Lecture 9

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Outline

- Announcements & Updates
- Surface Analysis
  - Overview
  - Raster data
  - Spatial Interpolation
  - Distance Analysis
  - Density Analysis
  - Surface Analysis Operations

Updates

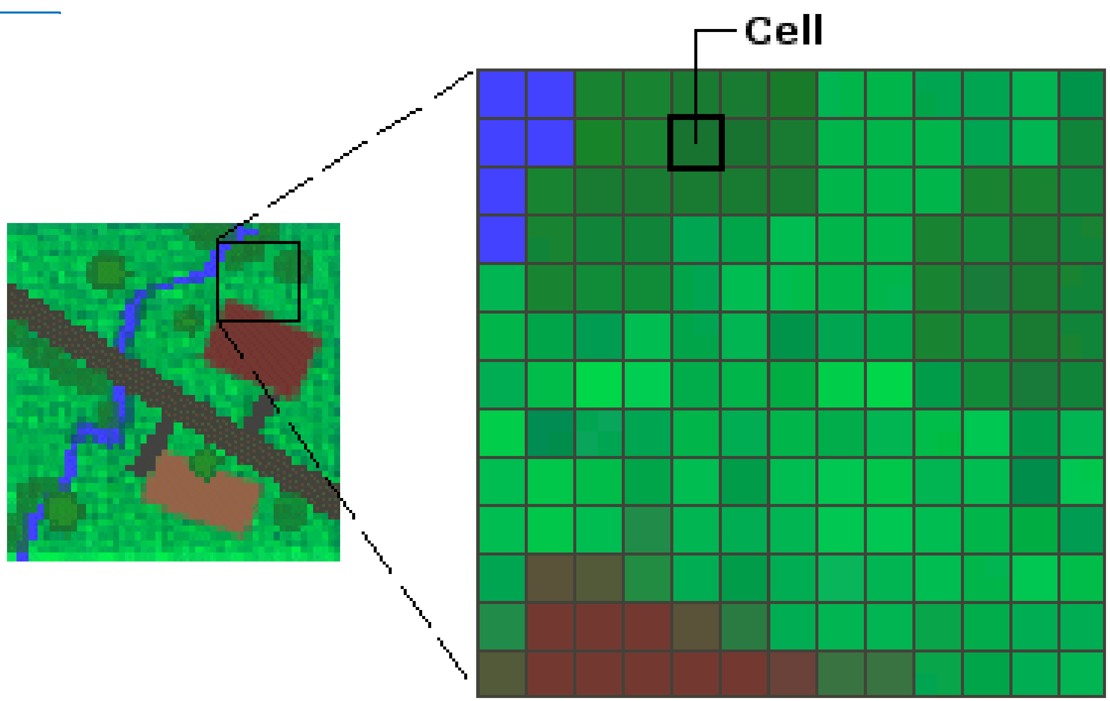
- Updates
  - Lab 5
  - Exercises
  - START Info Session: Internship Program
    - 10/13/2020, 1-2pm
    - https://www.start.umd.edu/events/virtual-information-session-internship-program-101320

Surface Analysis

- Overview
  - Surface analysis is used for identifying a specific pattern within a dataset.
    - Example: slope, aspect, viewshed

Raster Data

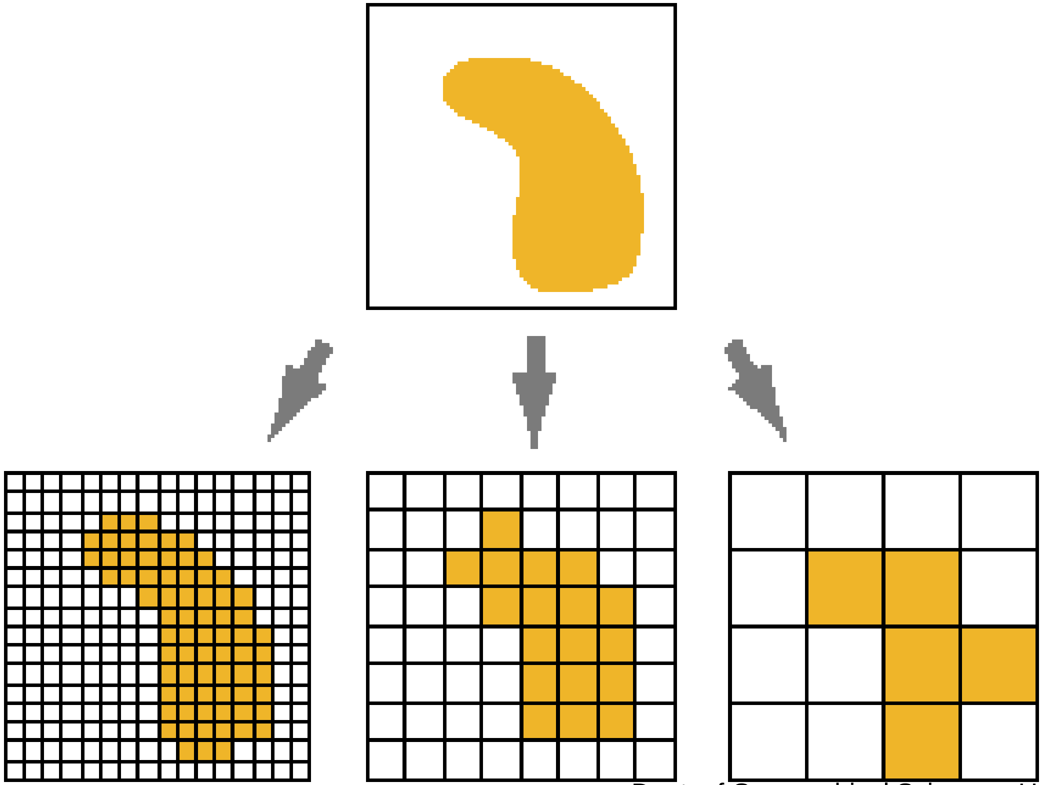
- Raster Data
  - Raster data is a matrix (grid) of cells.
  - Each cell has a width and height and is a portion of the entire area represented by the raster.



The cell size determines how coarse or fine the patterns or features in your extent will appear. The smaller the cell size, the more detail the area will have. However, the greater the number of cells, the longer it will take to process, and it will require more storage space.

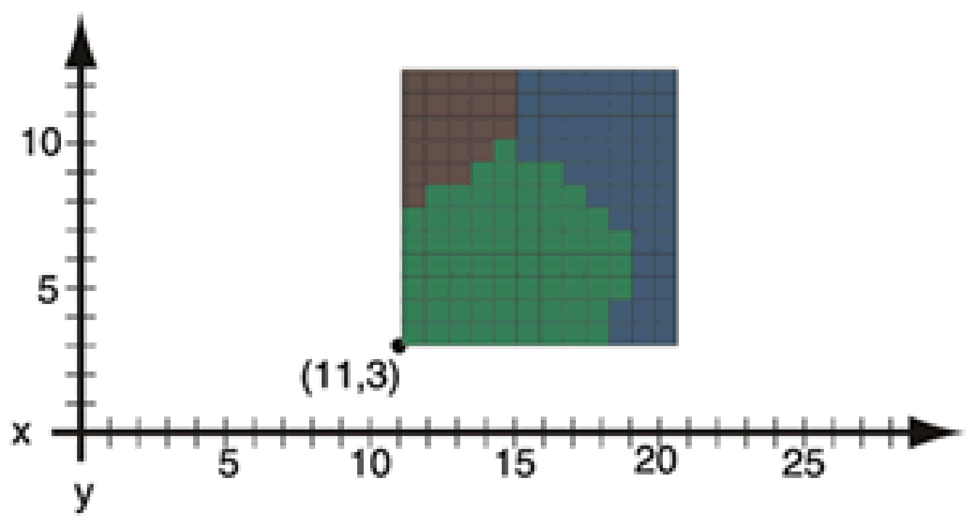
Raster Data

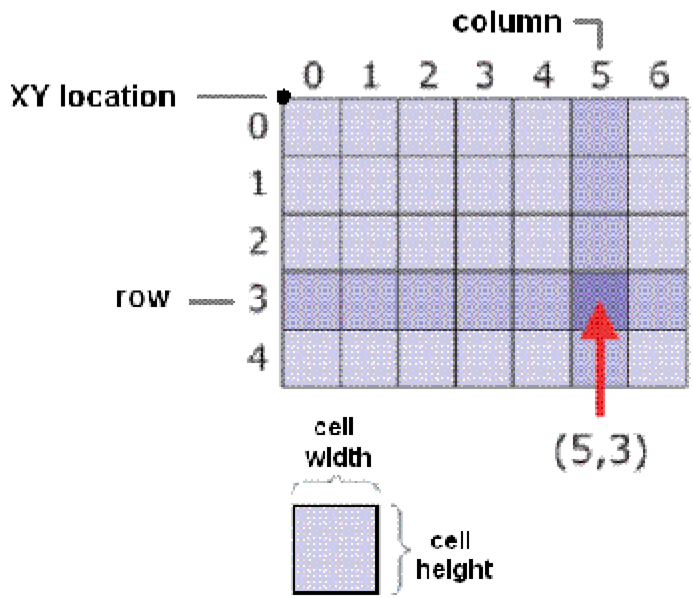
- Raster Data
  - The higher the resolution, the smaller the cell size and the greater the detail.



Raster Data

- Raster Data
  - Only one corner of the raster layer is georeferenced.
  - The location of each cell is defined by its row or column location within the raster matrix.
  - The matrix is represented by a Cartesian coordinate system, where the rows of the matrix are parallel to the x-axis and the columns to the y-axis of the Cartesian plane.





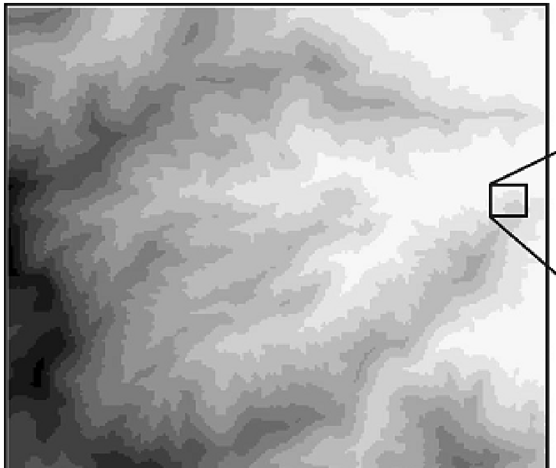
Raster Data

- Raster Data
  - Each cell has a value.
  - This value represents the property or attribute (e.g. elevation) of interest.
  - Cell values can be positive or negative, integer or floating-point, or even have a “nodata” value to represent the absence of data.

Cell with Value

66	66	49	49	52	52
66	66	49	49	44	44
66	49	52	52	52	52
66	52	50	50	82	85
74	52	50	50	82	74
74	68	80	74	85	82

Raster DEM



Detailed view of raster cells

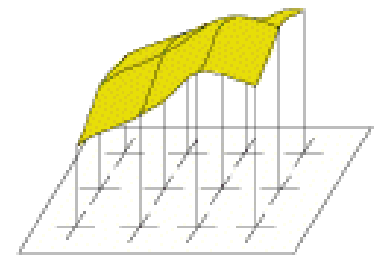
645	650	654	658	653	648
664	666	670	672	668	659
678	682	684	693	689	680
703	708	714	721	719	716
728	732	738	744	745	732
730	739	744	749	748	735

Raster Data

- Raster Data
  - The value of a cell can be determined in different ways depending on the attribute property.

Value applies to the center point of the cell

For certain types of data, the cell value represents a measured value at the center point of the cell. An example is a raster of elevation



315	319	321	323
317	323	328	326
313	318	325	323

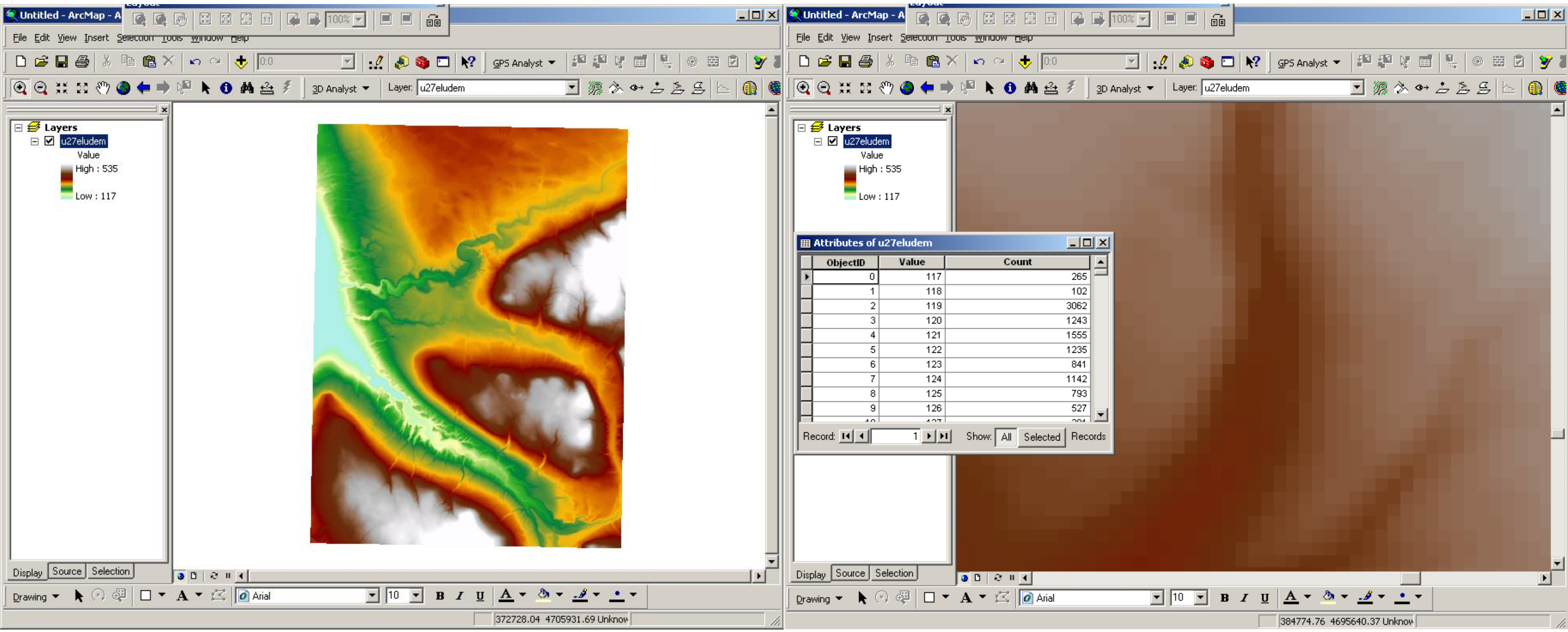
Value applies to the whole area of the cell

For most data, the cell value represents a sampling of a phenomenon, and the value is presumed to represent the whole cell square.

50	45	40	35
35	40	35	25
20	25	30	20

Raster Data

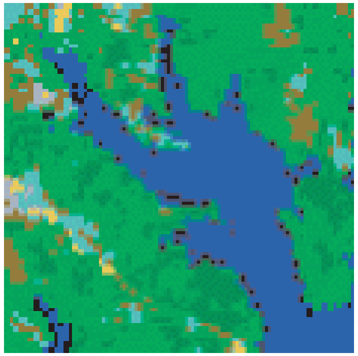
- Raster Data
  - Example: DEM



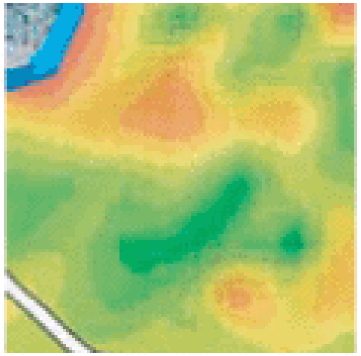
Raster Data

- Raster Data
  - Example: imagery

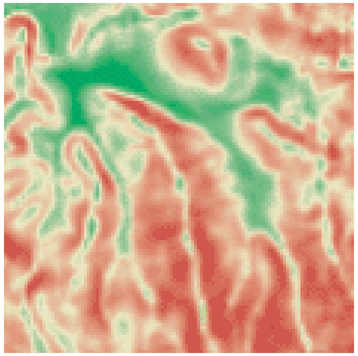
Photography



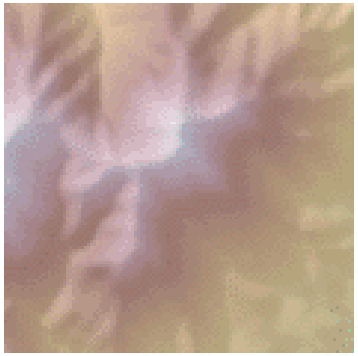
Land Use



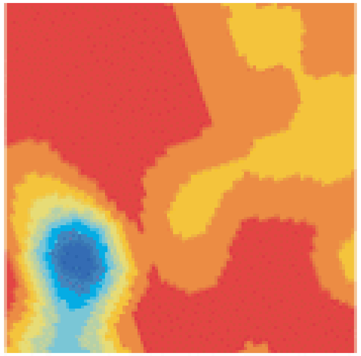
Concentration



Slope



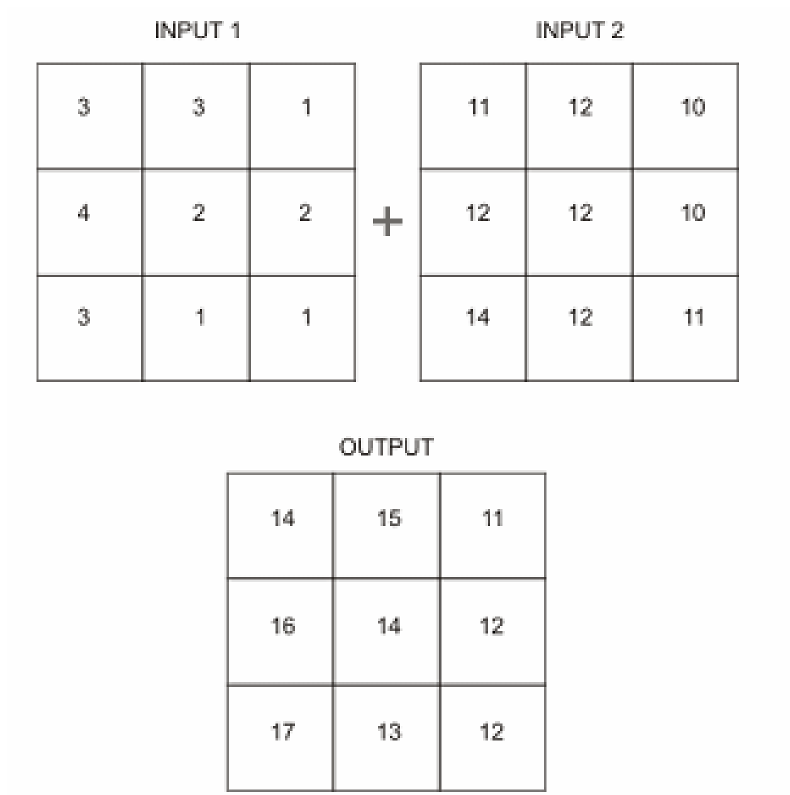
Elevation



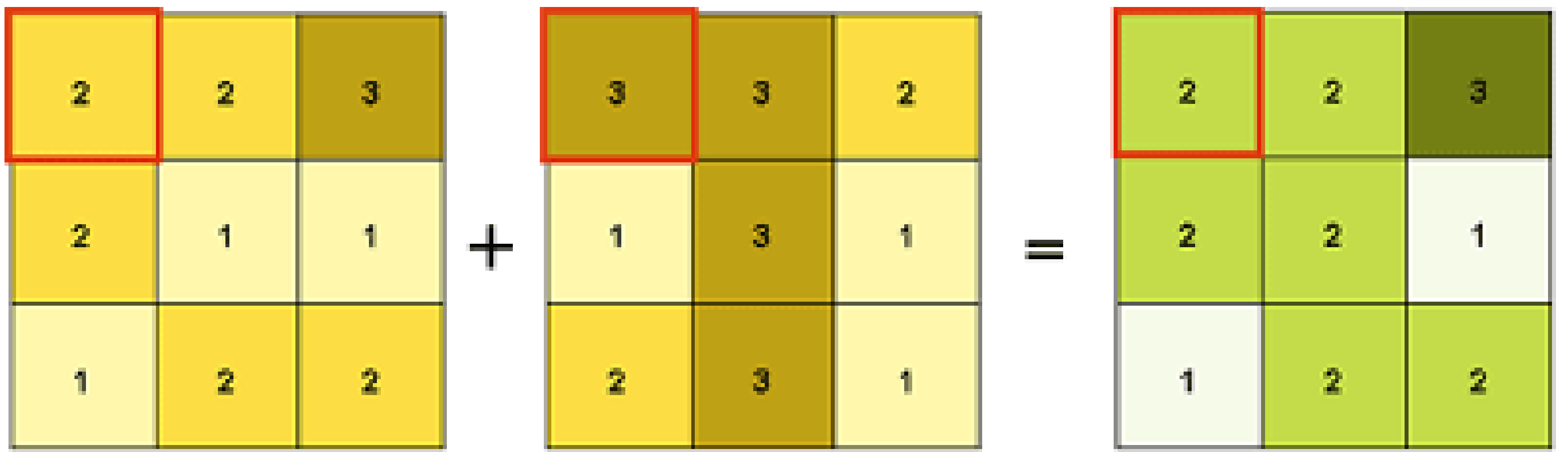
Population

Raster Data

- Raster Data
  - Overlay Analysis
    - Simple addition: Grid_A + Grid_B = Grid_C

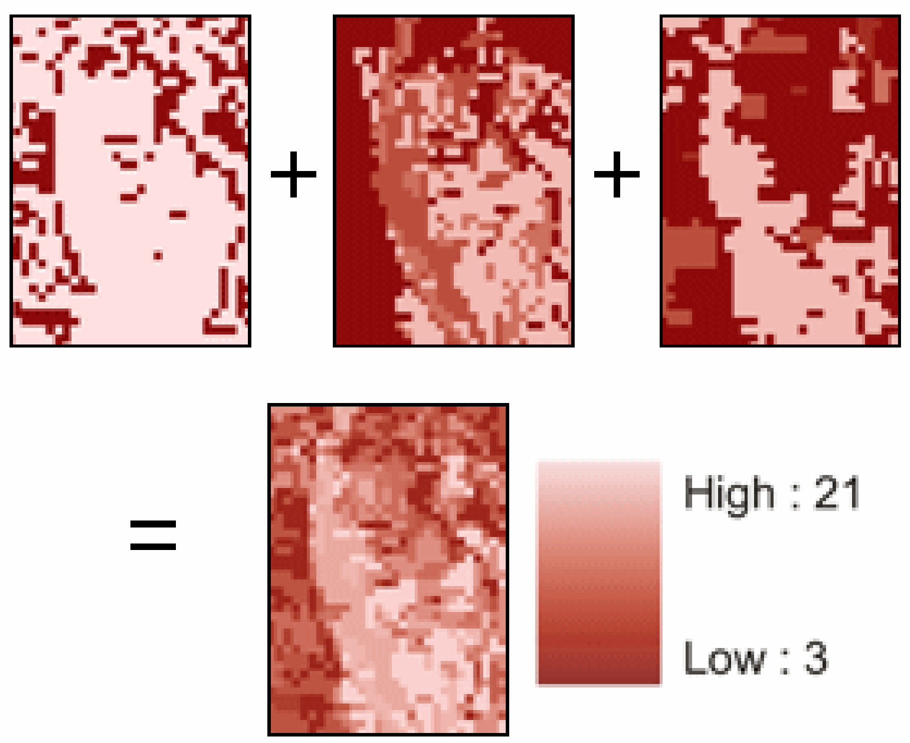


- Raster Data
  - Overlay Analysis
    - Weighted addition: 0.75*Grid_A + 0.25*Grid_B = Grid_C



Raster Data

- Raster Data
  - Overlay Analysis
    - Multiple input layers
      - Typically used in suitability analysis



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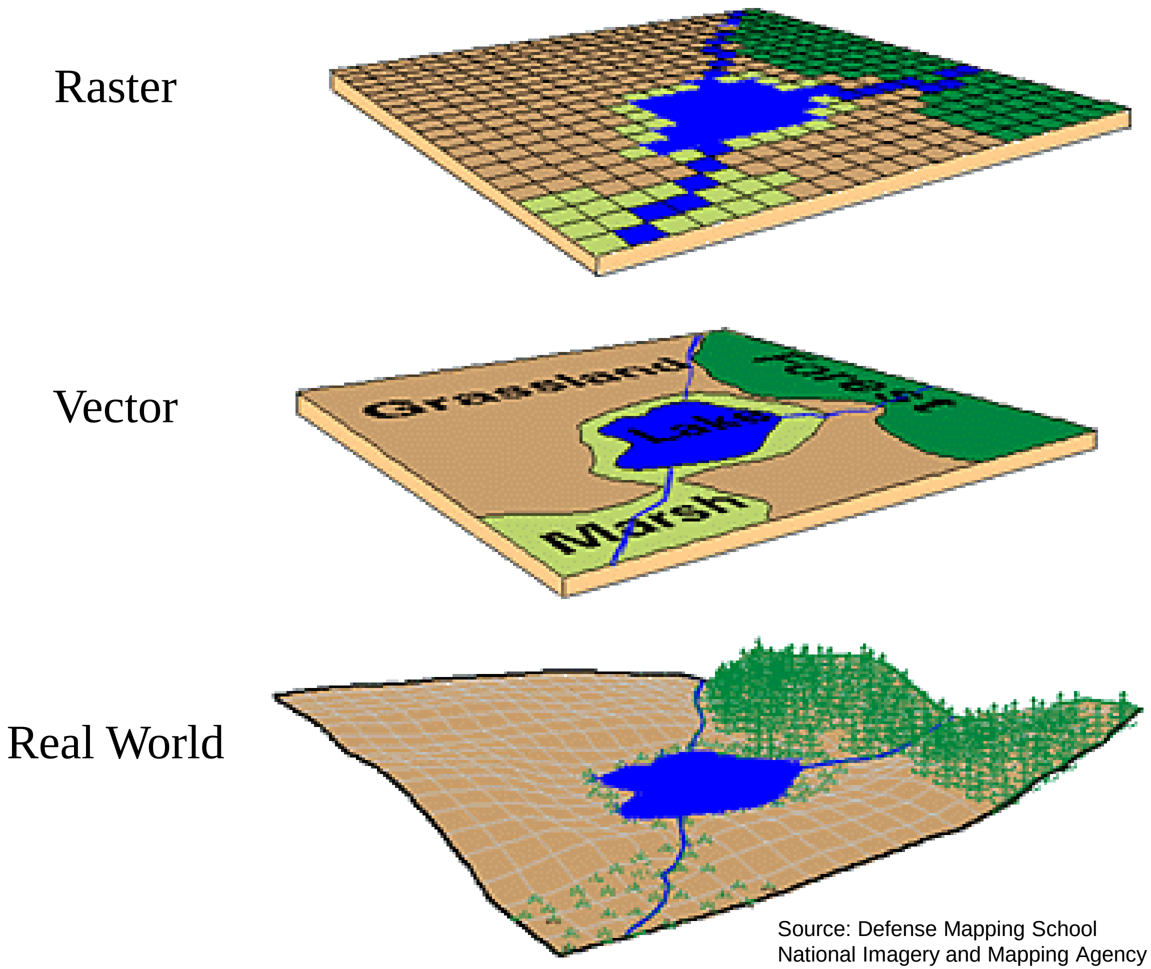
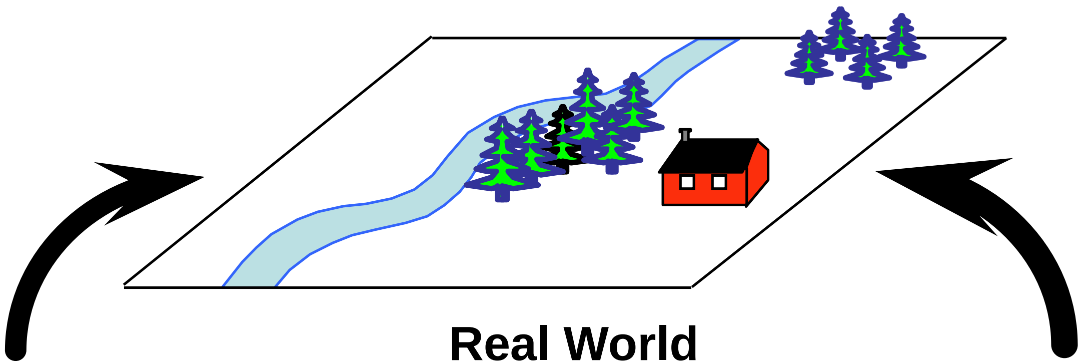
Raster Data

- Vector vs. Raster



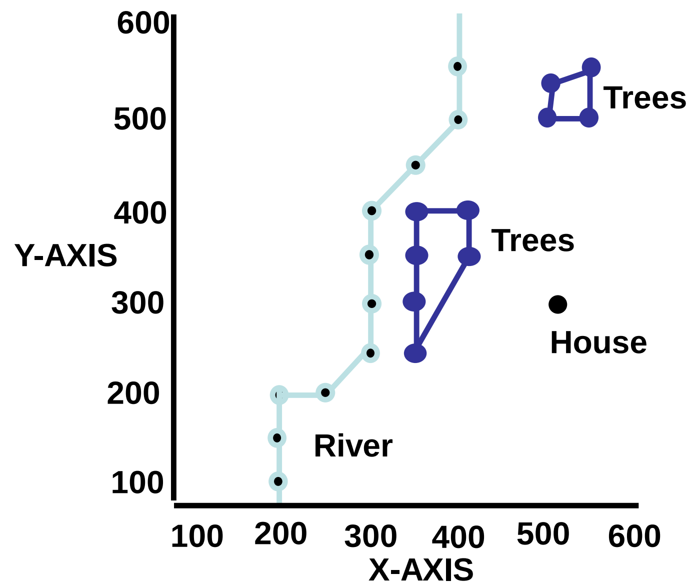
Raster Data

- Vector vs. Raster



	1	2	3	4	5	6	7	8	9	10
1							B			G
2							B		G	G
3						B				
4					B	G	G			
5					B	G	G			
6					B	G			BK	
7					B	G				
8			B	B						
9			B							
10			B							

Raster Representation



Vector Representation

Source: Defense Mapping School
National Imagery and Mapping Agency

Raster Data

- Vector vs. Raster
  - Vector Data Model
    - Advantages / Strengths
      - Good representation of reality
      - Compact data structure
      - Topology can be described in a network
      - Accurate graphics
    - Disadvantages / Limitations
      - Complex data structure
      - Simulation can be difficult
      - Representation of high spatial variability is inefficient.
      - Some spatial analysis is difficult or impossible to perform.

Raster Data

- Vector vs. Raster
  - Raster Data Model
    - Advantages / Strengths
      - Simple data structure
      - Easy and efficient overlay operations.
      - Good for various kinds of spatial or statistical analyses
      - The ability to represent continuous surfaces and perform surface analysis.
      - The ability to uniformly store points, lines, polygons, and surfaces.

Raster Data

- Vector vs. Raster
  - Raster Data Model
    - Disadvantages / Limitations
      - Inherent spatial inaccuracies due to the cell-based feature representation (approximation).
      - Large amount of data (smaller cell size means larger data file)
      - Information loss due to generalization

Raster Data

- Vector vs. Raster
  - Summary

Criteria	Remark
Accuracy	*Vector is more accurate.*
Storage	*Vector requires less.*
Analysis	*Vector is more complicated.*
Speed	*Depends on the specific task and the size of area.*
Data Sources	*Raster has more data sources (especially remote sensing data).*
Applications	*Raster is focused on modeling while vector is more about networks.*
Cost	*Depends on the specific study.*

Raster Data

- Common Raster Data Formats
  - GRID
  - JPG
  - JP2
  - TIFF
  - MrSID

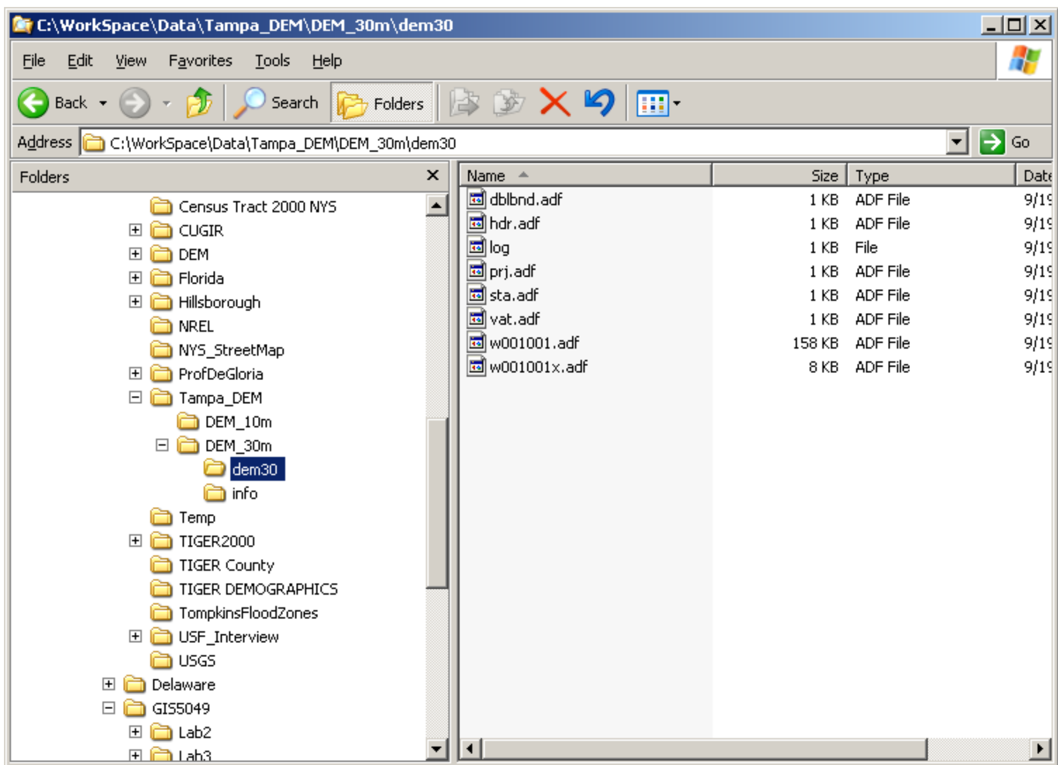
Raster Data

- Common Raster Data Formats
  - GRID
    - Most common raster data
    - The best for raster analysis
    - Spatial Analyst is needed to conduct analysis.
    - The spatial extent of a GRID is always rectangular in shape.
    - Locations outside of the extent are considered to have NoData.
    - There are two types of GRIDs:
      - Integer GRIDs
      - Real GRIDs

- Common Raster Data Formats
  - GRID
    - What is “NoData”?
      - The phenomenon of interest does not occur at that location.
      - Outside the study boundary
      - Data is missing at that location.
    - NoData vs. Value (0)
      - They are different!
    - NoData values are ignored when computing statistics.

