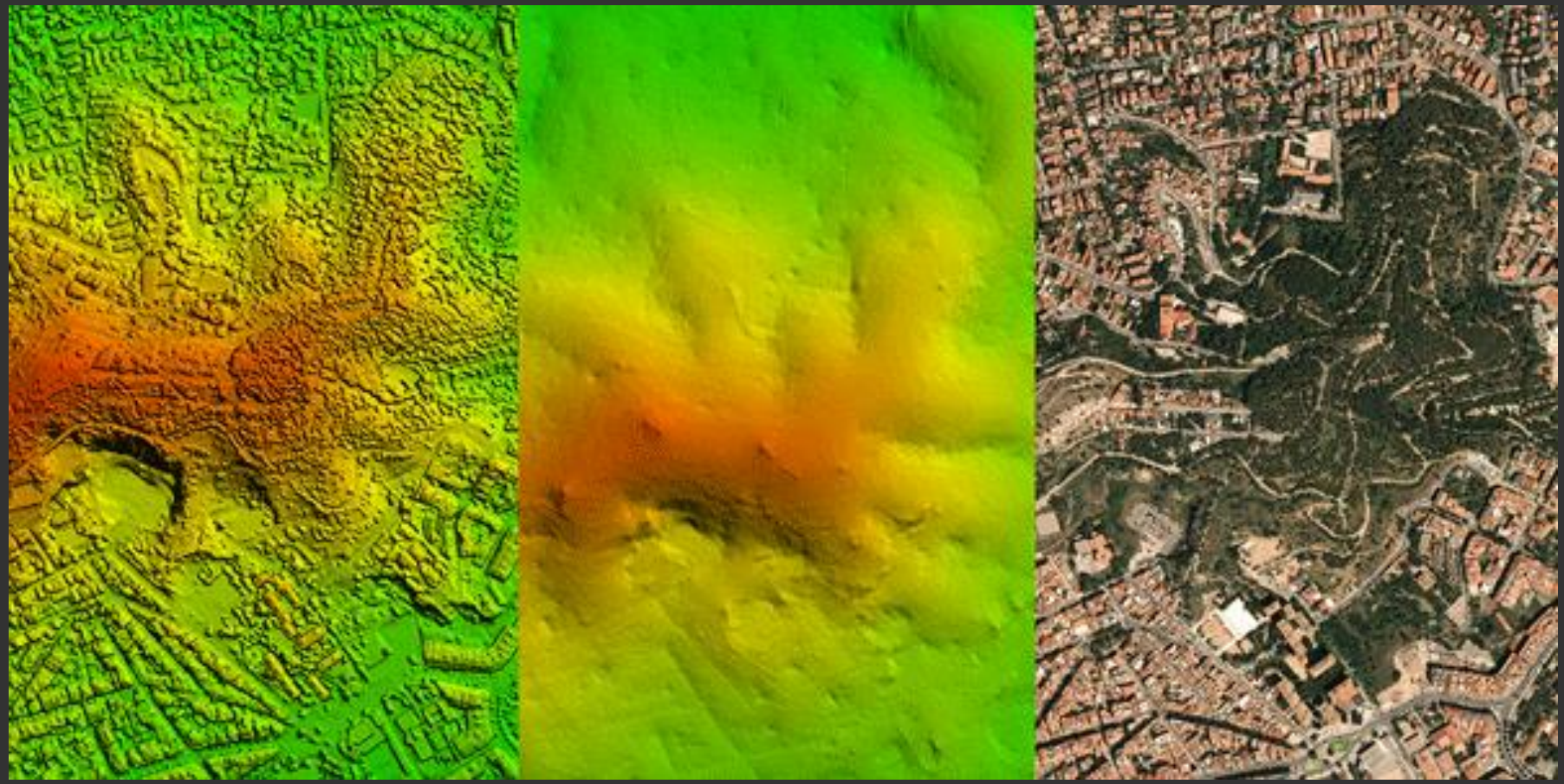
DSM VS DTM VS AERIAL PHOTOS



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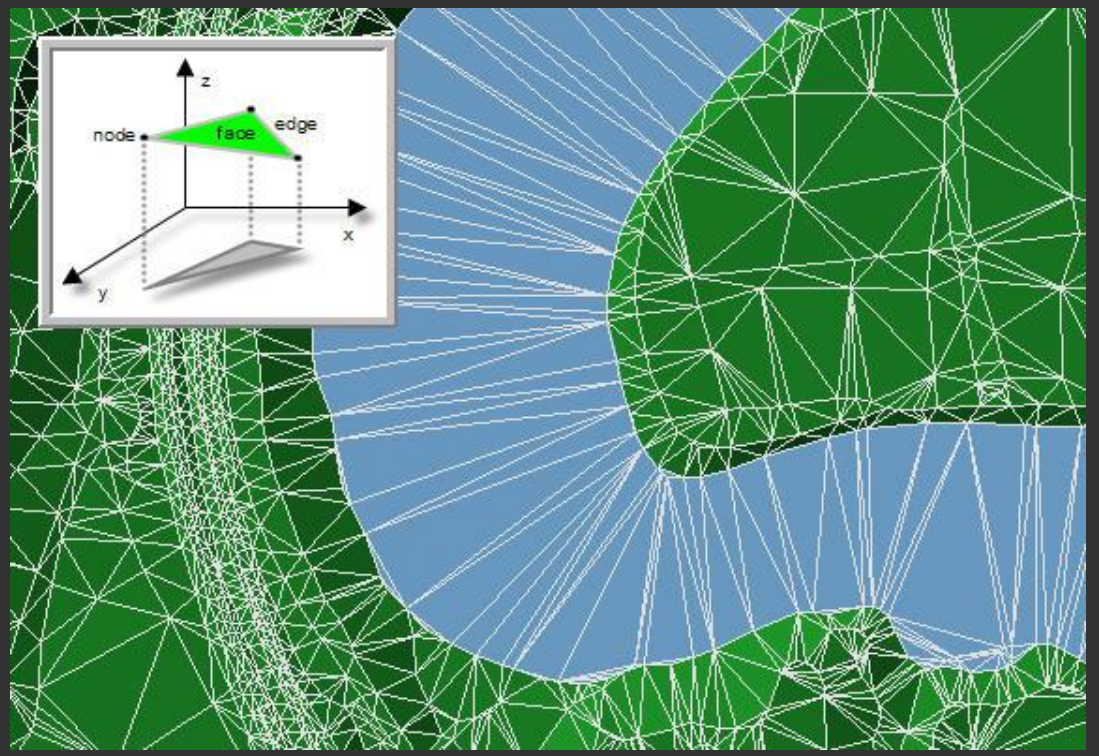
TIN

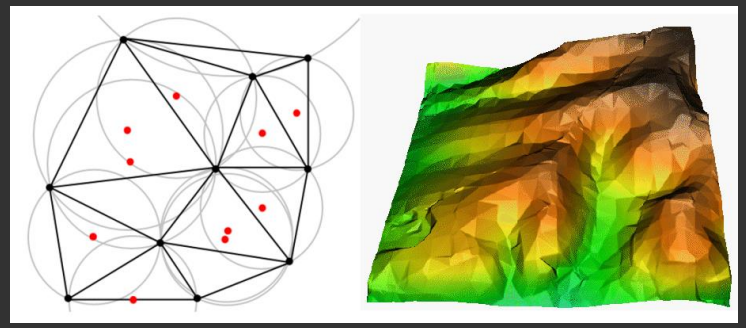
- Triangulated Irregular Network
- A vector-based digital geographic data and are constructed by triangulating a set of vertices (points)
- The edges of TINs form contiguous, non-overlapping triangular facets and can be used to capture the position of linear features that play an important role in a surface, such as ridgelines or stream courses



desktop.arcgis.com

TIN

- Many methods of interpolation to form these triangles
  - Delaunay Triangulation
    - 3 points form a Delaunay triangle if and only if the circle which passes through them contains no other point
  - Distance ordering
    - Compute the distance between all pairs of points, and sort from shortest to longest
    - Connect the closest pair of points
    - Connect the next closest pair if the resulting line does not cross earlier lines
    - Repeat until no further lines can be selected
  - Break lines
  - Contours



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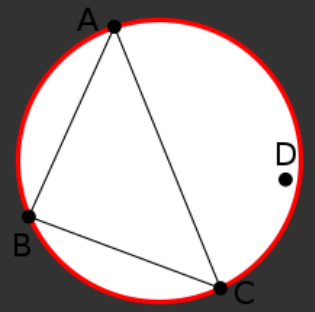

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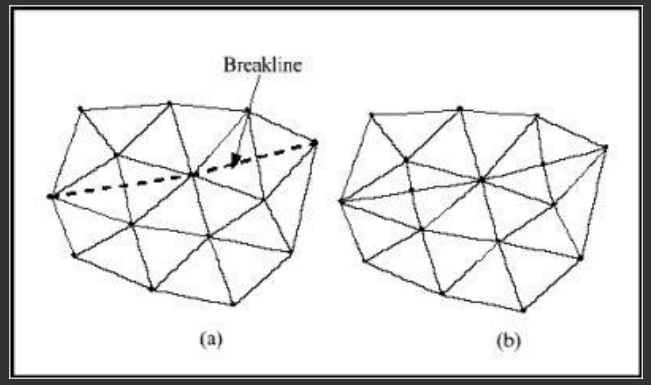

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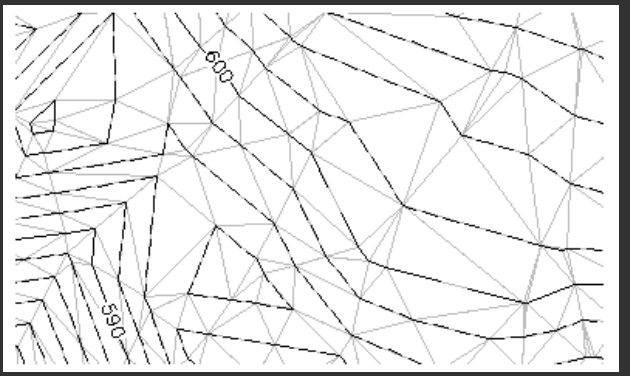

