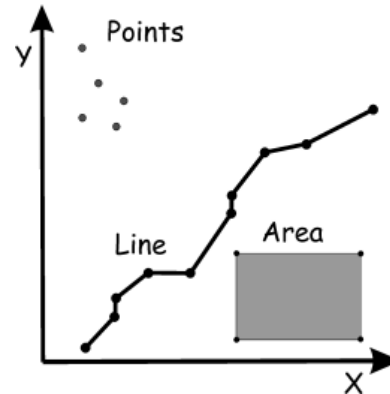


# Geographic Data Models

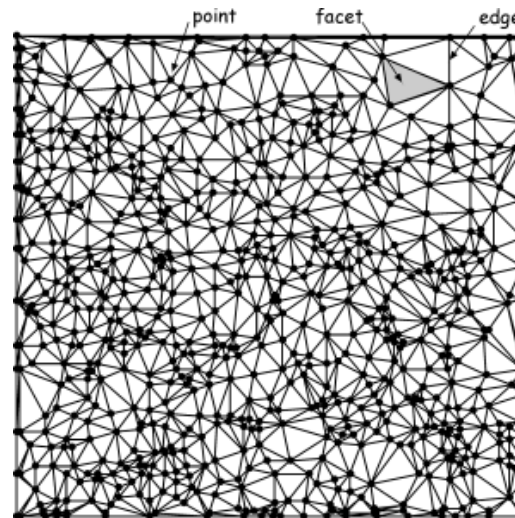
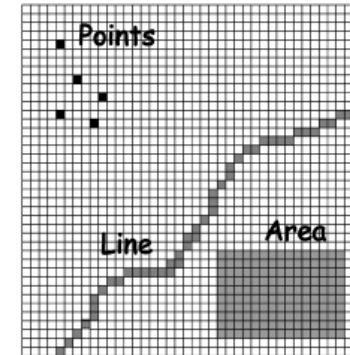
# Geographic Data Types

- Images
- Vector
- Raster (GRID/Surface)
- Attributes
- TIN
- Annotation

Vector



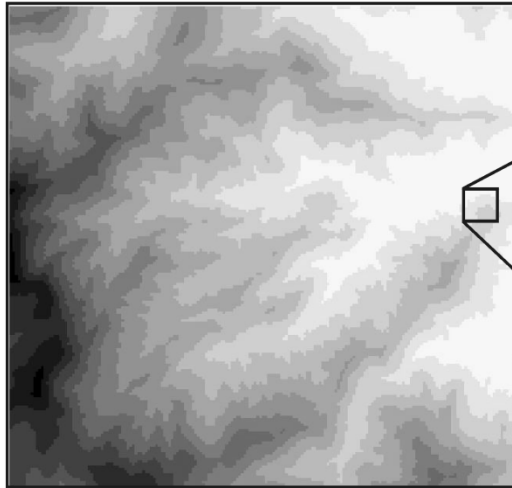
Raster



© Paul Bolstad, GIS Fundamentals

# Geographic Data Types

Raster DEM

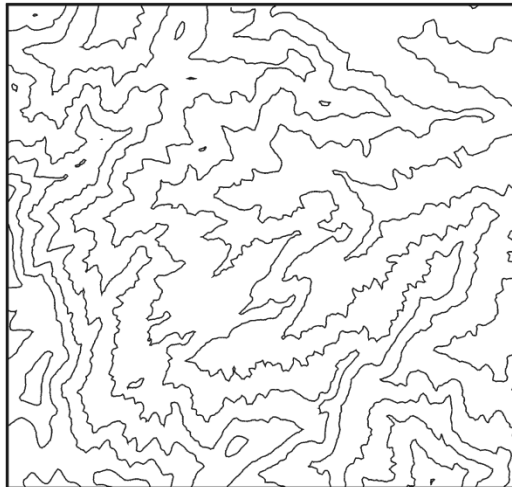


Detailed view of raster cells

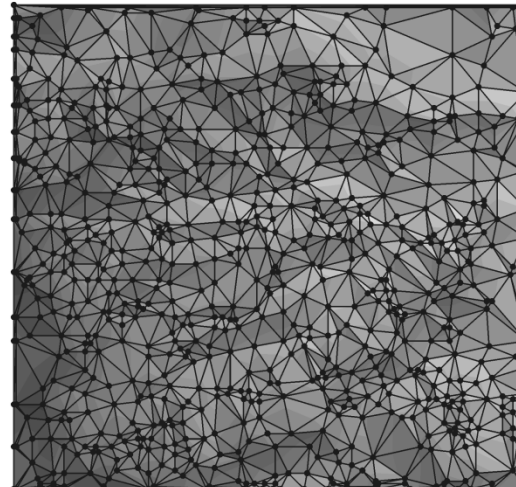
645	650	654	658	653	648
664	666	670	672	668	659
678	682	684	693	689	680
703	708	714	721	719	716
728	732	738	744	745	732
730	739	744	749	748	735

© Paul Bolstad, GIS Fundamentals

Vector contours

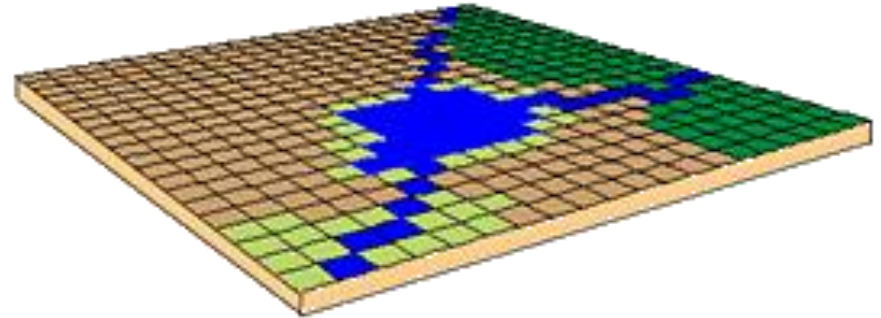


TIN



# DIGITAL SPATIAL DATA

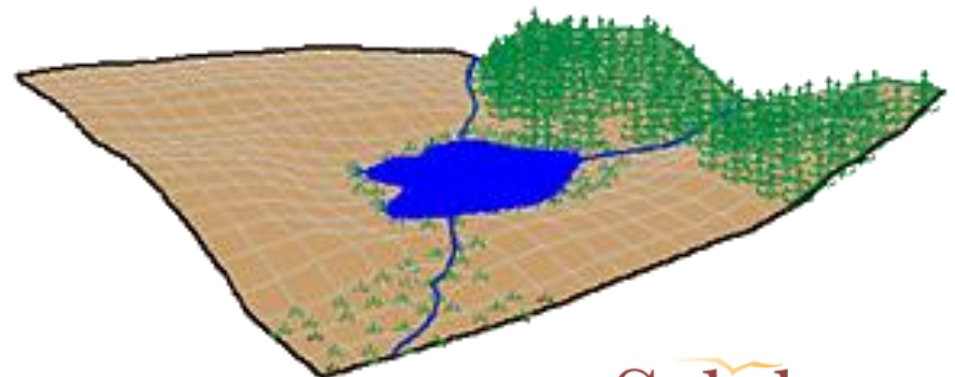
- RASTER →



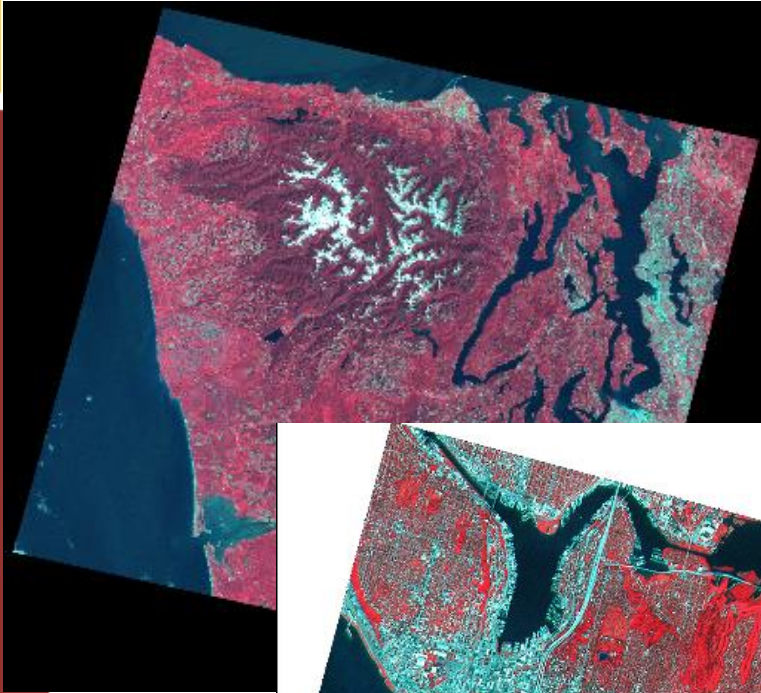
- VECTOR →



- Real World →

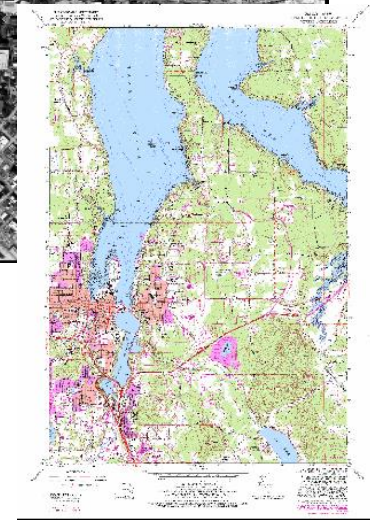
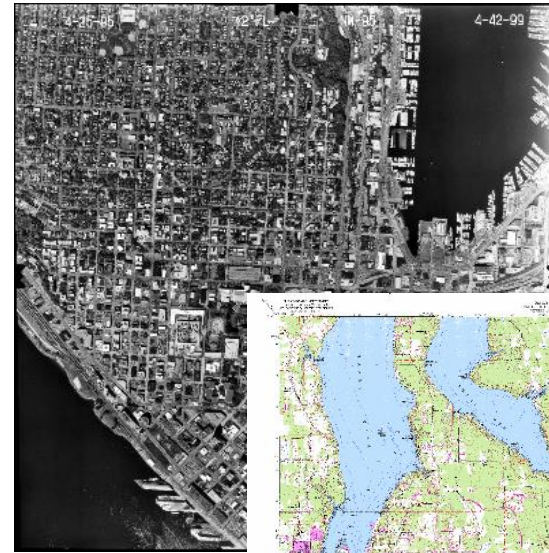


# Raster Data Sources



**Satellite  
Imagery**

**Air Photos**



**Scanned Maps**

# Digital Orthophotograph

A scanned photograph that has been mathematically rectified to eliminate the effects of displacement so that its view always appears as though it is perpendicular to the ground.