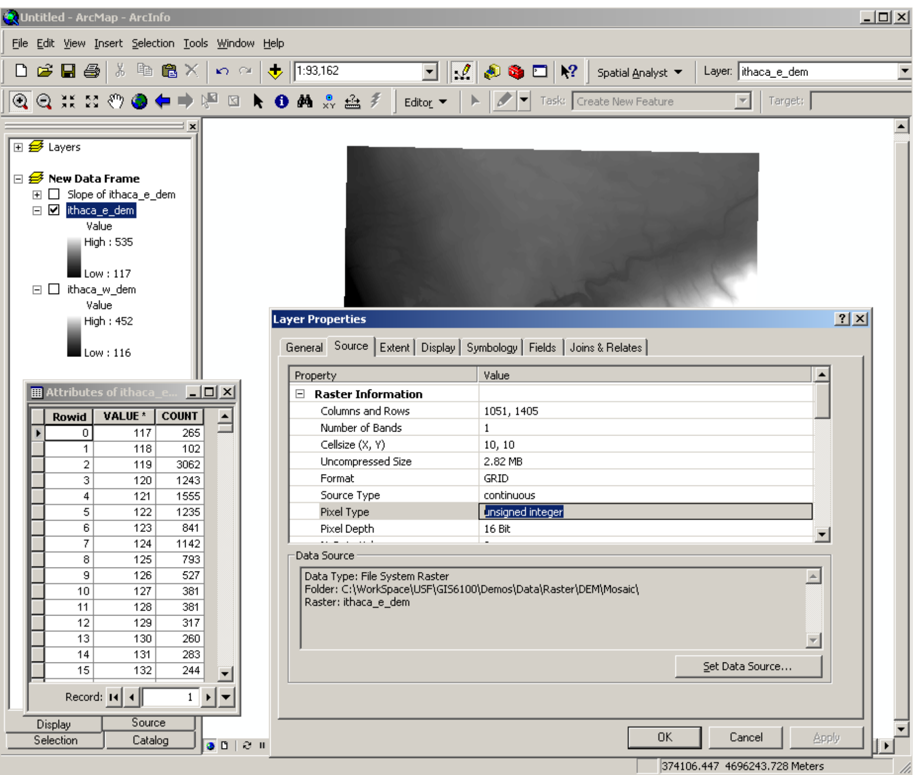
Raster Data

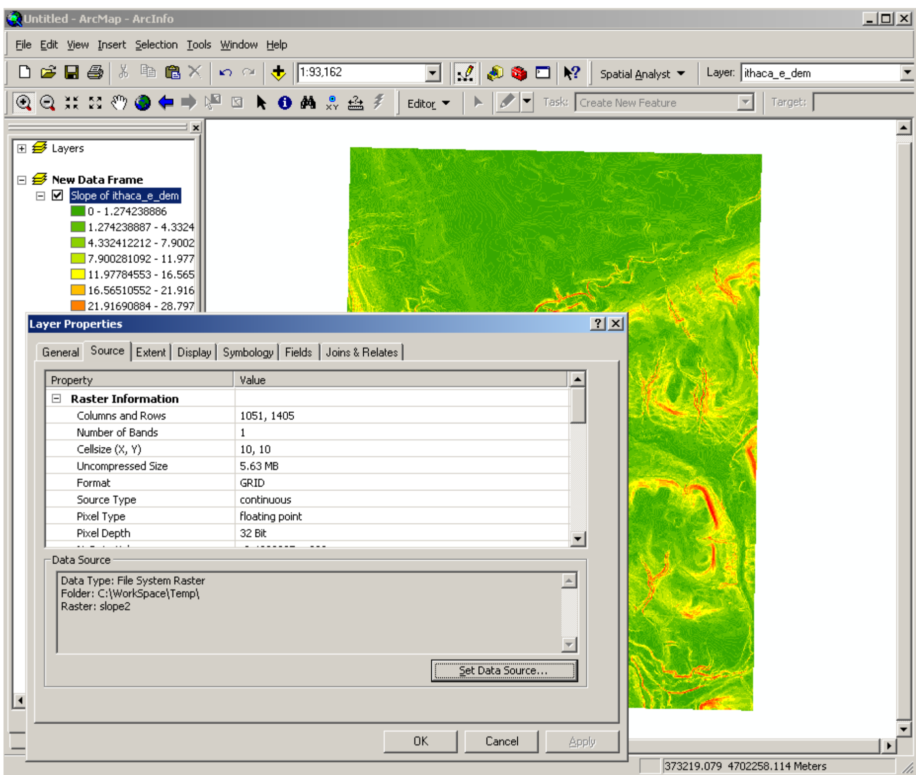
- Common Raster Data Formats
  - GRID
    - A GRID has two sub-folders:
      - ***INFO***: Contains the attribute data
      - "***GRID_Name***": Contains about 8 files of spatial information.



Raster Data

- Common Raster Data Formats
  - GRID
    - There are two types of GRIDs:
      - Integer GRIDs
      - Real GRIDs



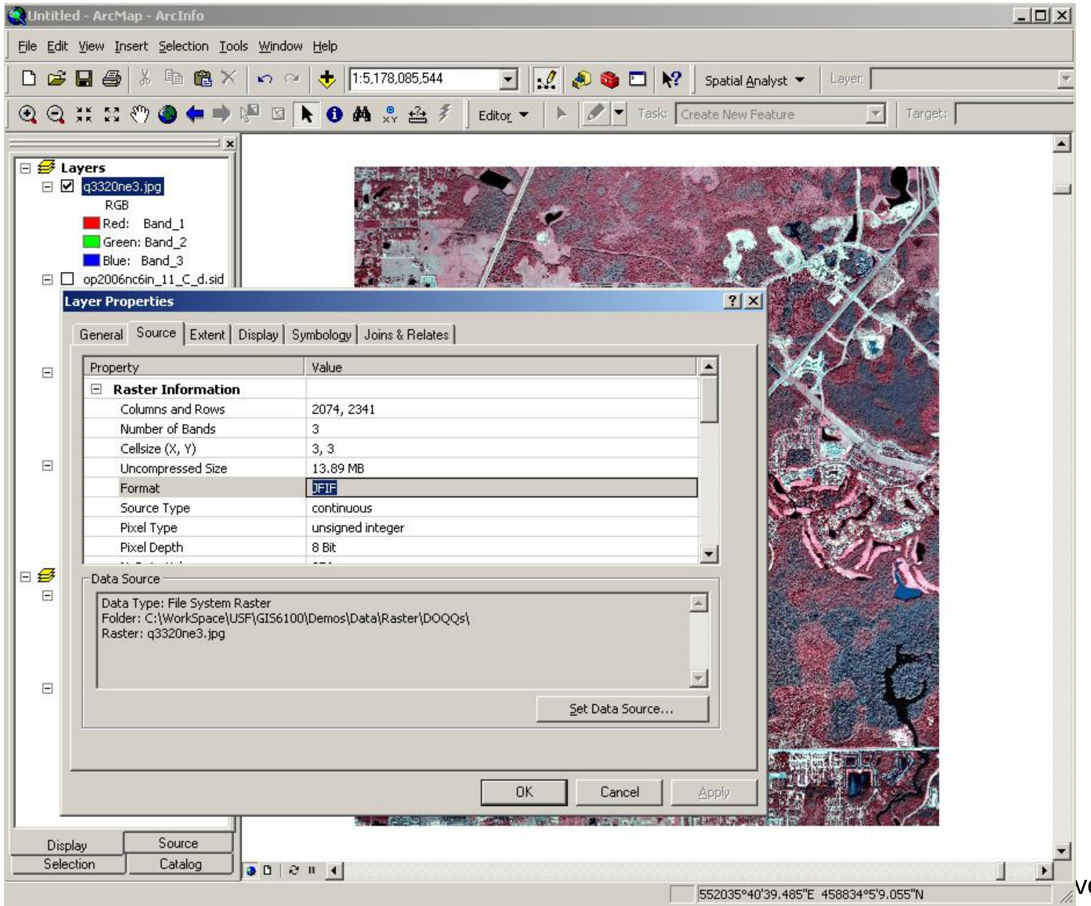


Raster Data

- Common Raster Data Formats
  - JPG/JPEG
    - “Joint Photographic Experts Group”
    - A standard compression technique for storing full-color and grayscale images.
      - Support 24-bit color.
      - Good for use on the Web .
    - Support for JPEG compression is provided through the JFIF file format.
      - JFIF: JPEG File Interchange Format

Raster Data

- Common Raster Data Formats
  - JPG/JPEG

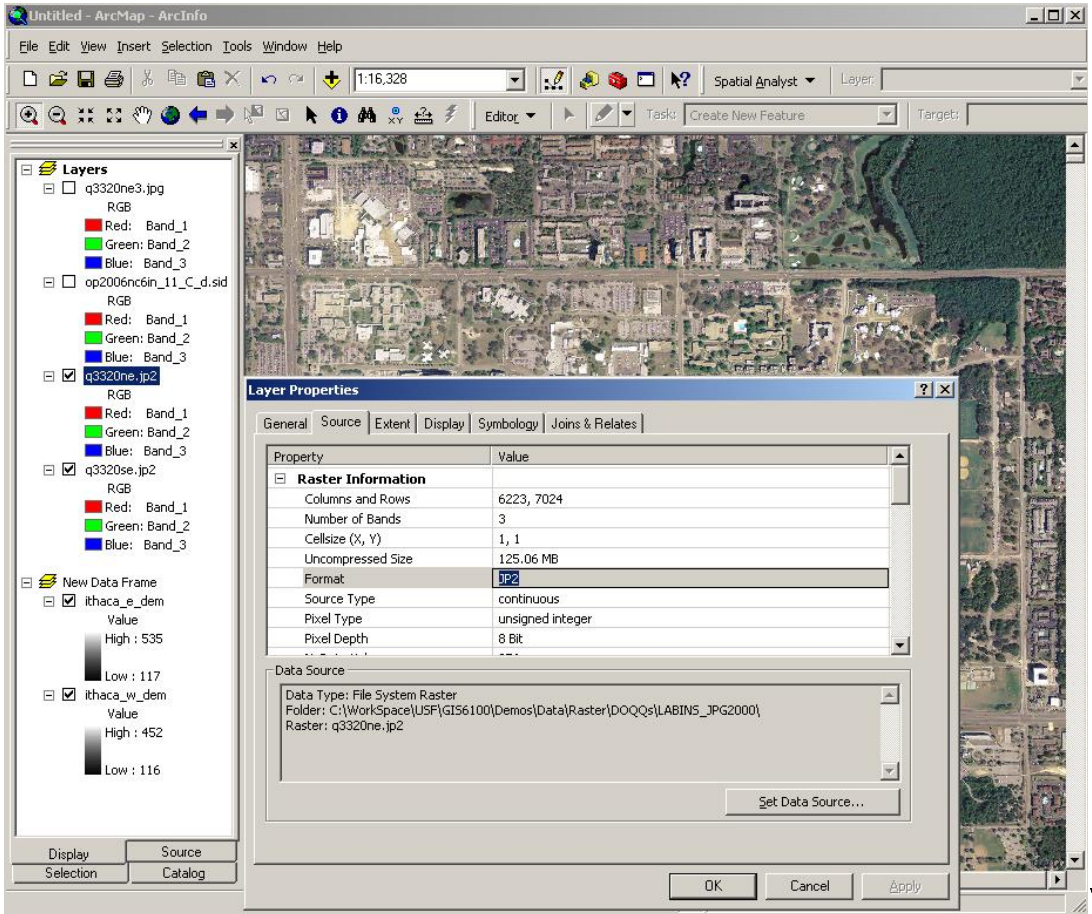


Raster Data

- Common Raster Data Formats
  - JP2 (JPEG2000)
    - A compression technique especially for maintaining the quality of large imagery.
    - Allows for a high-compression ratio and fast access to large amounts of data at any scale.

Raster Data

- Common Raster Data Formats
  - JP2 (JPEG2000)

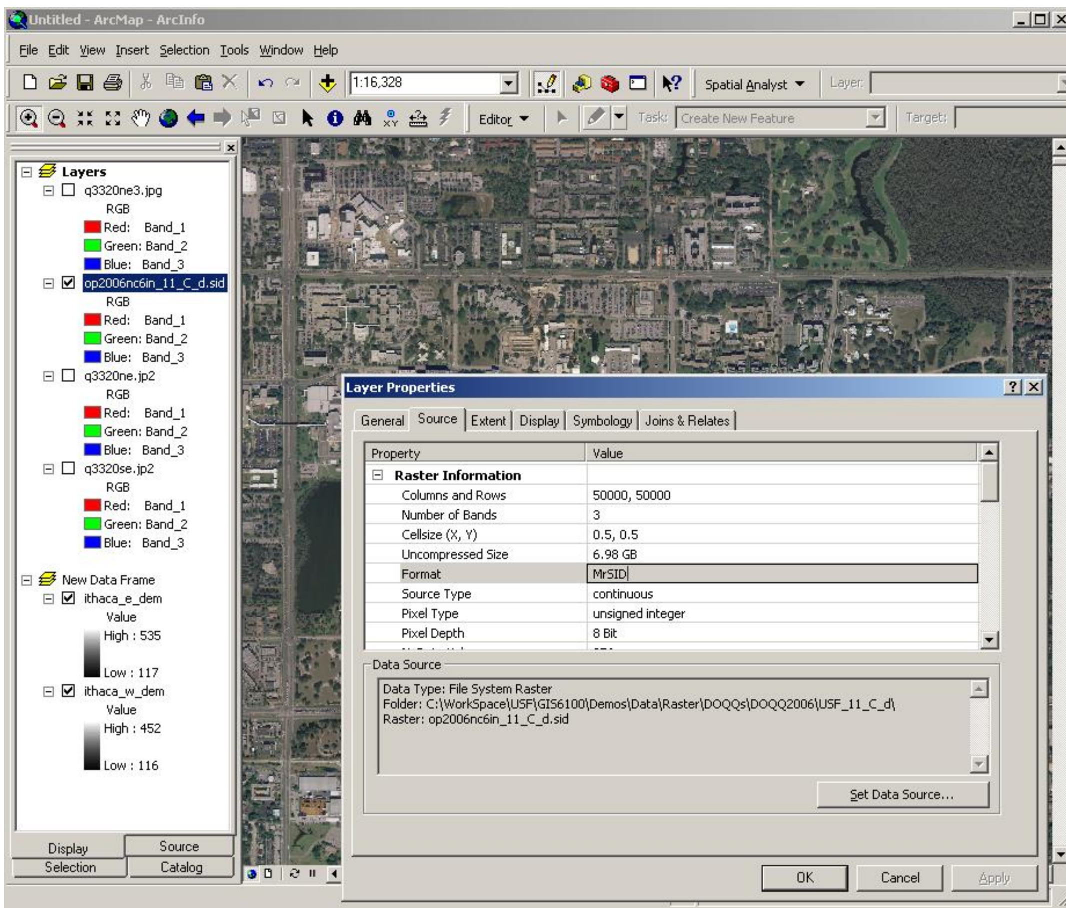


Raster Data

- Common Raster Data Formats
  - MrSID
    - "Multi-resolution Seamless Image Database"
    - A compression technique especially for maintaining the quality of large images.
    - Allows for a high-compression ratio and fast access to large amounts of data at any scale.

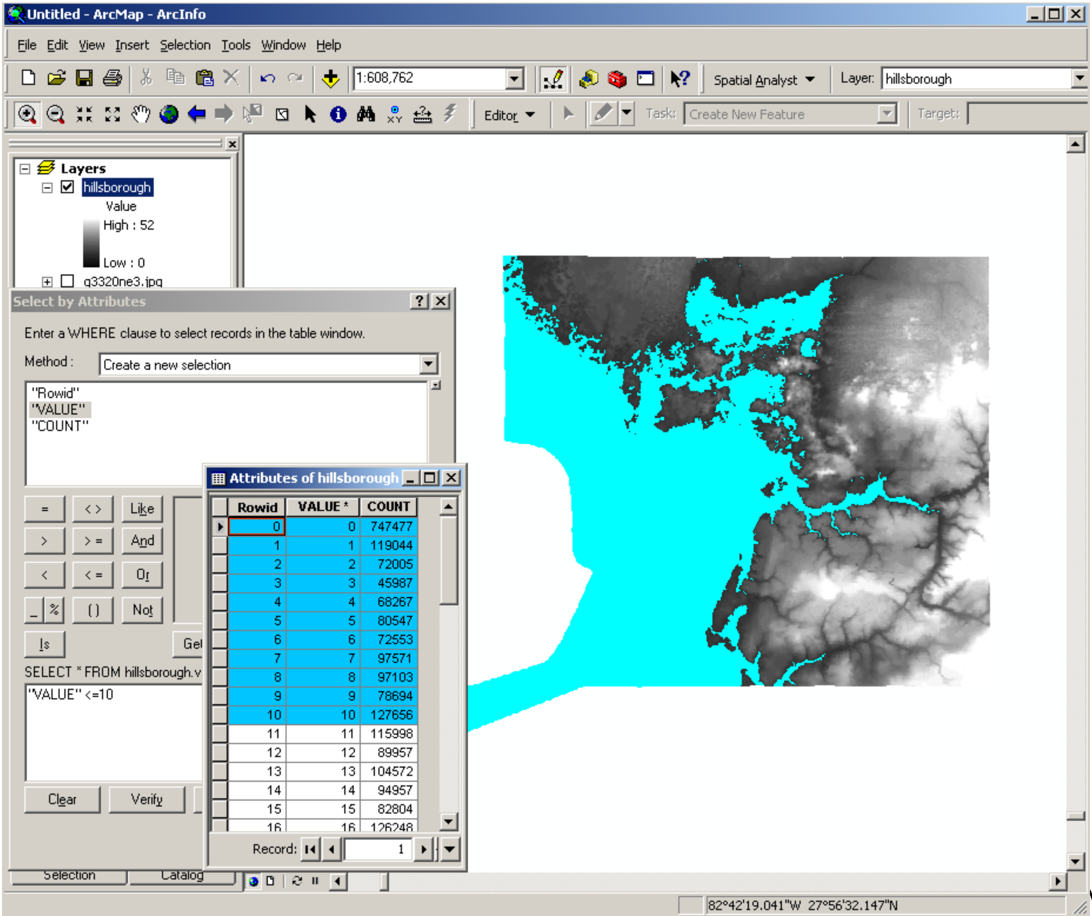
Raster Data

- Common Raster Data Formats
  - MrSID



Raster Data

- Querying
  - Only those raster data with integer values.

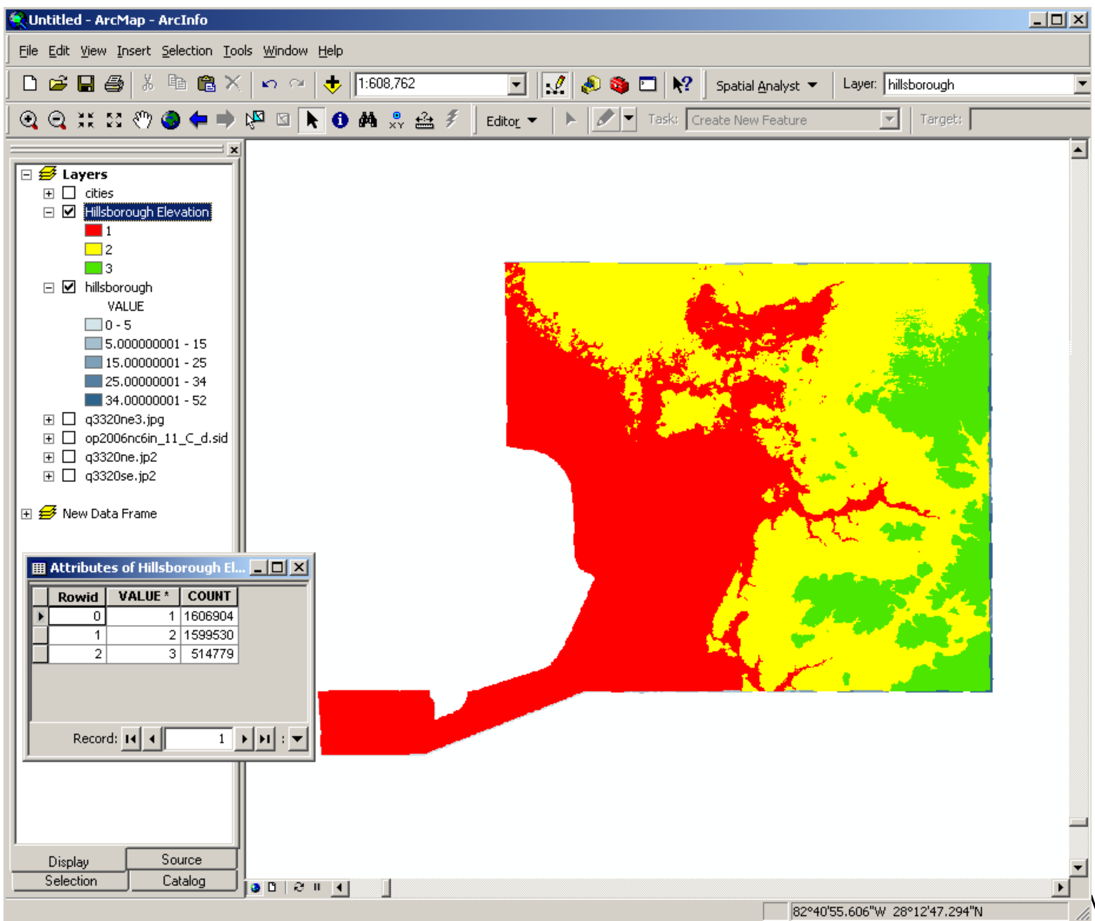


Raster Data

- Raster Symbology
  - Three types of displaying methods:
    - Unique Values
      - Used for nominal data (e.g. land use)
    - Classified
      - Used for continuous data (e.g. elevation, depth)
    - Stretched
      - Also used for continuous data
      - Applies a contrast stretch to the values to maximize the contrast based on different distributions.

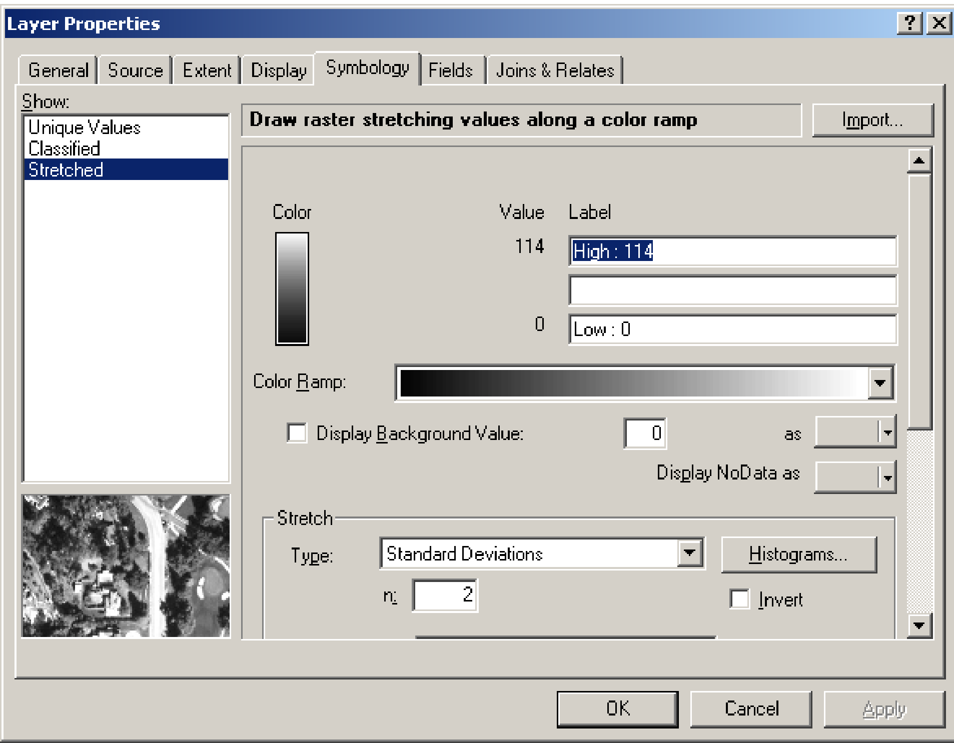
Raster Data

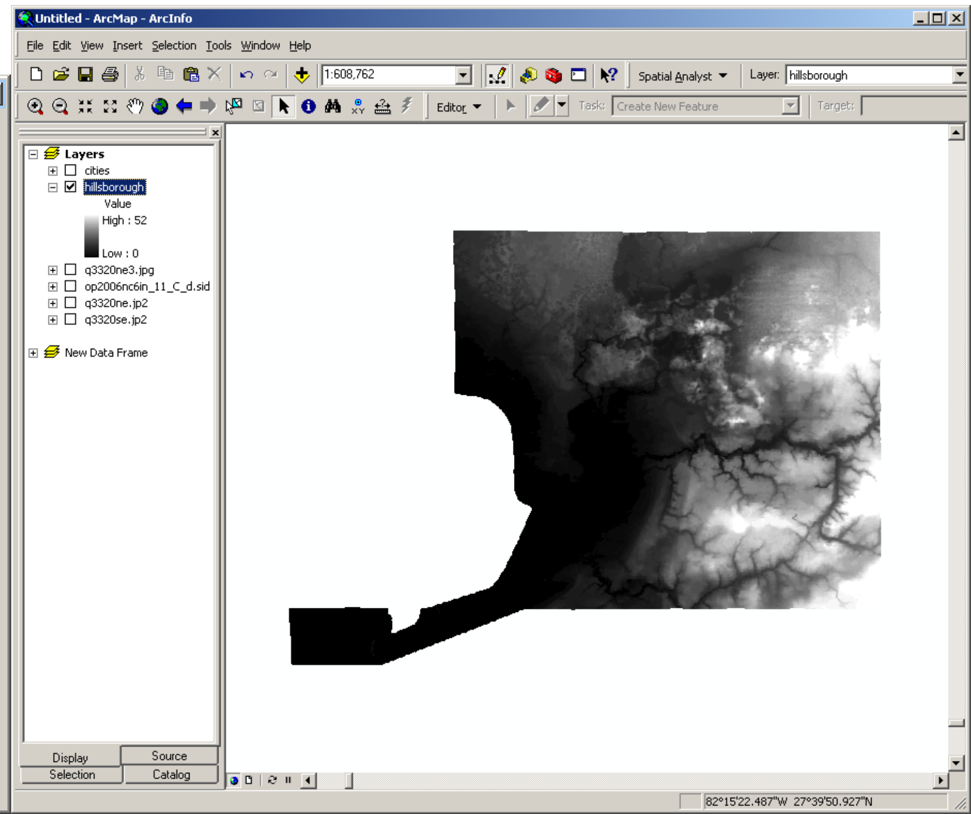
- Raster Symbology
  - Unique Values
    - Must have small attribute table (<=7 records).



Raster Data

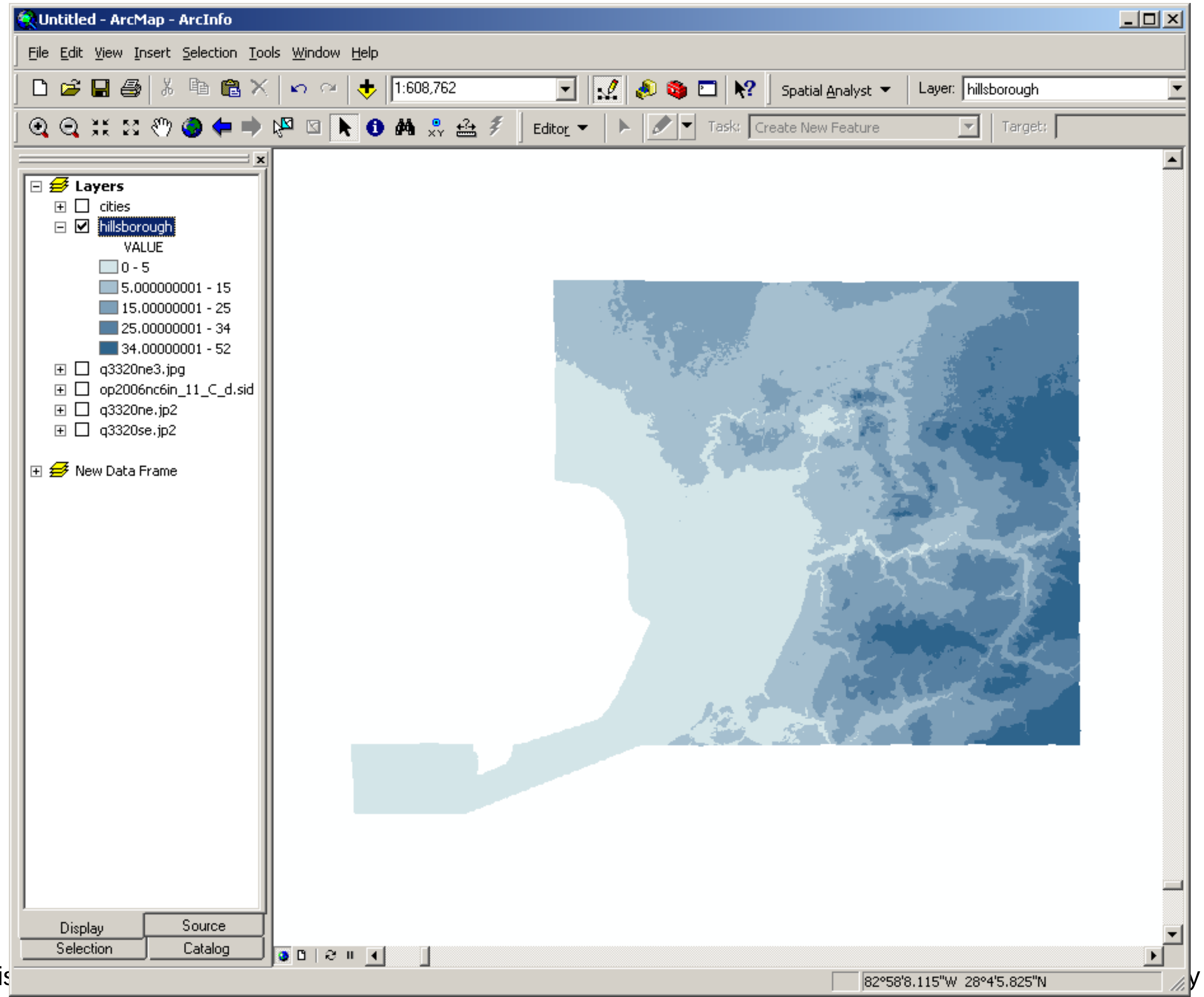
- Raster Symbology
  - Stretched
    - The default displaying method for raster.





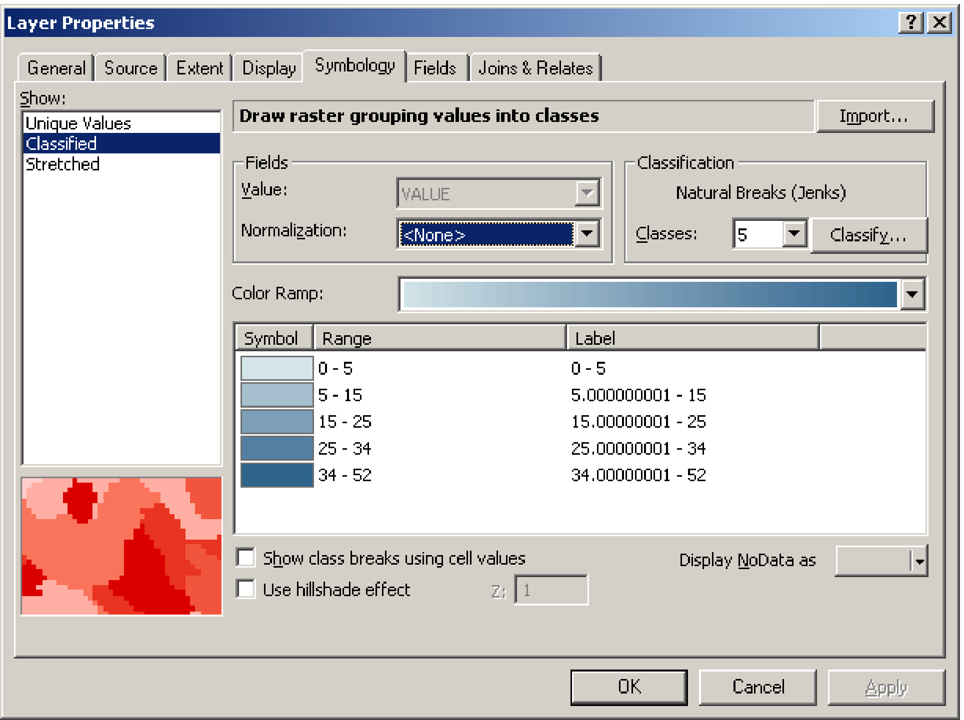
Raster Data

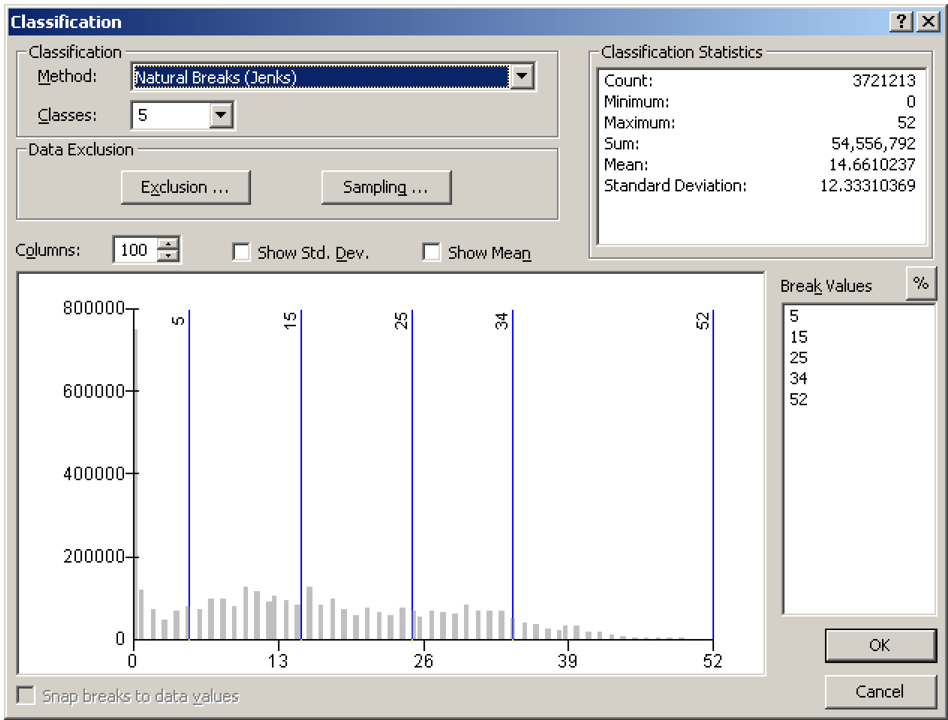
- Raster Symbology
  - Classified



Raster Data

- Raster Symbology
  - Classified
    - Classification is often useful.
    - Classification is similar to that for vector data.