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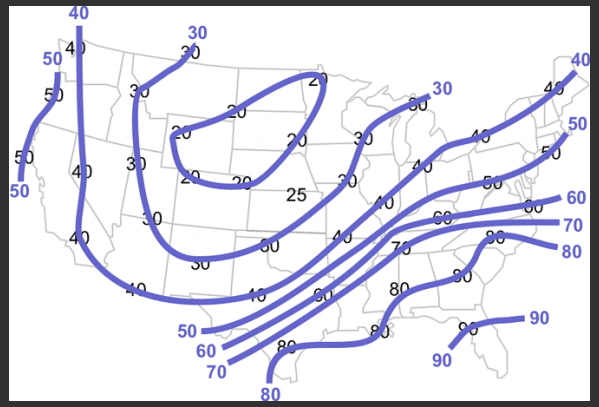
CONTOURS

- Lines of uniform elevation that connect to create a continuous dataset
  - Examples: elevation, temperature (isotherm), precipitation (isohyet)
- The shape and density of contour lines provide information on terrain height and shape

site.iugaza.edu.ps



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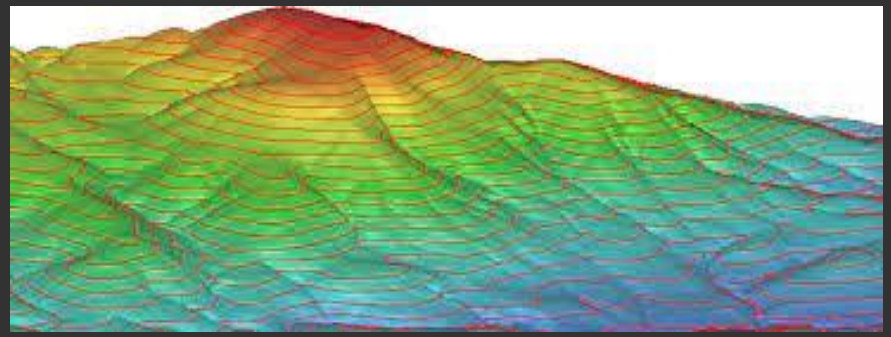

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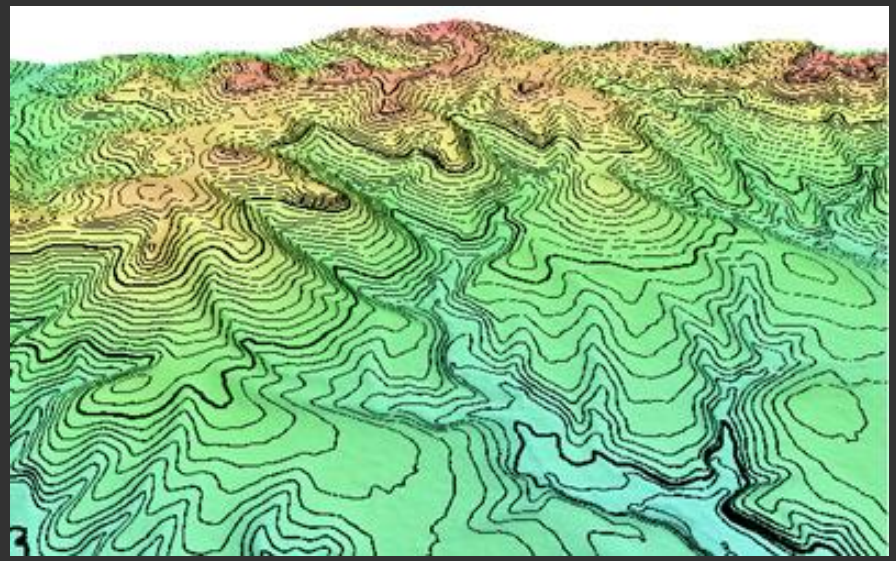

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TERRAIN VARIABLES

Variable	Description	Importance
Height	Elevation above base	Temperature, vegetation, visibility
Slope	Rise relative to horizontal distance	Water flow, flooding, erosion, travel cost, construction
Aspect	Downhill direction of steepest slope	Temperature, vegetation, soil characteristics and moisture
Flow length	Longest upstream flow path to a point	Sediment and erosion rates
Profile Curvature	Curvature parallel to slope direction	Erosion, water flow acceleration
Plan curvature	Curvature perpendicular to slope direction	Water flow convergence, soil water, erosion
Visibility	Site obstruction from given viewpoints	Utility location, viewshed preservation

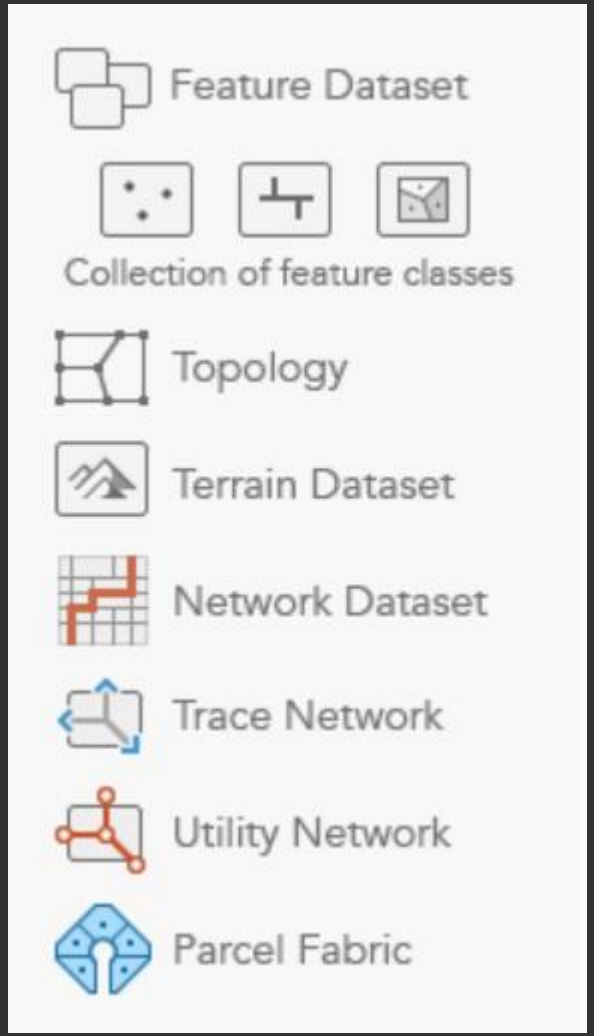
A subset of commonly used terrain varibales. Paul Bolstad, GIS Fundamentals (adapted from Moore et al., 1993)

ESRI TERRAIN DATASET

A TIN based terrain data format

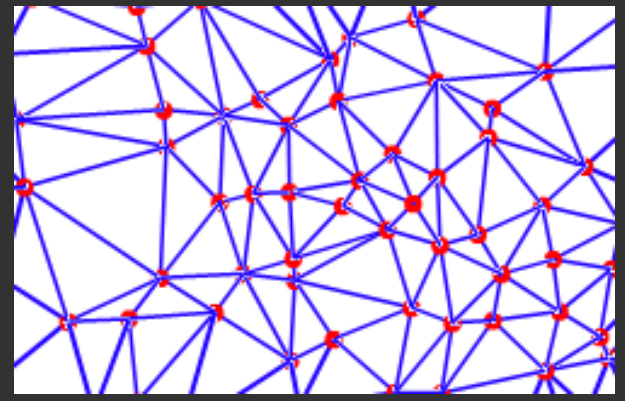
TERRAIN DATASET

- ESRI native format
- A multiresolution, TIN-based surface built from measurements stored as features in a geodatabase
- Typically made from LiDAR, Sonar, and photogrammetric sources (aerial triangulation, structure-from-motion, stereo images)
- Terrains reside in the geodatabase, inside feature datasets with the features used to construct them
- Terrains have participating feature classes and rules, similar to topologies
- Terrains use pyramids to represent multiple levels of resolution



BENEFITS

- Ability to store and manage vector-based terrain information in the geodatabase
- Scalable and seamless; collections can reach into the billions of points
- Terrain pyramids enable appropriate subsets, based on area of interest and accuracy requirements, to be retrieved quickly through optimized database queries
- The ability to be modified over time
- Edits are local and do not require rebuilding the entire model
- A capable platform for DEM production
- High-quality interpolation designed to handle a wide variety of input data types



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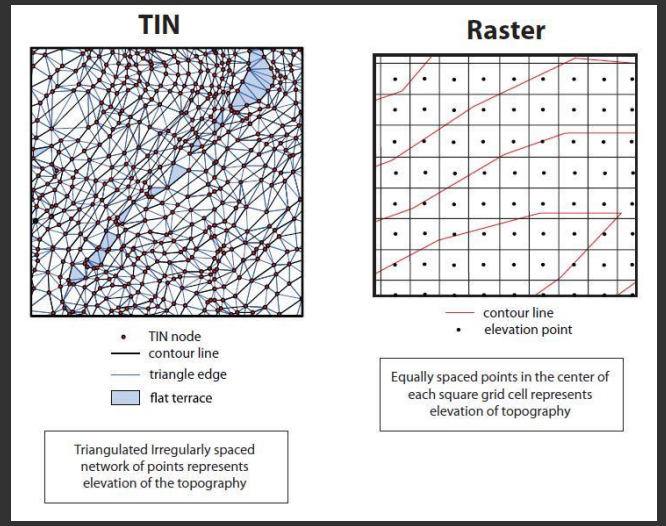
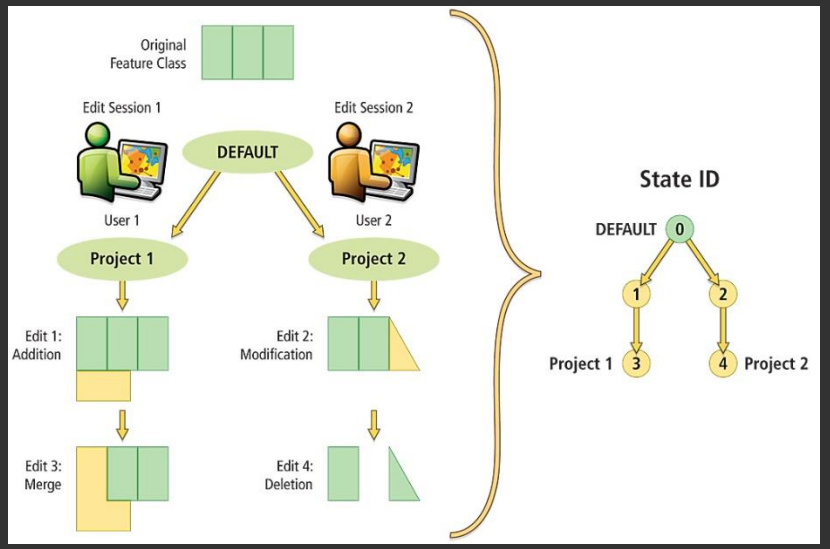


serc.carleton.edu

BENEFITS (CONTD.)