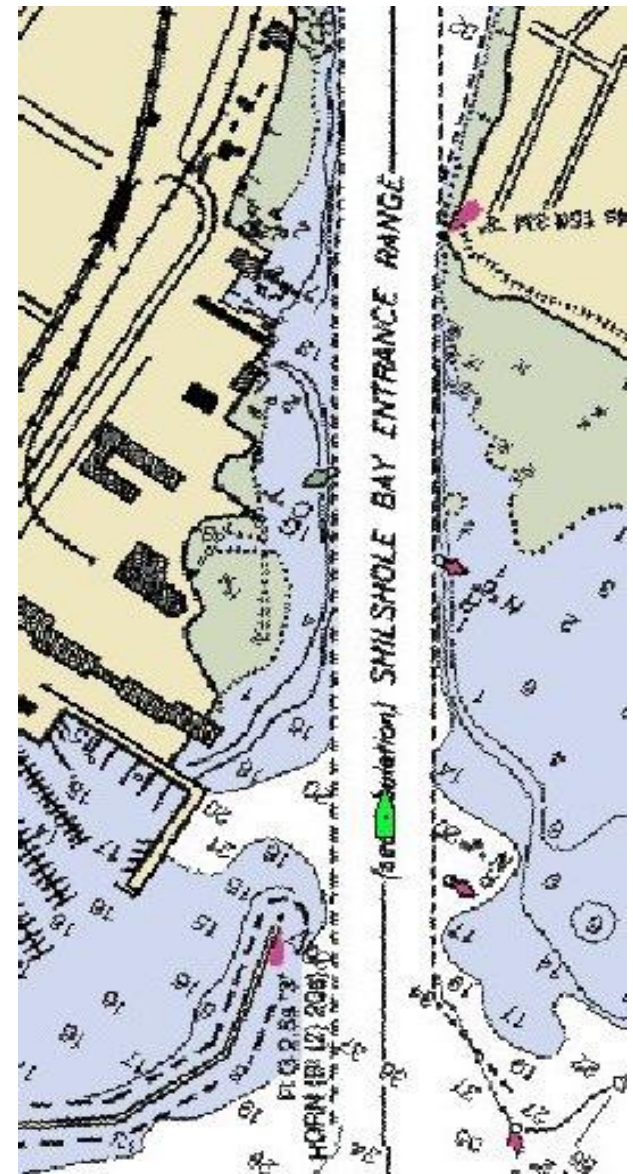


Image

Copyright 1993 Nassau County, NY

# Raster Maps (images)

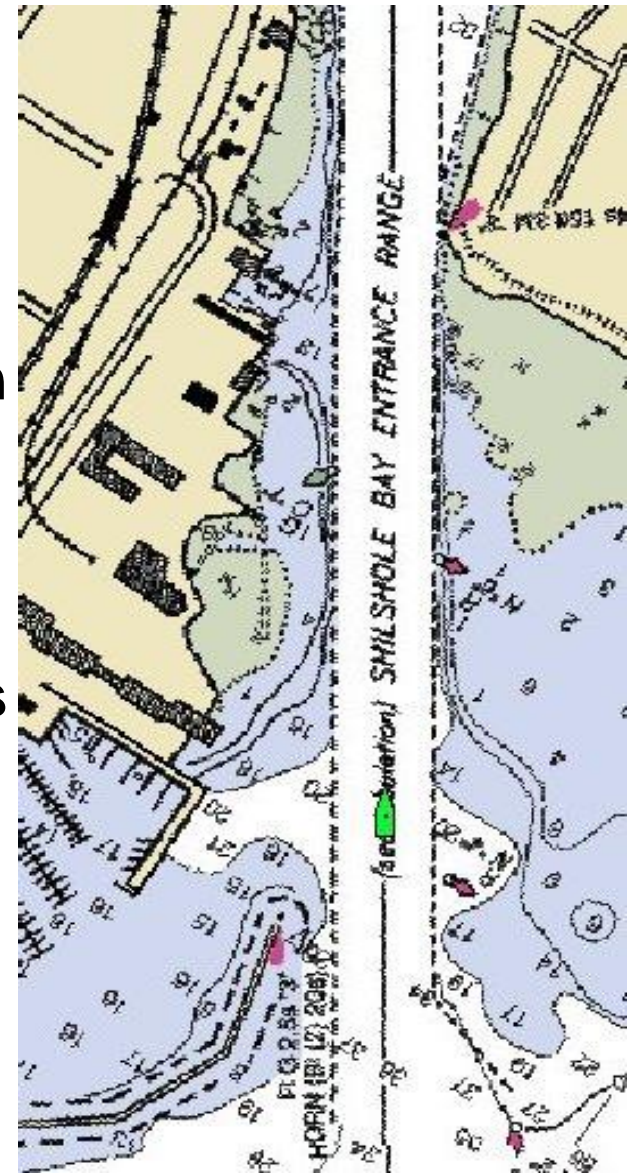
- A set of colored pixels representing chart information as a picture on computer screen
- Simply an array of pixels arranged in rows and columns
- Pixels are color coded, but do not represent features explicitly
- Rasters can have value attached





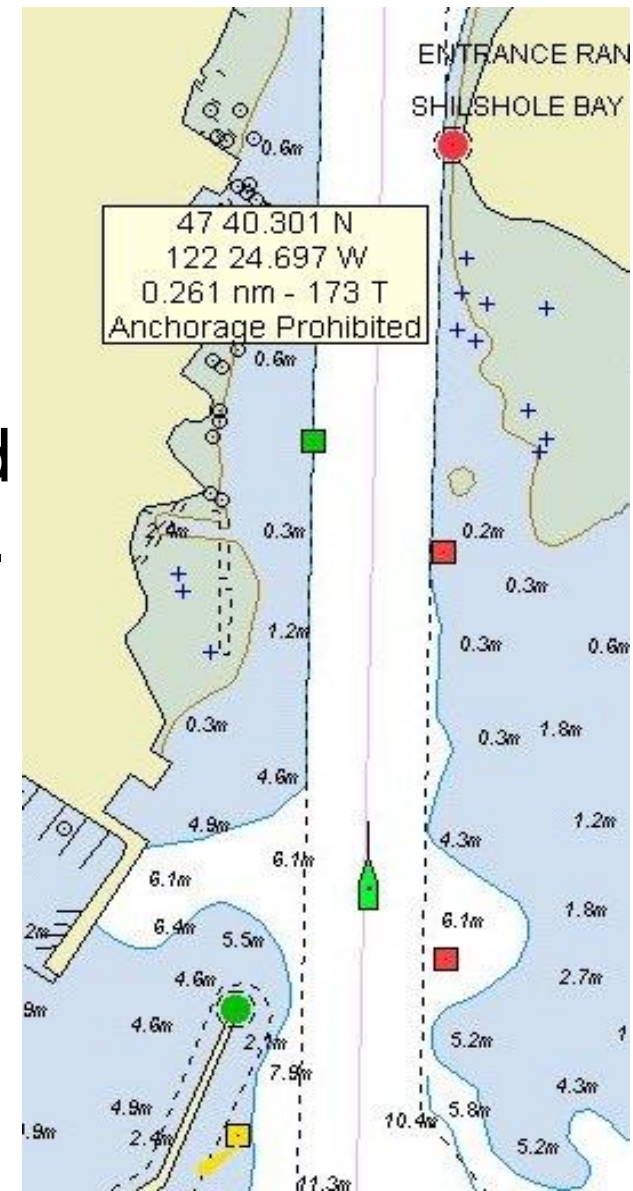
# The Appeal of Raster

- Looks like a paper map
- Cheap and easy to produce (scan existing paper chart)
- Runs easily on PC
- World-wide availability w/updates available
- Problems:
  - Datum may or may not be WGS84
  - Does not allow automated grounding avoidance or any other computer-aided analysis
  - Storage not as efficient



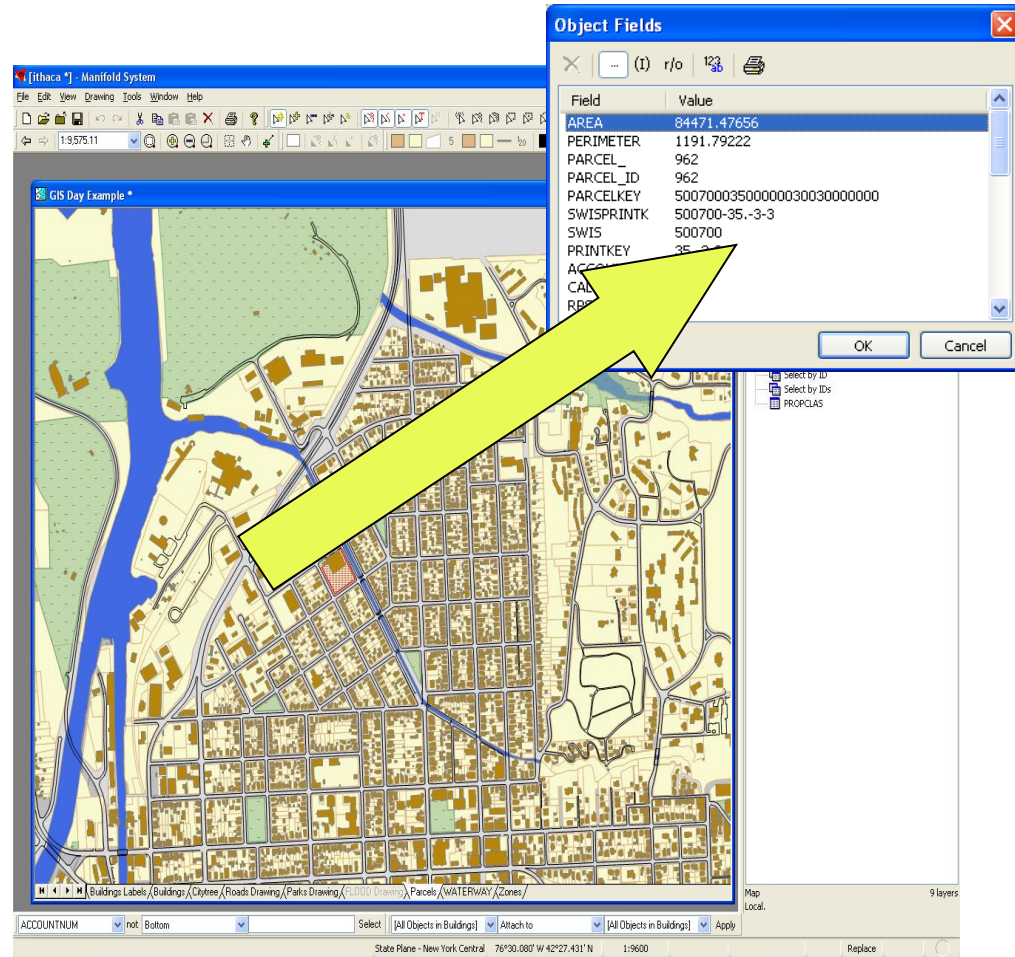
# Vector Data

- An intelligent form of digital geographic data where real world objects are represented by points, lines and polygons. An objects representation is described by attributes and coordinates.
- Examples include:
  - Digitized Maps
  - GIS Data



# Linking Attributes and Graphics

- In addition to Geography, GIS is also about Information. A GIS marries the capabilities of computer mapping with database management systems. So, a geospatial analyst can “click” on a geographic feature and find out information about it. Or, they can query the database to find out information about all the geographic objects that meet a specific criteria.
- Information about a geographic object is called an *attribute*.