Raster Data

- Raster Symbology
  - Classification vs. Reclassification
    - Classification only changes the display of the raster data but the original data remains the same. No new data will be created during this process.
    - Reclassification will create new raster data.
      - The values of the output raster are calculated based on the cell values of the input raster.

Raster Data

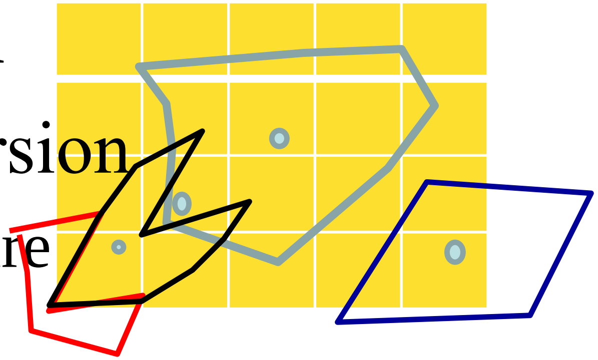
- Raster/Vector Conversion
  - Overview
    - There are fundamental differences between vector and raster data model.
    - The two data models have their own advantages/disadvantages.
    - Conversion between the two models are possible.
    - Conversion between the two models can be useful.
    - There is always information loss during any conversion processes.

Raster Data

- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Any feature layer can be converted into a GRID.
      - Convert from Point feature
        - » A cell is assigned the value of the point that is found within the cell.
      - Convert from Line feature
        - » Cells are assigned values based on the line that intersects the cell.
      - Convert from Polygon feature
    - Cells that do not intersect a feature are assigned the “NoData” value.

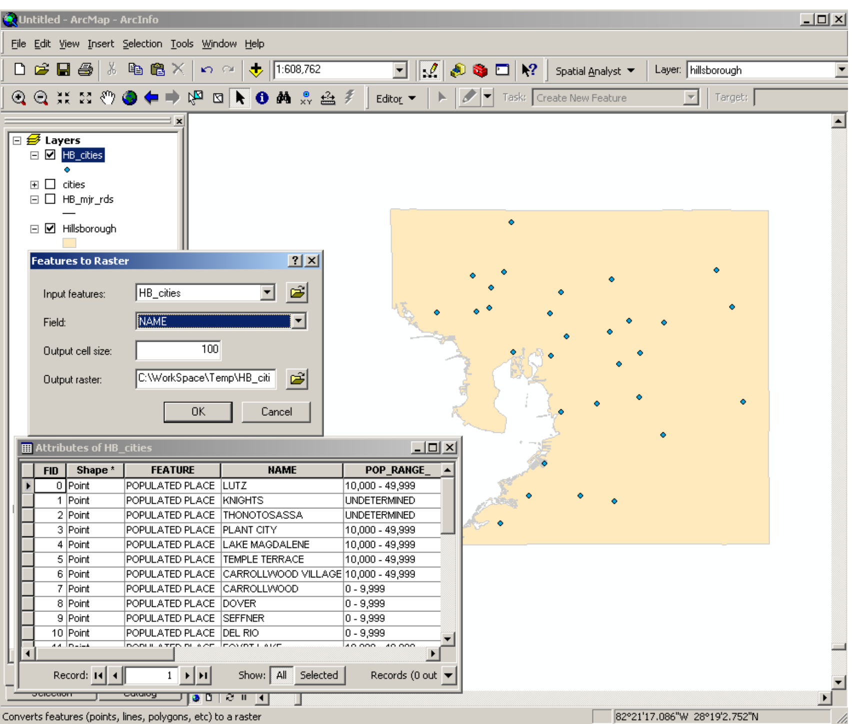
Raster Data

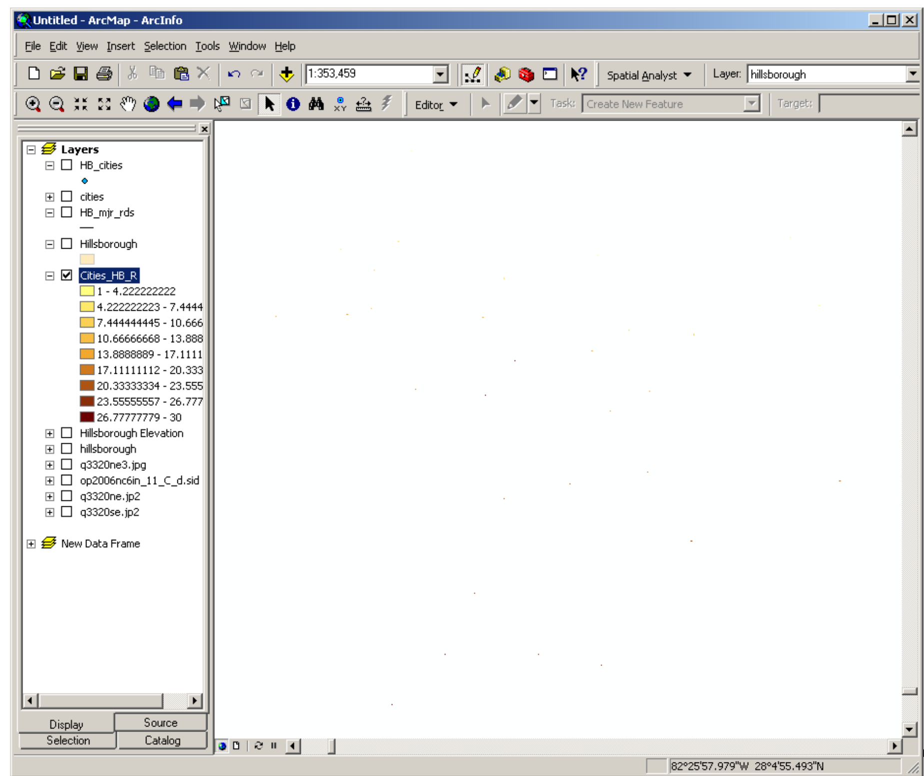
- Raster/Vector Conversion
  - "Vector → Raster" Conversion
    - Convert from Polygon feature
      - Centroid
        - » Assigns the value of the polygon found at the center of a grid cell.
        - » **Default in ArcGIS**.
      - Dominant
        - » Assigns the value of the polygon that occupies the largest portion of a cell area.
      - Most Important
        - » Assigns the value of the polygon based on some specified ranking or weighting of polygon values.



Raster Data

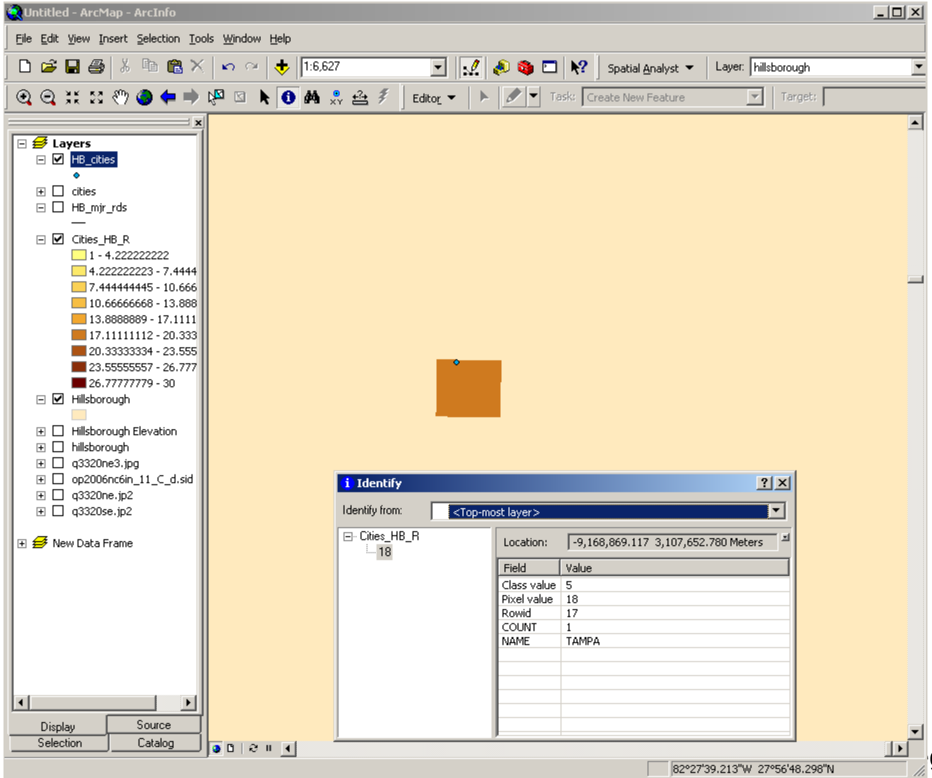
- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Example:
      - Point feature
        - » A cell is assigned the value of the point that is found within the cell.





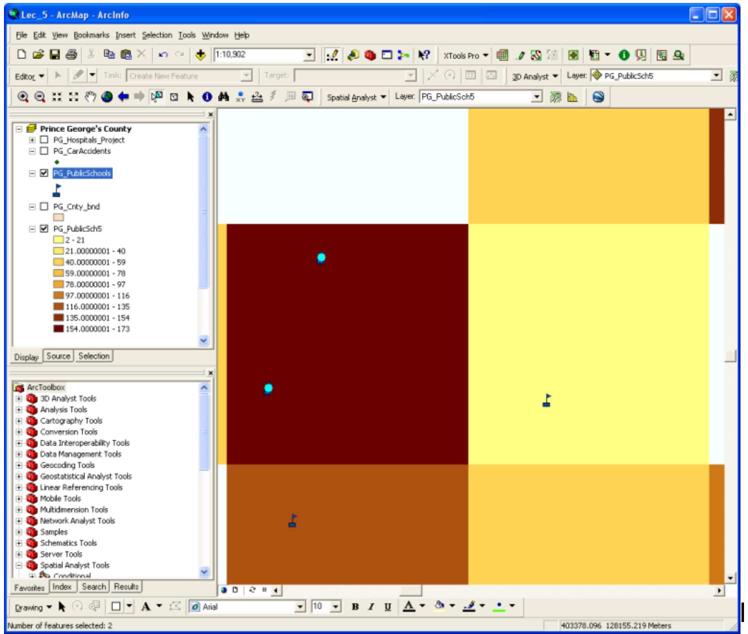
Raster Data

- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Example:
      - Point feature
        - » A cell is assigned the value of the point that is found within the cell.



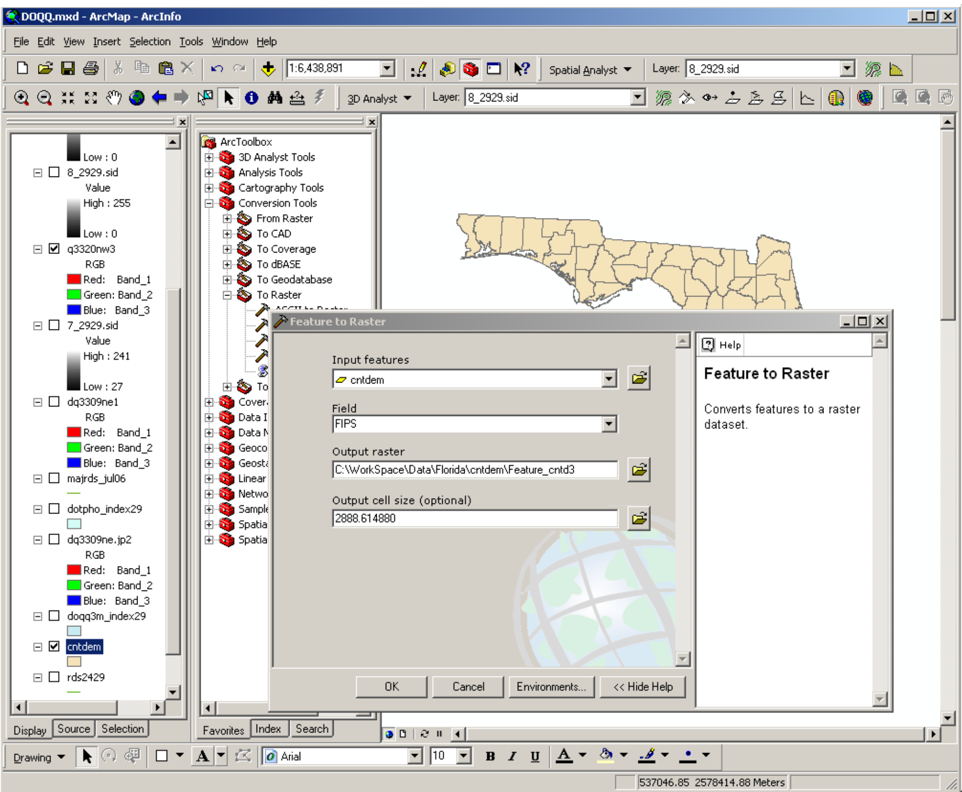
Raster Data

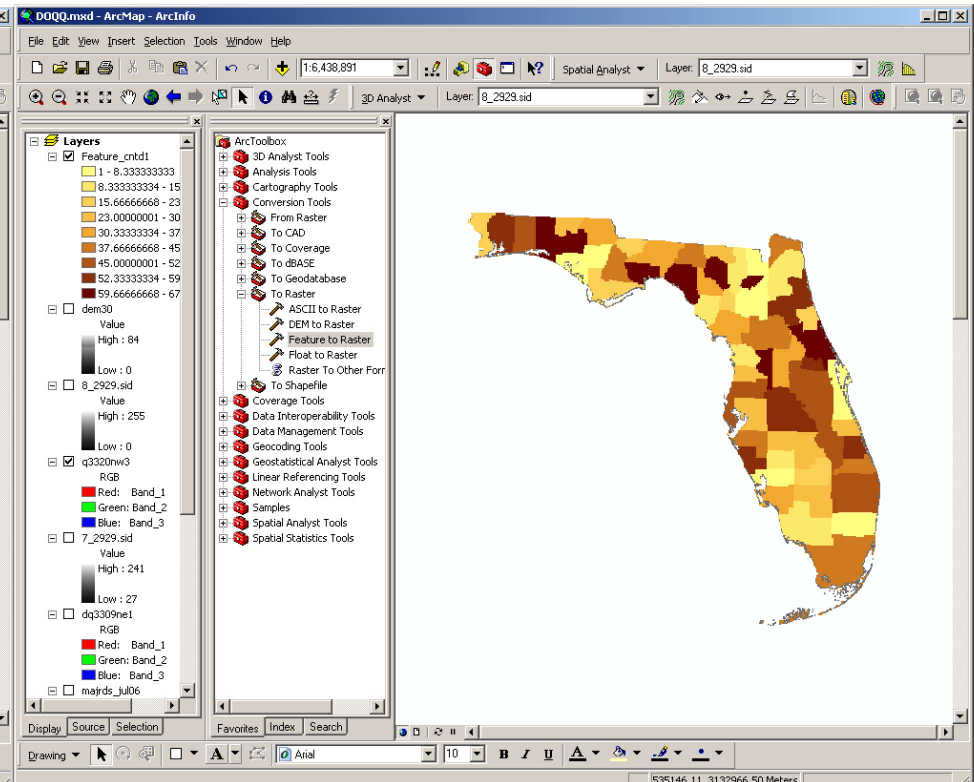
- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Example:
      - Point feature
        - » **Exercise**: What if the cell size is large enough so that there are multiple points overlap with a cell? How is the cell value determined in this case?



Raster Data

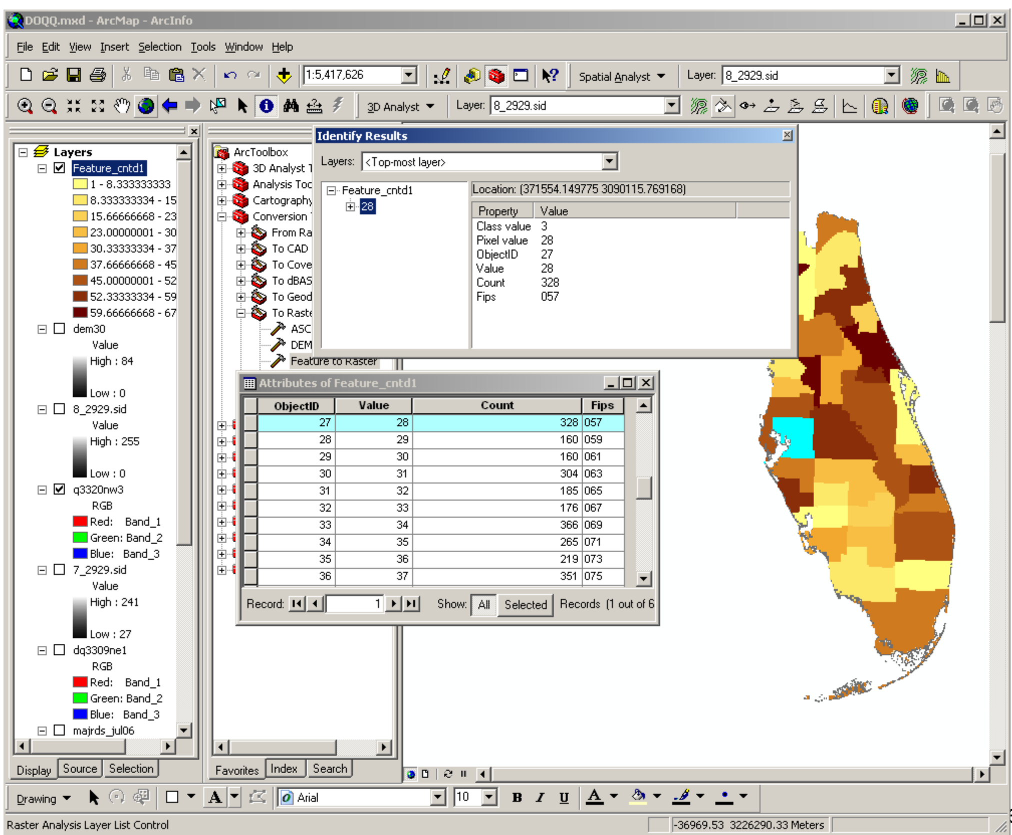
- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Example:
      - Polygon feature





Raster Data

- Raster/Vector Conversion
  - “Vector → Raster” Conversion
    - Example:
      - Polygon feature

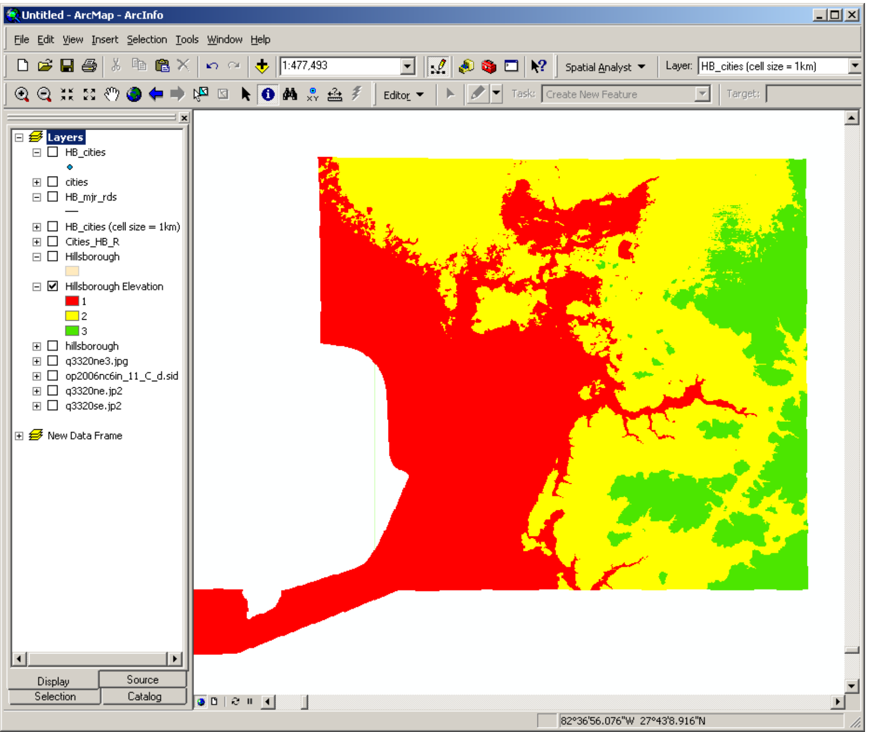


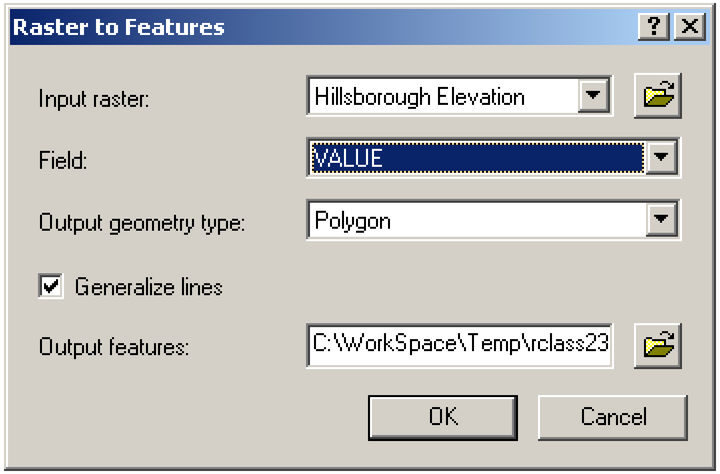
Raster Data

- Raster/Vector Conversion
  - “Raster → Vector” Conversion
    - Creating point features
      - A point is created at the center of each cell for all cells that don’t have “NoData” values.
    - Creating line features
      - A line is created that links the center of all contiguous cells that have same values.
    - Creating polygon features
      - A polygon is built from regions of cells that have the same values and are contiguous.

Raster Data

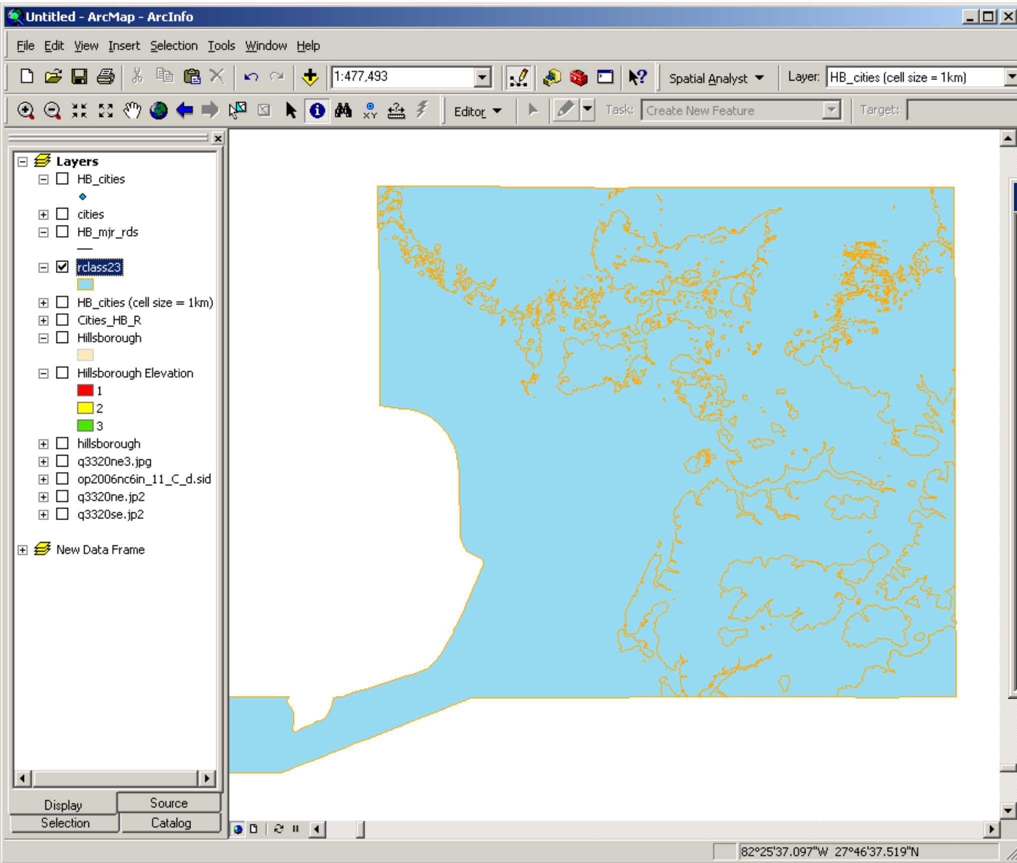
- Raster/Vector Conversion
  - "Raster → Vector" Conversion
    - This kind of conversion is rarely used, especially if the raster data has complex patterns.
    - Example:

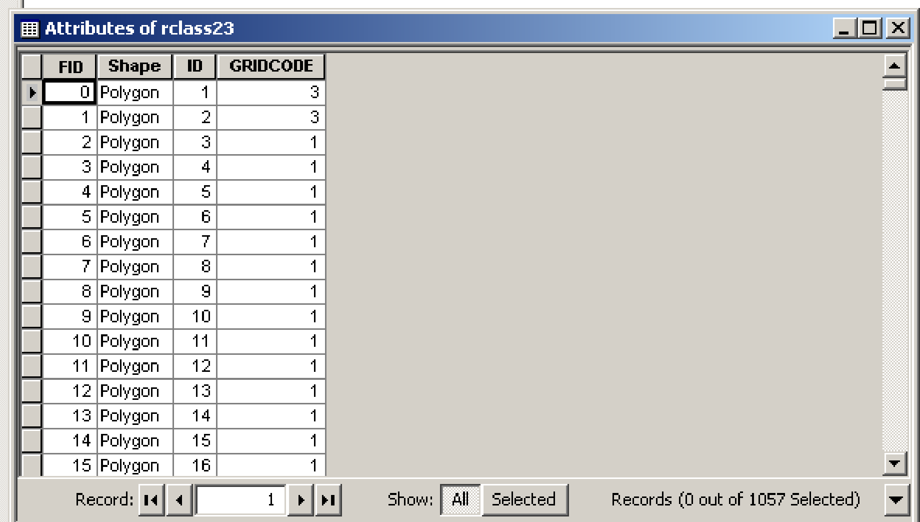




Raster Data

- Raster/Vector Conversion
  - "Raster → Vector" Conversion
    - Example: ('continued)



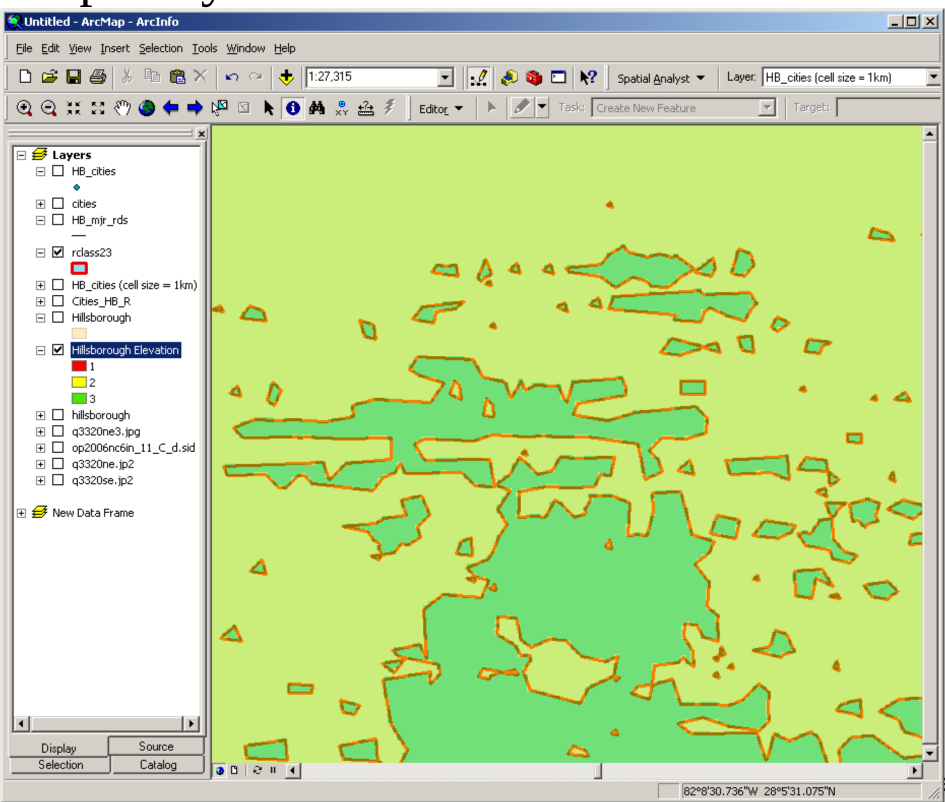

Attributes of rclass23

FID	Shape	ID	GRIDCODE
0	Polygon	1	3
1	Polygon	2	3
2	Polygon	3	1
3	Polygon	4	1
4	Polygon	5	1
5	Polygon	6	1
6	Polygon	7	1
7	Polygon	8	1
8	Polygon	9	1
9	Polygon	10	1
10	Polygon	11	1
11	Polygon	12	1
12	Polygon	13	1
13	Polygon	14	1
14	Polygon	15	1
15	Polygon	16	1

Record: 1 Show: All Selected Records (0 out of 1057 Selected)

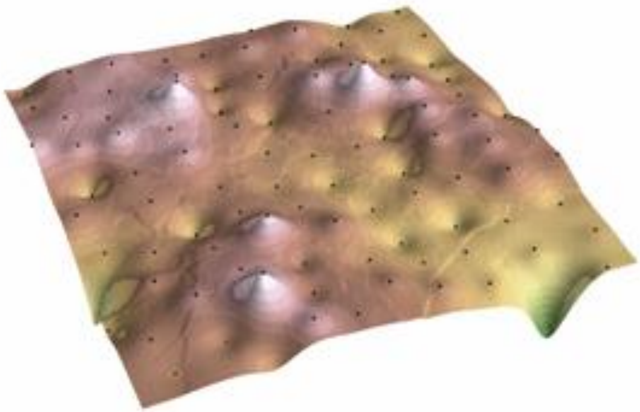
Raster Data

- Raster/Vector Conversion
  - "Raster → Vector" Conversion
    - Example: ('continued)
      - Zoomed in an area that has a lot of polygons due to the complexity of the raster data.



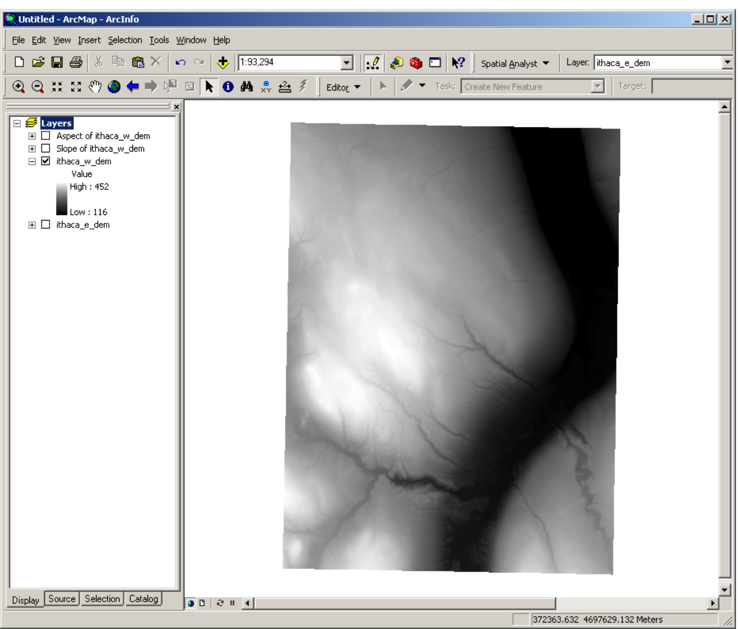
Surface Analysis

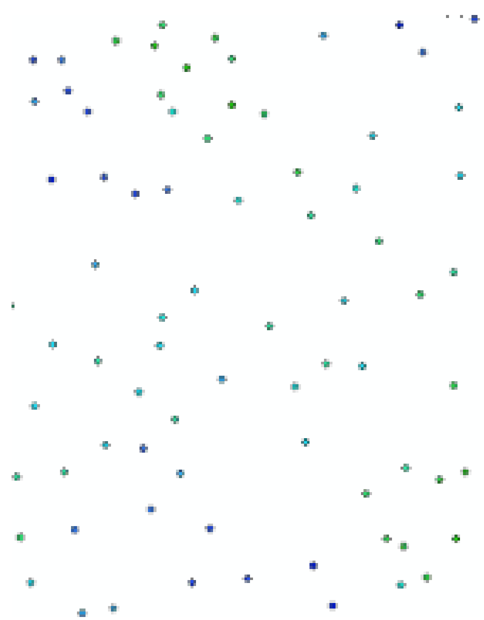
- Overview
  - What is a surface?
    - A surface is a geographic object that explicitly contains height (Z) values at any location (X, Y) through space.
      - A surface is continuous.
        - » Polygons are discrete.
      - A surface is defined by a single boundary.
      - There is an infinite number of locations on a surface.
      - Z values must be interval or ratio data.