- In ArcSDE, terrains can be versioned; as with other data types, versioning offers a powerful approach for editing data and deriving what-if scenarios in multiuser environments
- Terrain layer for interactive display and query of the terrain surface; the layer's surface representation updates itself automatically as you pan and zoom around the display; TINs are built on the fly based on measurements and level of detail (LOD) information stored in the geodatabase
- Supported geometry: Points, Multipoints, Lines, Polygons
- Supported data types: Stereo-captured photogrammetric features, Bare earth LiDAR, First/All return Lidar, Sonar data



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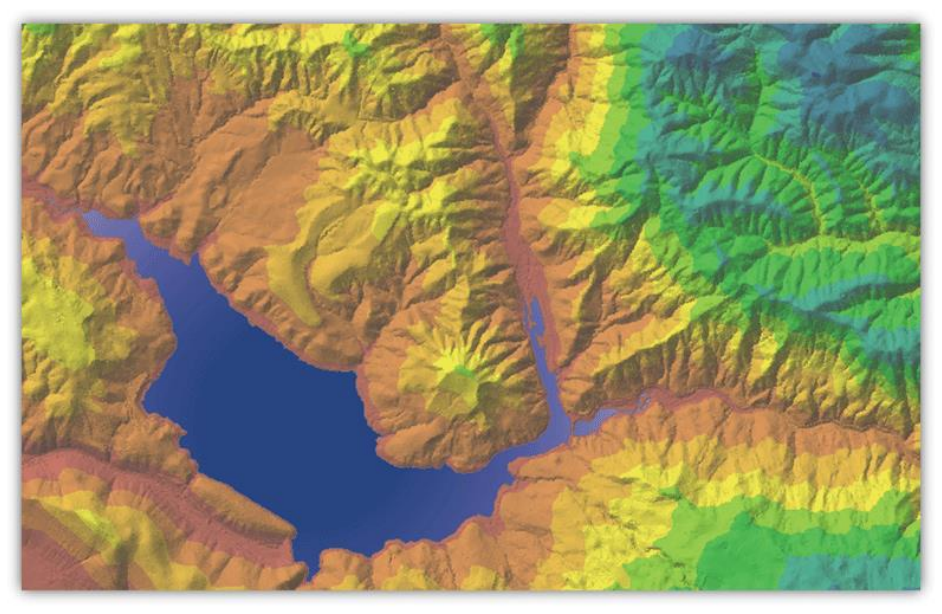
TERRAIN DATASET



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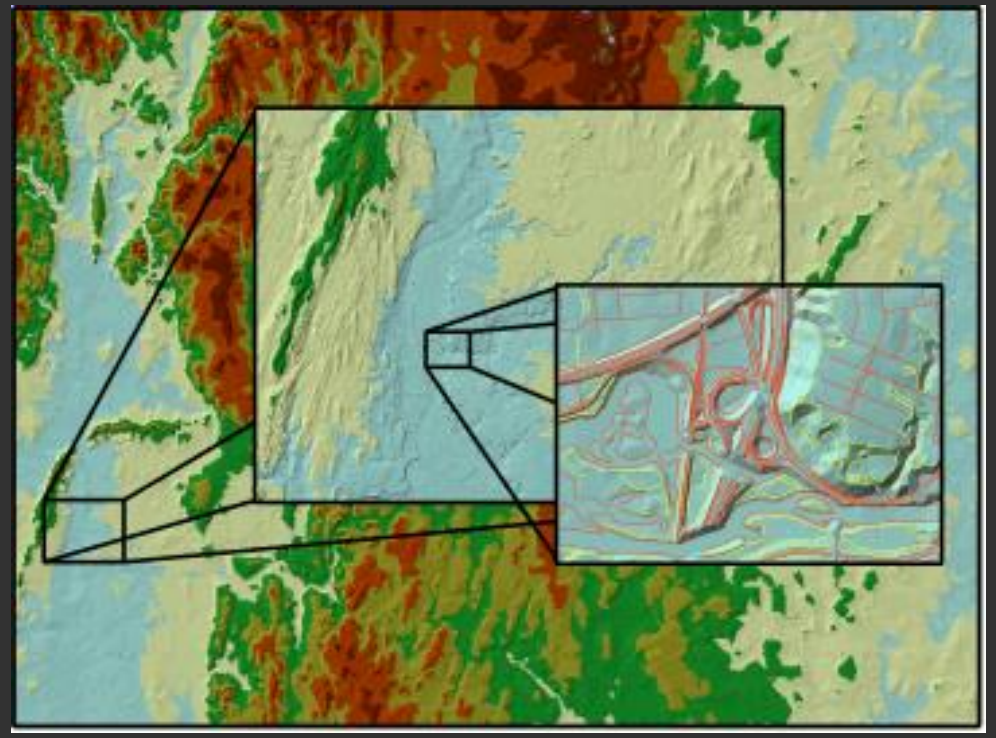

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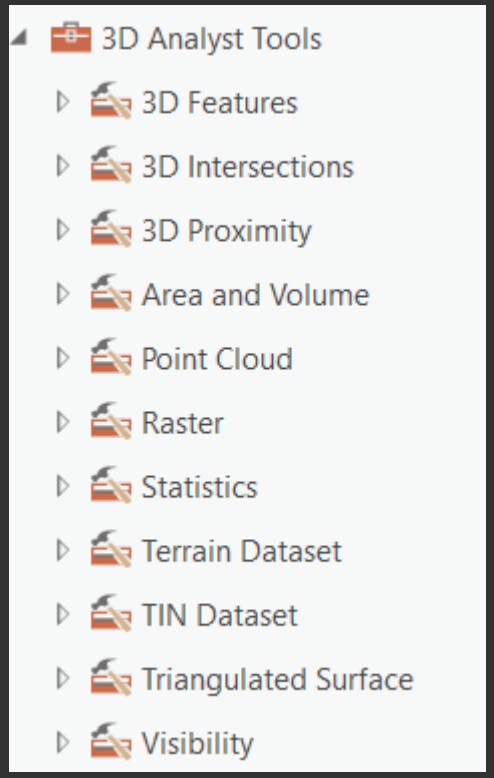
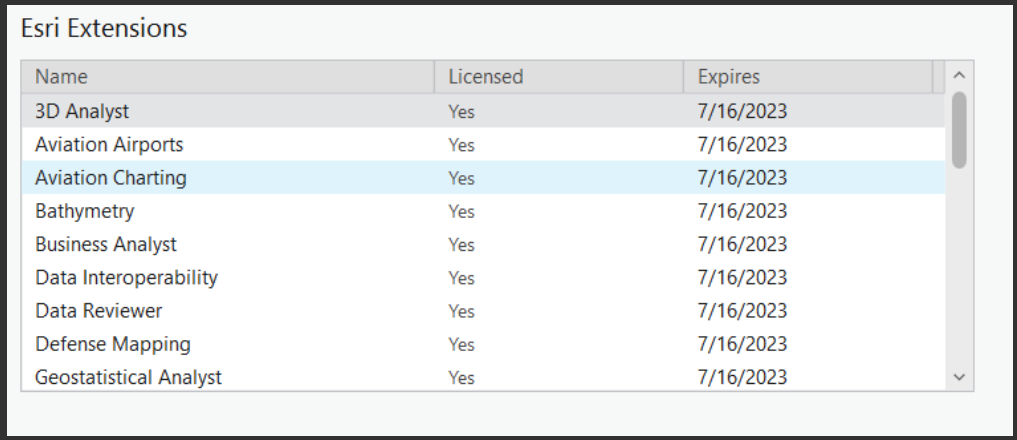
3D ANALYST

Data visualization and analysis in 3D

3D ANALYST EXTENSION

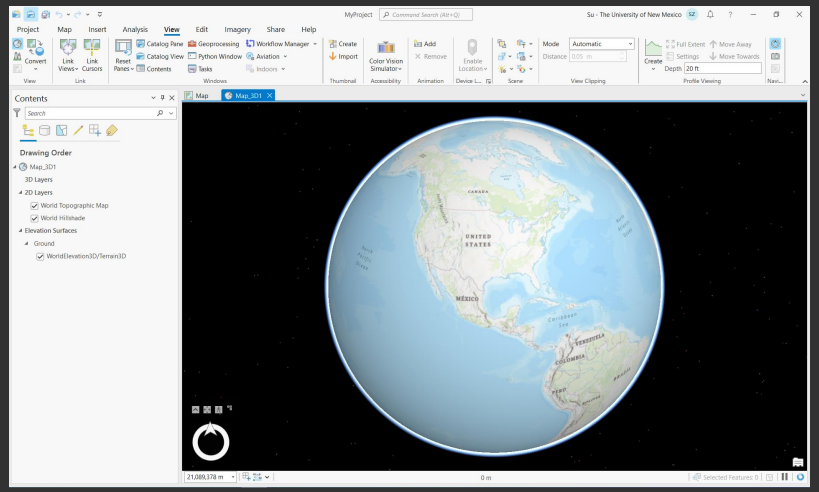
- The ArcGIS 3D Analyst extension provides tools for creating, visualizing, and analyzing GIS data in a 3D context
- 3D Analyst tools provide the ability to create and analyze surface data represented in raster, terrain, triangulated irregular network (TIN), and LAS dataset formats
  - Conversion
  - Functional Surface
  - Triangulated Surface
  - Visibility
  - More…