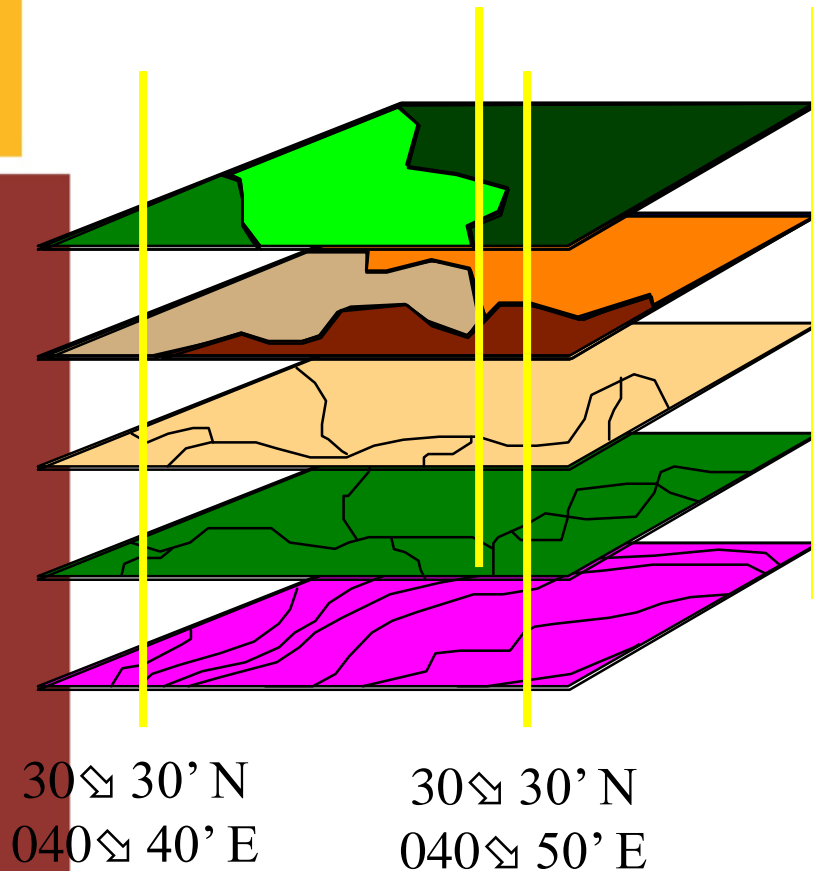
# Linking Attributes with Graphics

- In this example, the user has issued a query to select all the properties whose classification is single family residential (210), and colored the selection red.

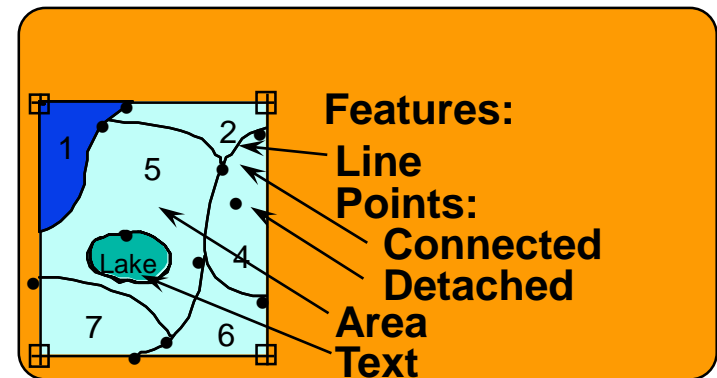
The screenshot displays the Manifold System interface. A data table titled "Parcel Table" is open, showing a list of parcels with columns for ID, AREA, PERIM., PARCELKEY, SWES, FRONTY, FLUXE29, DEE..., DEE..., and ACCRNO. The table contains 10 rows of data, with the first row highlighted in red. The map below the table shows a grid of parcels, with several parcels highlighted in red, corresponding to the selected rows in the table. The interface includes a menu bar, a toolbar, and a project panel on the right.

ID	AREA	PERIM.	PARCELKEY	SWES	FRONTY	FLUXE29	DEE...	DEE...	ACCRNO
42639	96750.0...	1760.40...	50570001400000010	505700	16-1-4-2	50570001400000010	717	230	715-21
42640	2831.12...	213.06543	50570001200000030	505700	12-3-2	50570001200000030	885	313	303
42641	4895.69...	352.37263	50570001200000030	505700	12-3-1	50570001200000030	808	302	1109-1111
42642	17263.0...	525.29579	50570001200000010	505700	30-1-1-6	50570001200000010	866	142	225
42643	18879.8...	627.38956	50570001900000030	505700	19-3-5	50570001900000030	859	332	625
42644	3563.09...	257.68717	50570001200000040	505700	12-4-4	50570001200000040	9	9	1118
42645	18276.2...	846.32209	50570001200000010	505700	30-1-1-4	50570001200000010	846	837	207-15
42646	4079.58...	280.78196	50570001200000040	505700	12-4-3	50570001200000040	399	62	205
42647	2966.85...	259.62596	50570001200000040	505700	12-4-2	50570001200000040	800	345	203
42648	2022.65...	183.26265	50570001200000040	505700	12-4-1	50570001200000040	605	194	201
42649	18173.2...	586.44356	50570001900000020	505700	19-2-2	50570001900000020	0	0	167
42650	1776.56...	309.71244	50570001400000020	505700	14-2-9	50570001400000020	890	144	1110-12
42651	67881.8...	1641.36	50570001100000010	505700	11-3-1-2	50570001100000010	440	607	171-05

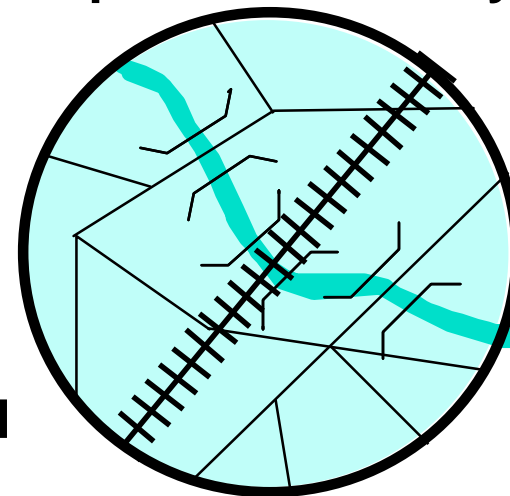
# Vector Data is Layered



**Geographic data are separated into themes, tiled for speed of access and placed on CD-ROM**



## Spatial Data Analysis



## Network Analysis

Source: Defense Mapping School  
National Imagery and Mapping Agency

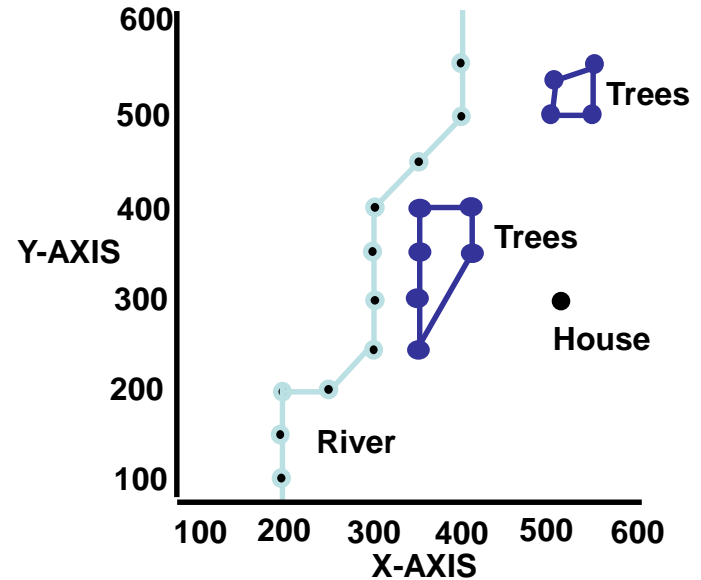
# Raster and Vector Data Models



Real World

	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

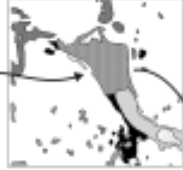
# Vector GIS

A GIS in which graphic data is stored in the form of discrete points, lines, or areas.

Real world



Data model

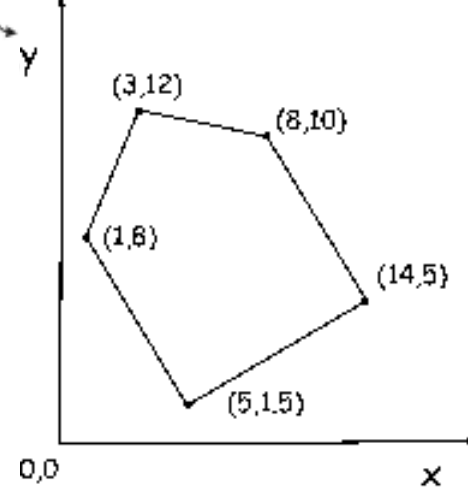


ID	Area	Type
1	16.3	PUB
2	7.9	PEM
3	121.8	U
4	10.1	PUB
...	...	...