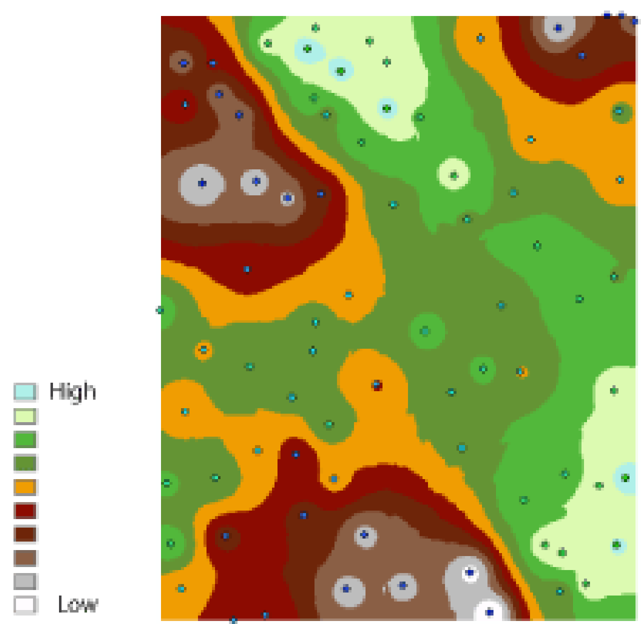


Surface Analysis

- Overview
  - What is a surface?
    - It is a digital representation of features, either real or hypothetical, in 3D space.
      - Example of real feature representing surface: elevation
      - Example of hypothetical/imaginary features representing surface: population density, precipitation, etc.







Surface Analysis

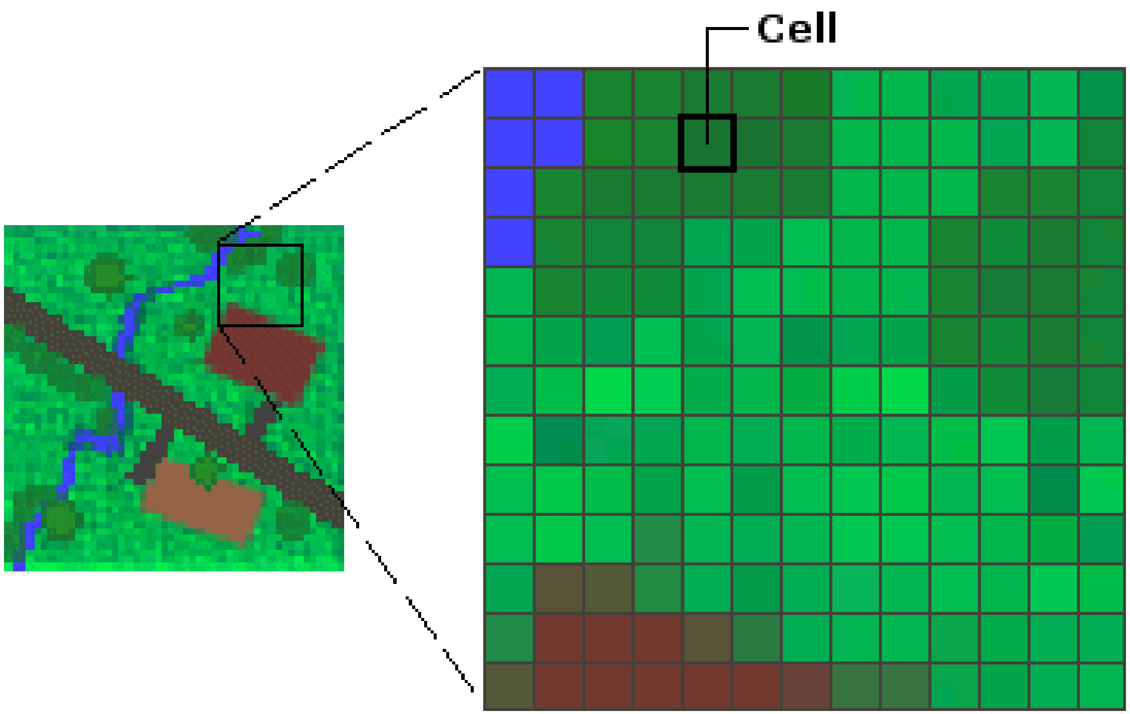
- Characteristics of surfaces:
  - They cover an entire area.
    - "No data" can occur, but there are no areas where the phenomenon itself does not occur.
    - "No data" can be caused by various reasons.
  - They tend to vary gradually across the area, forming patterns which are not easily captured with distinct shapes.
  - Their values tend to be measured (in numbers) rather than named or categorized.

Surface Analysis

- Overview
  - Surface can be created and stored in three types of model:
    - Raster
    - TIN (Triangulated Irregular Networks)
    - Terrain
      - ArcGIS format

Surface Analysis

- Overview
  - Raster
    - A spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands.



Surface Analysis

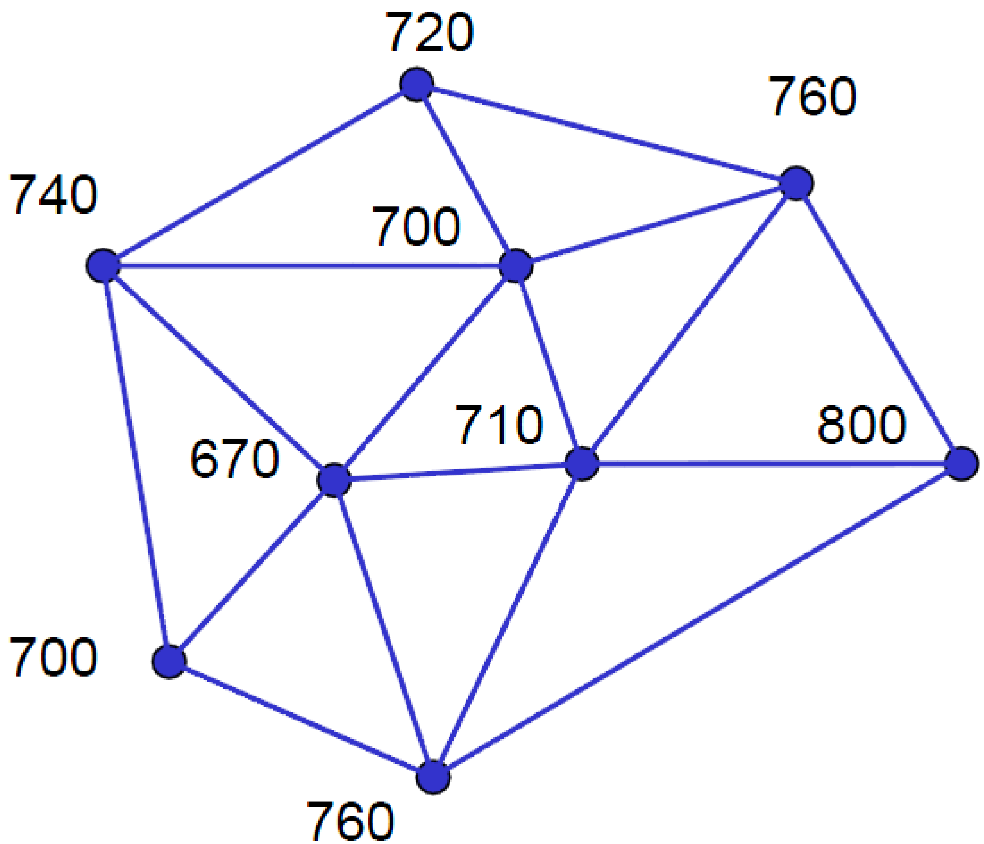
- Overview
  - TIN
    - Triangulated Irregular Network
    - TIN is a network of linked triangles drawn between irregularly spaced points with x, y, and z values.
      - Contiguous and non-overlapping triangles
      - The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles.

Surface Analysis

- Overview
  - TIN
    - A TIN is a network of linked triangles drawn between irregularly spaced points with x, y, and z values.
    - Each triangle assumes a constant gradient. The slope and aspect are computed from the *x*, *y*, and *z* values at the three points that make up the triangle.
    - More complex than vector or raster data.
    - Mostly used to store and analyze surfaces (e.g. elevation).

Surface Analysis

- Overview
  - TIN
    - Lines and Nodes

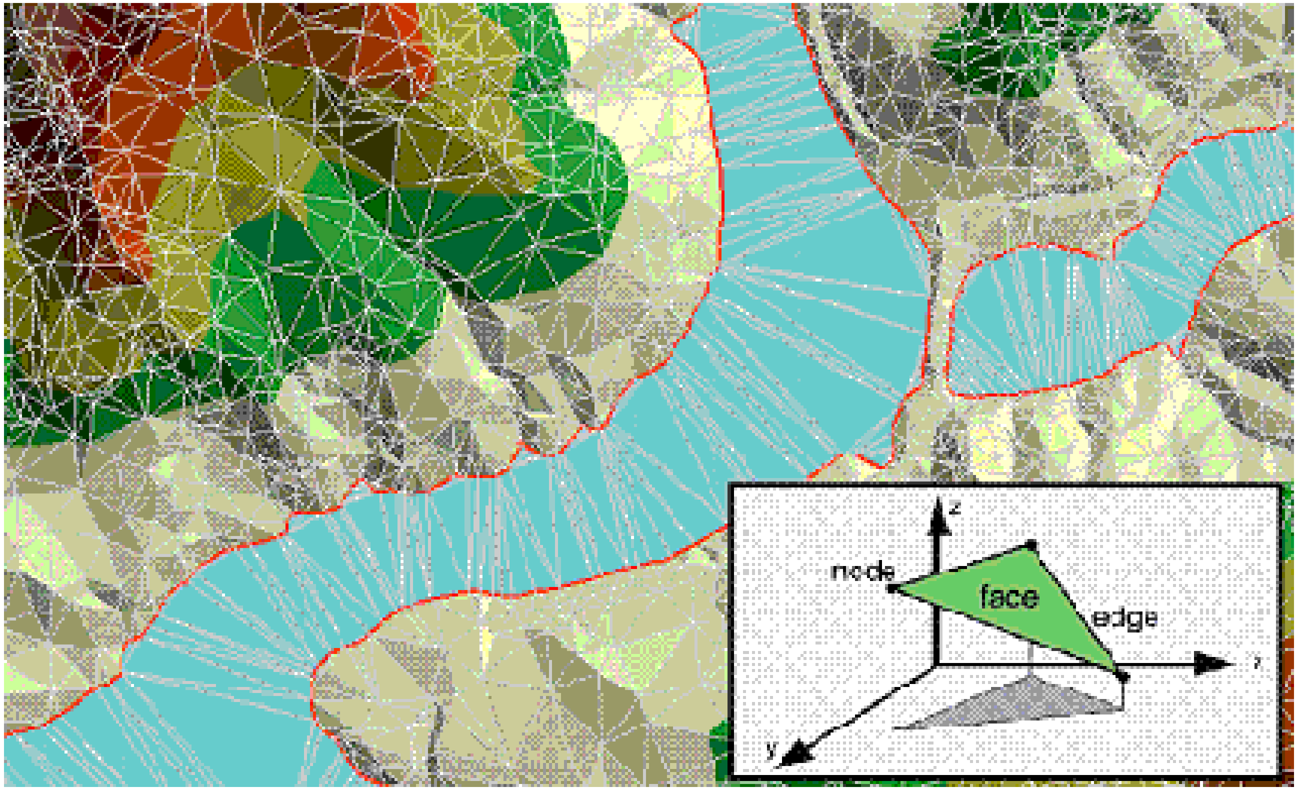


Surface Analysis

- Overview
  - TIN
    - A TIN is good for applications where you need...
      - Flexibility to change resolution or add breaklines
      - The surface to look like the sampled points
      - To simplify flat areas with fewer surface points

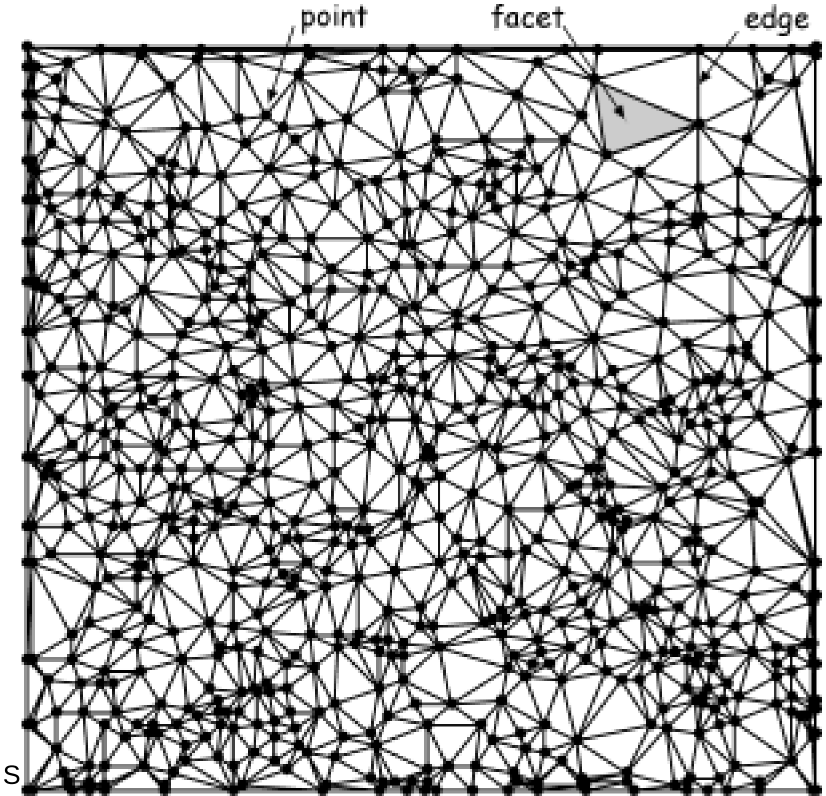
Surface Analysis

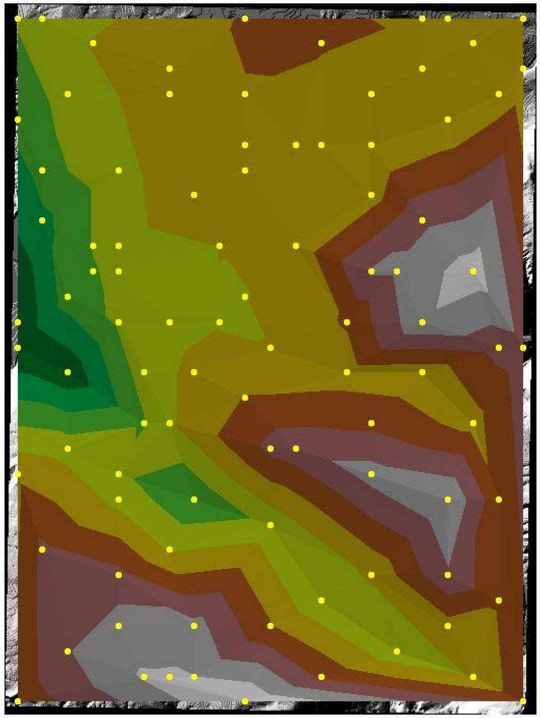
- Overview
  - TIN



Surface Analysis

- Overview
  - Surface can be created and stored in three types of model:
    - TIN





Surface Analysis

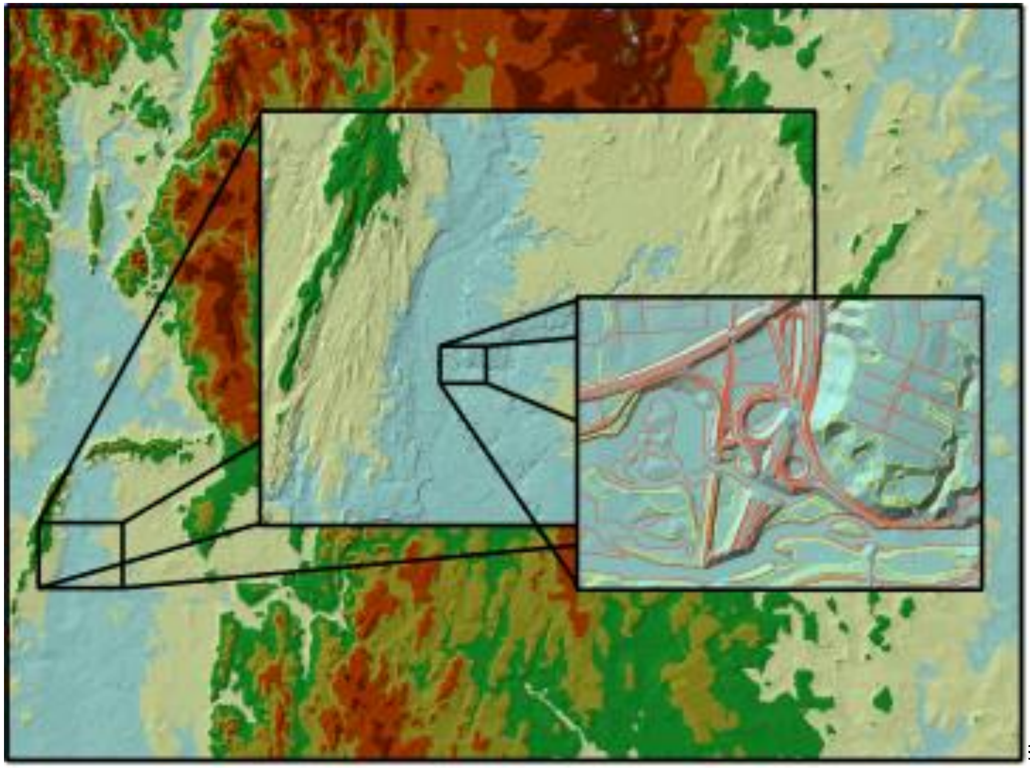
- Overview
  - TIN
    - Creating TINs
      - Triangulation of existing sampling points
        - » Example: field observations
      - Interpolation of existing contours
        - » Example: topographic maps
      - Transformation of existing grid theme
        - » Example: DEM

Surface Analysis

- Overview
  - Terrain
    - An area of land having a particular characteristic, such as sandy terrain or mountainous terrain.
    - It's a new data model that has been introduced to ArcGIS9.2.
    - It is an efficient way to manage large point based data in a geodatabase and produce high quality, accurate surfaces on the fly.
    - A terrain dataset in the geodatabase references the original feature classes. It doesn't actually store a surface as a raster or TIN. Rather, it organizes the data for fast retrieval and derives a TIN surface on the fly.

Surface Analysis

- Overview
  - Terrain

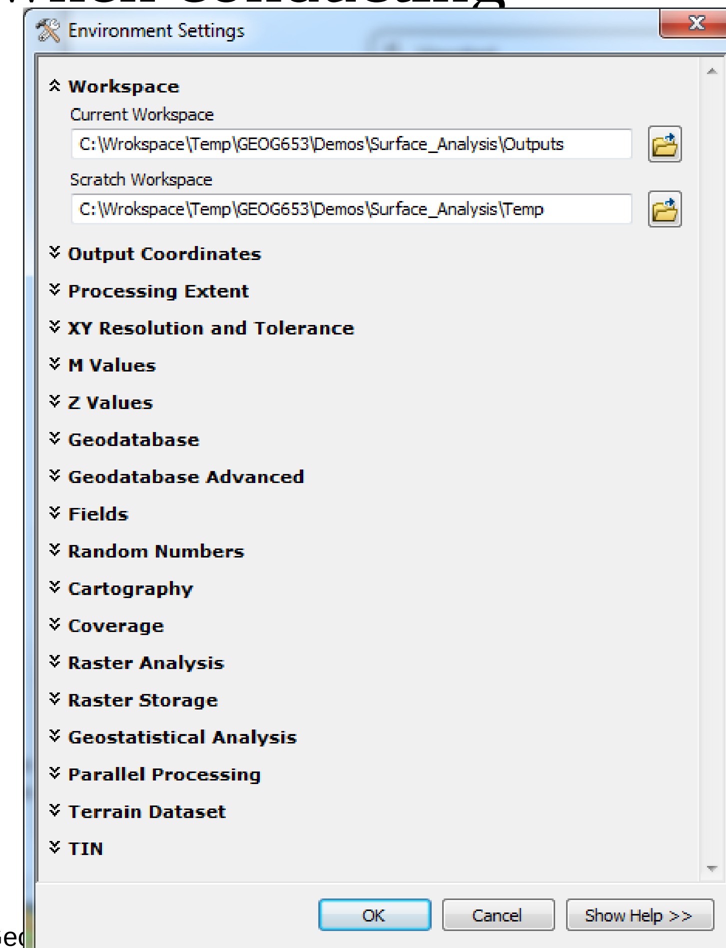


Surface Analysis

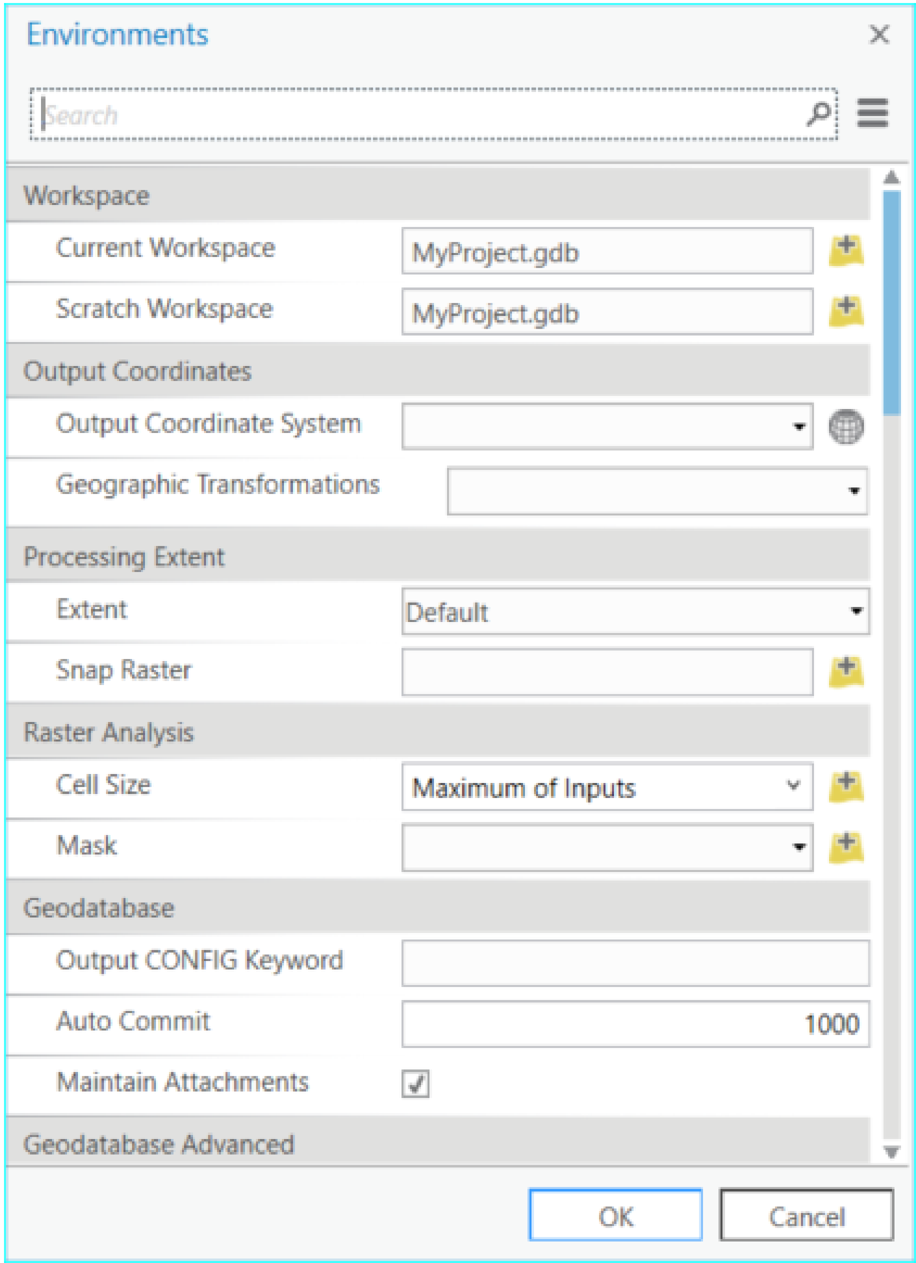
- Overview
  - There are many ways of creating surface data:
    - Spatial Interpolation
    - Distance Analysis
    - Density Analysis
    - Surface Analysis Operations

Surface Analysis

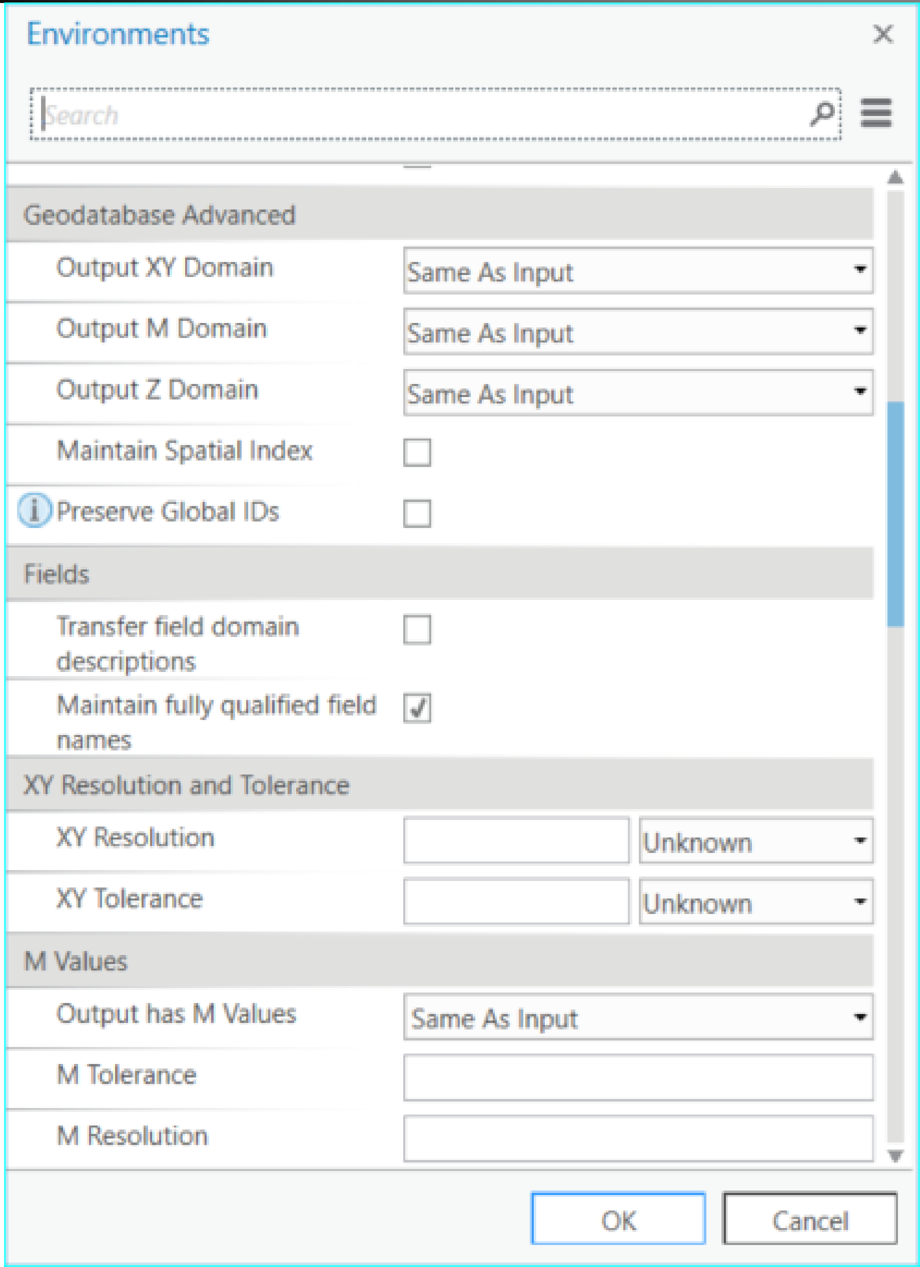
- Environment Settings
  - There are a number of analysis properties and options that can be controlled when conducting analysis on raster dataset.
  - ArcMap



- Environment Settings
  - ArcGIS Pro



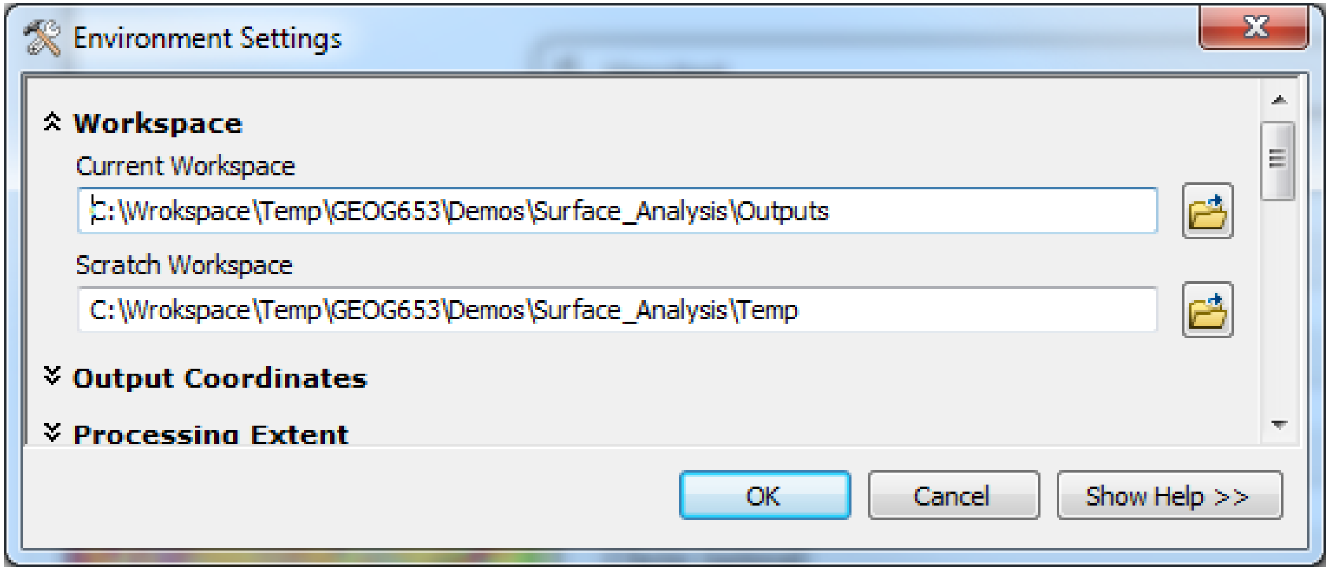
- Environment Settings
  - ArcGIS Pro



Surface Analysis

- Environment Settings
  - Three options: General, Extent, and Cell Size
    - The directory where new GRIDs will be located (saved).
    - Analysis Mask:
      - Identifies those cells within the analysis extent that will be considered when running a tool.
    - The cell size (resolution) of the output GRID can be specified.

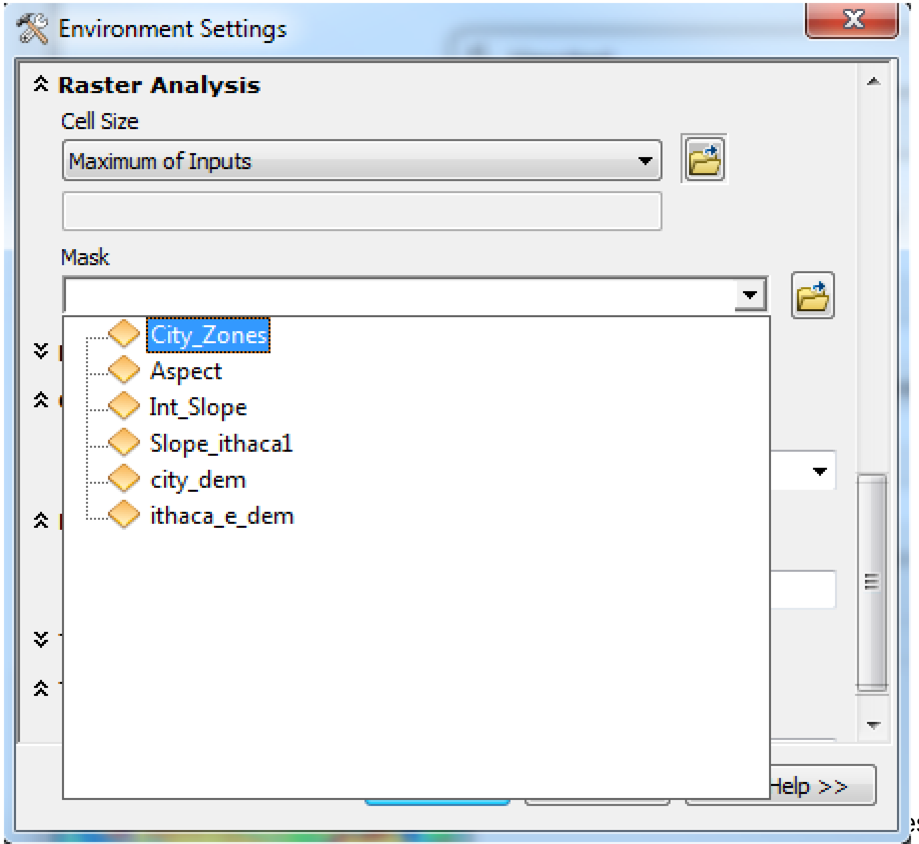
- Environment Settings
  - Workspace
    - Current Workspace
      - The directory where new GRIDs will be saved
    - Scratch Workspace
      - Used for "temporary" raster data layers



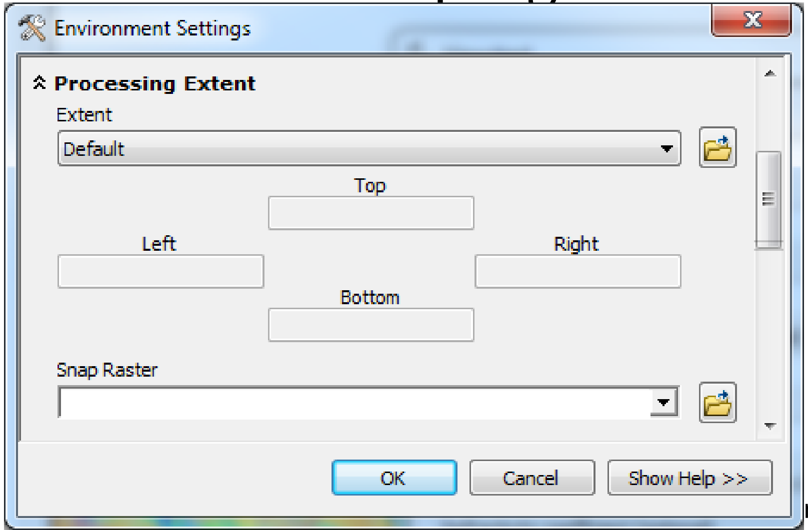
Surface Analysis

- Environment Settings
  - Analysis Mask:
    - If the mask is overlaid on the input raster you want to use for analysis, only cells covered by the mask will be processed. All other cells will be assigned the NoData value in the result after running a tool.
    - The "NoData" cells in the mask Grid will carry through to any GRIDs created subsequently.
    - The coordinate systems of different raster data layers should be defined as the same to avoid errors during projection transformation.