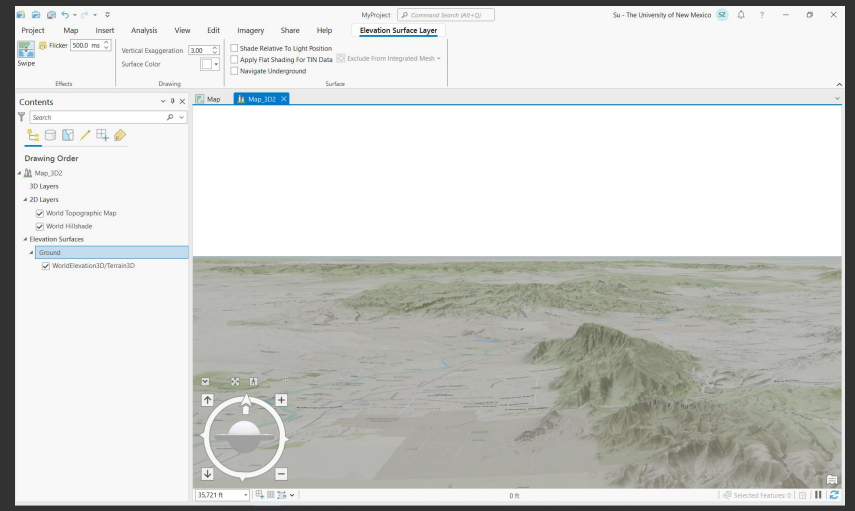




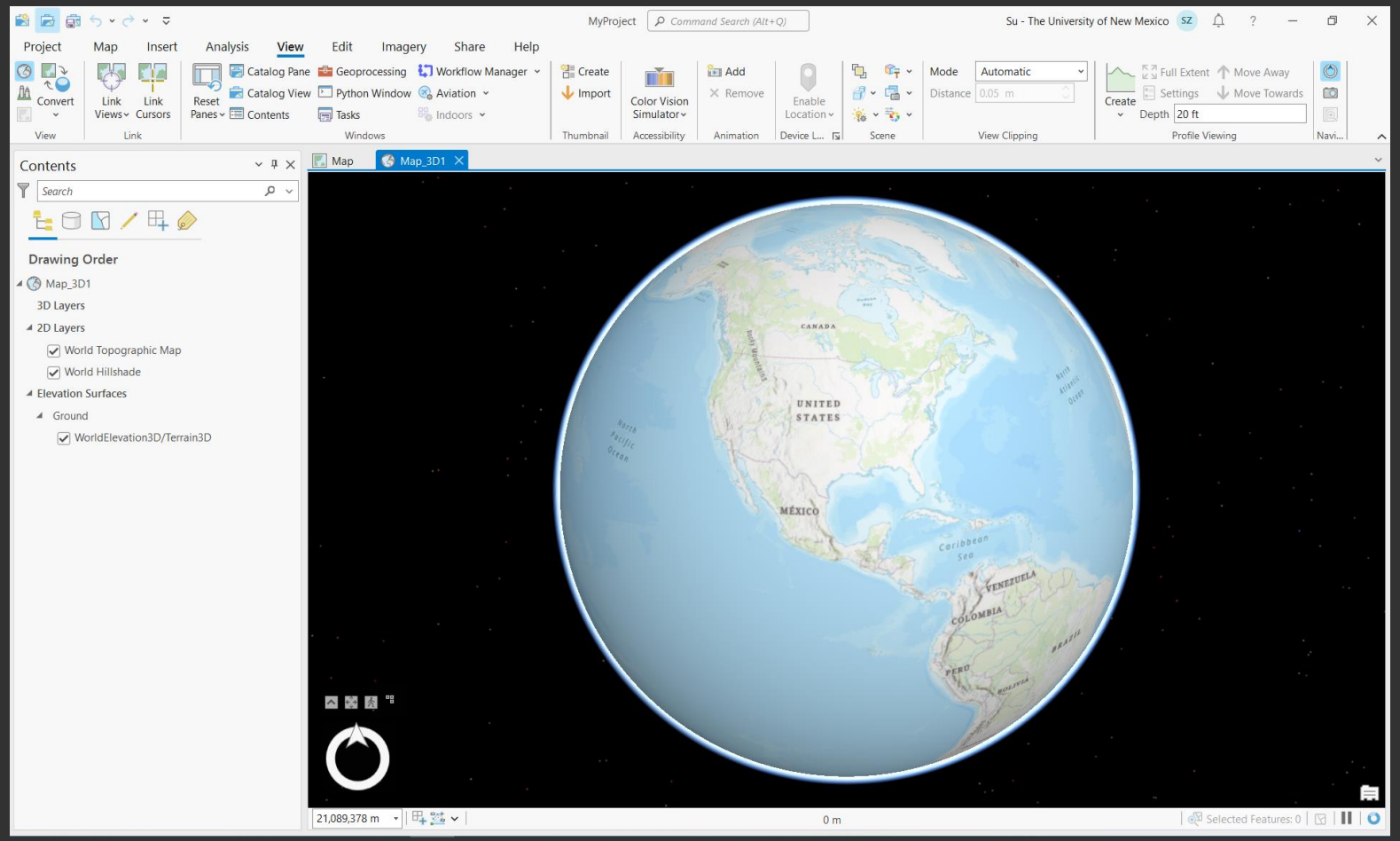
GLOBAL SCENE VS. LOCAL SCENE

- Global Scene allows to view GIS data on a 3D globe
- Local Scene allows to view GIS data within a 3D planimetric view