Data structure

x	y
1.2	4.7
5.8	3.6
8.9	7.2
.	.
.	.

Machine



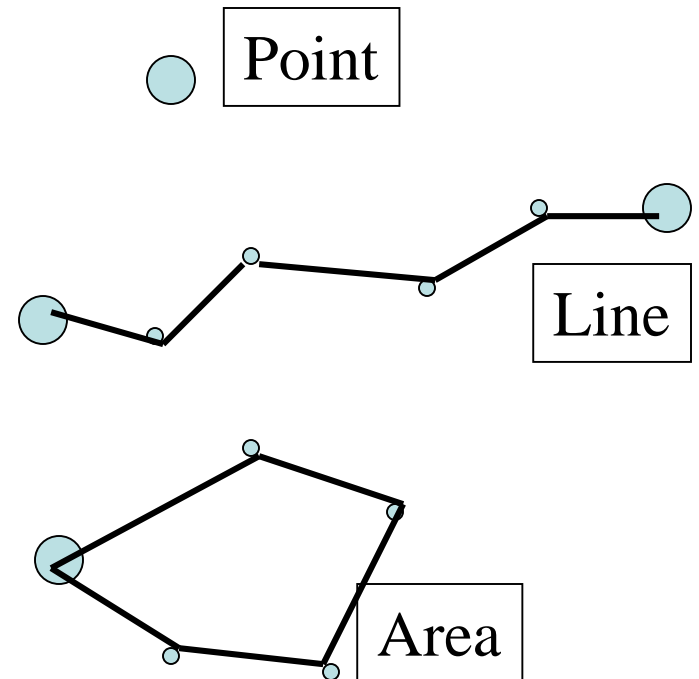
Coordinates:  
1,8  
3,12  
8,10  
14,5  
5,1.5  
1,8

Attributes:  
Lot #: 1347  
Street: Willow Lane  
Town: Hopkins

© Paul Bolstad, GIS Fundamentals

# Structure of Vector Data

- There is a certain amount of relationship between vector data types. Sort of an inheritance, as each data type is often dependent upon one another. When representing geographic data in vector format, data is typically stored as:
- **Points:** points are zero dimensional objects, and represent geographic features such as wells, sample locations, or trees.
- **Lines:** lines represent one dimensional objects, or linear features, such as road and stream centerlines. Lines are made up of a series of interconnected points. A line typically starts and end with a special point called a **node**, and the points that make up the rest of a line are called **vertices**.
- **Polygons/Area:** polygons represent two dimensional objects such as the boundaries of a field, or property, or the outline of a building or lake. Polygons are made up of a series of connected lines where the starting point of a polygon is the same as the ending point.

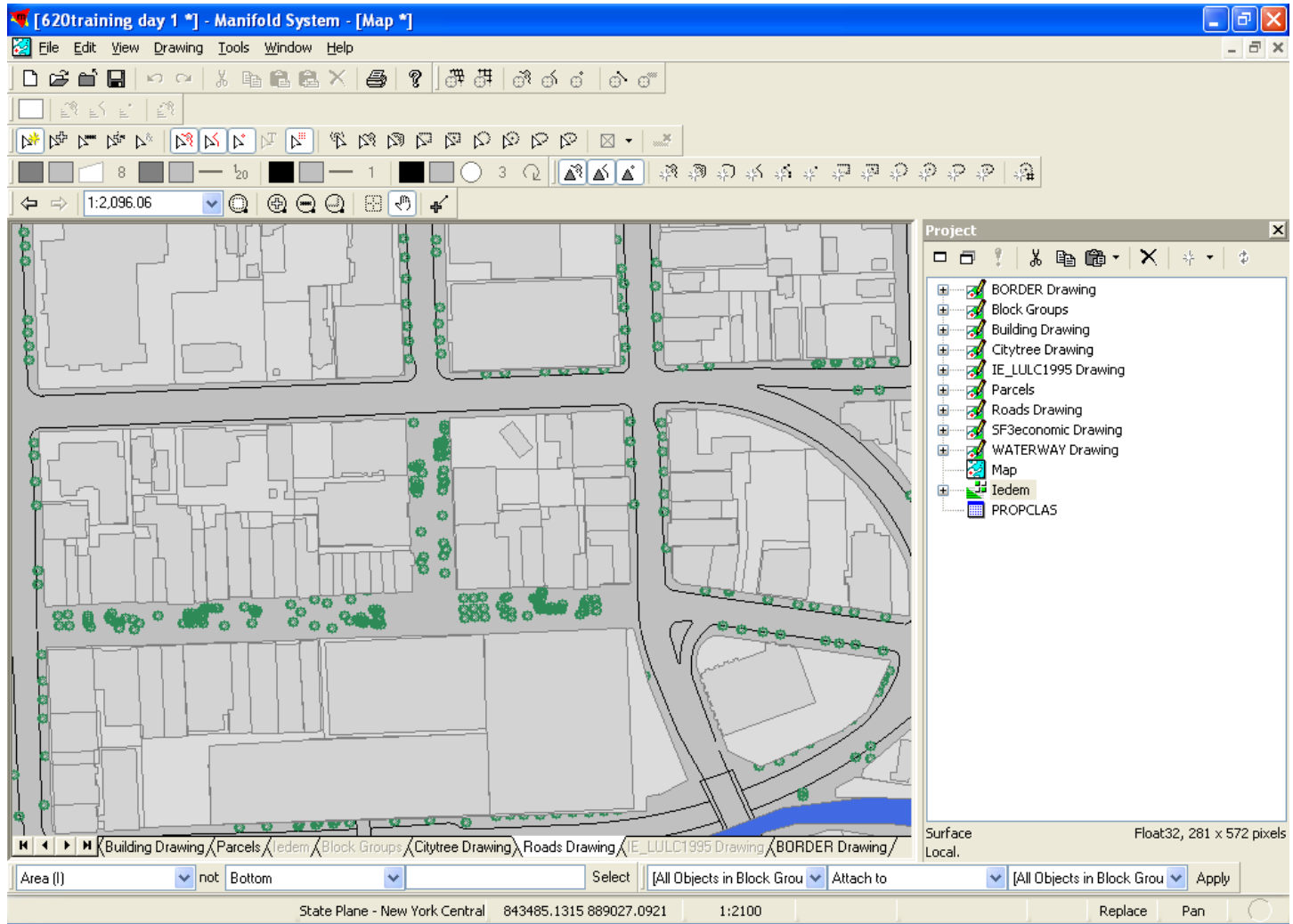


# Graphic Features

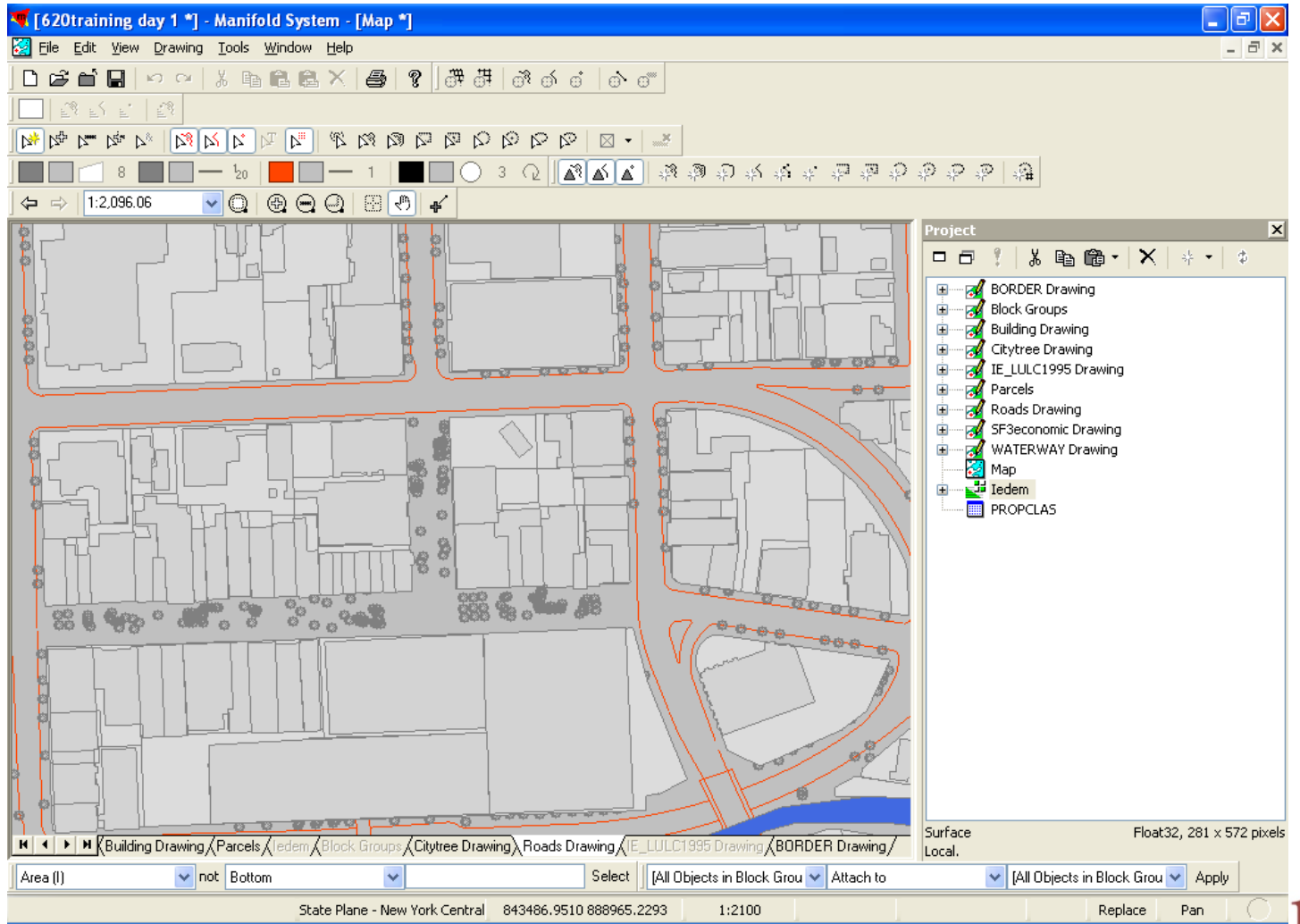
Digital representation of physical or man made elements:

- Vectors
  - Points or Nodes
  - Lines or Arcs
  - Areas
- Raster Cells or Pixels
  - Images
  - Digital Orthophotography