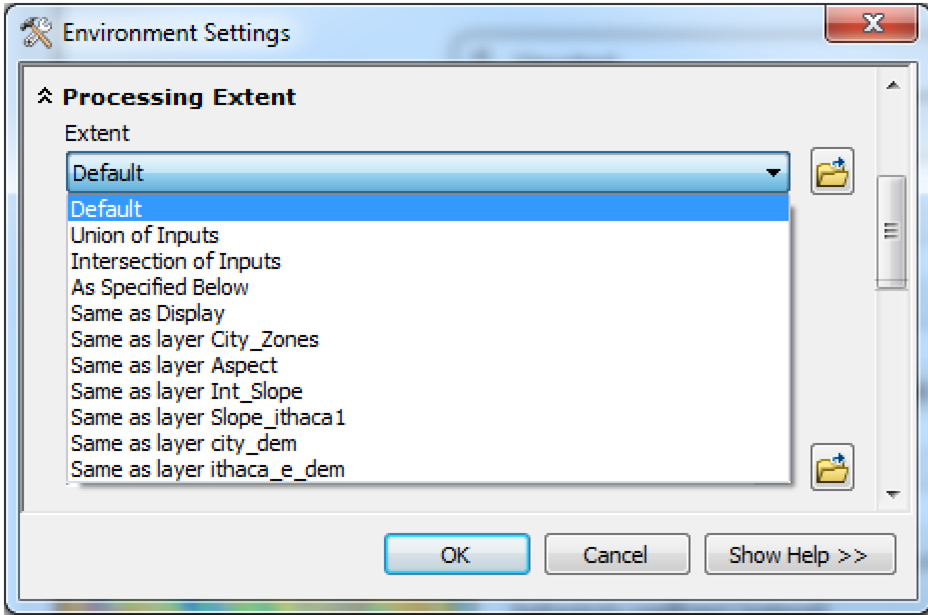
- Environment Settings
  - Analysis Mask:
    - The “mask” can be either raster dataset or vector dataset.



- Environment Settings
  - Processing Extent
    - Different from “Mask”.
    - The mask identifies those locations within the analysis extent that will be included when performing an operation or function.
    - The extent of a layer refers to the (x, y) coordinates for the bottom-left and the top-right corners.

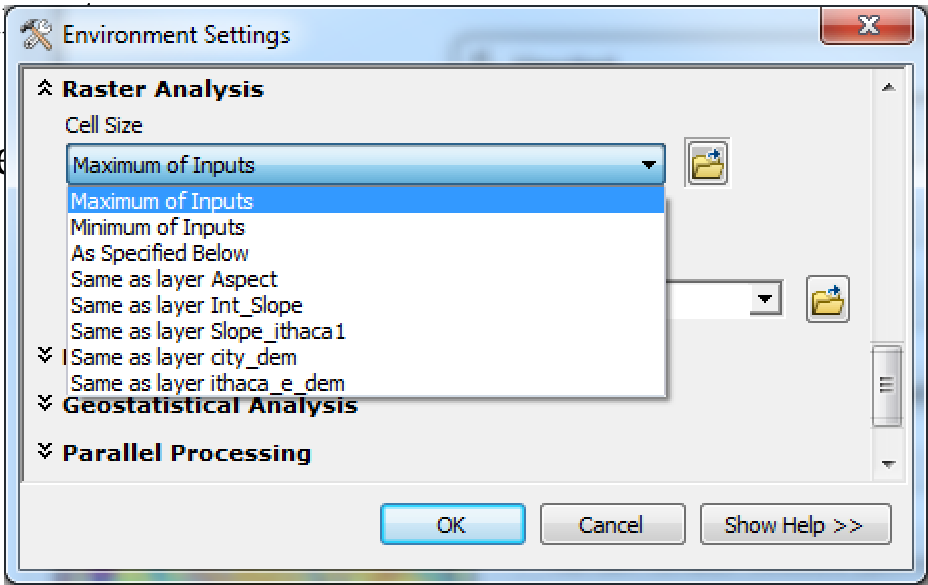


- Environment Settings
  - Processing Extent options:
    - Same as Display
    - Intersection of Inputs (default)
    - Union of Inputs
    - As Specified Below
    - Same as Layer “ ”



Surface Analysis

- Environment Settings
  - Cell Size
    - Maximum of Inputs
      - The largest cell size of inputs
      - The resolution of output raster layer is only as good as the input layer of the coarsest resolution.
      - Default cell size
    - Minimum of Inputs
      - The smallest cell size of i
      - Not used often
      - Cell values are interpolate
      - No new data created.
    - As Specified Below
    - Same as Layer “ ”

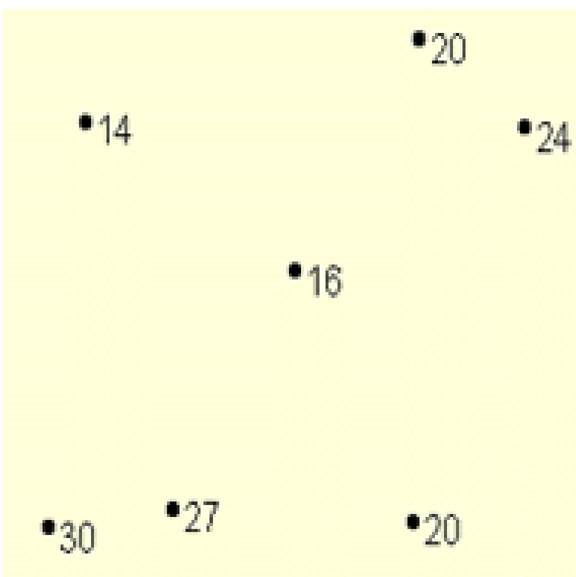


Surface Analysis

- Spatial Interpolation
  - Spatial Interpolation is a process to create a surface from sampled data in order to estimate/predict the values at all locations that are not sampled or lack of values.
  - It can be used to predict unknown values for any geographic point data: elevation, rainfall, chemical concentrations, noise levels, and so on.
    - Example: create your own DEM based on GPS readings at sampling sites.

Surface Analysis

- Spatial Interpolation
  - Assumes that things that are close to one another are more alike than those that are farther apart. (Again, the 1st Law of Geography!)
    - Example:



13	14	16	20	23
14	14	16	19	24
18	16	16	18	22
24	22	19	19	21
30	27	23	20	20

Surface Analysis

- Spatial Interpolation
  - Why is interpolation important?
    - Geographic data are often sampled at various locations, rather than a complete census due to time and cost constraint.
      - For example: To make a precipitation map, it is impossible to find a regular array of weather stations like a DEM. Therefore, it is important to find a way to fill in data between the sample points.

Surface Analysis

- Spatial Interpolation
  - Interpolation requirements:
    - Input is a point layer.
    - Surface values need to be quantitative and continuous (i.e. interval or ratio data).
  - Three major types of interpolation methods:
    - Inverse Distance Weighted (IDW)
    - Spline
    - Kriging

Surface Analysis

- Spatial Interpolation
  - The Interpolation methods can be divided into two groups:
    - Deterministic
      - Examples: IDW, Spline
      - These methods assign values to locations based on the surrounding measured values and on specified mathematical formulas that determine the smoothness of the resulting surface
    - Geostatistical
      - Example: Kriging
      - This method is based on statistical models that include autocorrelation (the statistical relationship among the measured points).

Surface Analysis

- Spatial Interpolation
  - IDW
    - Determines cell values using a linearly weighted combination of a set of sample points.
    - The weight is a function of inverse distance. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance.
    - The surface being interpolated should be that of a locationally dependent variable such as elevation or precipitation.

Surface Analysis

- Spatial Interpolation
  - IDW
    - The interpolation algorithm uses either a specified number of nearest points or all points within a given radius.
    - The power parameter affects the rate of decline in influence with distance. (inverse relationship)
      - A power of 1.0 means a constant rate of change in value between points, i.e. linear interpolation.
    - A barrier layer breaks the limit of search for sample points using linear features (e.g. ridges, cliff, rivers)
    - All predicated values are within the range of maximum and minimum values of the known points.

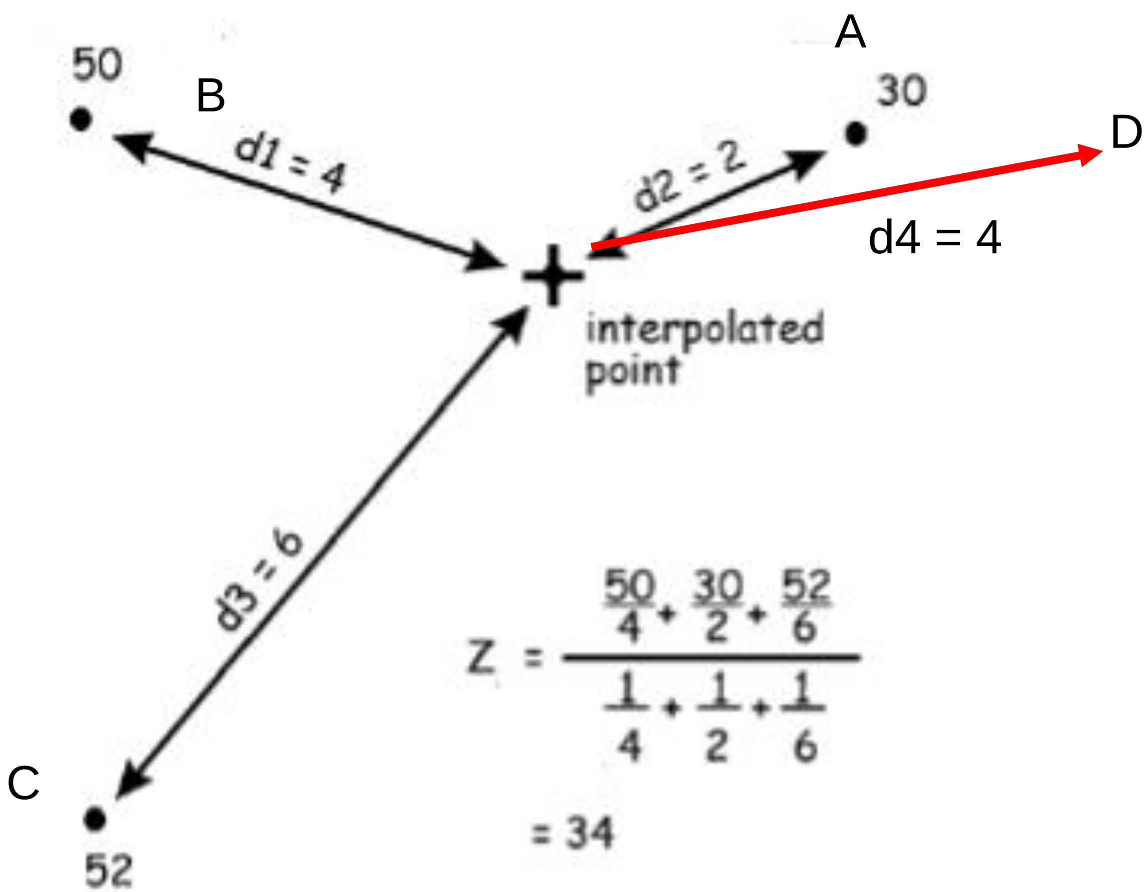
- Spatial Interpolation
  - IDW

$$Z = \frac{\sum_{i=1}^{n} (w_i \times Z_i)}{\sum_{i=1}^{n} w_i} \qquad w_i = \frac{1}{d_i^k}$$

- Z_i is the measured value at point *i*.
- d_i is the distance from an unmeasured location to a measured location.
- k is the power parameter.

Surface Analysis

- Spatial Interpolation
  - IDW
    - Example:



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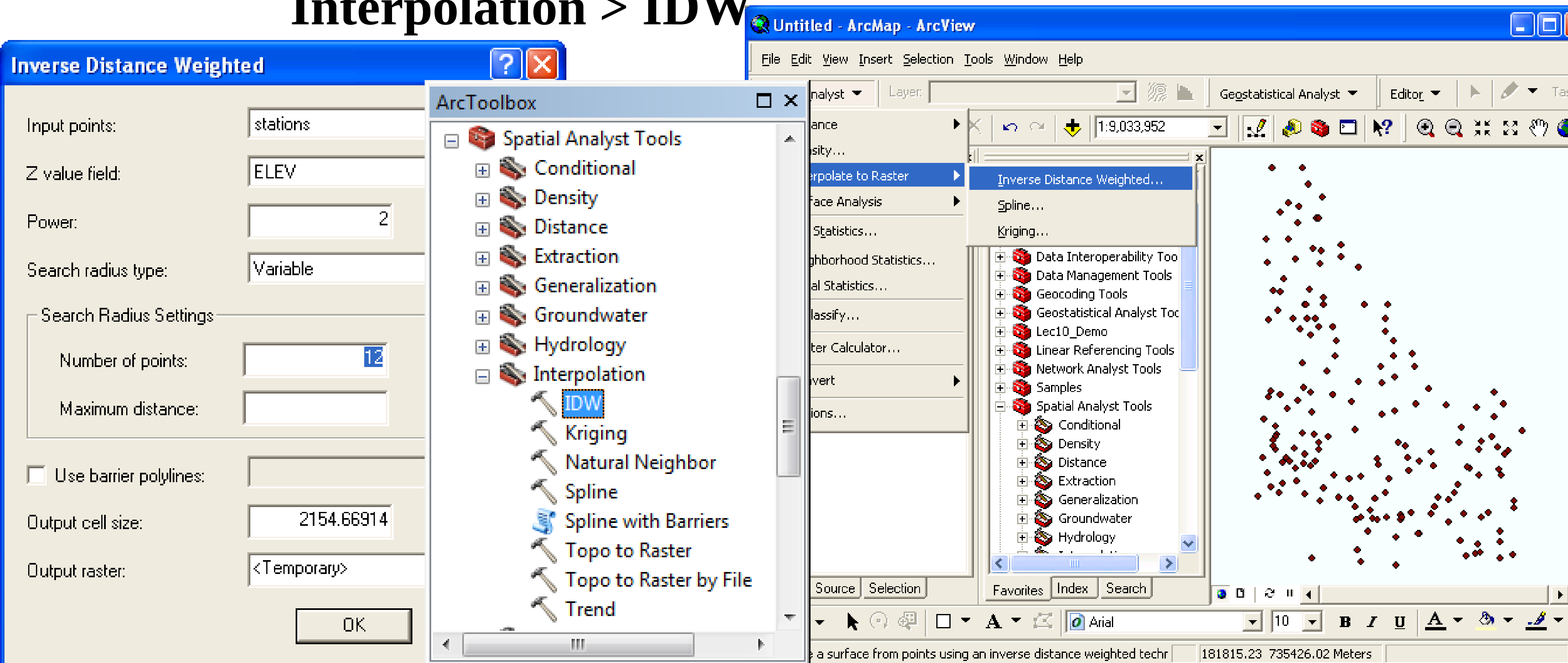
Surface Analysis

- Spatial Interpolation
  - IDW
    - Characteristics
      - Exact interpolator
      - Interpolated values equal sample point values at the sample locations
        - » Passed through the surface
        - » Note: This is no longer true since ArcGIS 10.2.
      - Reduction of the formula at sample point locations
      - Smoothed surfaces
        - » No value jumps
      - The input data should be projected.

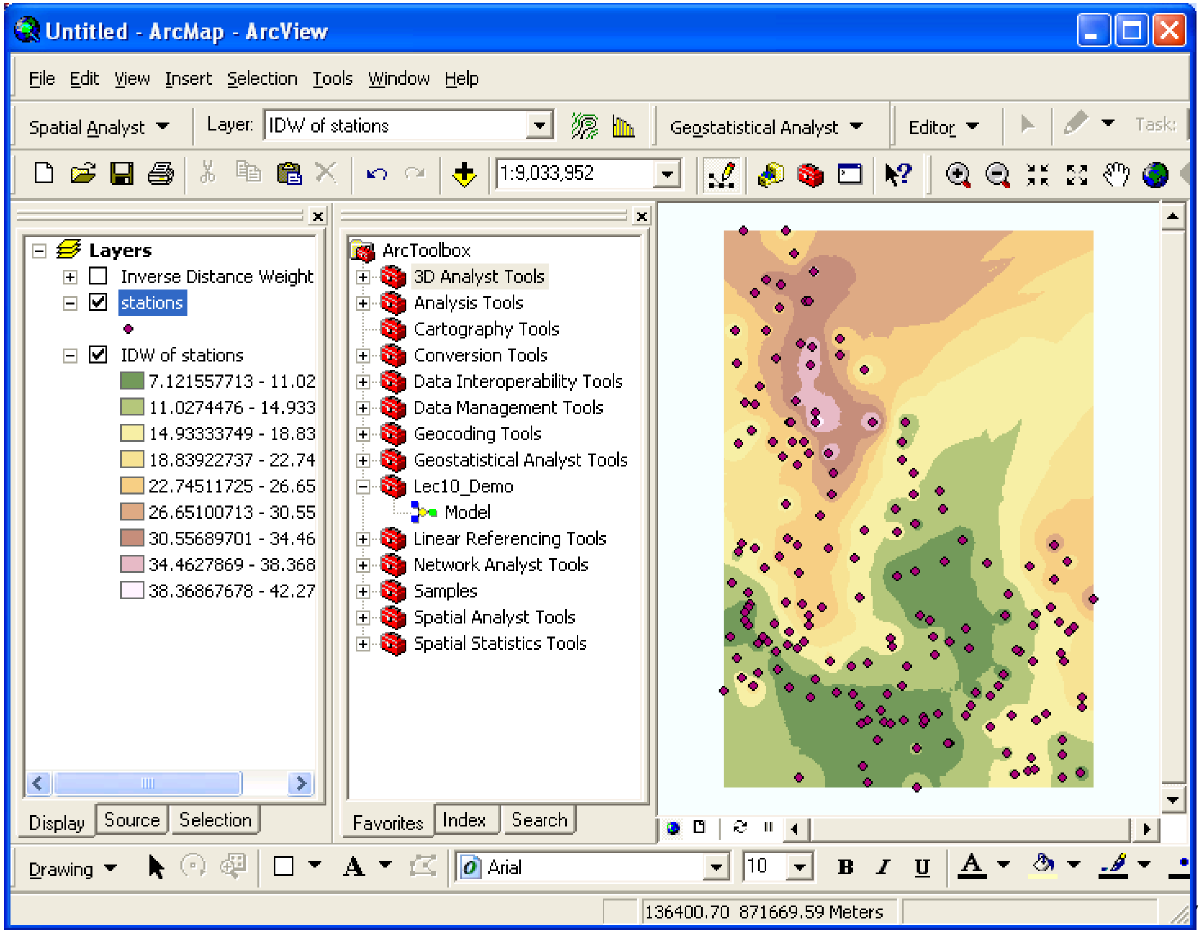
Surface Analysis

- Spatial Interpolation
  - IDW
    - There are multiple ways to conduct IDW analysis.
    - Example 1: **ArcToolbox** > **Spatial Analyst Tools** > **Interpolation** > **IDW**



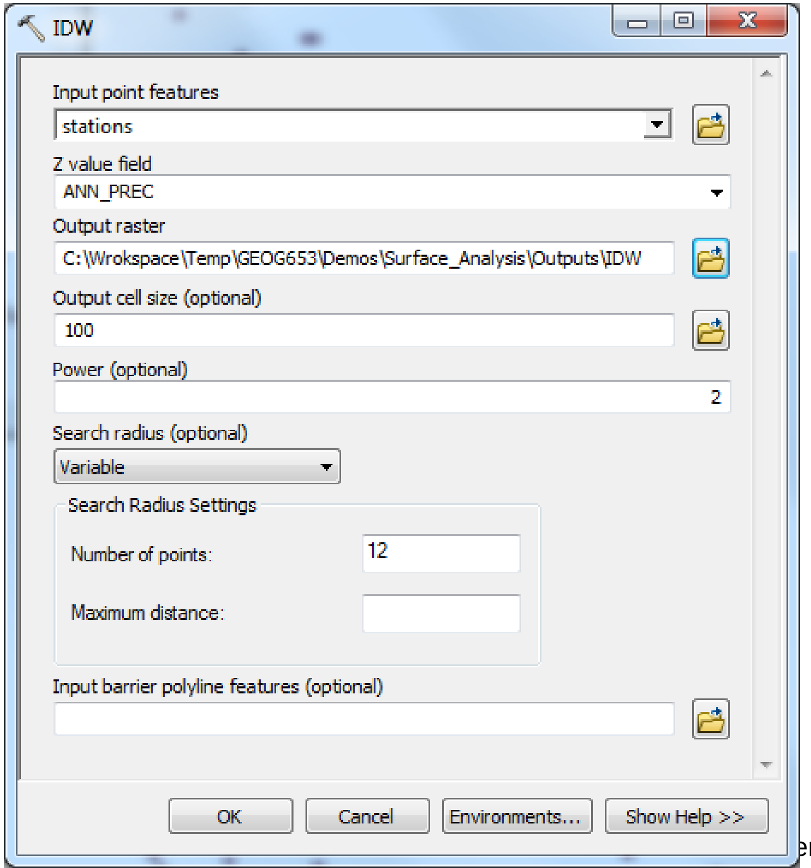
Surface Analysis

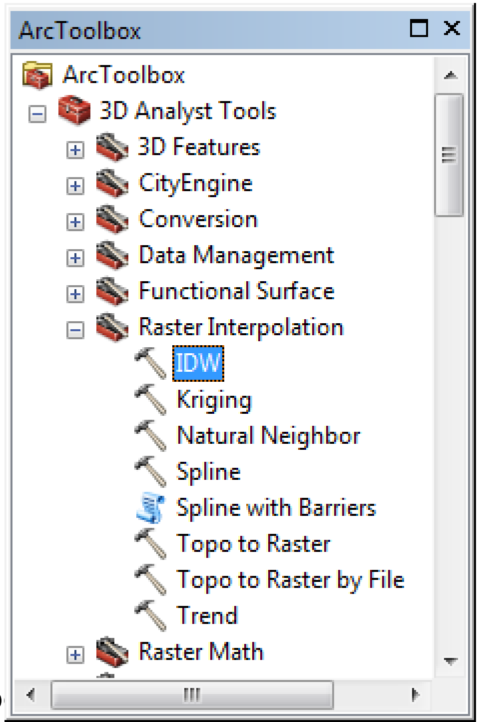
- Spatial Interpolation
  - IDW
    - Example 1: (‘continued)



Surface Analysis

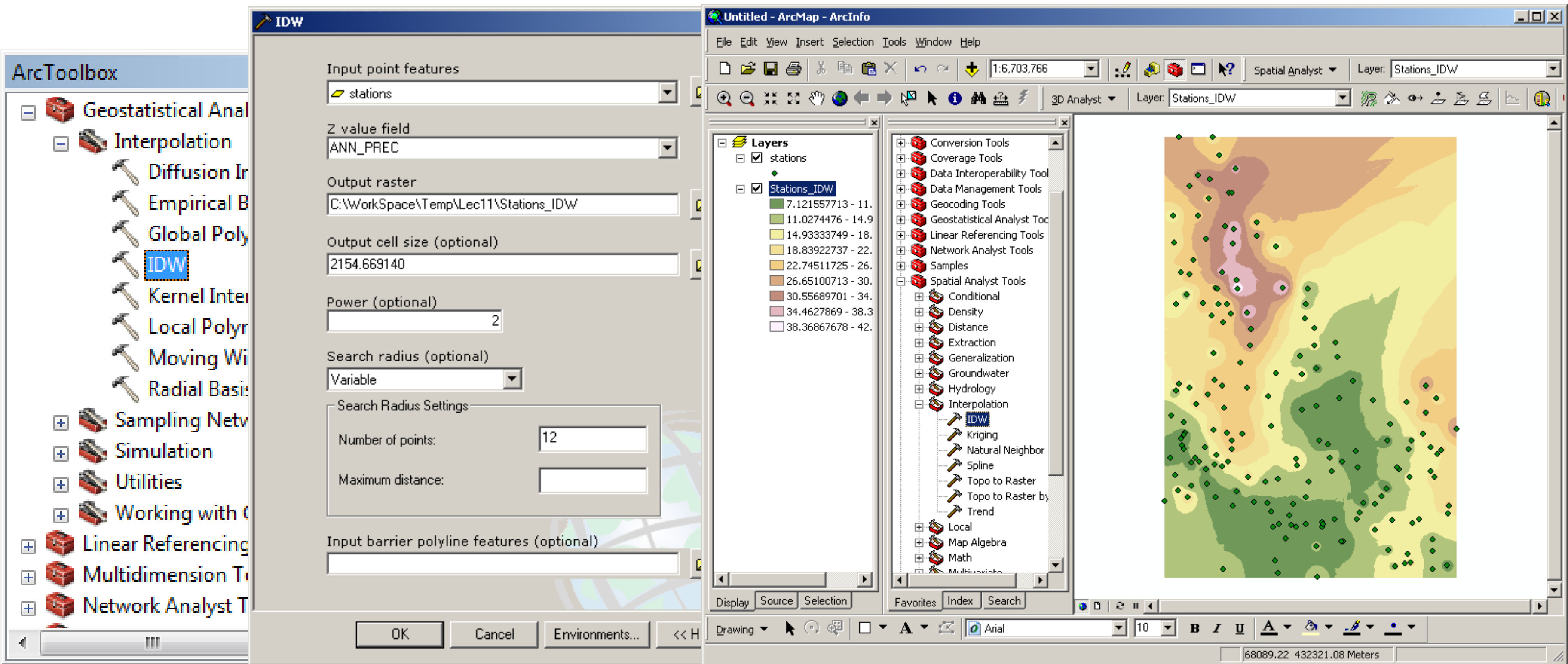
- Spatial Interpolation
  - IDW
    - Example 2: ArcToolbox > 3D Analyst Tools > Raster Interpolation > IDW





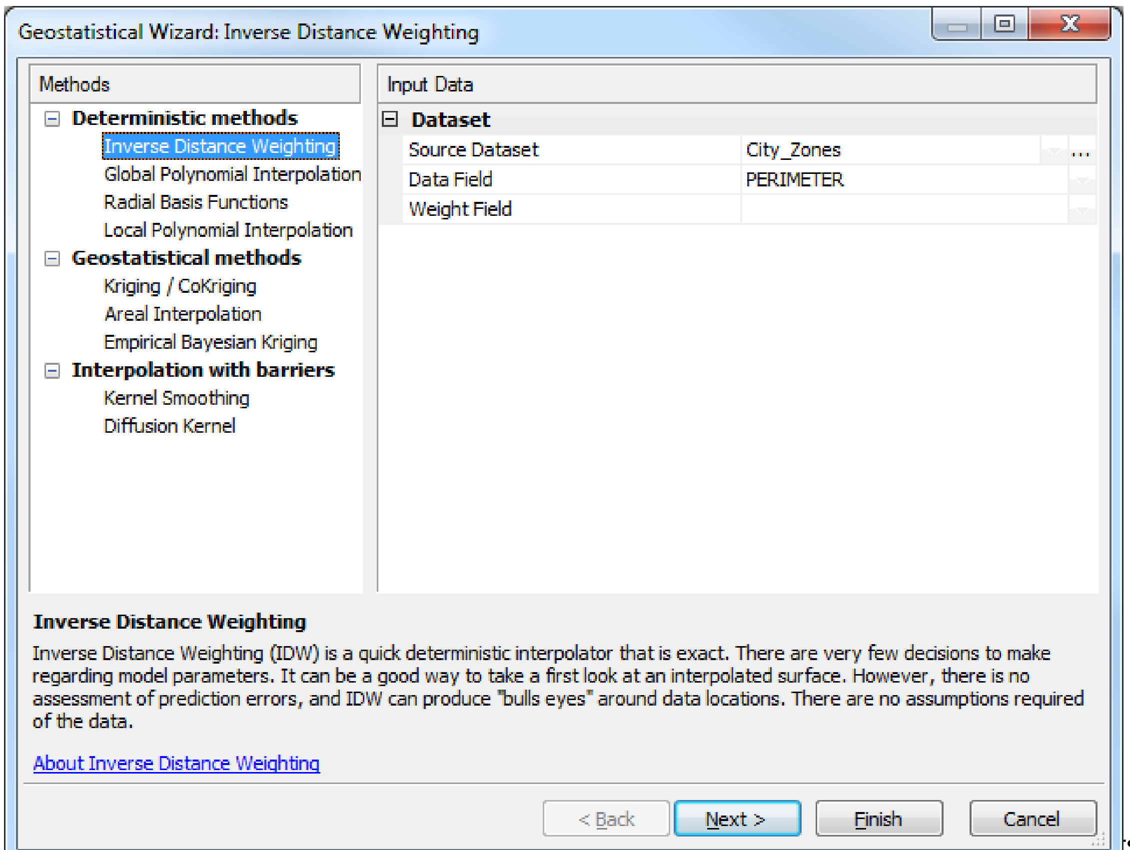
Surface Analysis

- Spatial Interpolation
  - – IDW
    - Example 3: ArcToolbox > Geostatistical Analyst Tools > Interpolation > IDW



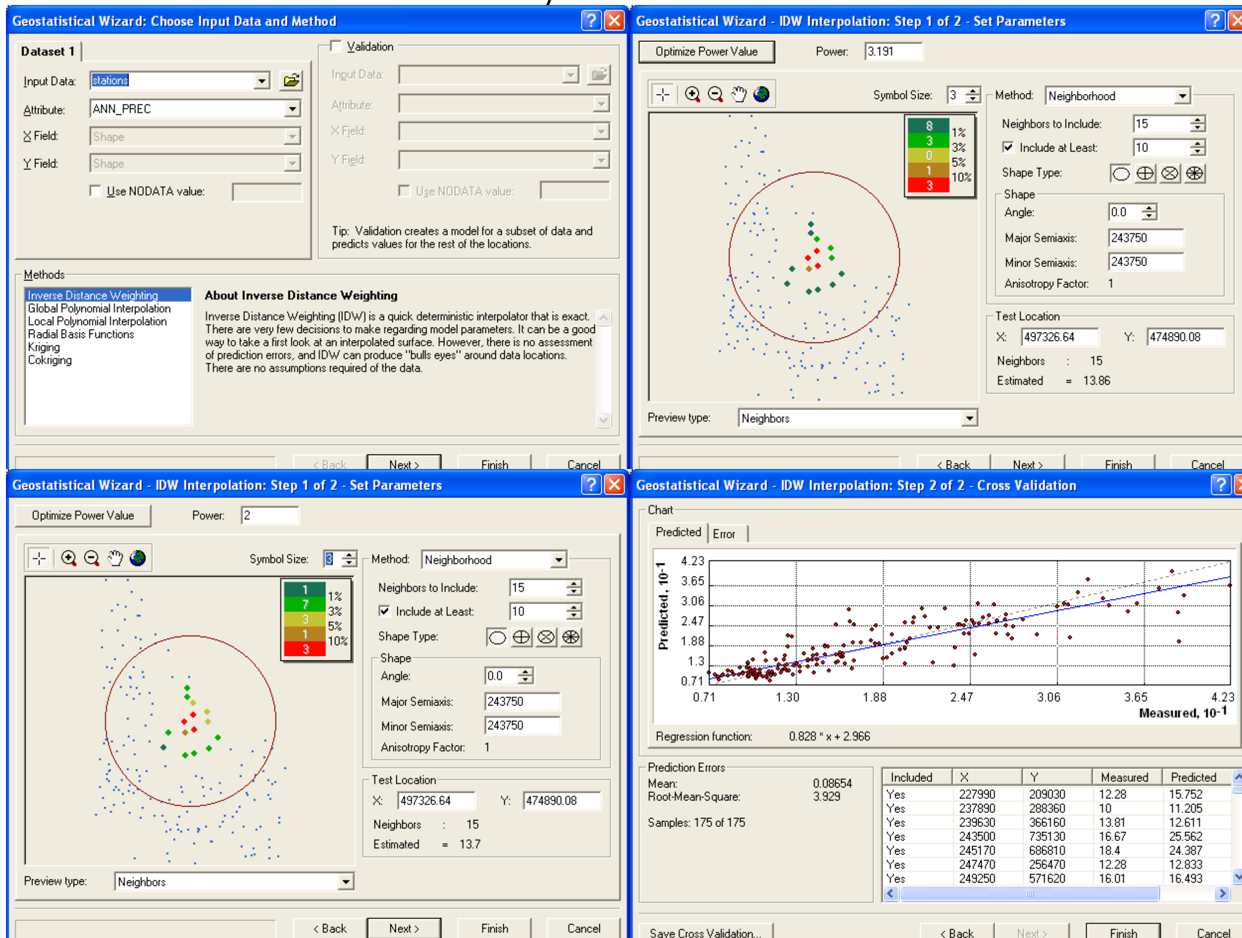
Surface Analysis

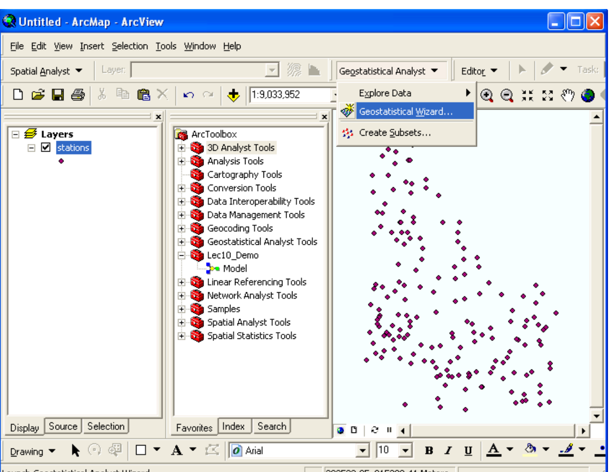
- Spatial Interpolation
  - IDW
    - Example 4: Geostatistical Analyst > Geostatistical Wizard