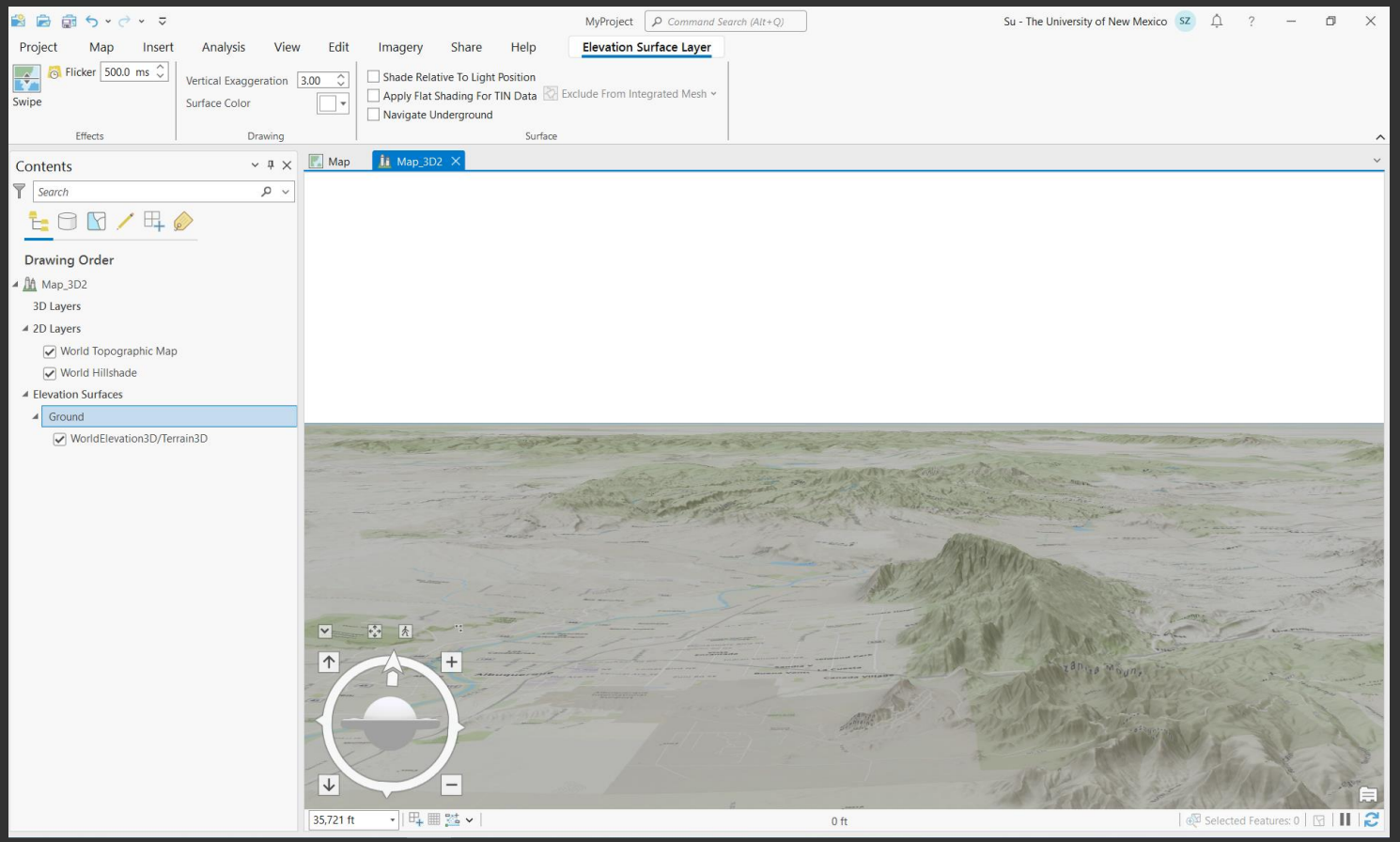




GLOBAL SCENE



LOCAL SCENE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Surface Color
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Shade Relative To Light Position
Apply Flat Shading For TIN Data
Exclude From Integrated Mesh
Navigate Underground
Surface
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3D Layers
2D Layers
World Topographic Map
World Hillshade
Elevation Surfaces
Ground
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0 ft
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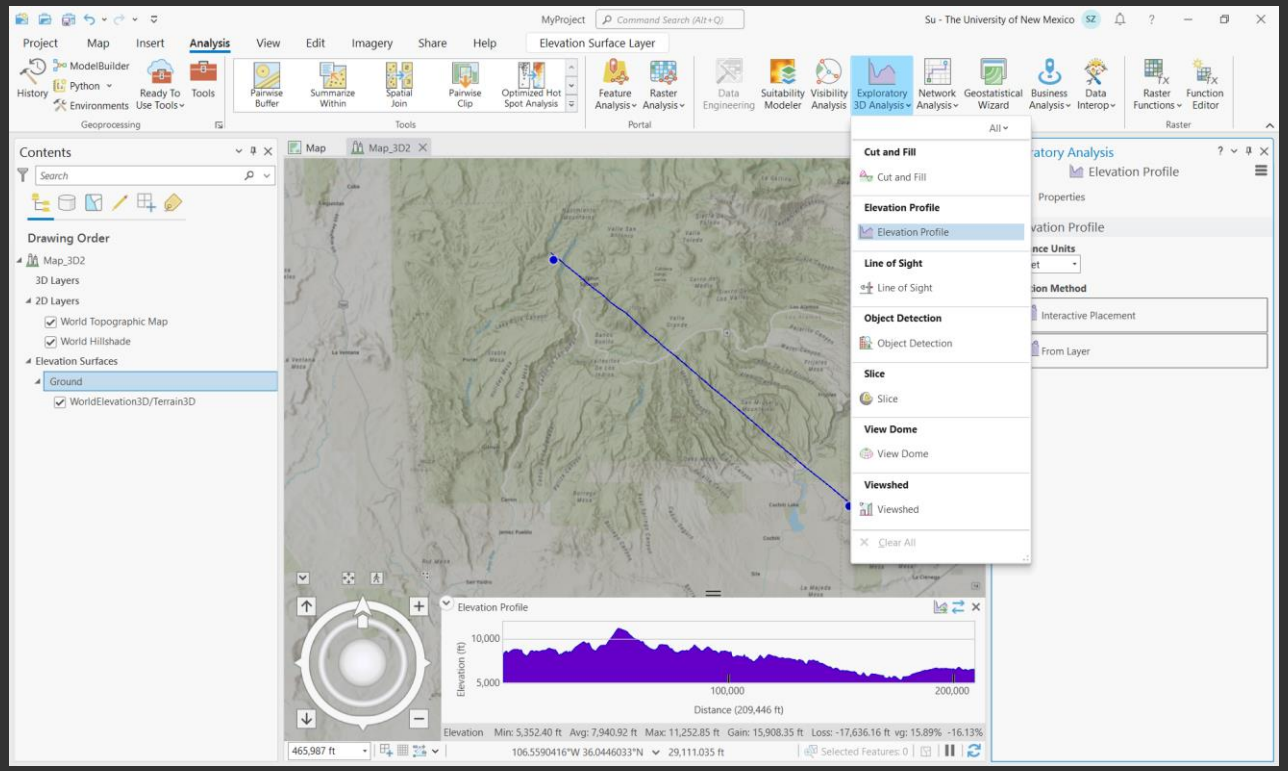
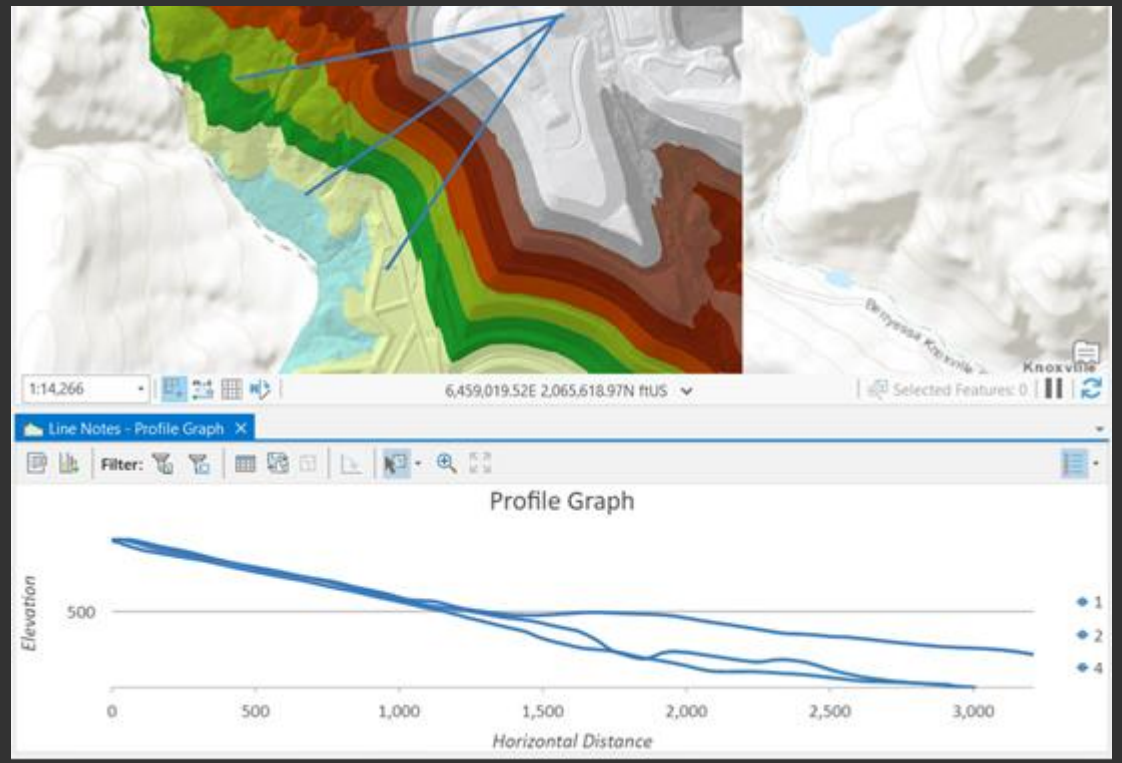
EXPLORATORY 3D ANALYSIS

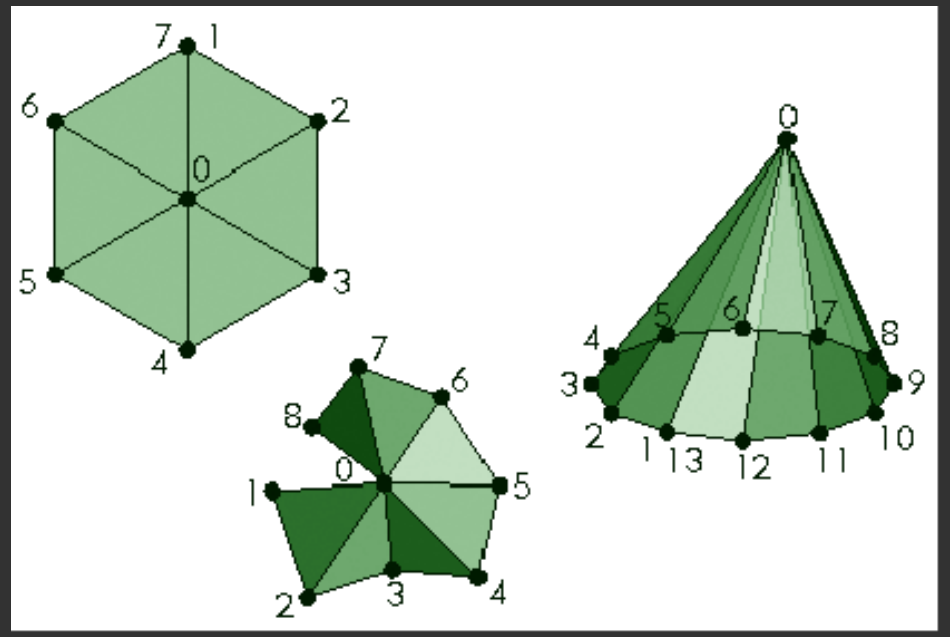




pro.arcgis.com

3D DATA

- Features
  - 3D point – underground subway stations, locations of aircraft,…
  - 3D polyline – underground transportation lines, aircraft flight paths,…
  - 3D polygon – building footprints, street curbs,…
  - Multipatches - a GIS object that stores a collection of patches to represent the boundary of a 3D object as a single row in a database; Patches store texture, color, transparency, and geometric information representing parts of a feature
- Surfaces
  - Raster
  - TIN
  - Terrain dataset
  - LAS dataset



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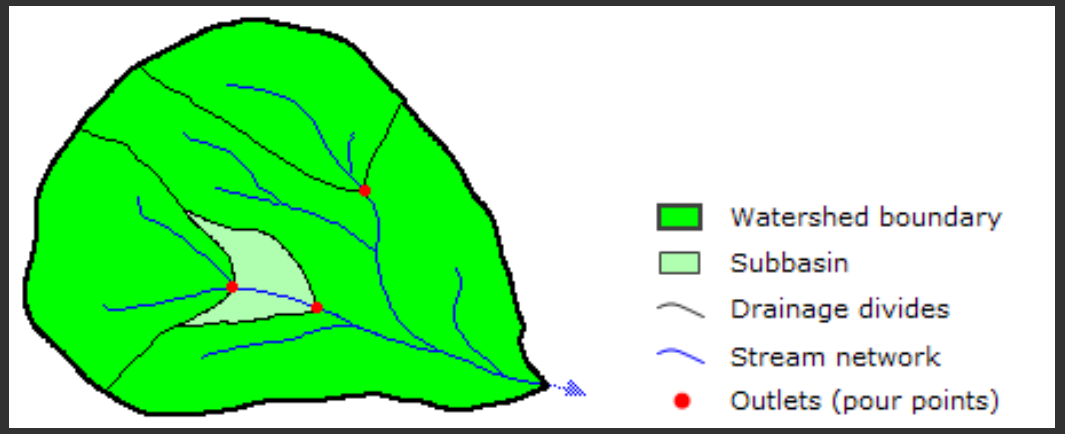
HYDROLOGY TOOLS

Model the flow of water across a surface

WATERSHED AND DRAINAGE

- Watershed
  - An area that contributes flow to a point on the landscape
  - The uphill area that drains to any point on a landscape is the watershed for that point
  - Also called as basins, catchments, …
- Drainage network
  - A set of cells through which surface water flows
  - Based on the flow direction surface
  - Streams, creeks, and rivers occur where flow directions converge