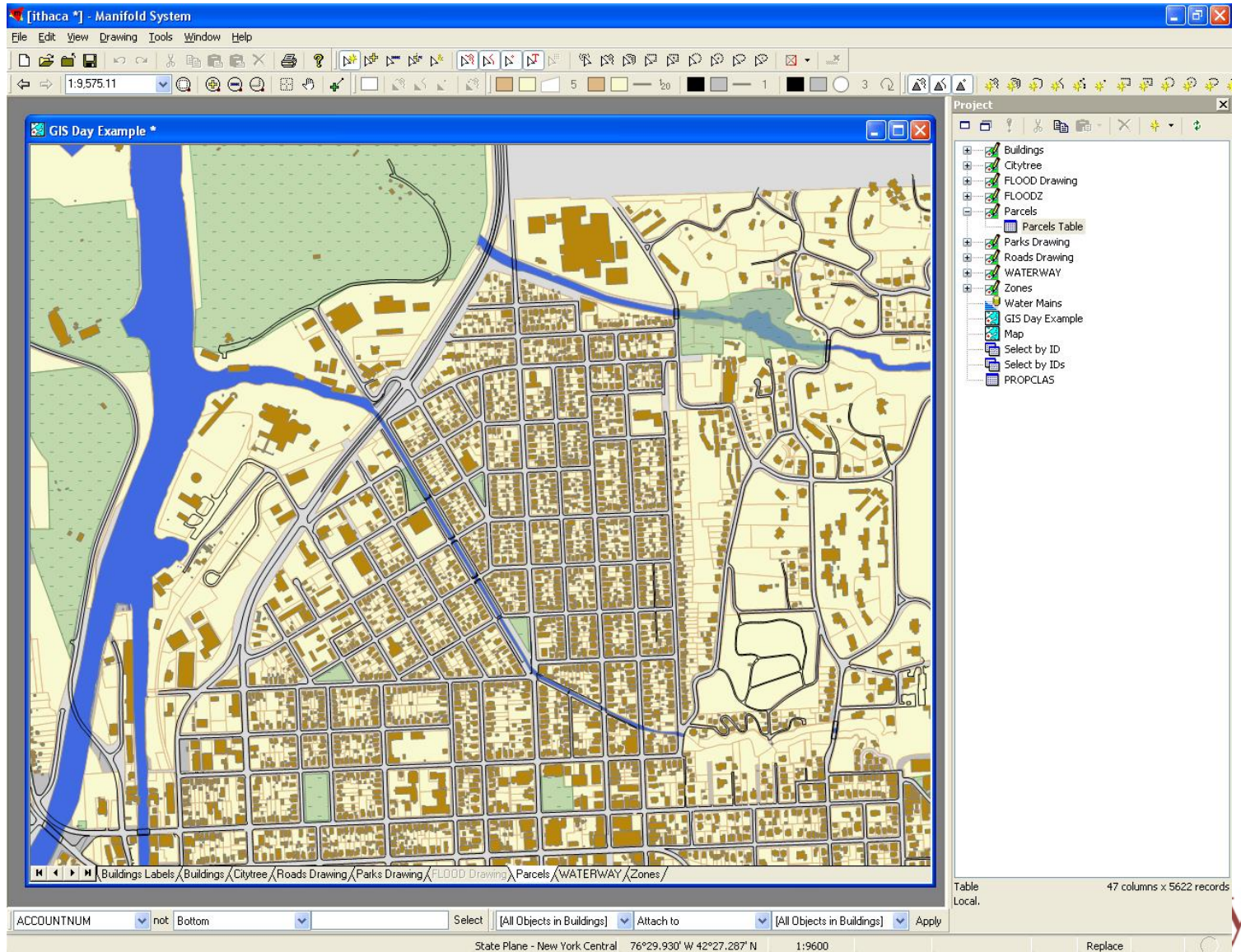
# Trees



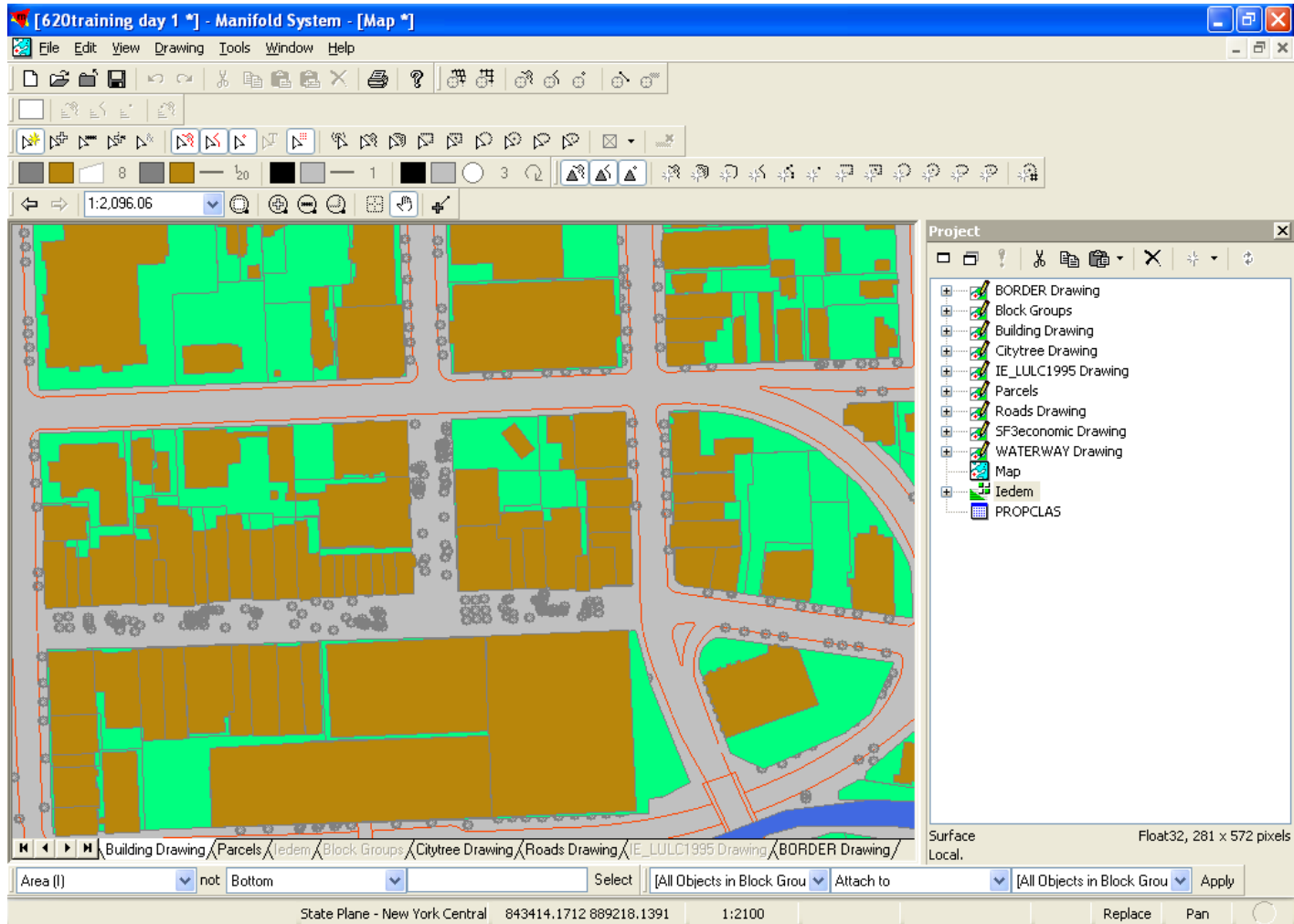
# Street Edge



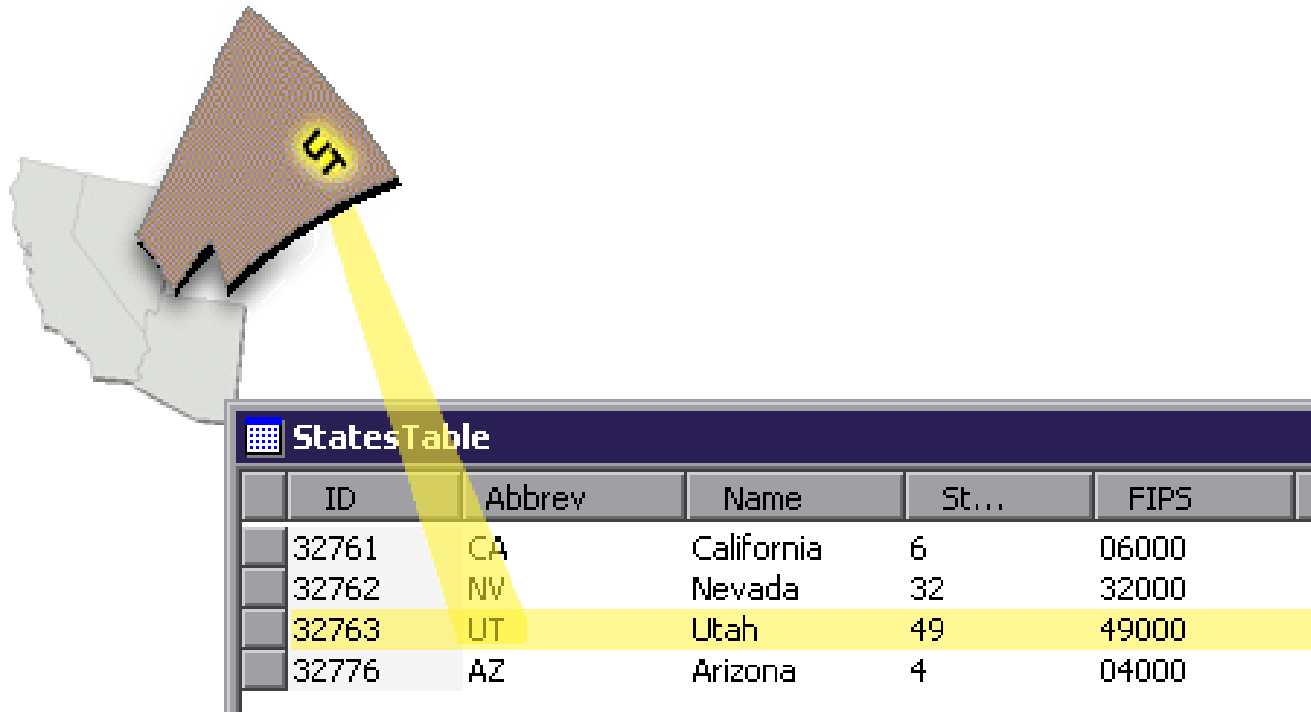
# Areas



# Areas



# “Linked” Attribute Data



# Attribute Data

Information about a graphic feature

- Each piece of attribute information is related to a specific graphic element
- Traditional database type fields
  - Numeric, text, dates, currency
- Images
- Photos
- Video

# “Linked” Attributes

The screenshot shows the Manifold System interface. The main map area displays a parcel highlighted in red. An 'Object Fields' dialog box is open, showing a table of attributes for the selected object. The table has two columns: 'Field' and 'Value'. The 'AREA' field is highlighted in blue.