Surface Analysis

- Spatial Interpolation
  - IDW
    - Example 4: Geostatistical Analyst > Geostatistical Wizard





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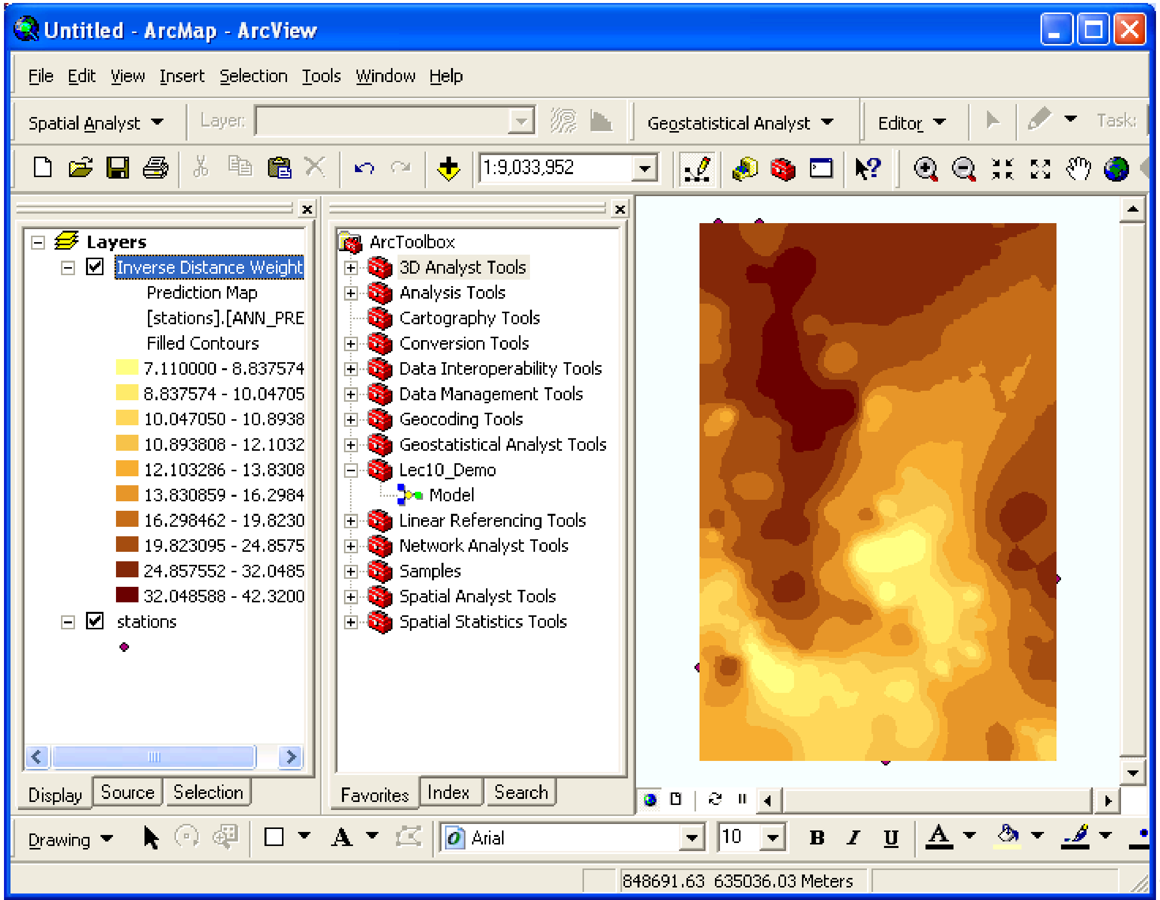
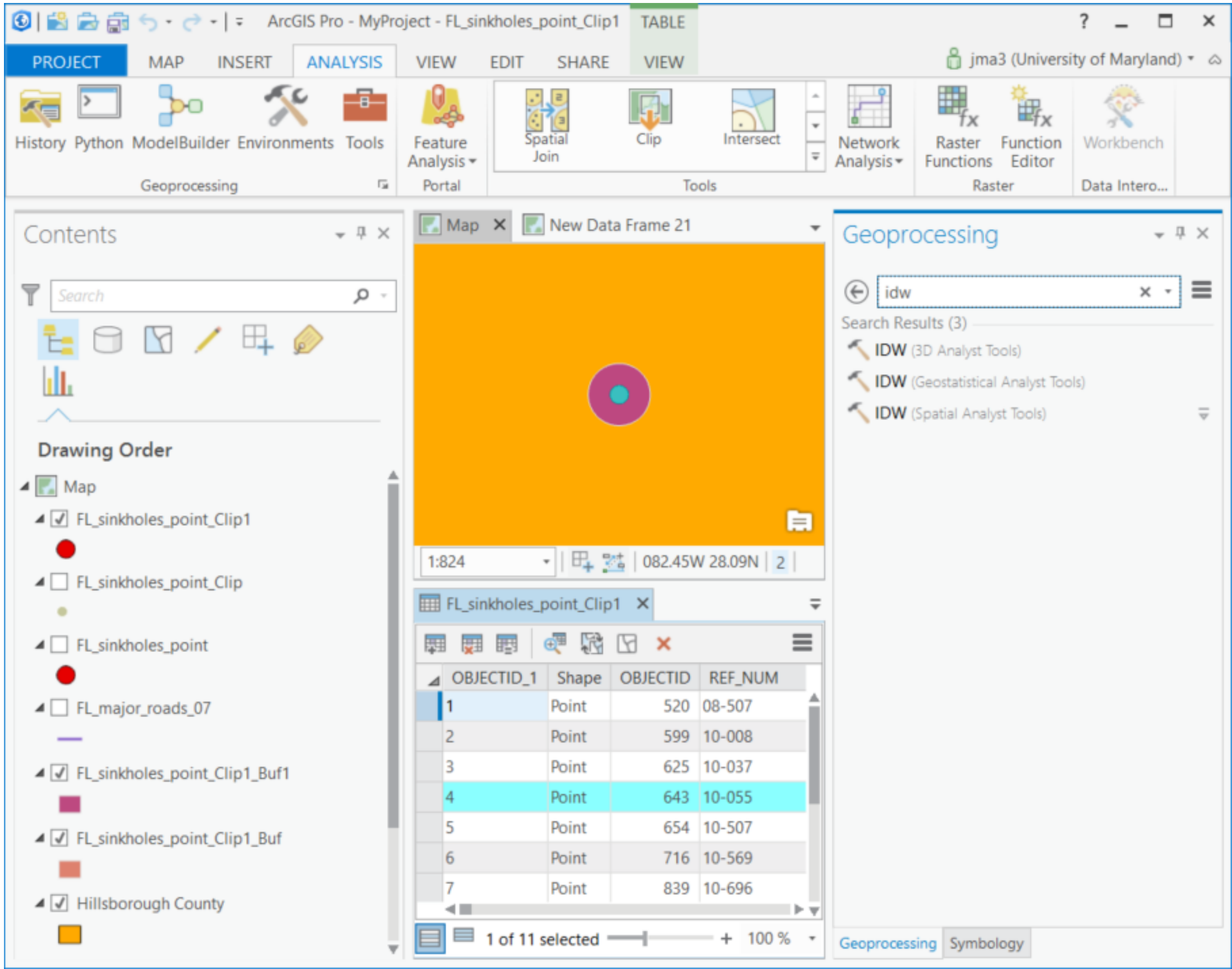
- Spatial Interpolation
  - IDW
    - Example 4: (‘continued)



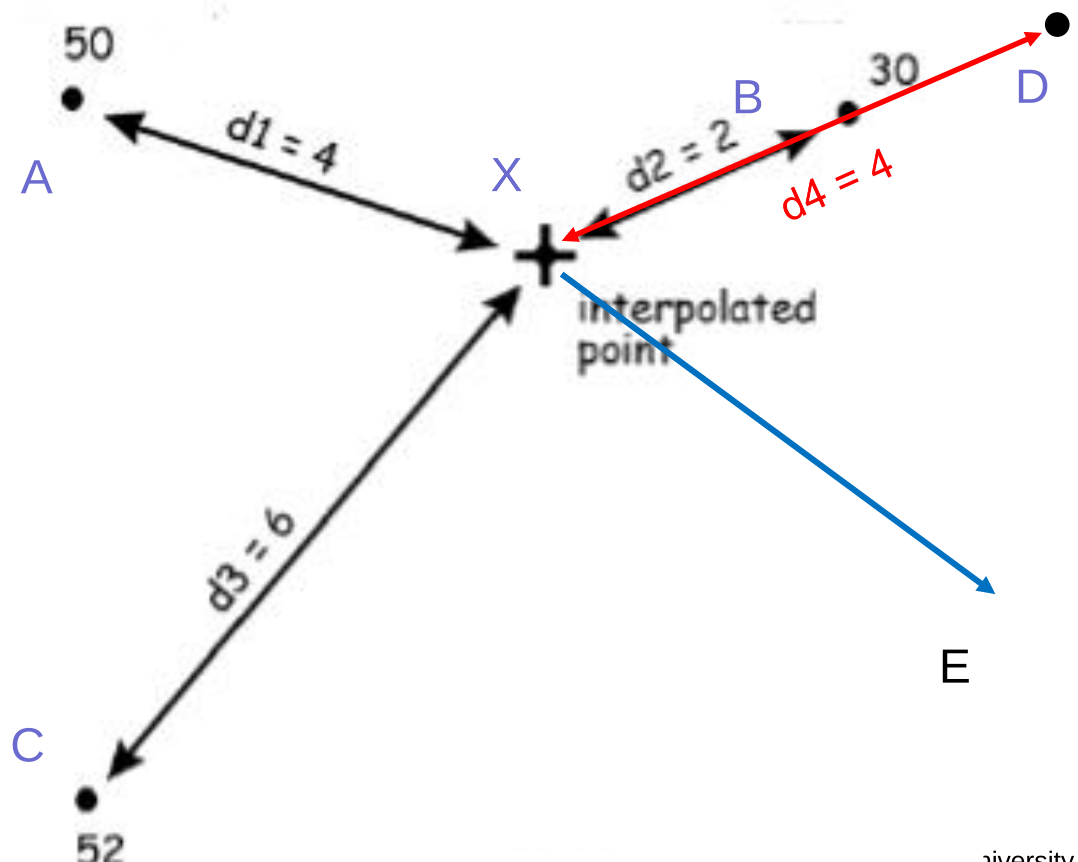
Surface Analysis

- Spatial Interpolation
  - IDW
    - ArcGIS Pro



- Spatial Interpolation
  - Kriging
    - Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for each location.
    - However, the weights in Kriging are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement among the measured points.
    - To use the spatial arrangement in the weights, the spatial autocorrelation must be quantified. The autocorrelation is a function of distance. This is a defining feature of geostatistics.

- Spatial Interpolation
  - Kriging
    - Example: Point D is in the same direction as Point B. (Overlap of influence of B-on-X and D-on-X.)



Surface Analysis

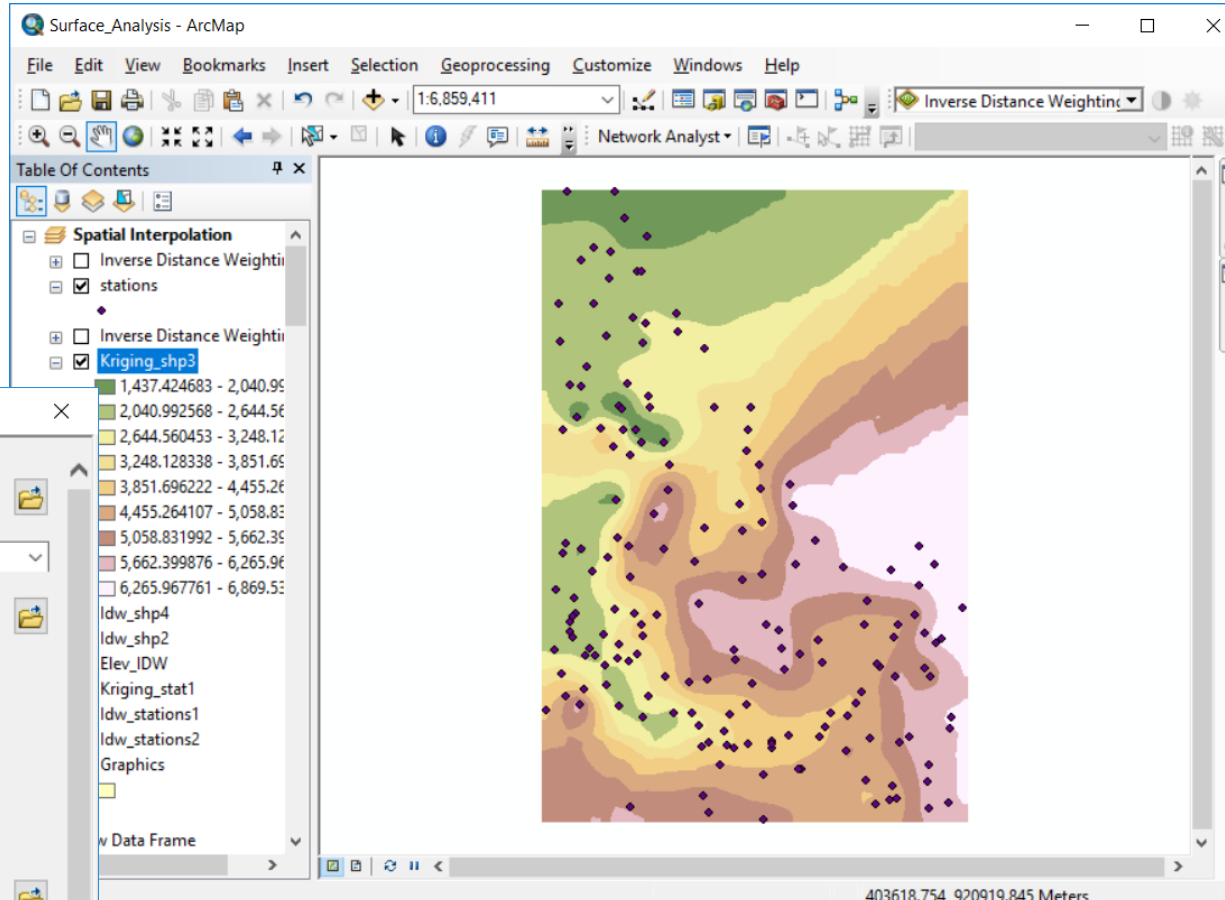
- Spatial Interpolation
  - Kriging
    - Depend on both mathematical and statistical models.
    - Not only produce prediction surface, but also provide some measure of the accuracy of these predictions.
    - Most appropriate when you know there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology.

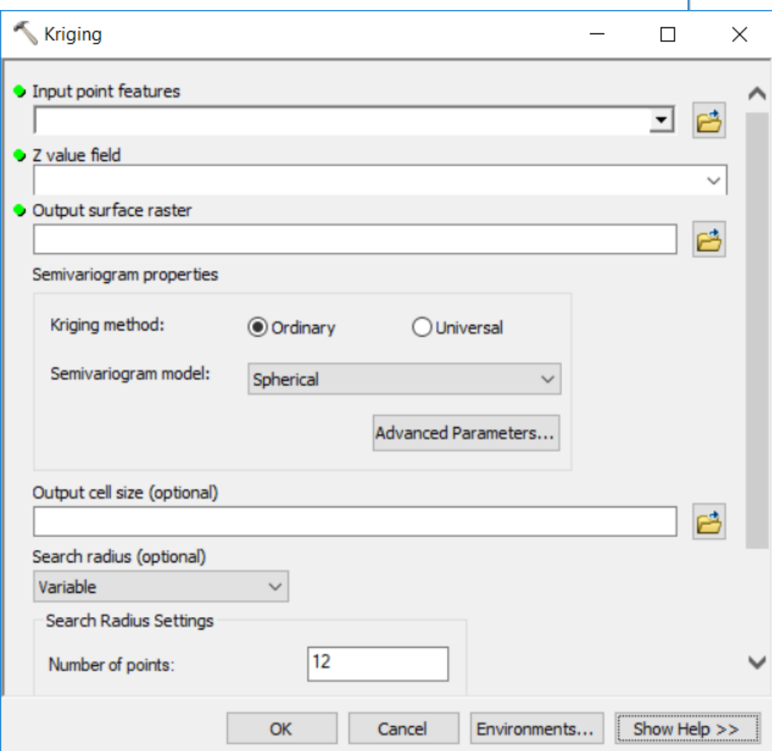
Surface Analysis

- Spatial Interpolation
  - Kriging
    - Ordinary vs. Universal
    - Universal kriging assumes that the spatial variation in z values has a drift or trend in addition to the spatial correlation between the sample points.
    - Ordinary kriging assumes no overall trend.

Surface Analysis

- Spatial Interpolation
  - Kriging





Surface Analysis

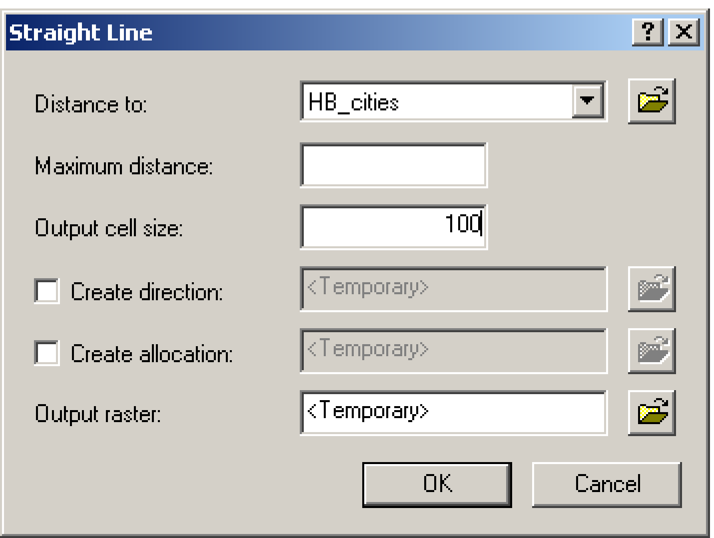
- Distance Analysis
  - Distance is a fundamental factor in spatial relationships.
  - Four methods of calculating distances:
    - Straight line distance (Euclidean Distance)
    - Allocation Distance
    - Cost Weighted
    - Shortest Path

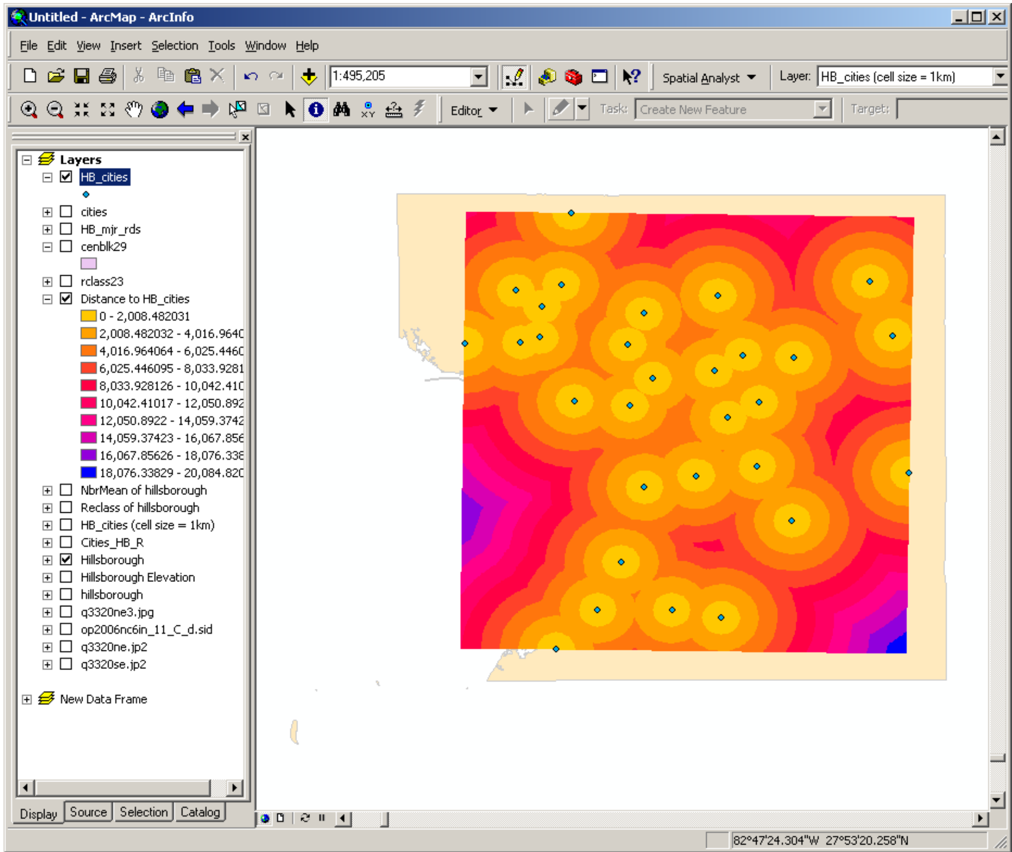
Surface Analysis

- Distance Analysis
  - Straight line distance (Euclidean Distance)
    - Measures the distance from a location to the nearest feature of interest.
    - Typically used for conducting a suitability analysis.
    - The values of cells in the output raster cells are real numbers, not integer.

Surface Analysis

- Distance Analysis
  - Straight line distance (Euclidean Distance)
    - Be careful about the Analysis Extent.





- Distance Analysis
  - Allocation Distance
    - Identifies the cells that are to be allocated to a source based on closest proximity.
    - Often used to locate the “service area” of an business/institute.
    - Every cell in the output raster is assigned the value of the source to which it is closest.
    - Compare to the network analysis….?

Surface Analysis

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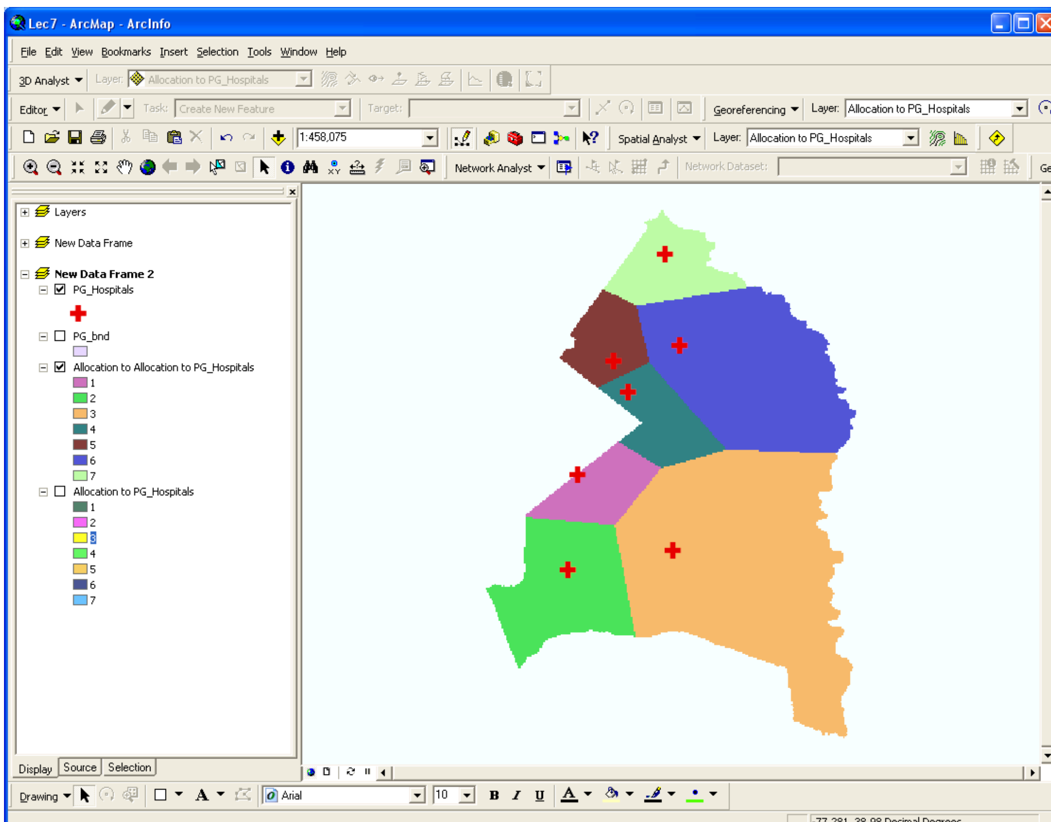
- Distance Analysis
  - Allocation Distance
    - Example: service areas of hospitals in Prince George’s County, Maryland



- Distance Analysis
  - Cost Weighted
    - They are similar to Euclidean functions, but instead of calculating the actual distance from one point to another, they determine the shortest weighted distance (or accumulated travel cost) from each cell to the nearest cell in the set of source cells.
    - They apply distance not in geographic units but in cost units.
    - All weighted-distance functions require a source raster and a cost raster.
    - It creates an output raster in which each cell is assigned the accumulative cost to the closest source cell.

Surface Analysis

- Distance Analysis
  - Cost Weighted
    - Example: estimating "cost" of road construction

Slope

3	2	2
4	4	2
6	5	3

*0.66 =

1.98	1.32	1.32
2.64	2.64	1.32
4.62	3.30	1.98

Landuse

1	1	1
6	6	1
6	3	3

*0.34 =

0.34	0.34	0.34
2.04	2.04	0.34
2.04	1.02	1.02

1.98	1.32	1.32
2.64	2.64	1.32
4.62	3.30	1.98

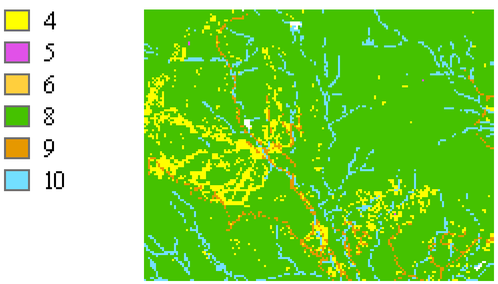
+

0.34	0.34	0.34
2.04	2.04	0.34
2.04	1.02	1.02

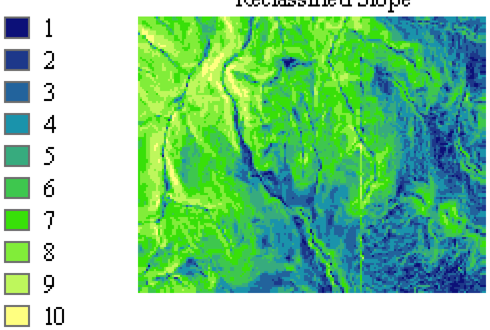
=

2.32	1.66	1.66
4.68	4.68	1.66
4.02	4.68	3.00

Reclassified Landuse

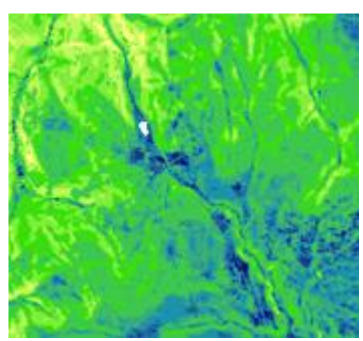


Reclassified Slope

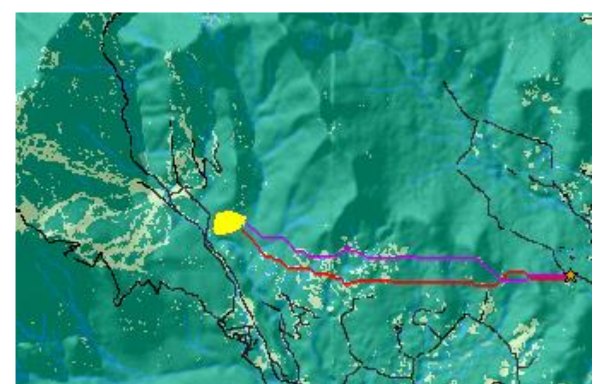


High cell values are the more costly cells through which to route the road.

Cost Raster



Cost Distance Raster



Surface Analysis

- Distance Analysis
  - Shortest Path (Path Distance)
    - "Actual travel distance" vs. "straight line distance" (e.g. two points separated by a lake)
    - It is similar to Cost Distance in that both functions determine the minimum accumulative travel cost from a source to each cell location on a raster.
    - But Path Distance not only calculates the accumulative cost over a cost surface, it does so while compensating for the actual surface distance that must be traveled and for the horizontal and vertical factors influencing the total cost of moving from one location to another.

Surface Analysis

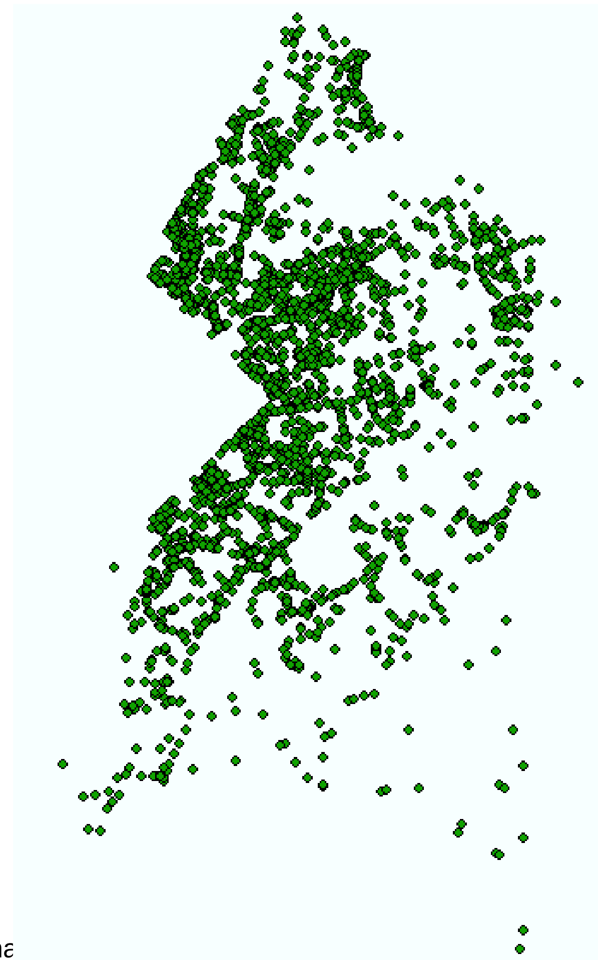
- Density Analysis
  - The Density function distributes a measured quantity of an input layer throughout a landscape to produce a continuous surface.
  - Density surfaces are good for showing where point or line features are concentrated.