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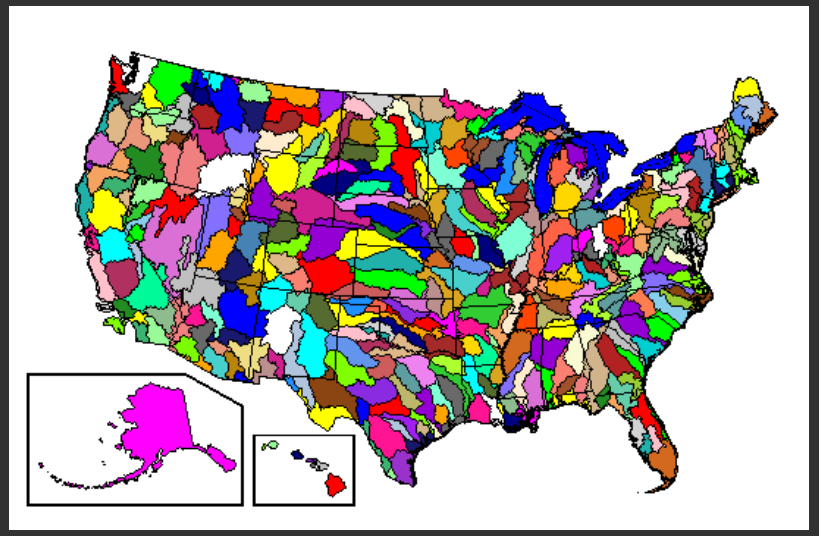

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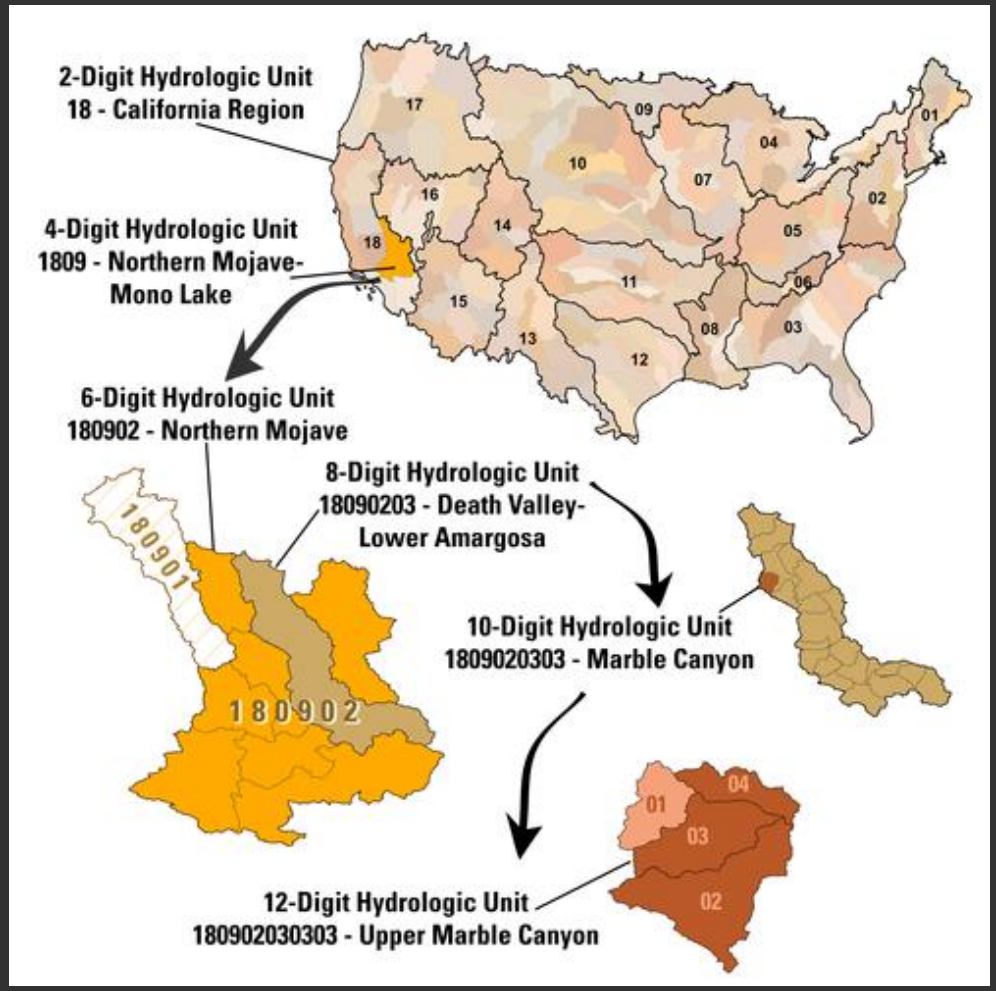
HYDROLOGIC UNIT CODE (HUC)

- A hierarchical hydrologic unit code (HUC) consisting of 2 additional digits for each level in the hydrologic unit system is used to identify any hydrologic area
- Each hydrologic unit is assigned a 2-digit to 12-digit number that uniquely identifies each of the six levels of classification within six two-digit fields. An example is shown below using hydrologic unit code 180902030303



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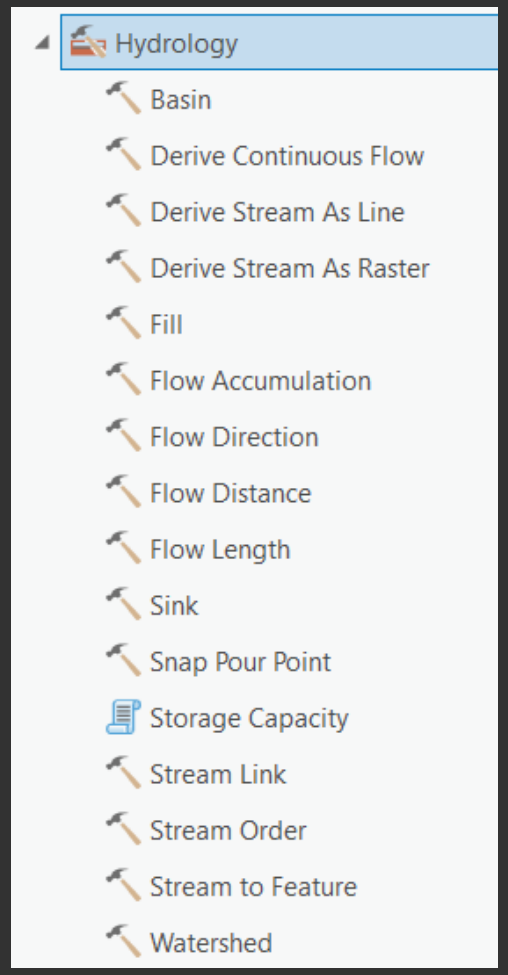
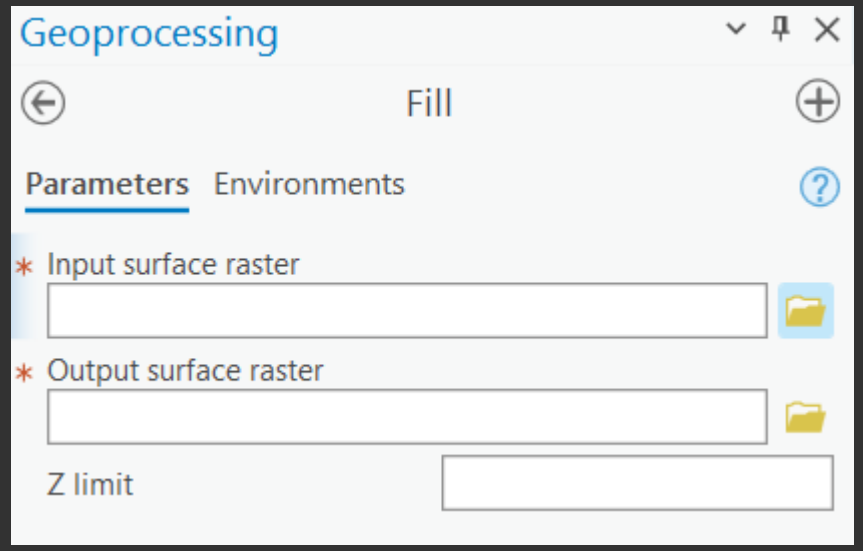
HYDROLOGY TOOLS

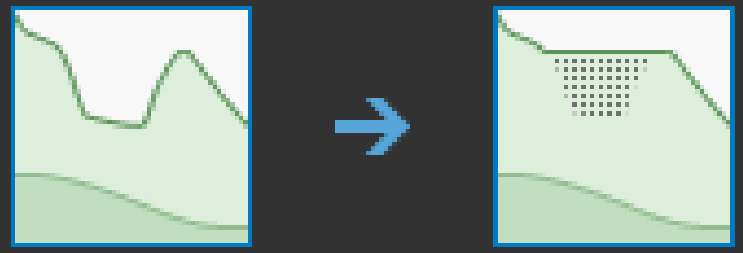


- Fill
- Flow Direction
- Flow Accumulation
- Flow Length
- Flow Distance
- Basin
- Watershed

HYDROLOGY TOOLS

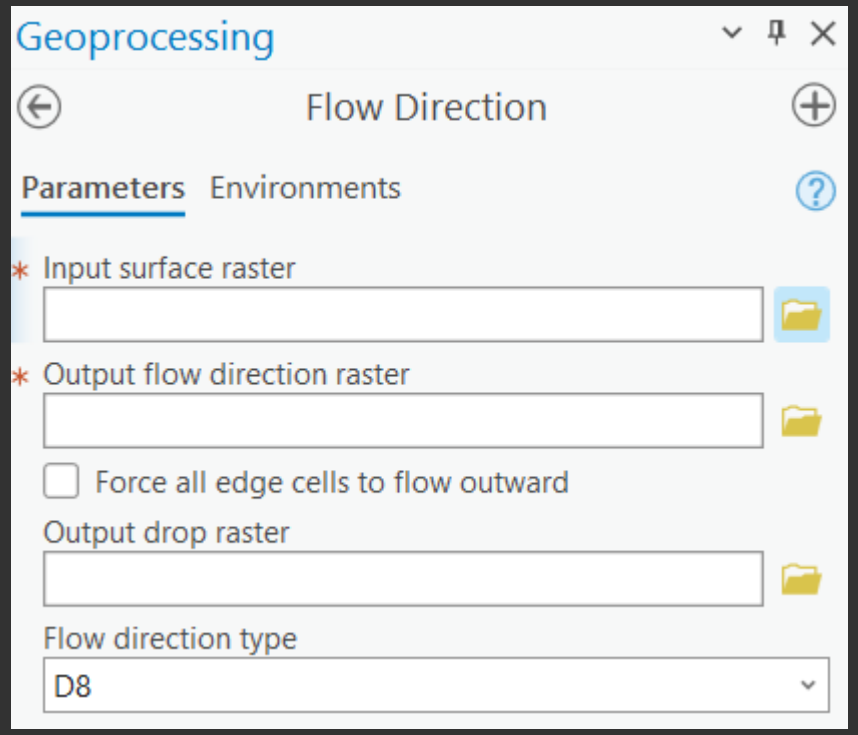
Fills sinks in a surface raster to remove small imperfections in the data