Field	Value
AREA	58669.05078
PERIMETER	954.0679
PARCEL_	1467
PARCEL_ID	1467
PARCELKEY	50070003100000010010040000
SWISPRINTK	500700-31.-1-1.4
SWIS	500700
PRINTKEY	31.-1-1.4
ACCOUNTNUM	
CALCARES	0
RPSACRES	0

80 of 96 fields

Project Panel (9 layers):

- BORDER Drawing
- Block Groups
- Building Drawing
- Citytree Drawing
- IE\_LULC1995 Drawing
- Parcels
- Roads Drawing
- SF3economic Drawing
- WATERWAY Drawing
- Map
- Iedem
- PROPCLAS

Map: Local

Area (I) | not | Bottom | Select | [All Objects in Block Grou] | Attach to | [All Objects in Block Grou] | Apply

State Plane - New York Central | 846057.9447 891278.9312 | 1:7300 | Replace

Windows Taskbar: [620trainin...], Manifold@..., Wireless N..., 2 Microso..., CSS 420 - ... | 9:19 AM

# Raster GIS

A GIS in which graphic data is stored in the form of grid cells or pixels.

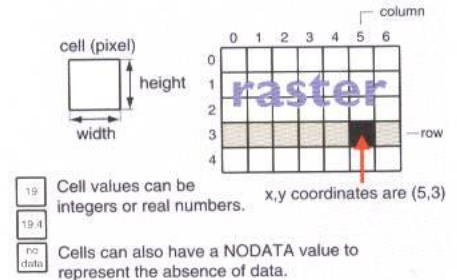
# An ESRI View

## Inside a raster

Rasters are two-dimensional arrays of cells (or pixels). The height and width of each cell are fixed and the same. A raster spans a rectangular area.

Each cell has a value. This value can represent many qualities of a location, including reflectance, color, precipitation, and elevation.

Rasters have an integer coordinate space. You can determine the coordinate of a cell by counting columns from the left and rows from the top. Row and column values begin with 0.



## The attribute table

Value	Count	Type	Code
23	7	Fir	400
29	18	Juniper	410
31	10	Aspen	420
37	18	Piñon	500
41	4	Cottonwood	510
43	7	Walnut	600

Rasters that have integer valued cells can be defined with an optional attribute table, which records attributes for each unique cell value.

You can add custom fields to the attribute table.

## Types of data represented in cells

The data stored in a raster can be categorized as one of these types.

<p><b>Nominal data</b></p>	<p> <ul style="list-style-type: none"> <li><span style="color: orange;">■</span> Fir</li> <li><span style="color: blue;">■</span> Juniper</li> <li><span style="color: green;">■</span> Aspen</li> <li><span style="color: grey;">■</span> Piñon</li> <li><span style="color: yellow;">■</span> Cottonwood</li> <li><span style="color: brown;">■</span> Walnut</li> </ul> </p>	<p>Nominal data values are categorized and have names. The data value is an arbitrary type code. Examples are soil types and land use.</p>	<table border="1"> <tr><td>21</td><td>17</td><td>17</td><td>18</td><td>22</td><td>18</td></tr> <tr><td>18</td><td>16</td><td>17</td><td>19</td><td>24</td><td>19</td></tr> <tr><td>21</td><td>19</td><td>19</td><td>19</td><td>22</td><td>22</td></tr> <tr><td>26</td><td>23</td><td>21</td><td>20</td><td>18</td><td>21</td></tr> <tr><td>24</td><td>23</td><td>18</td><td>16</td><td>20</td><td>19</td></tr> <tr><td>18</td><td>14</td><td>18</td><td>17</td><td>19</td><td>20</td></tr> </table>	21	17	17	18	22	18	18	16	17	19	24	19	21	19	19	19	22	22	26	23	21	20	18	21	24	23	18	16	20	19	18	14	18	17	19	20	<p>Nominal and ordinal data represent discrete categories. They are best represented with integer cell values.</p>
21	17	17	18	22	18																																			
18	16	17	19	24	19																																			
21	19	19	19	22	22																																			
26	23	21	20	18	21																																			
24	23	18	16	20	19																																			
18	14	18	17	19	20																																			
<p><b>Ordinal data</b></p>	<p> <ul style="list-style-type: none"> <li><span style="color: green;">■</span> very good</li> <li><span style="color: yellow;">■</span> good</li> <li><span style="color: orange;">■</span> moderate</li> <li><span style="color: red;">■</span> poor</li> </ul> </p>	<p>Ordinal data values are categorized, have names, and the value is in a numerical rank. Examples are land suitability classifications and soil drainage rank.</p>																																						
<p><b>Interval data</b></p>	<p> <ul style="list-style-type: none"> <li><span style="color: lightgreen;">■</span> 700-709</li> <li><span style="color: green;">■</span> 710-719</li> <li><span style="color: darkgreen;">■</span> 720-729</li> <li><span style="color: forestgreen;">■</span> 730-739</li> <li><span style="color: darkslategrey;">■</span> 740-749</li> <li><span style="color: black;">■</span> 750-759</li> </ul> </p>	<p>Interval data values are numerically ordered and the interval difference is meaningful. Examples are voltage potential and difference in concentration.</p>																																						
<p><b>Ratio data</b></p>	<p> <ul style="list-style-type: none"> <li><span style="color: lightblue;">■</span> 0.0-10.0</li> <li><span style="color: blue;">■</span> 10.1-20.0</li> <li><span style="color: darkblue;">■</span> 20.1-30.0</li> <li><span style="color: navy;">■</span> 30.1-40.0</li> <li><span style="color: black;">■</span> 40.1-50.0</li> </ul> </p>	<p>Ratio data values measure a continuous phenomenon with a natural zero point. Examples are rainfall and population.</p>	<table border="1"> <tr><td>21.1</td><td>17.3</td><td>17.2</td><td>18.1</td></tr> <tr><td>18.5</td><td>16.2</td><td>17.3</td><td>19.1</td></tr> <tr><td>21.0</td><td>19.1</td><td>19.4</td><td>19.2</td></tr> <tr><td>26.3</td><td>23.1</td><td>21.6</td><td>20.5</td></tr> </table>	21.1	17.3	17.2	18.1	18.5	16.2	17.3	19.1	21.0	19.1	19.4	19.2	26.3	23.1	21.6	20.5	<p>Interval and ratio data present continuous phenomena and are usually measured with real cell values.</p>																				
21.1	17.3	17.2	18.1																																					
18.5	16.2	17.3	19.1																																					
21.0	19.1	19.4	19.2																																					
26.3	23.1	21.6	20.5																																					

## The rendition of rasters

A raster can have one or many bands. The cell values of rasters can be drawn in a variety of ways. These are some of the ways to display rasters by cell values.

### Displaying single-band rasters

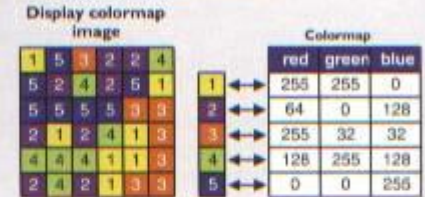
Cell values in single-band rasters can be drawn in these three basic ways.



In a monochrome image, each cell has a value of 0 or 1. They are often used for scanning maps with simple linework, such as parcel maps.



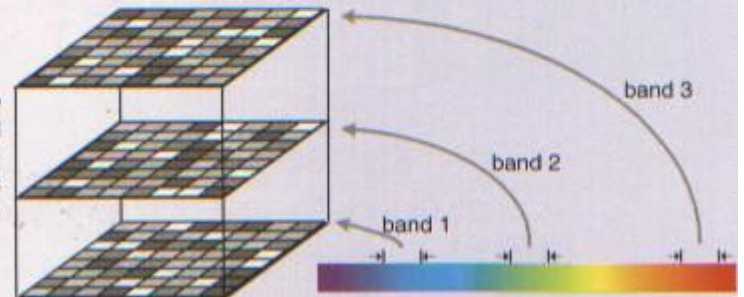
In a grayscale image, each cell has a value from 0 to 255. They are often used for black-and-white aerial photographs.



One way to represent colors on an image is with a colormap. A set of values is arbitrarily coded to match a defined set of red-green-blue values.

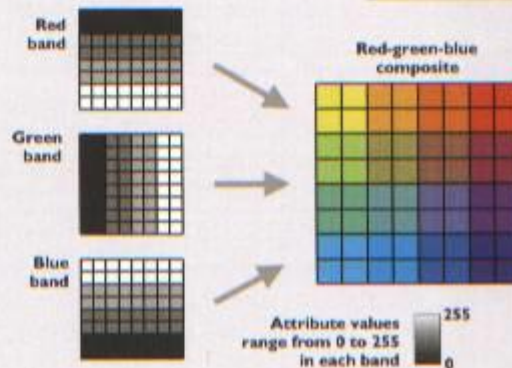
### Displaying multiband rasters

Raster datasets have one or many bands. In multiband rasters, a band represents a segment of the electromagnetic spectrum that has been collected by a sensor.



Electromagnetic spectrum

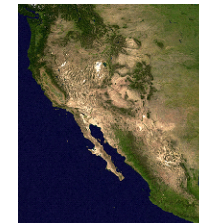
Bands often represent a portion of the electromagnetic spectrum, including ranges not visible to the eye—the infrared or ultraviolet sections of the spectrum.



Multiband rasters are often displayed as red-green-blue composites. This band configuration is common because these bands can be directly displayed on computer displays, which employ a red-green-blue color rendition model.