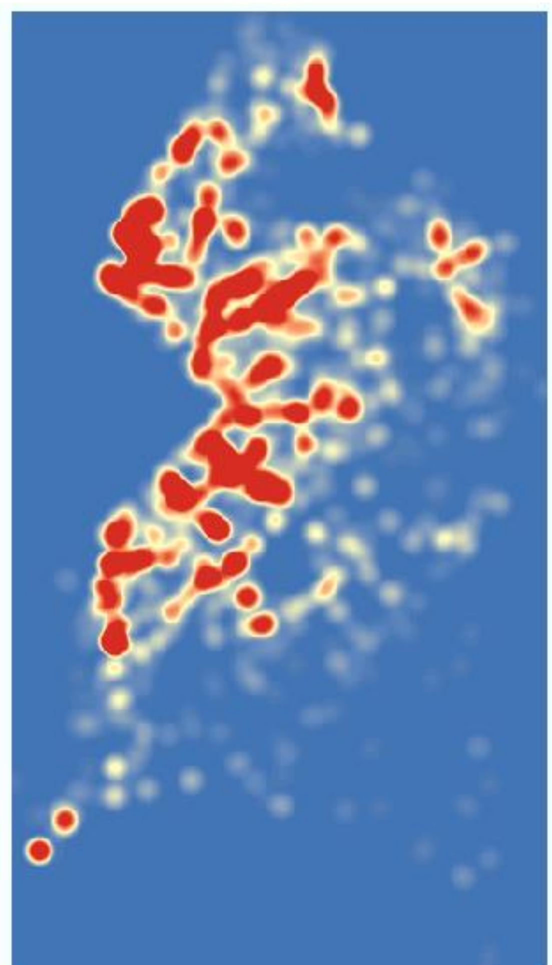
Surface Analysis

- Density Analysis
  - Point Density: Magnitude-per-unit area from point features that fall within a neighborhood around each cell.
  - Line density: Average total length of lines within a unit size of area

Surface Analysis

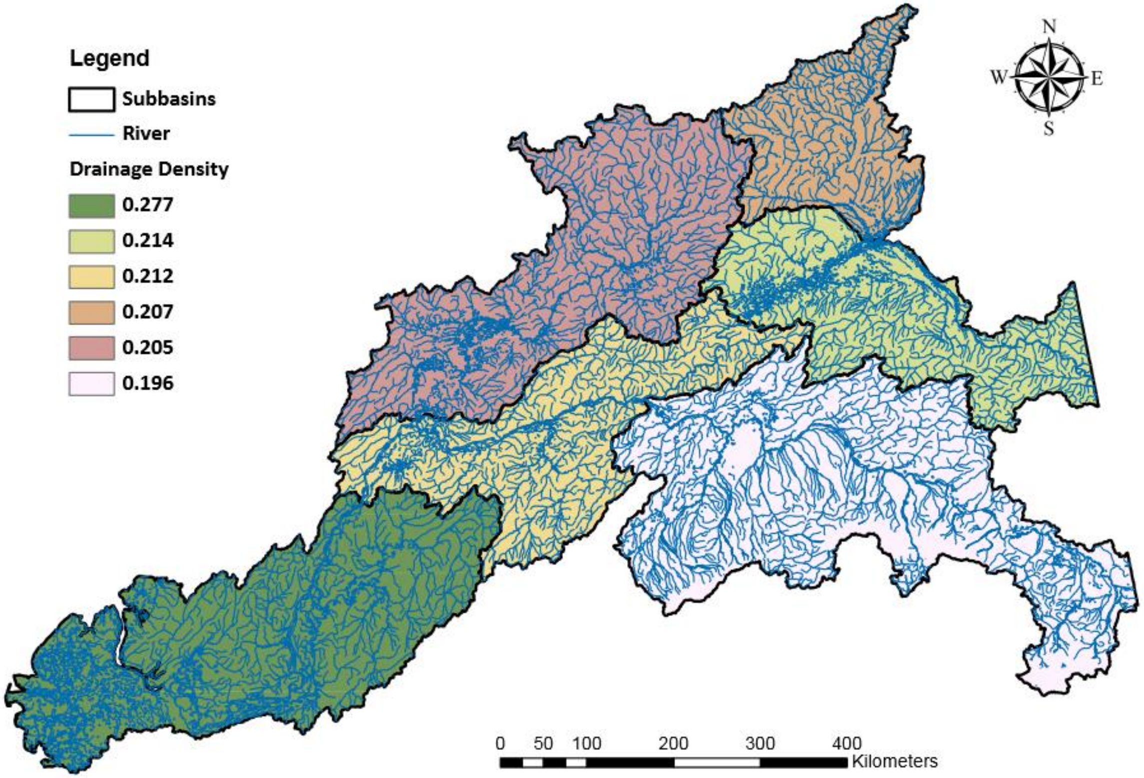
- Density Analysis
  - Example: density surface of car accidents





Surface Analysis

- Density Analysis
  - Example: Higher stream density → Higher flood potential



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Source: Alaska Geospatial Data Clearinghouse

Surface Analysis

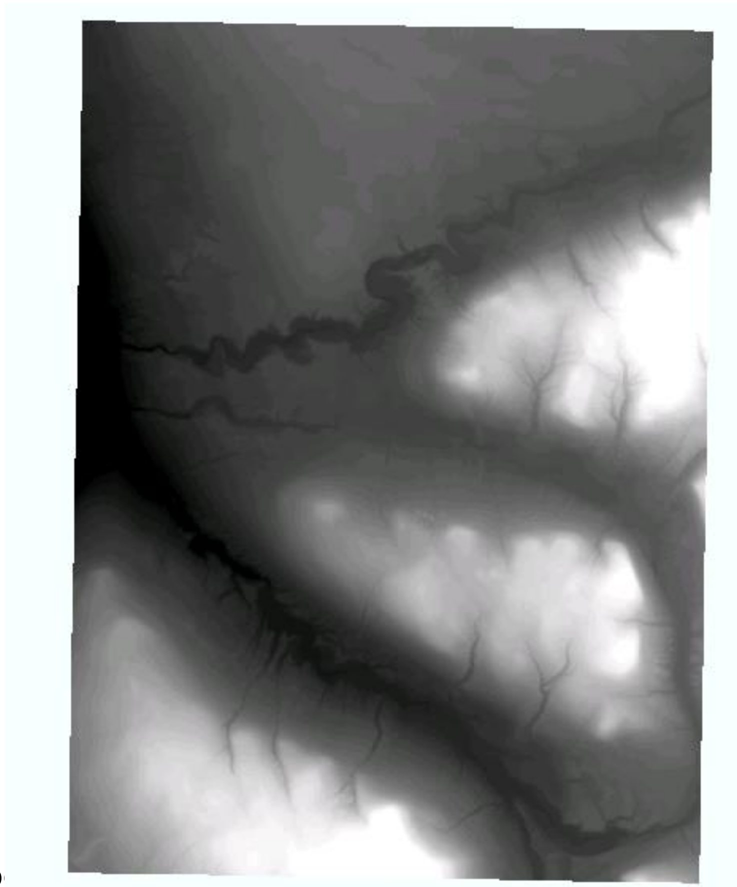
- Surface Analysis Operations
  - Contour
  - Slope
  - Aspect
  - Hillshade
  - Viewshed
  - Cut/Fill

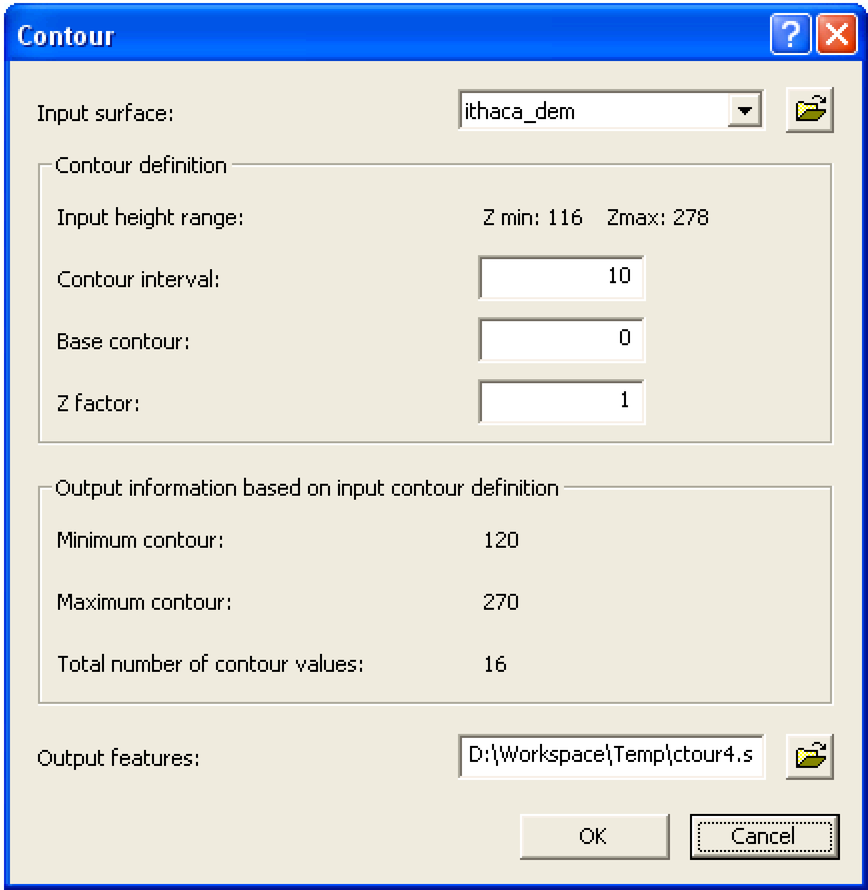
Surface Analysis

- Surface Analysis Operations
  - Contour
    - Contours are polylines that connect points of equal value.
      - Example: elevation, temperature, precipitation, pollution, or atmospheric pressure.
      - By following the polyline of a particular contour, you can identify which locations have the same value. Contours are also a useful surface representation, because they allow you to simultaneously visualize flat and steep areas (distance between contours) and ridges and valleys (converging and diverging polylines).

Surface Analysis

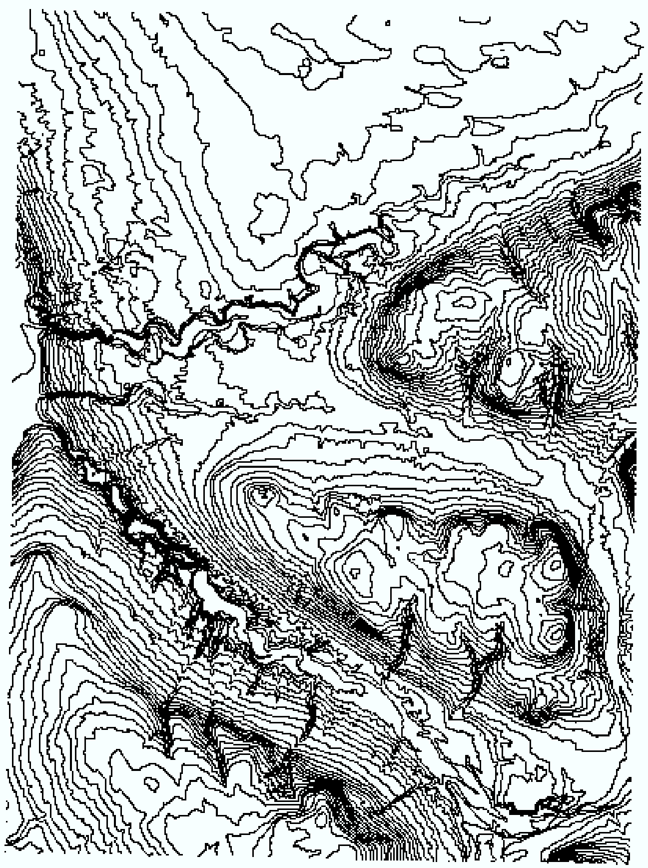
- Surface Analysis Operations
  - Contour
    - Example:

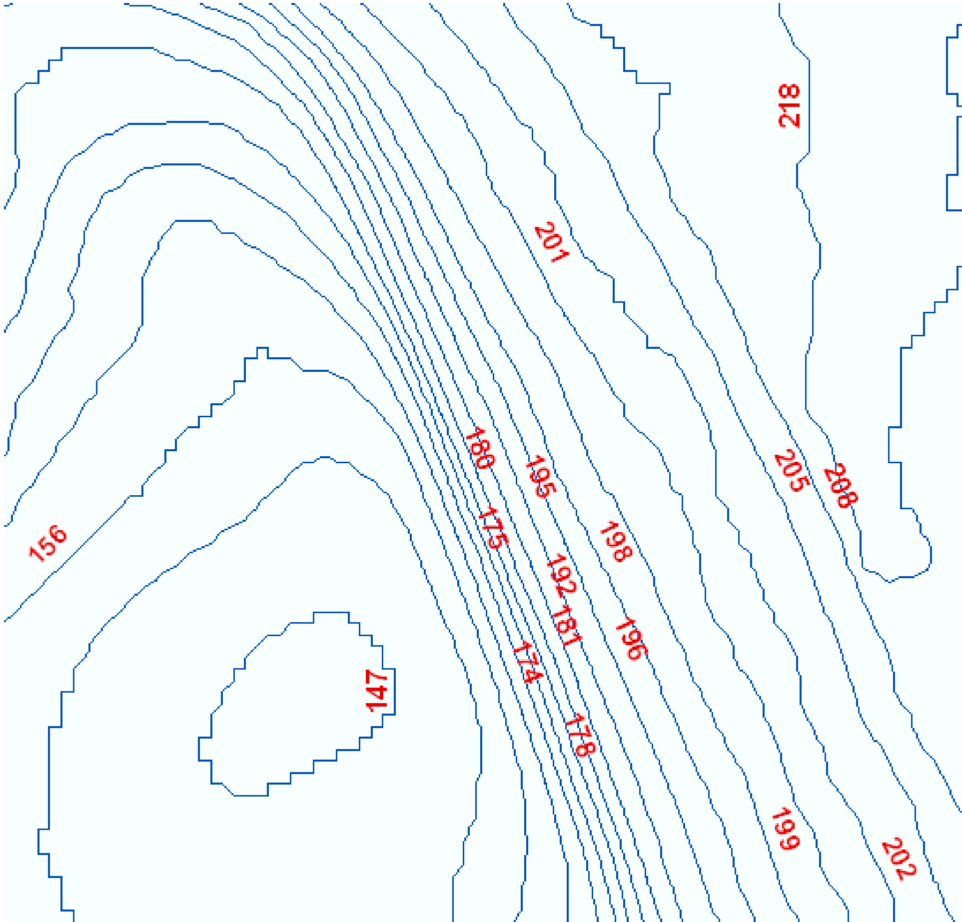




Surface Analysis

- Surface Analysis Operations
  - Contour
    - Example:





- Surface Analysis Operations
  - Hillshade
    - This tool creates a shaded relief from a surface raster by considering the illumination source angle and shadows.
    - This tool obtains the hypothetical illumination of a surface by determining illumination values for each cell in a raster.
      - It does this by setting a position for a hypothetical light source and calculating the illumination values of each cell in relation to neighboring cells.
      - The hillshade raster has an integer value range of 0 to 255.

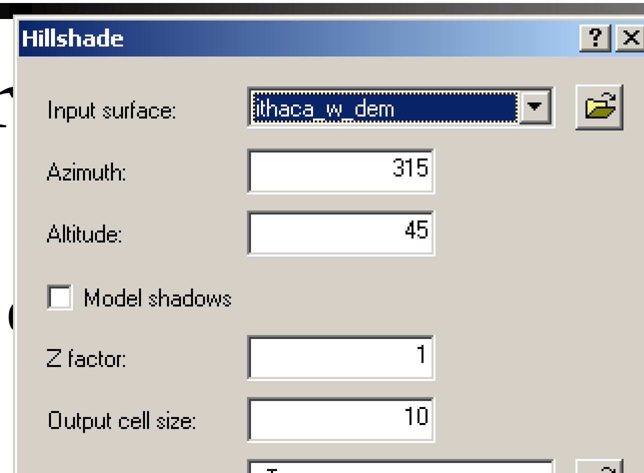
Surface Analysis

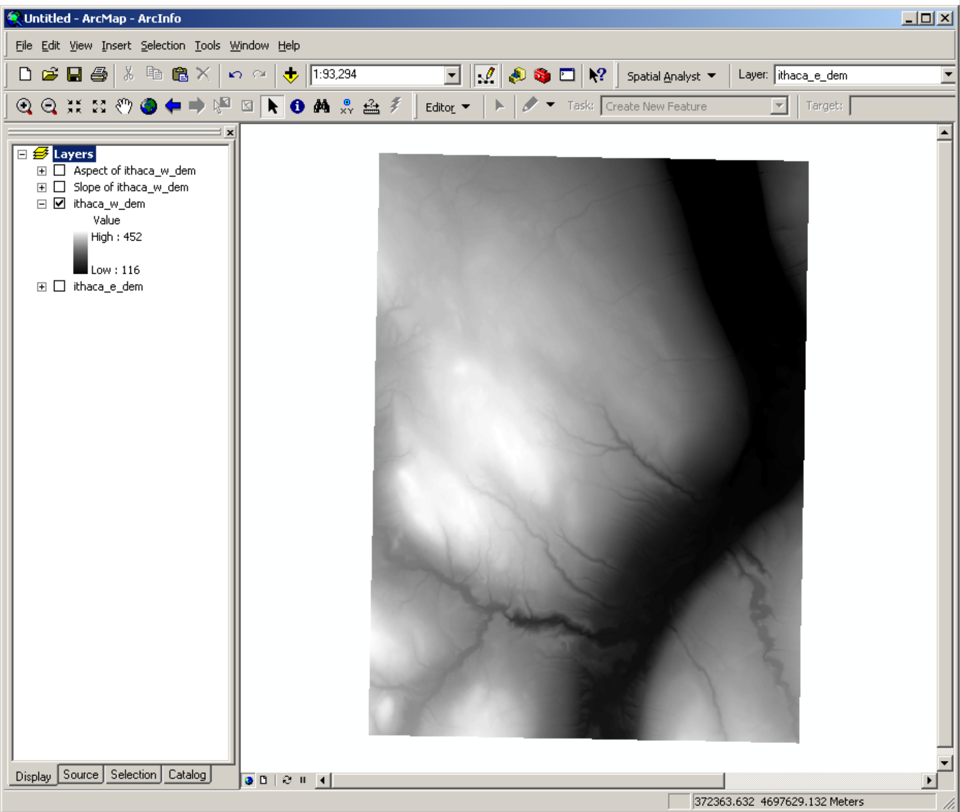
- Surface Analysis Operations
  - Hillshade
    - The primary factor when creating a hillshade map for any particular location is the location of the sun in the sky.
      - Azimuth
      - Altitude

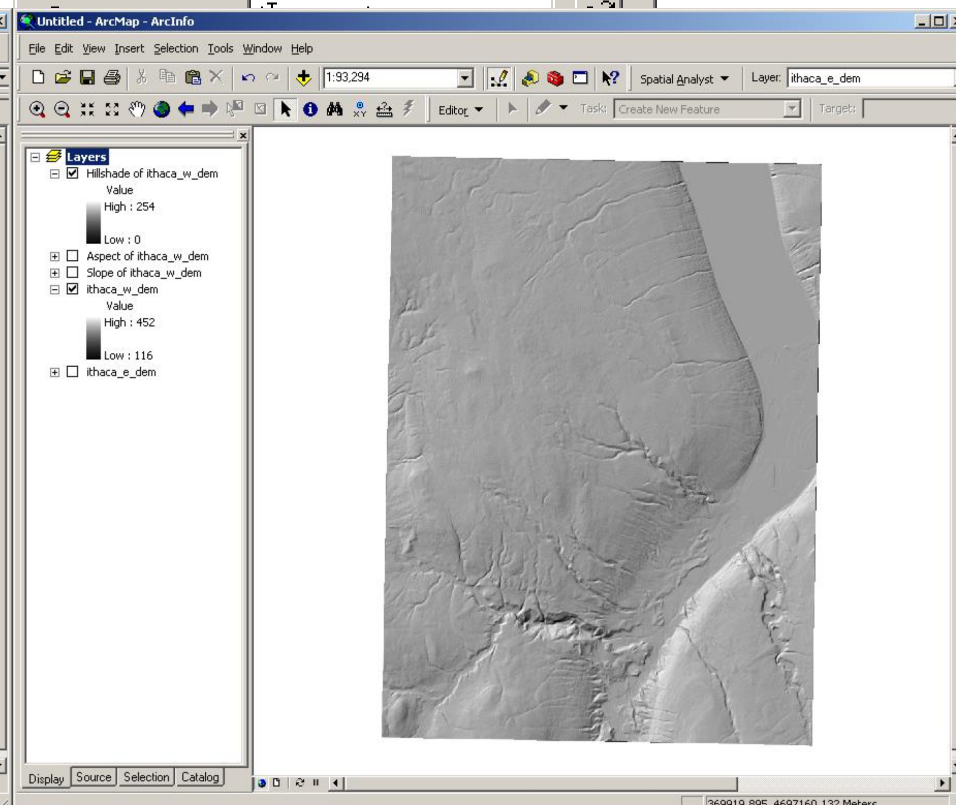
- Surface Analysis Operations
  - Hillshade
    - Hillshade Parameters
      - Azimuth
        - » The azimuth is the angular direction of the sun, measured from north in clockwise degrees from 0 to 360.
        - » An azimuth of 90º is east.
        - » The default azimuth is 315º (NW).
      - Altitude
        - » The altitude is the slope or angle of the illumination source above the horizon.
        - » The units are in degrees, from 0 (on the horizon) to 90 (overhead).
        - » The default is 45 degrees.

Surface Analysis

- Surface Analysis Oper
  - Hillshade
    - Example: creating 3-D

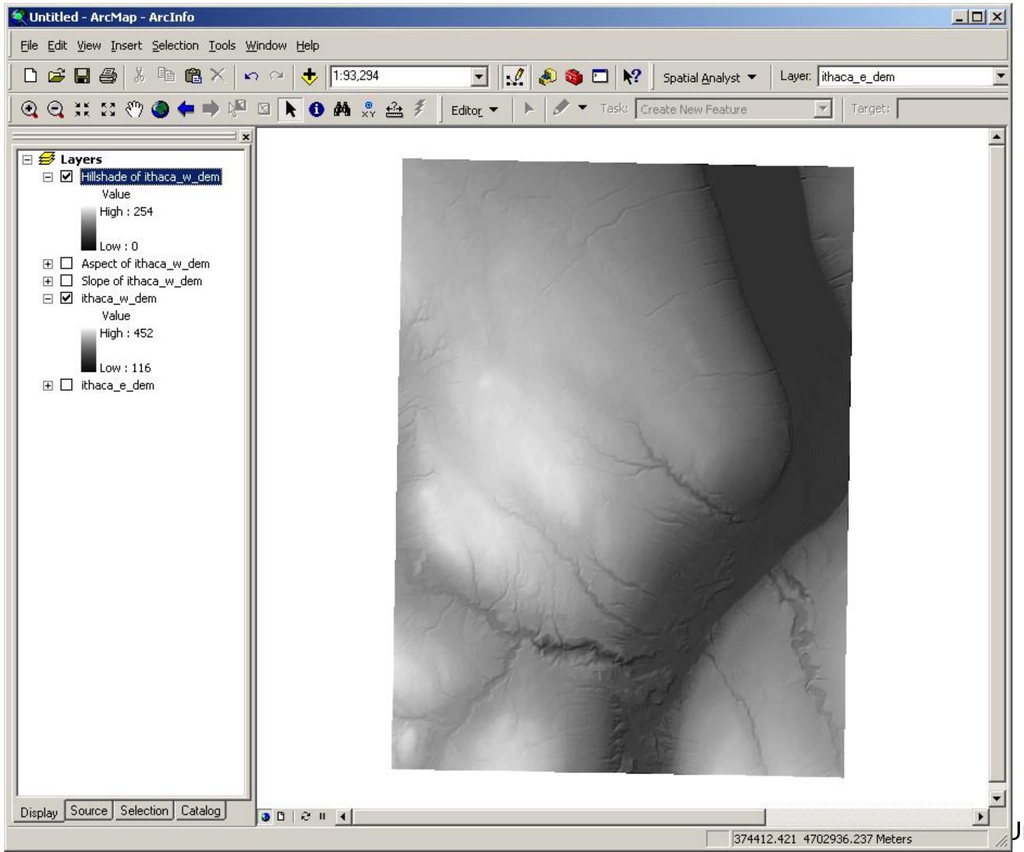






Surface Analysis

- Surface Analysis Operations
  - Hillshade
    - Example: creating 3-D effect



- Surface Analysis Operations
  - Slope
    - Slope identifies the steepest downhill slope for a location on a surface.
      - Slope is the rate of maximum change in z-value from each cell.
      - For each cell, the Slope tool calculates the maximum rate of change in value from that cell to its neighbors.

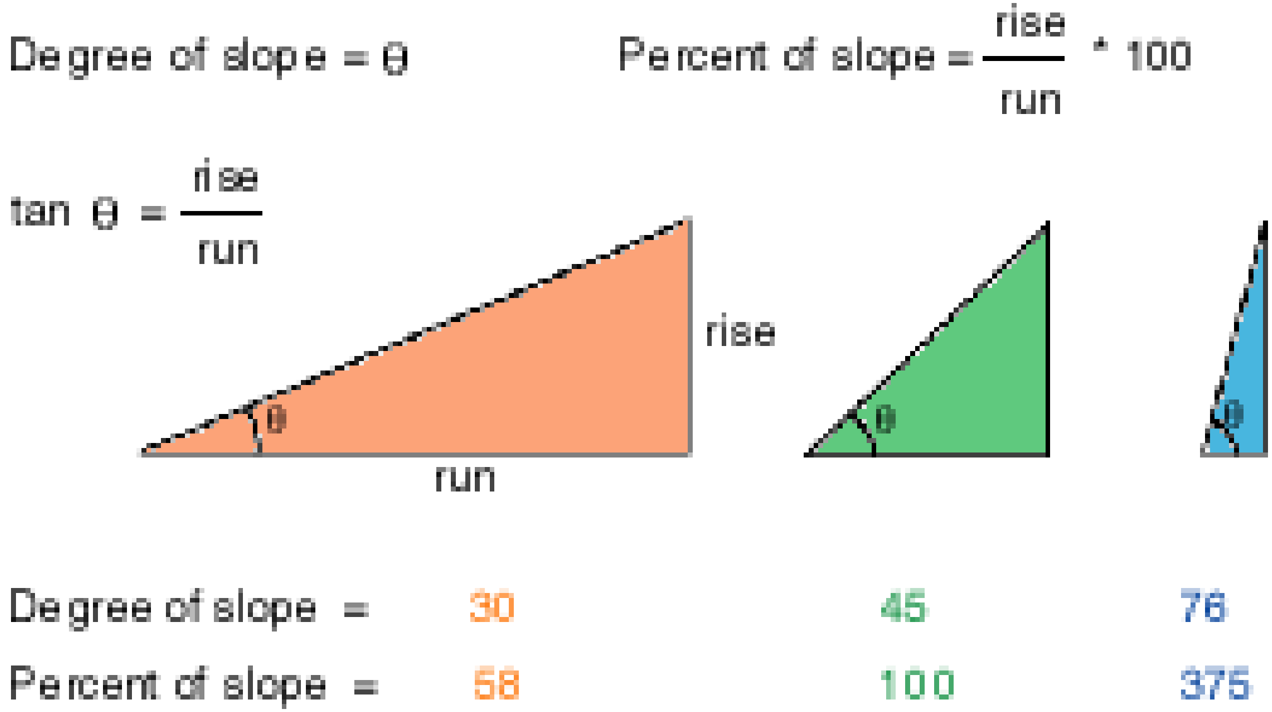
10	**20**	**50**	**100**	**200**
25	30	60	60	40
35	40	70	50	40
20	50	60	60	20

Surface Analysis

- Surface Analysis Operations
  - Slope
    - The range of values in the output depends on the type of measurement units.
      - Degree
        - » The range of slope values is 0 to 90.
      - Percent
        - » The range is 0 to essentially infinity.
        - » A flat surface is 0 percent, a 45 degree surface is 100 percent, and as the surface becomes more vertical, the percent rise becomes increasingly larger.

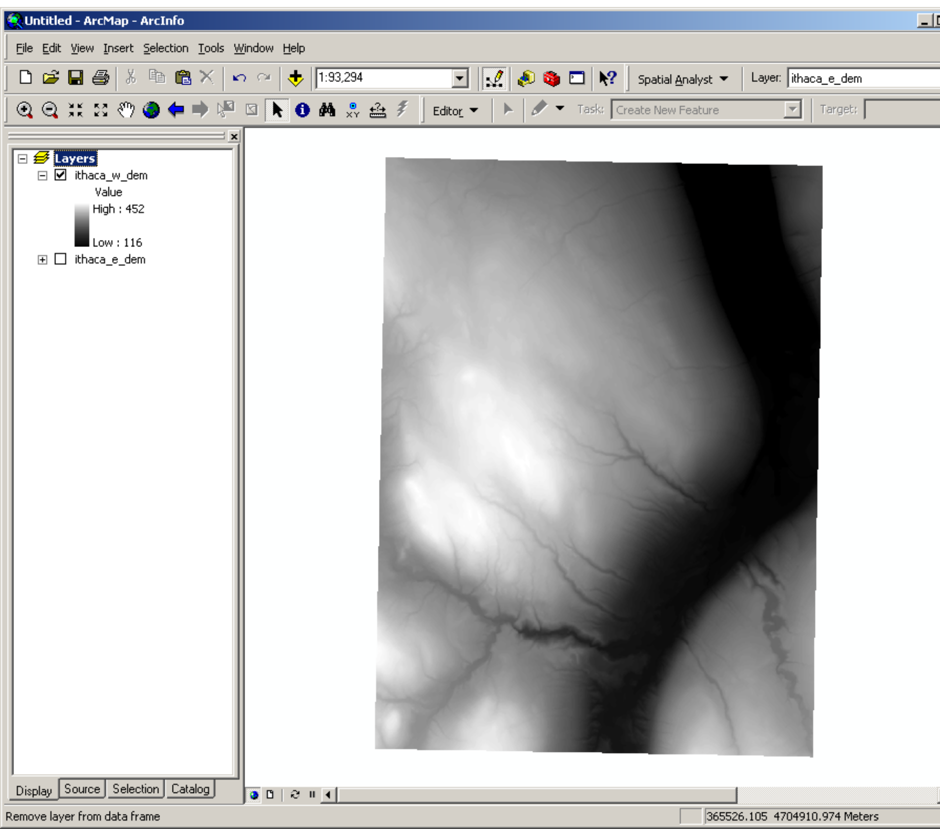
Surface Analysis

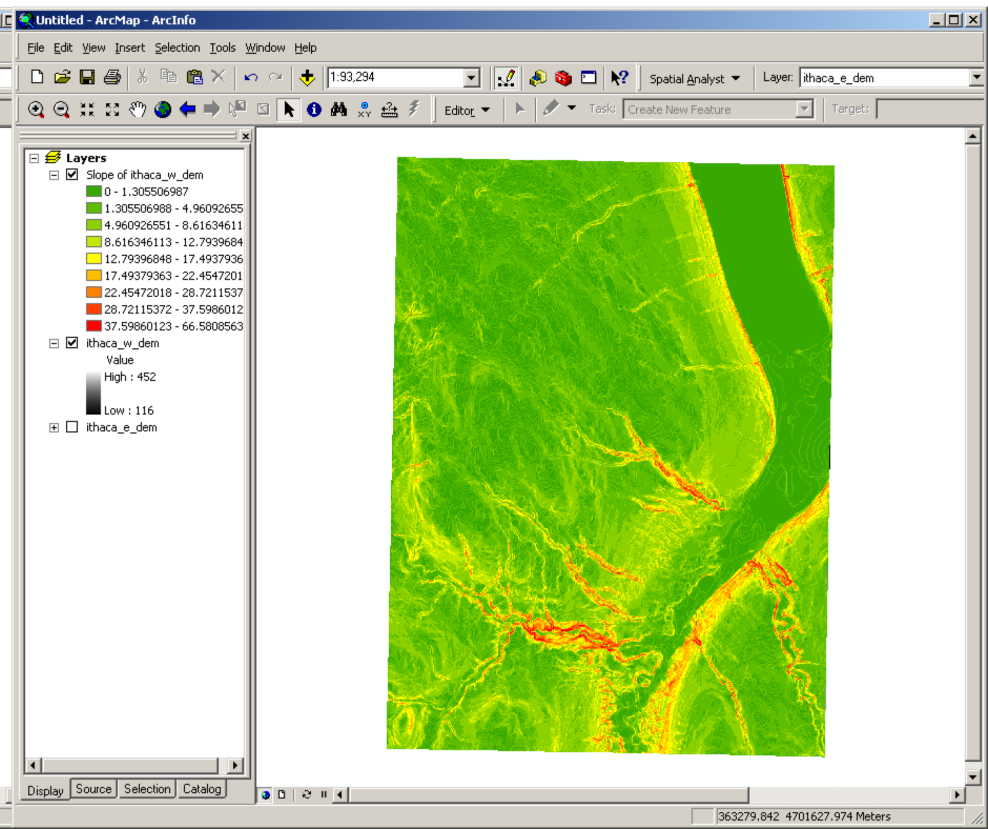
- Surface Analysis Operations
  - Slope
    - Slope identifies the steepest downhill slope for a location on a surface.



Surface Analysis

- Surface Analysis Operations
  - Slope
    - Example:

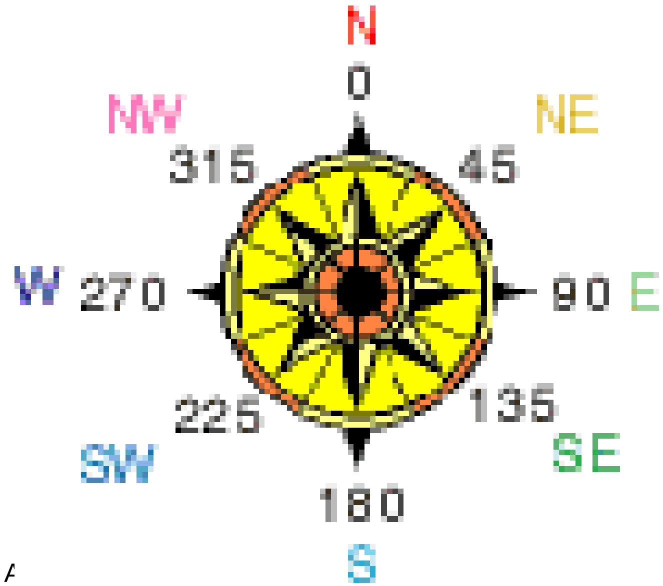


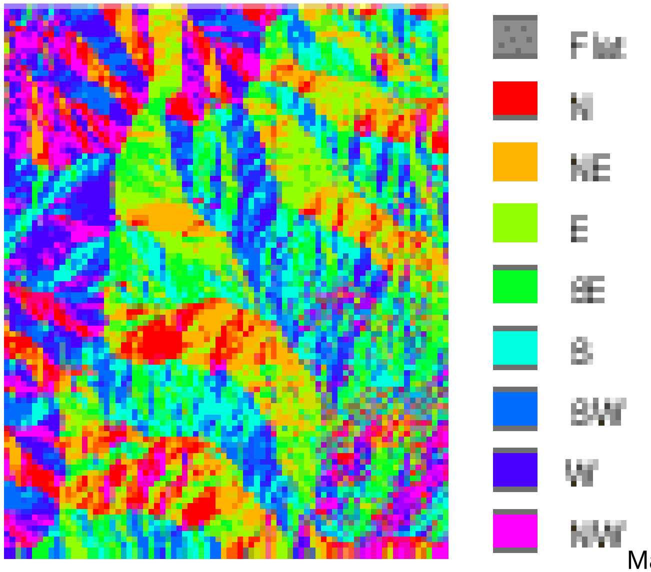


Surface Analysis

- Surface Analysis Operations
  - Aspect
    - Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors.
    - It can be thought of as the slope direction. The values of each cell in the output raster indicate the compass direction that the surface faces at that location.
    - Aspect is measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle.
    - Flat slopes have no direction and are given a value of -1.