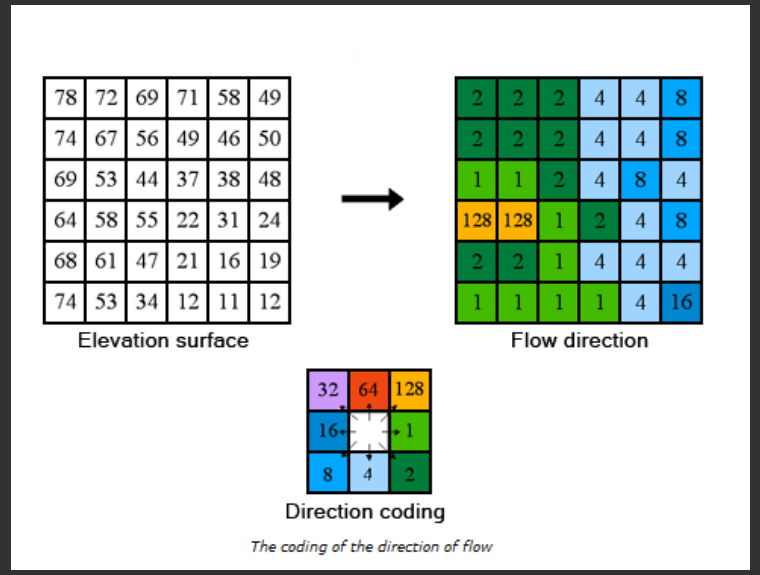




HYDROLOGY TOOLS

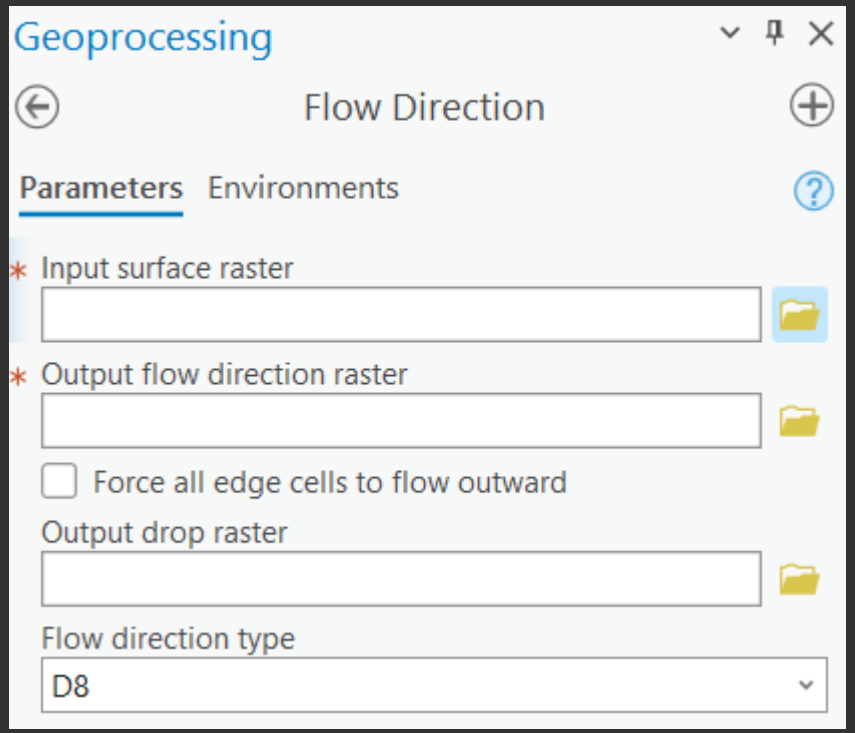
Creates a raster of flow direction from each cell to its downslope neighbor, or neighbors, using D8, Multiple Flow Direction (MFD) or D-Infinity (DINF) methods

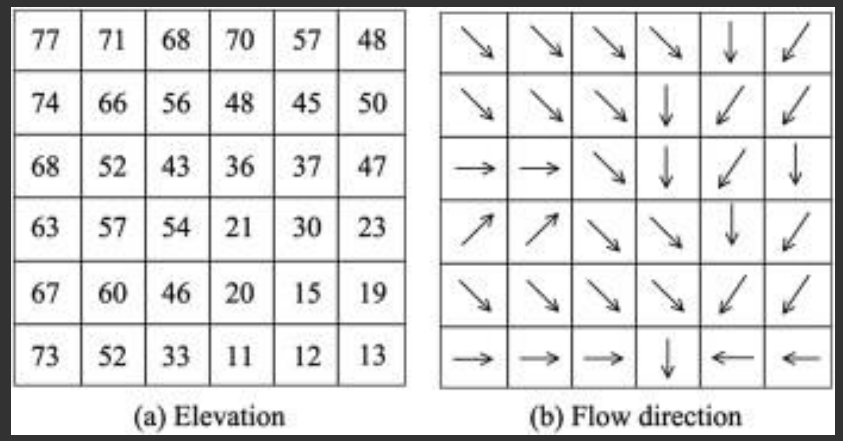




FLOW DIRECTION

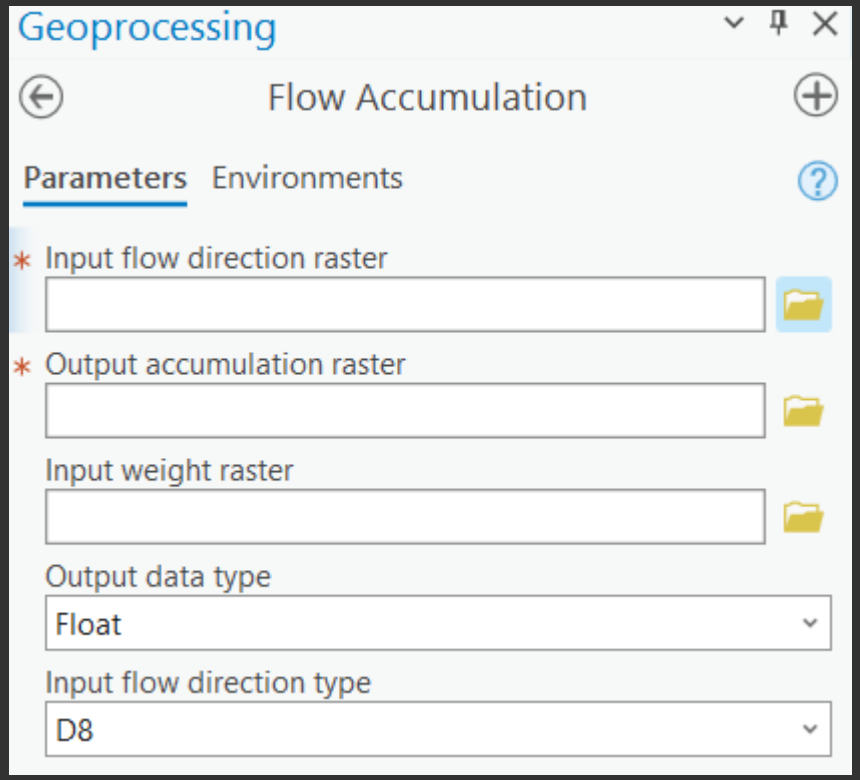
Calculated by estimating the aspect

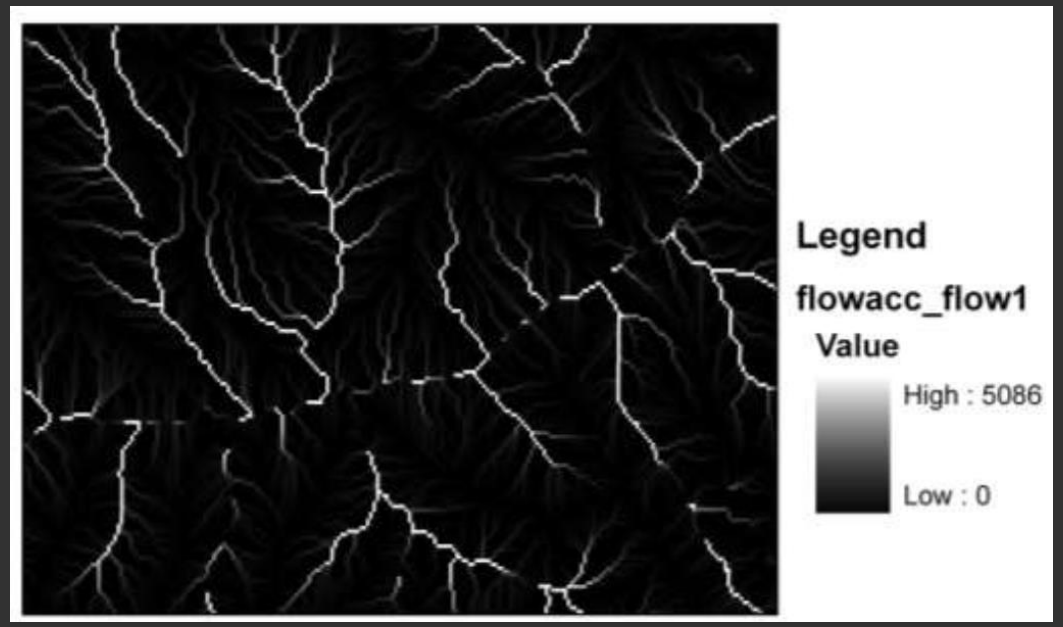




FLOW ACCUMULATION

Creates a raster of accumulated flow into each cell; a weight factor can optionally be applied