# Images

- **Grayscale Images** - These are coded using one number per pixel representing one of 256 different gray tones ranging from black to white.
- **Palette Images** - These are images coded using one number per pixel, where the number specifies which color in a palette of up to 256 different colors should be displayed for that pixel. The colors in the palette can be True Color RGB colors. Palette images save space at the cost of a reduced total number of colors available for use in the image.
- **RGB Images** - These images use three numbers for each pixel, allowing possible use of millions of colors within the image at the cost of requiring three times as much space as grayscale or palette images. They are often called True Color RGB images in Microsoft applications.
- **RGBa Images** - These images are RGB images with a fourth number added for each pixel that specifies the transparency of that pixel in the range 0 to 255. RGBa images are used when combining multiple images in maps for elaborate graphics composition or creation of special visual effects in maps.
- **Compressed Images** - Compressed images use sophisticated wavelet compression technology to not only compress the amount of data an image requires but also to reconstitute the image on the fly on demand. At any given zoom level the desired view of the image is reconstituted from the compressed data store. Compressed images in general may be viewed but not altered or otherwise manipulated.



# Images

- **Image libraries** An image library component is a type of linked image component that shows what appears to be a single image that is created by automatically forming a mosaic from one or more images saved in image files within a folder on disk. The individual images that comprise the image library are called image tiles.
- Types of libraries
  - **ECWP image servers** - Servers providing compressed image data streams using ECW format.
  - **Google servers** - Google servers providing images rendering maps or satellite images.
  - **Manifold IMS Web Sites** - Manifold IMS can be configured, in addition to standard IMS usage or to OGC WMS image serving, to serve images as an image server.
  - **OGC WMS servers** - Servers providing data streams of image data using OGC WMS format.
    - <https://basemap.nationalmap.gov/arcgis/services/USGSTopo/MapServer/WmsServer?>
    - [http://geodata.md.gov/imap/services/Demographics/MD\\_CensusData/MapServer/WmsServer?](http://geodata.md.gov/imap/services/Demographics/MD_CensusData/MapServer/WmsServer?)
  - **Oracle servers** - Oracle DBMS servers providing Oracle Spatial or Locator facilities within standard Oracle databases to store images.
  - **Tables and Queries** - Linked images may be created dynamically from tables or queries.

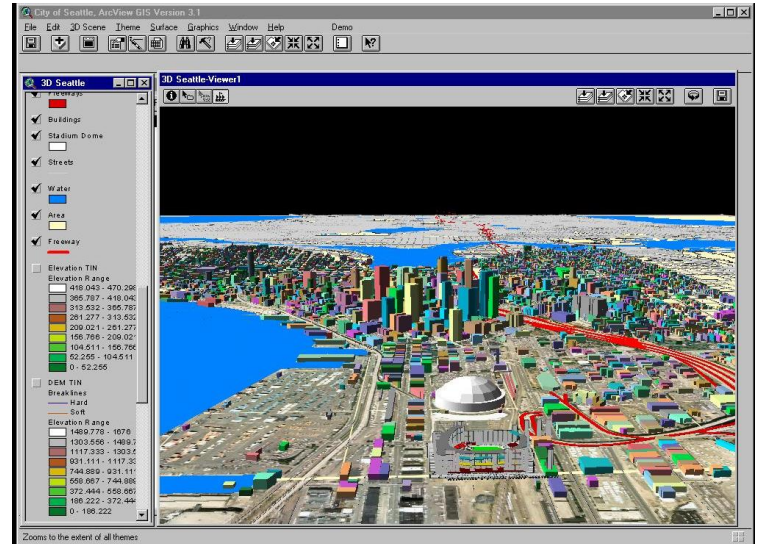
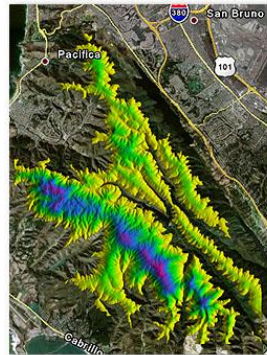
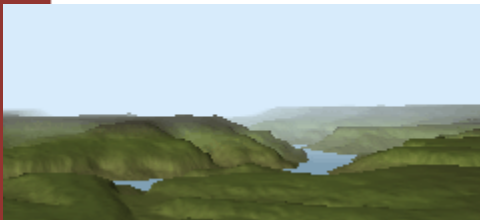
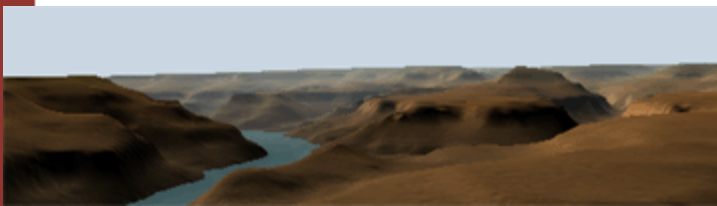
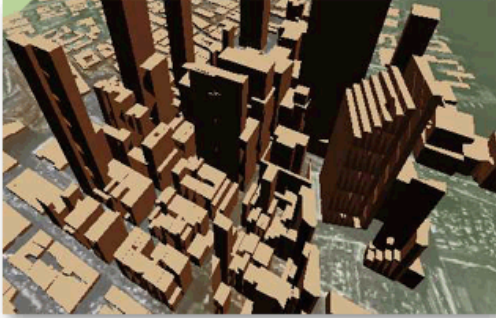


# Image Pyramids

- Most technologies for displaying very large images will include the use of intermediate level images or pyramids to allow much faster display of images, including zooming in or out and panning the image.
- If we compute intermediate levels of zoom and save extra images that takes time. If we compute and store very many intermediate levels of zoom that will also increase the storage size required for images
- The need for extra storage space also is not usually a burden, since most people would happily see an image increase in storage space by, say, 50% if thereafter display was virtually instantaneous instead of taking minutes for each change in zoom



# Visualization



# Raster Data

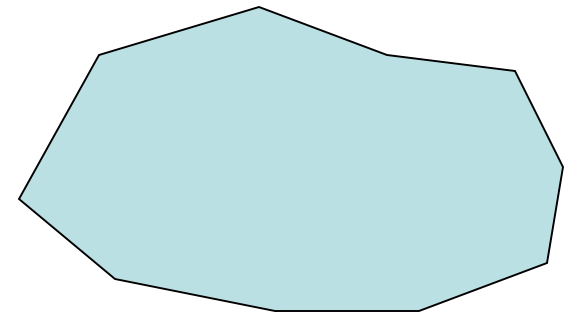
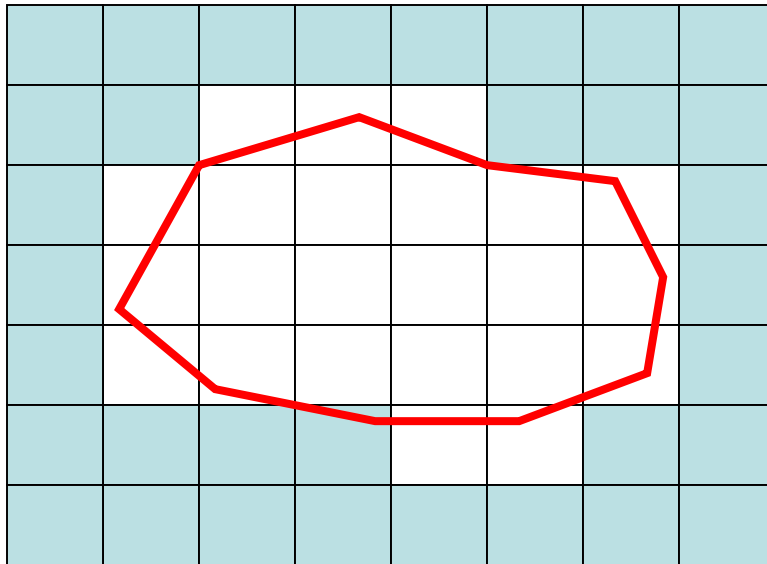
- **Geographic Data Sets**
  - Land Use/Land Cover
  - Vegetation Index
  - Soil Stability
- **Digital Photography**
  - Building Photos
  - Accident Scenes
  - Crop Damage
  - Full Motion Video
- **Digital Orthophotography**
  - Rectified Aerial Photos

# Raster Analysis

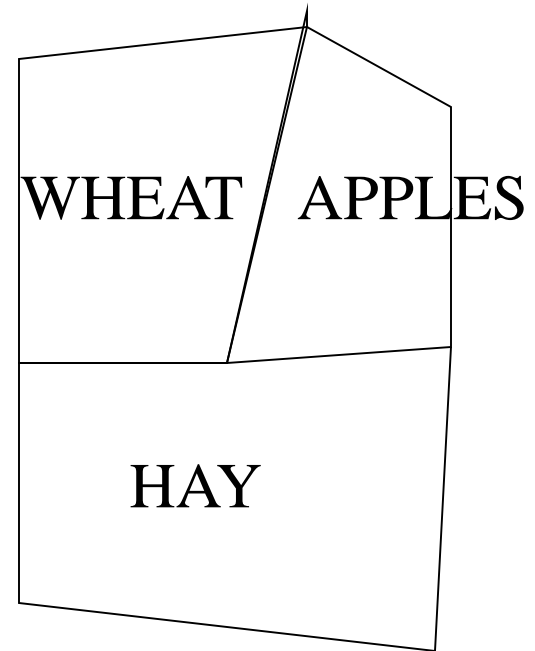
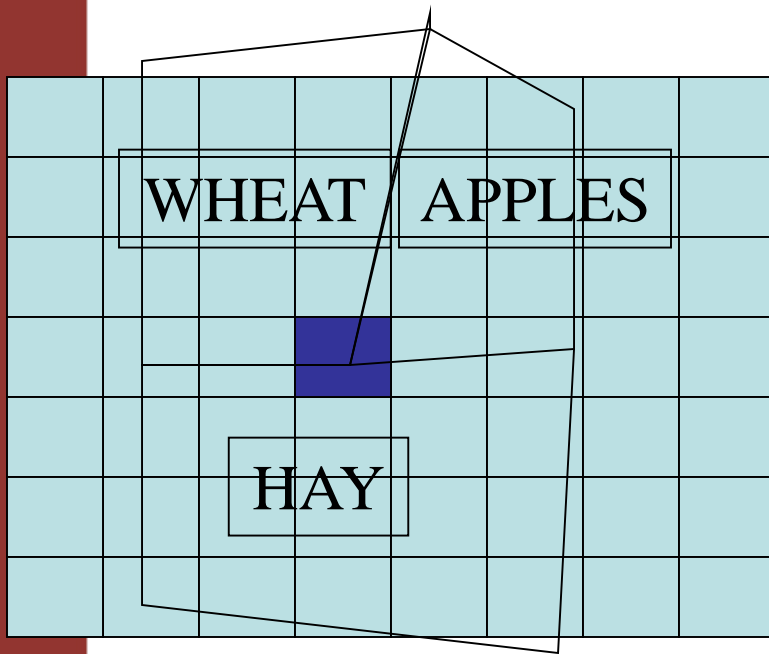
- Spatial Transformations
- Spatial Coincidence
- Proximity
- Surface Analysis
- Dispersion
- Least Cost Path