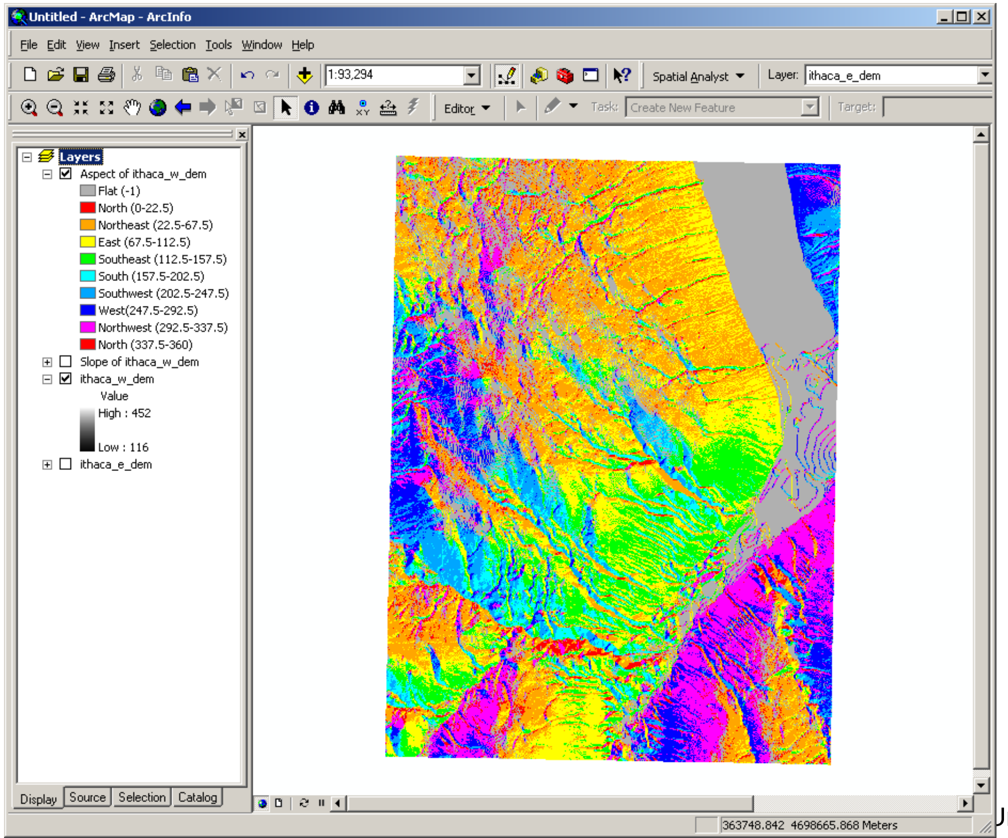
- Surface Analysis Operations
  - Aspect
    - Aspect identifies the steepest down slope direction at a location on a surface.
    - Flat slopes have no direction and are given a value of -1.





Surface Analysis

- Surface Analysis Operations
  - Aspect
    - Example:



Surface Analysis

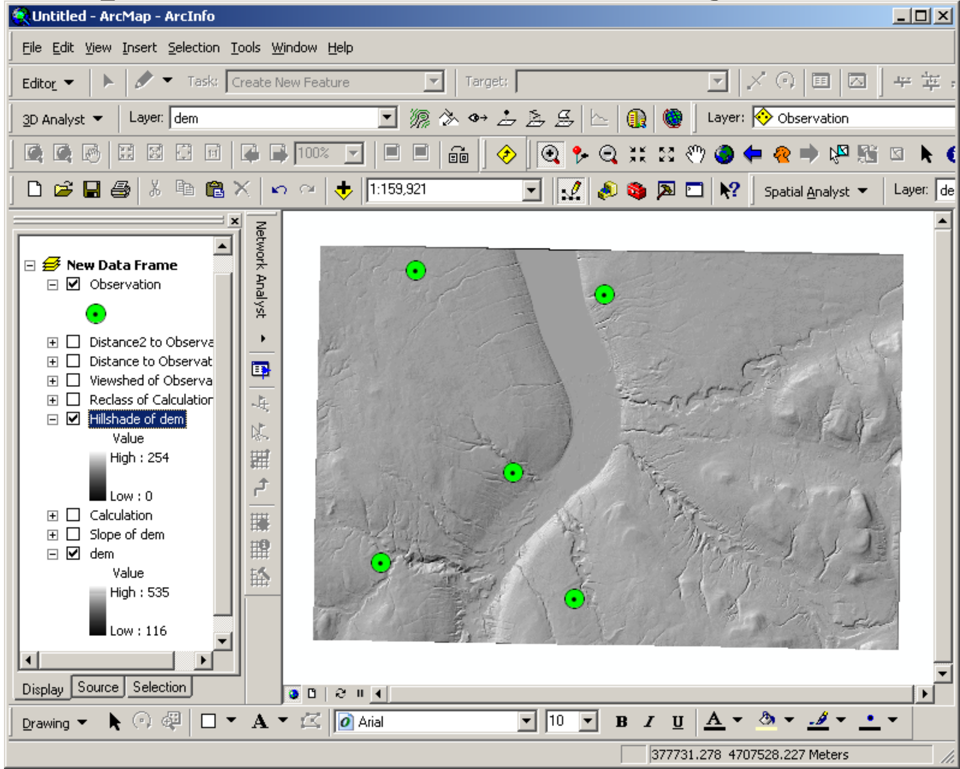
- Surface Analysis Operations
  - Viewshed Analysis
    - Viewshed determines the raster surface locations visible to a set of observer features.
    - A viewshed identifies the cells in an input raster that can be seen from one or more observation locations. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location.

Surface Analysis

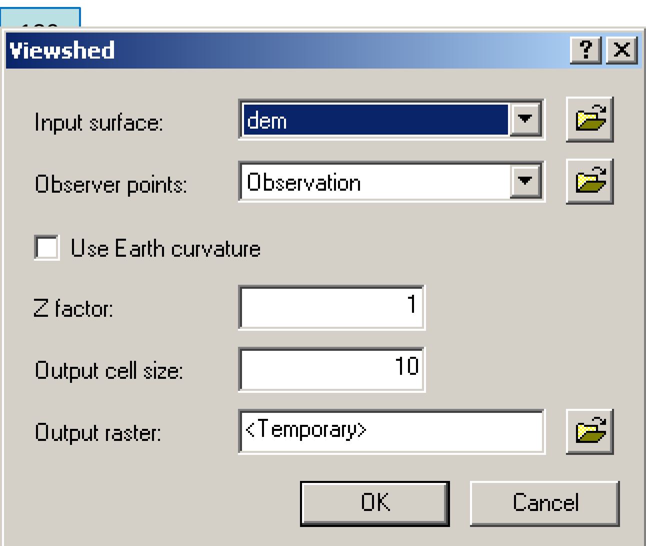
- Surface Analysis Operations
  - Viewshed Analysis
    - The visibility of each cell center is determined by comparing the altitude angle to the cell center with the altitude angle to the local horizon. The local horizon is computed by considering the intervening terrain between the point of observation and the current cell center. If the point lies above the local horizon, it is considered visible.

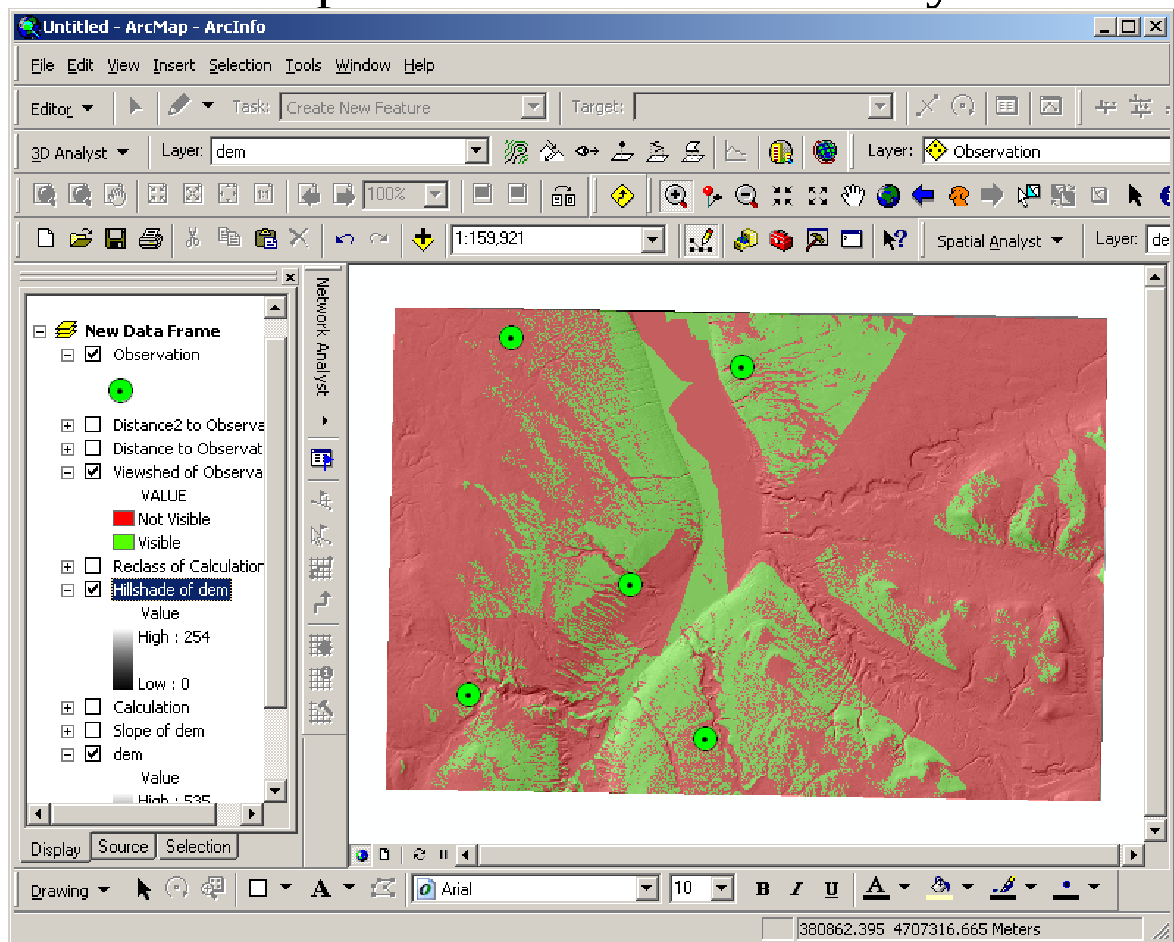
Surface Analysis

- Surface Analysis Operations
  - Viewshed Analysis
    - Viewshed determines the raster surface locations visible to a set of observer features.
    - Example: Five observation points and their visibility



- Surface Analysis Operations
  - Viewshed Analysis
    - Example: Five observation points and their visibility

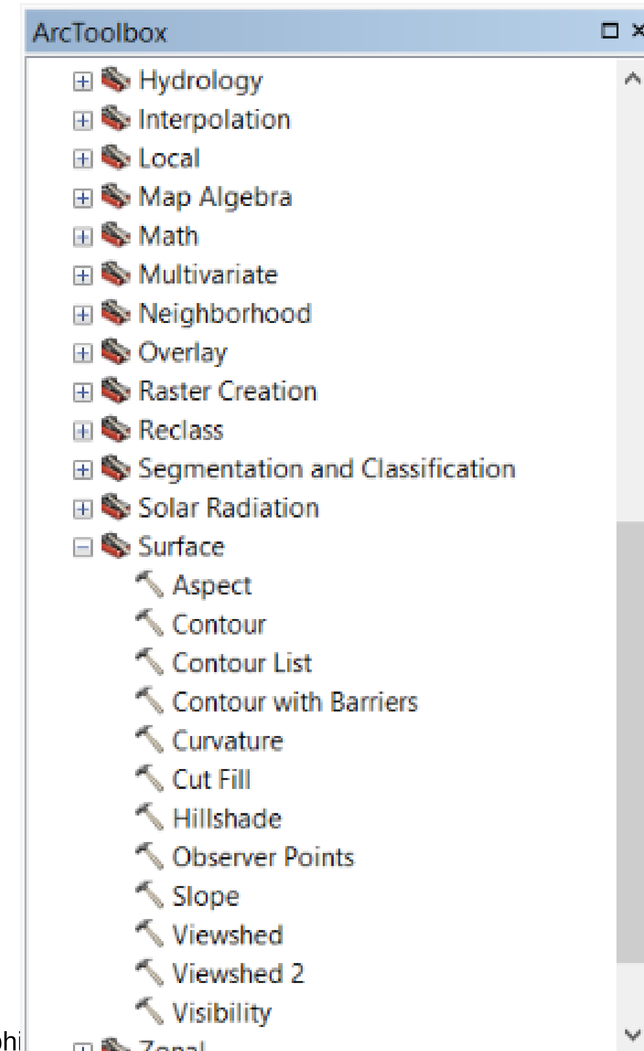




Surface Analysis

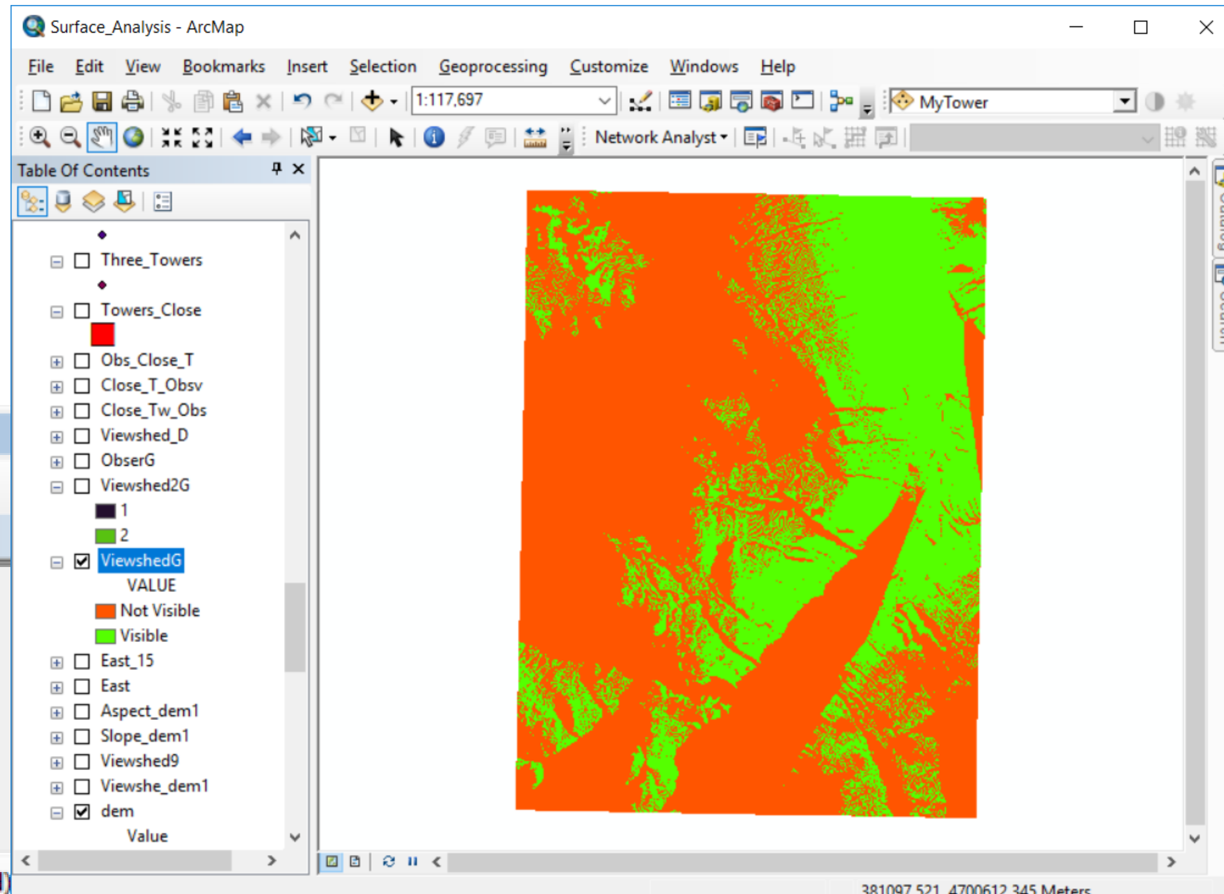
- Surface Analysis Operations
  - Viewshed Analysis
    - There are a few different tools or options for Viewshed analysis.
      - Viewshed
      - Viewshed 2
      - Visibility
      - Observer Points

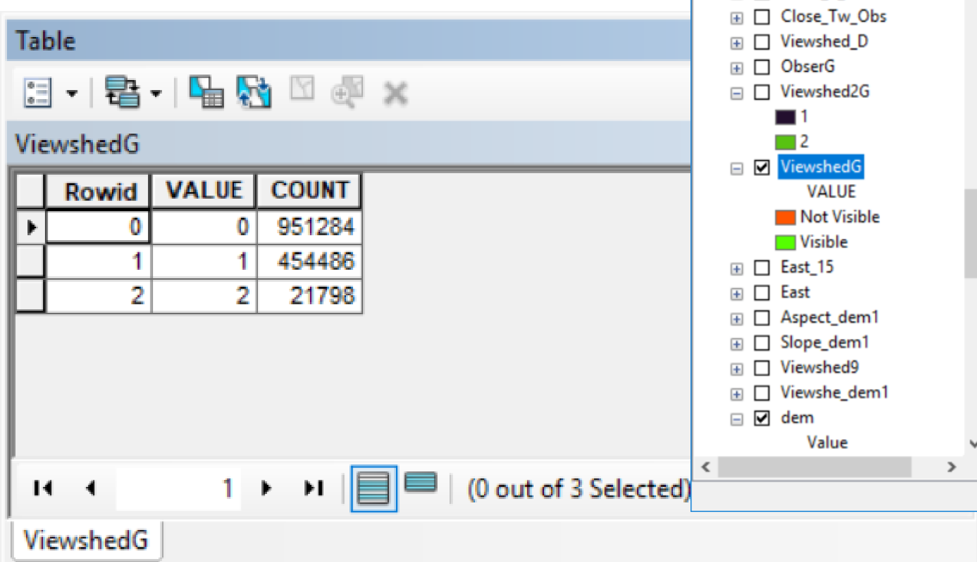
- Surface Analysis Operations
  - Viewshed Analysis
    - Four similar tools:
      - Viewshed
      - Viewshed 2
      - Visibility
      - Observer Points
    - Can answer different questions.
    - Need to know the differences.
    - Know when to use which.
    - Be able to interpret the results.



Surface Analysis

- Surface Analysis Operations
  - Viewshed Analysis
    - Viewshed

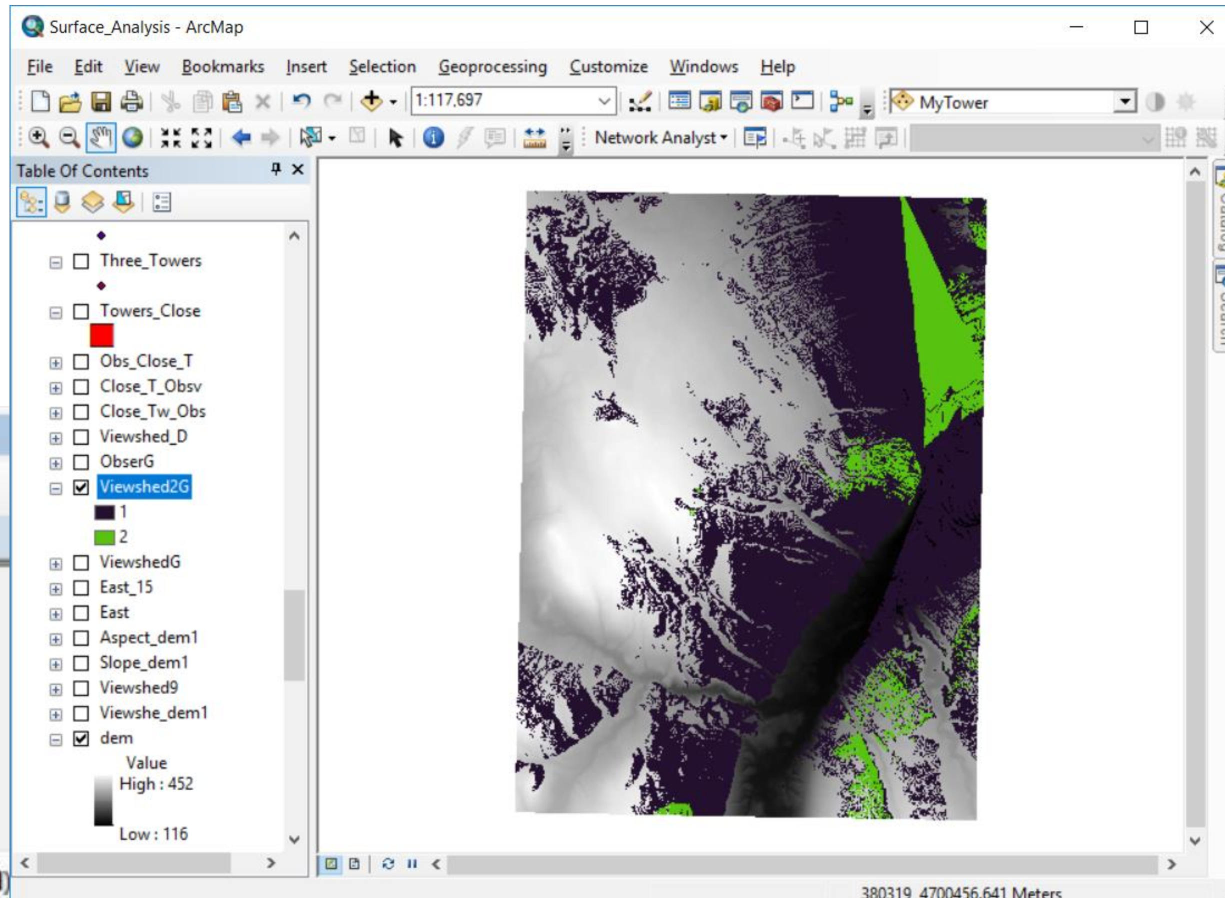


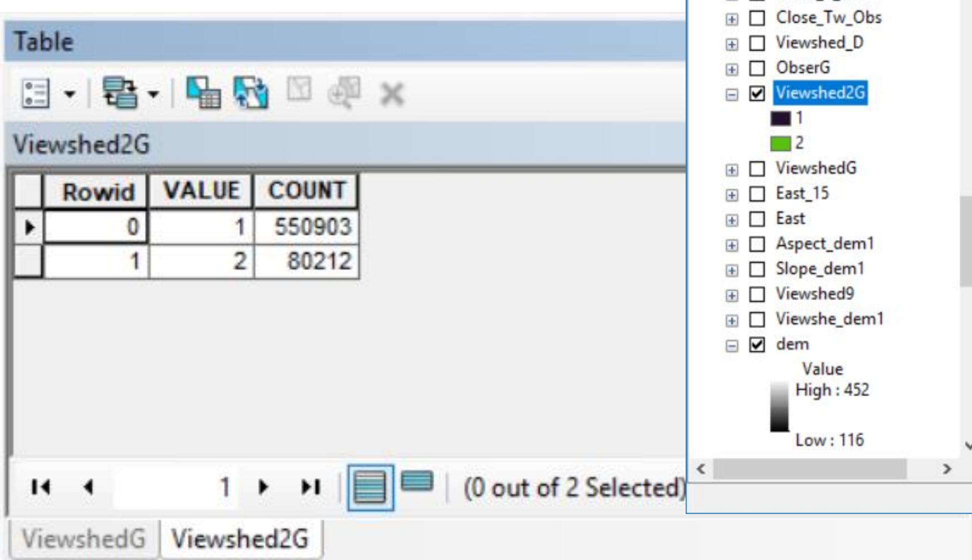


Rowid	VALUE	COUNT
0	0	951284
1	1	454486
2	2	21798

Surface Analysis

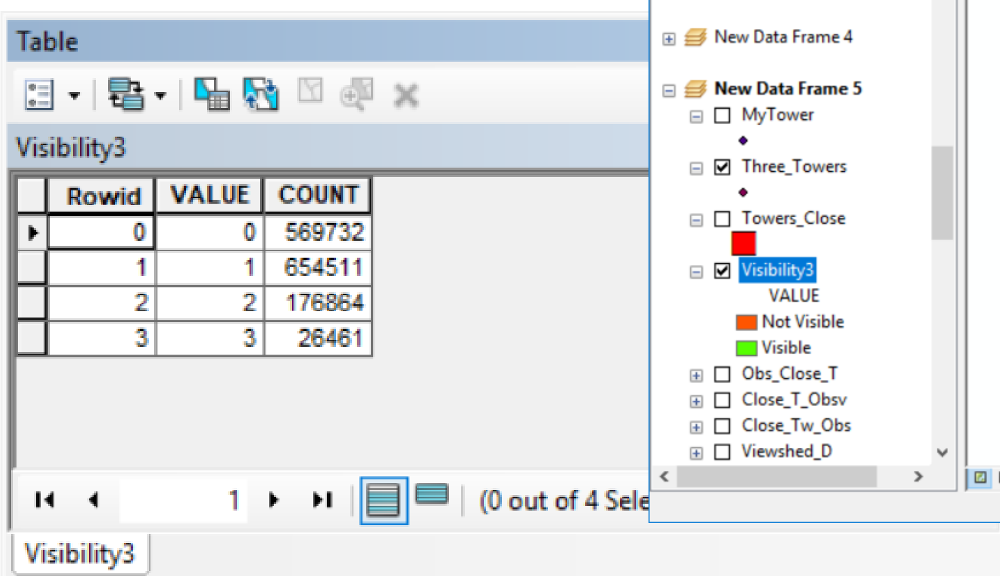
- Surface Analysis Operations
  - Viewshed Analysis
    - Viewshed 2



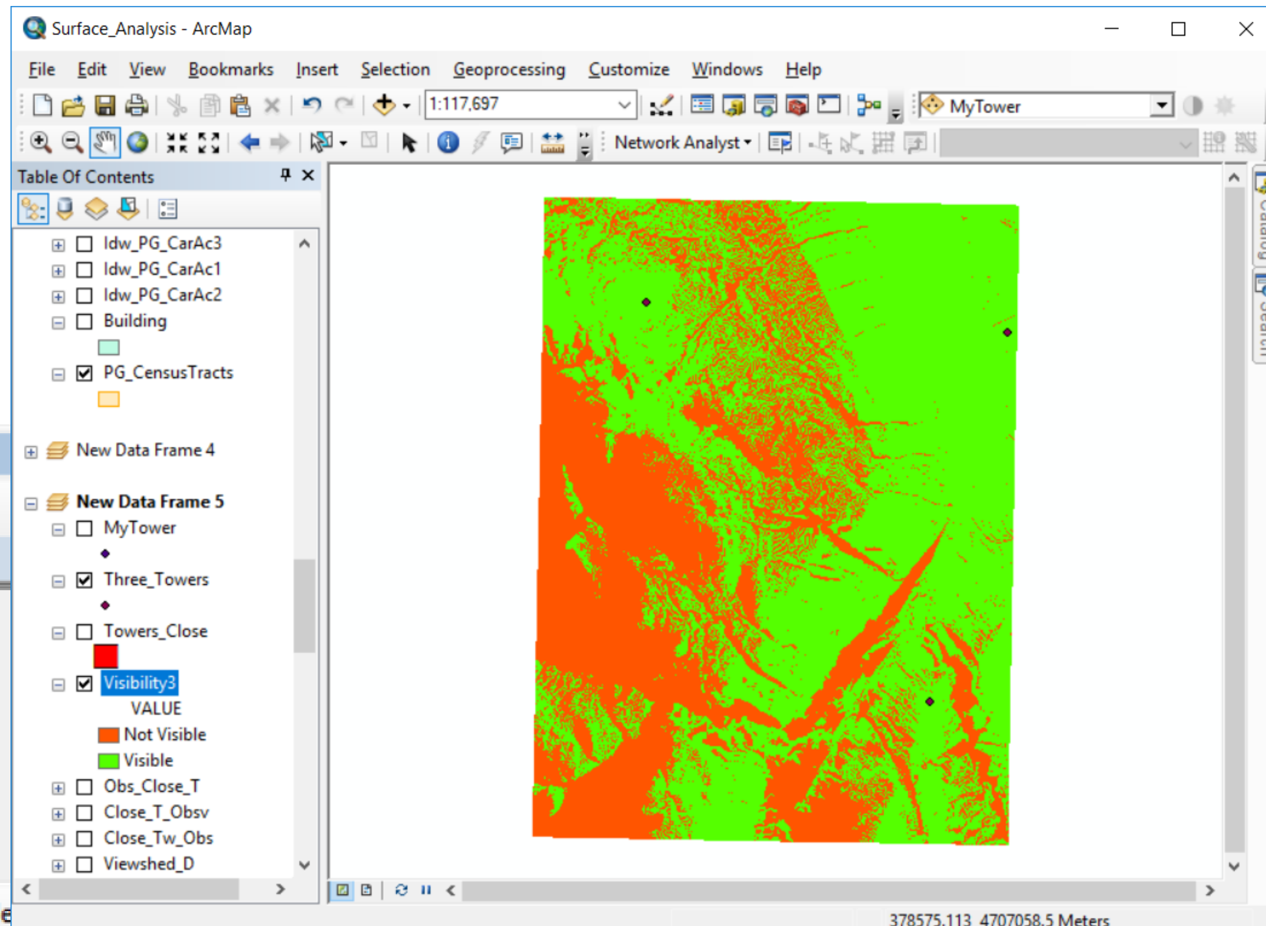


Rowid	VALUE	COUNT
0	1	550903
1	2	80212

- Surface Analysis Operations
  - Viewshed Analysis
    - Visibility

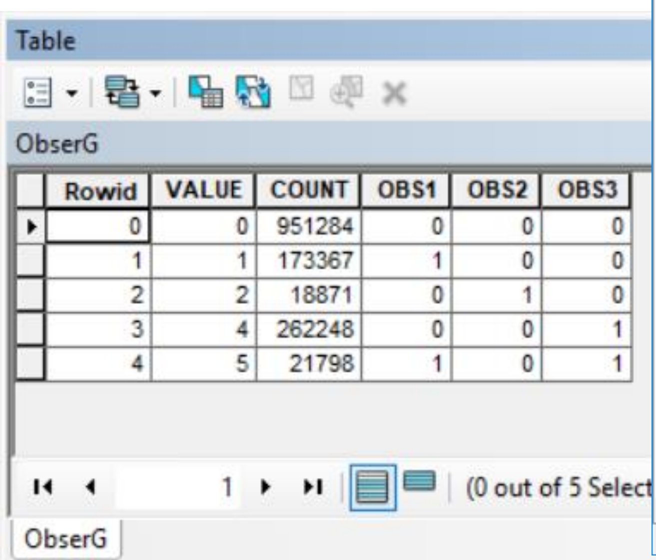


Rowid	VALUE	COUNT
0	0	569732
1	1	654511
2	2	176864
3	3	26461

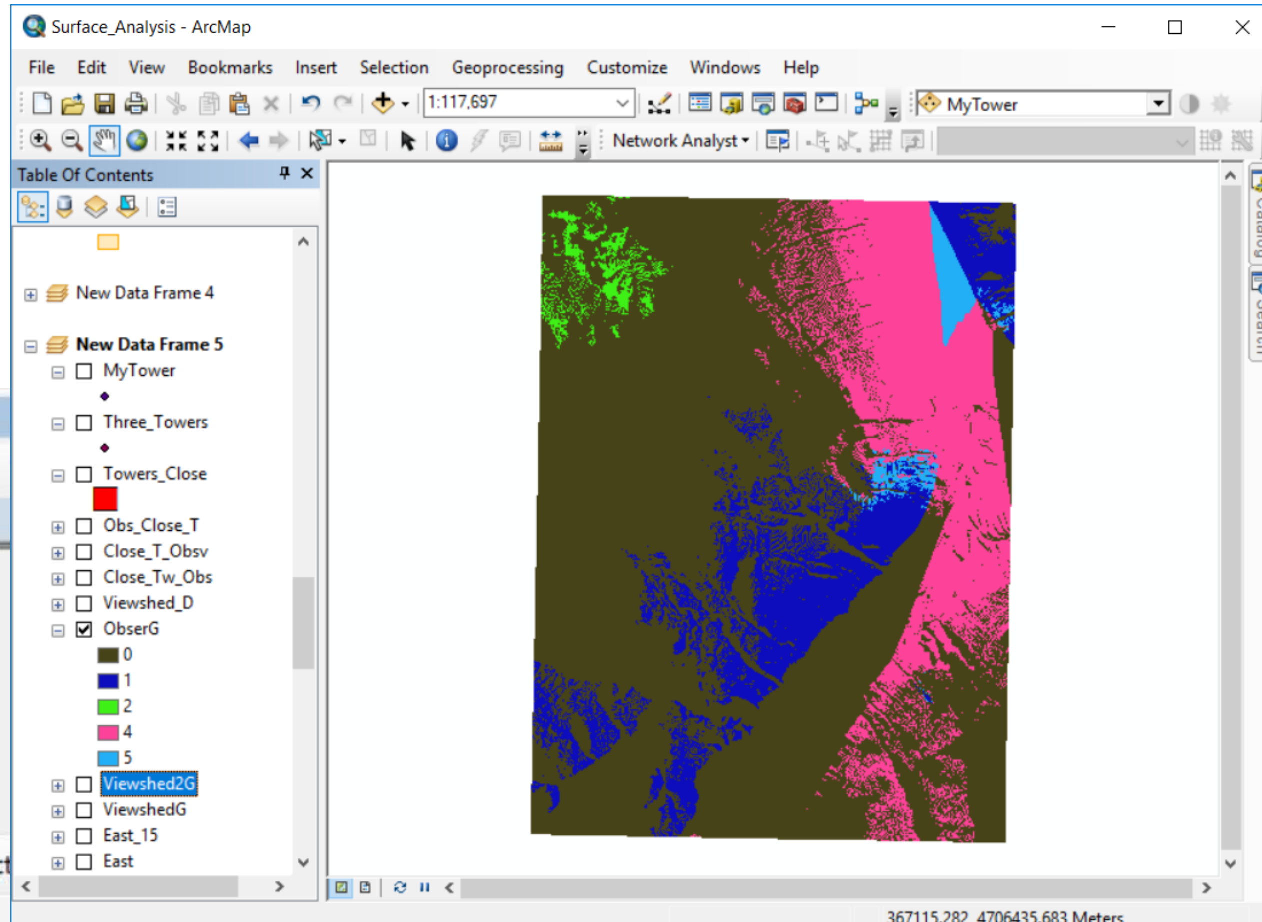


Surface Analysis

- Surface Analysis Operations
  - Viewshed Analysis
    - Observer Points



Rowid	VALUE	COUNT	OBS1	OBS2	OBS3
0	0	951284	0	0	0
1	1	173367	1	0	0
2	2	18871	0	1	0
3	4	262248	0	0	1
4	5	21798	1	0	1



Surface Analysis

- Surface Analysis Operations
  - Viewshed Analysis
    - Viewshed
    - Viewshed 2
    - Visibility
    - Observer Points
  - Must be able to interpret both map and information contained in the attribute table.
    - Otherwise you will not be able decide when to use which of those tools.
  - Can design ways to test and verify your interpretation.

THE END