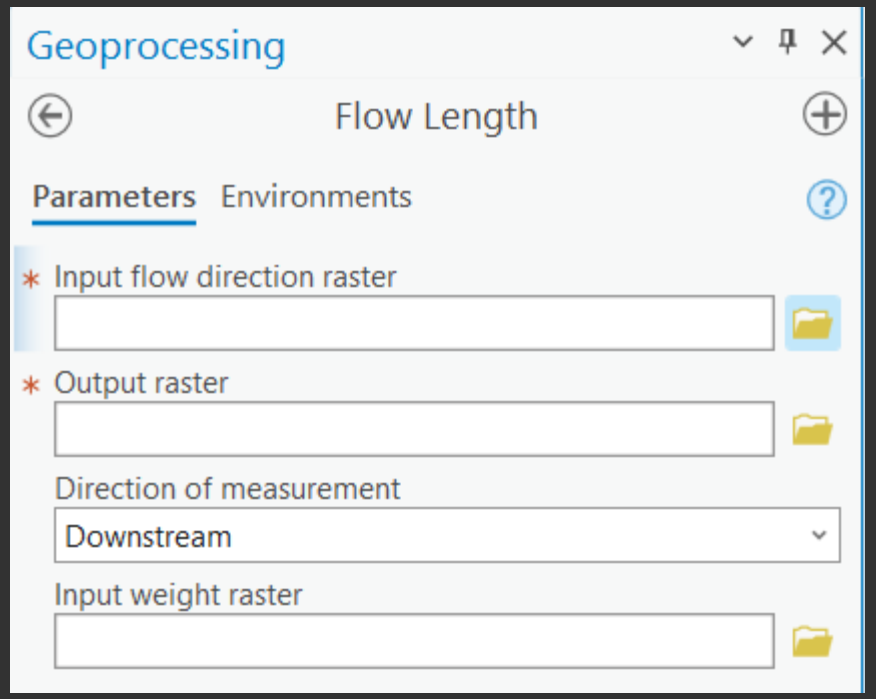


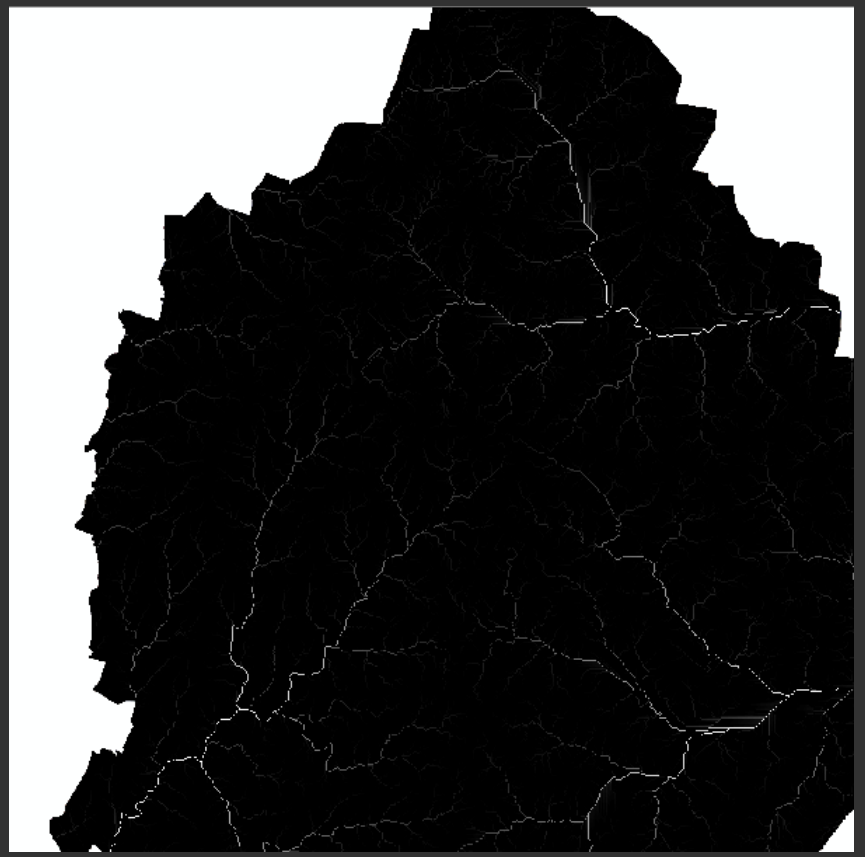


Archarjee and Sarma 2011

FLOW LENGTH

Calculates the upstream or downstream distance, or weighted distance, along the flow path for each cell





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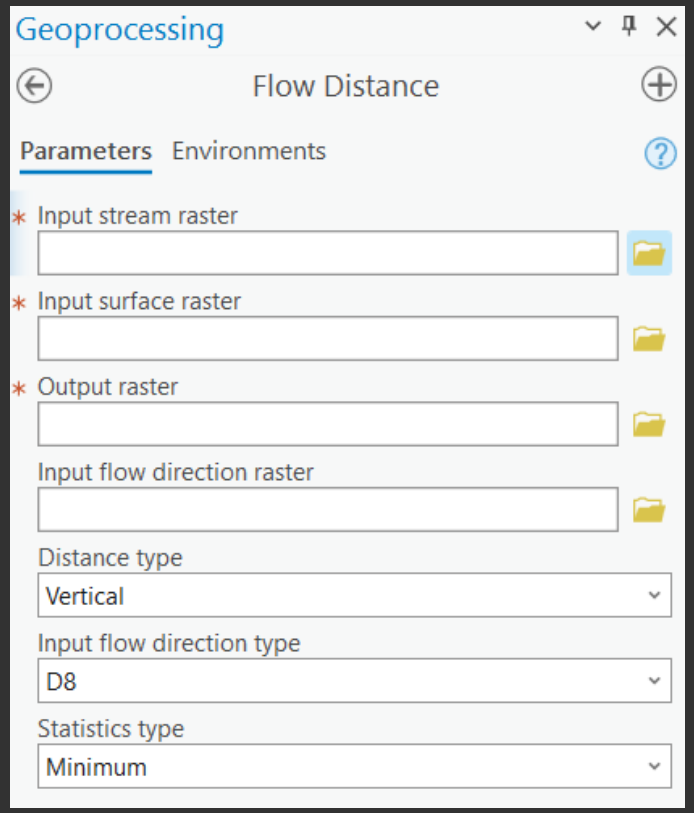
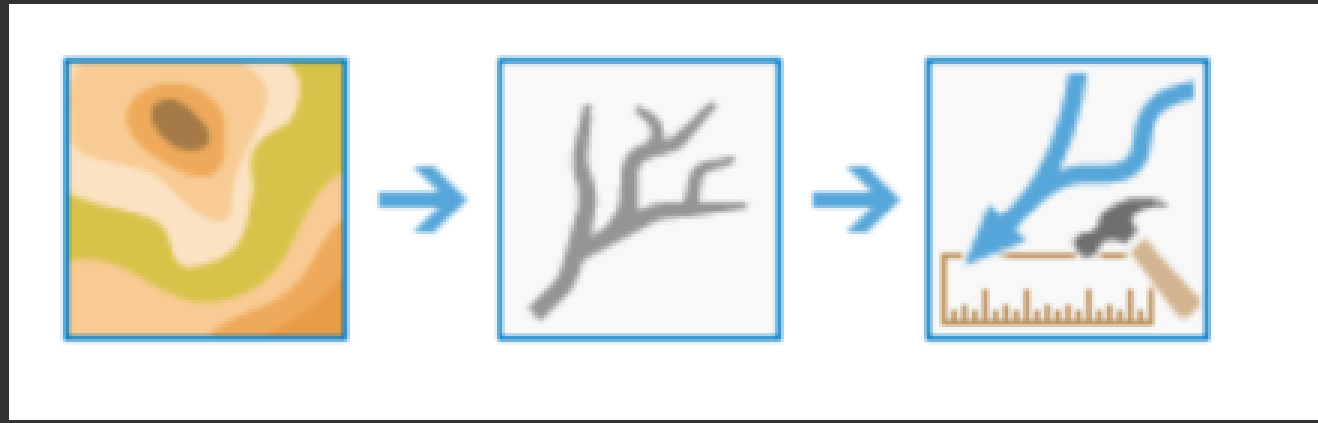
FLOW DISTANCE

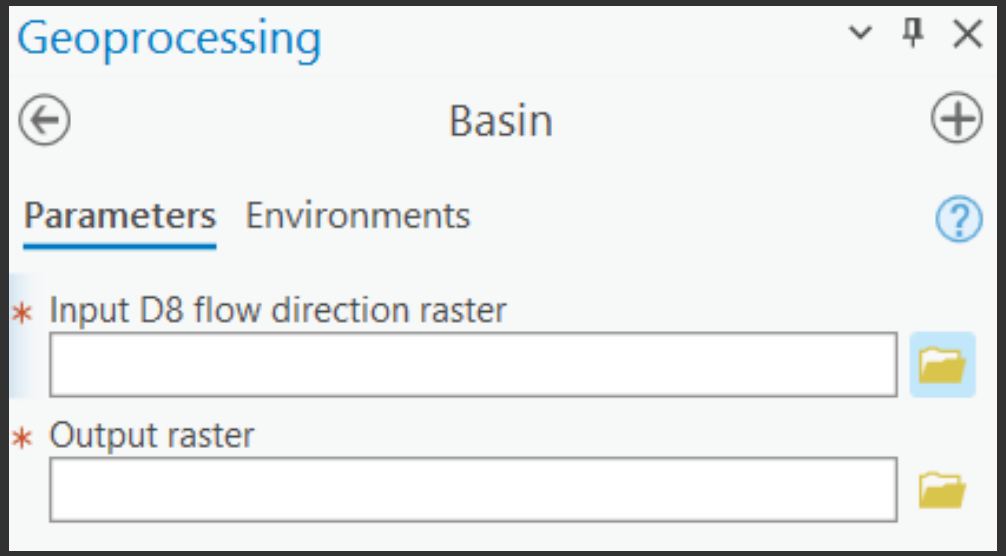
Computes, for each cell, the horizontal or vertical component of downslope distance, following the flow path(s), to cell(s) on a stream into which they flow





BASIN

Creates a raster delineating all drainage basins



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WATERSHED

Determines the contributing area above a set of cells in a raster