# Raster Data Structure

- Matrix of Equal-Area Cells



# Issue of Resolution



# Raster Vs. Vector

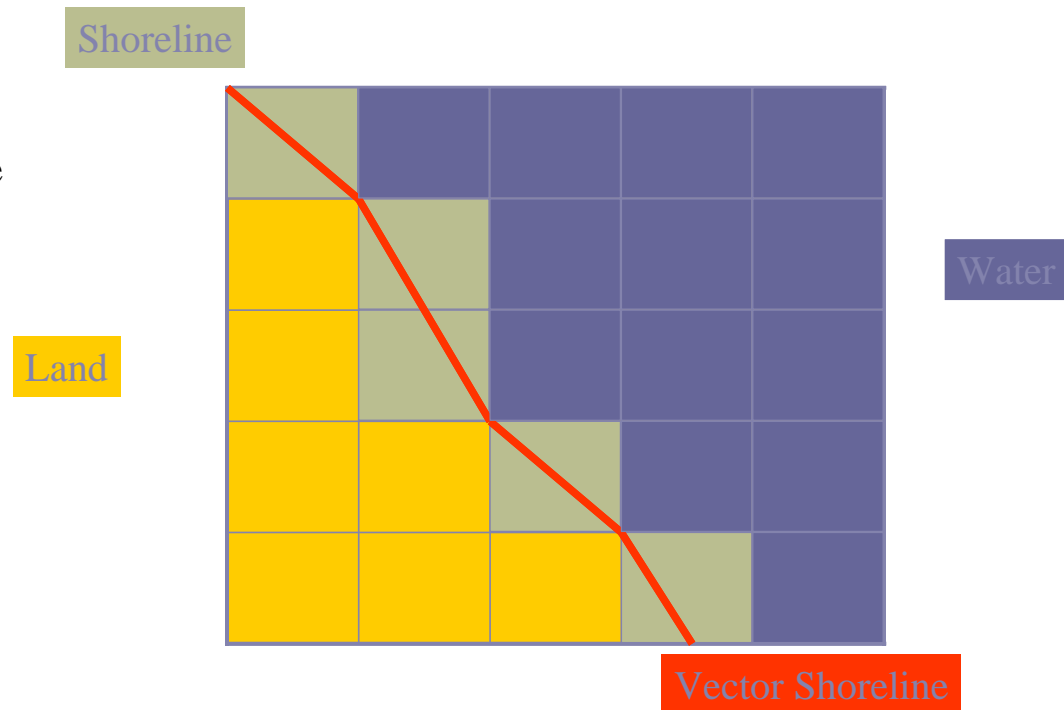
- Must Consider
  - Discreteness of the entity being depicted
  - Intended application (efficiencies)
  - Source data
  - Storage considerations
    - Resolution
    - Color

# Raster vs. Vector Model

People often ask: “what is the best format to represent geographic objects in a GIS, raster or vector?” The answer is actually neither and both! That is, neither data model is better in every circumstance, and both data models fulfill very specific roles in GIS.

In this example, the vector data source representing the shoreline appears to have greater detail, and possibly greater accuracy. Vector data can often store the information in a more compact format than raster data, and also work well with linear objects such as stream networks.

However, raster data models are much better at representing information that is continuous in nature, such as temperature where the value of temperature may be different between neighbors.



Source: Defense Mapping School  
National Imagery and Mapping Agency

# Vector – Advantages and Disadvantages

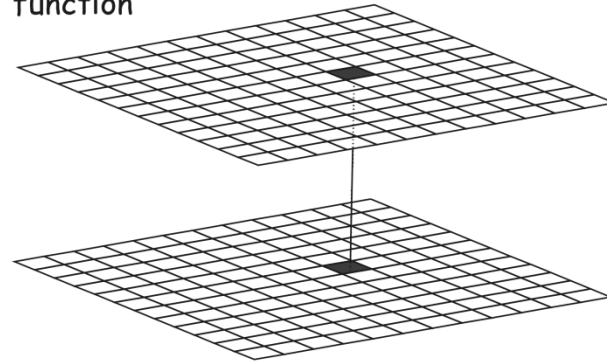
- Advantages
  - Good representation of reality
  - Compact data structure
  - Topology can be described in a network
  - Accurate graphics
- Disadvantages
  - Complex data structures
  - Simulation may be difficult
  - Some spatial analysis is difficult or impossible to perform

# Raster – Advantages and Disadvantages

- Advantages
  - Simple data structure
  - Easy overlay
  - Various kinds of spatial analysis
  - Uniform size and shape
  - Cheaper technology
- Disadvantages
  - Large amount of data
  - Less “pretty”
  - Projection transformation is difficult
  - Different scales between layers can be a nightmare
  - May lose information due to generalization

# Raster Functions

Local function



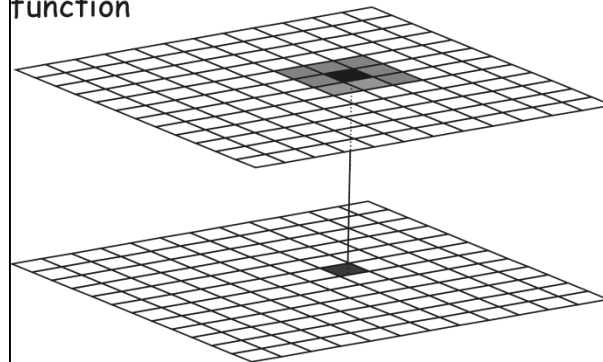
e.g.,

10	12	42
30	9	4
-12	8	15

plus 4

14	16	46
34	13	8
-8	12	19

Neighborhood function



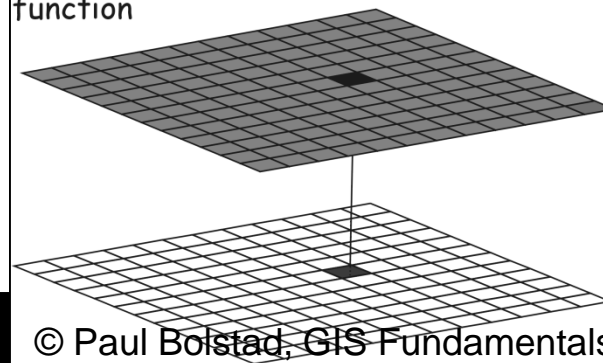
e.g.,

10	12	42
30	9	4
-12	8	15

neighborhood maximum

33	42	42
30	42	42
30	30	17

Global function



e.g.,

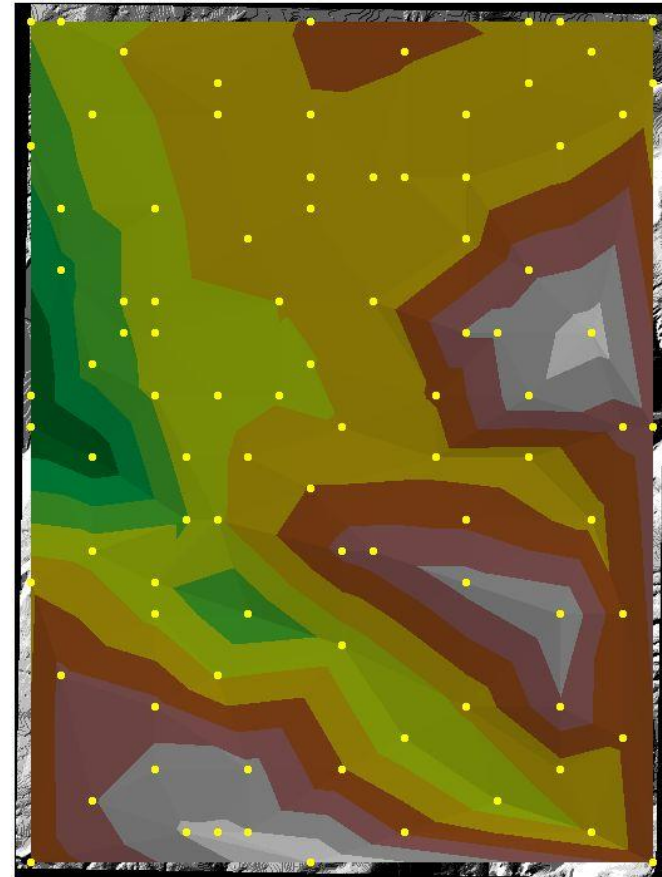
10	12	42
30	9	4
-12	8	15

global maximum

42	42	42
42	42	42
42	42	42

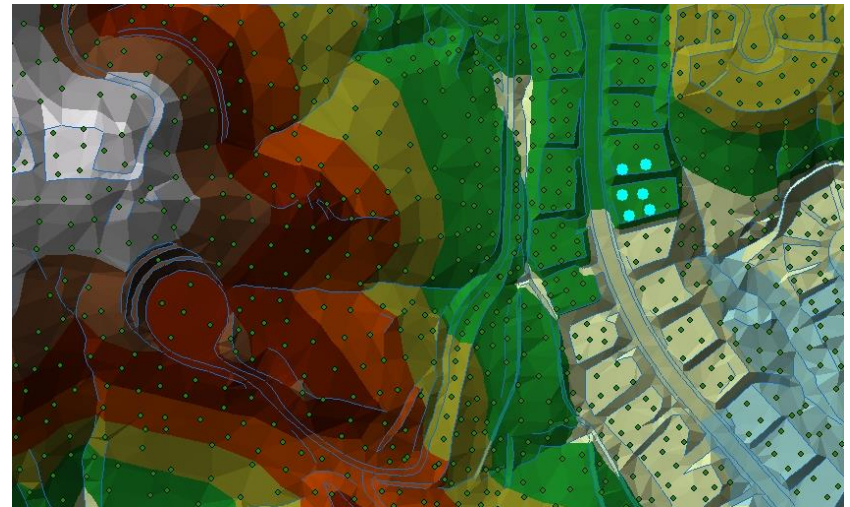
# Triangulated Irregular Network

- A triangulated irregular network (TIN) is a data model that is used to represent three dimensional objects. In this case, x,y, and z values represent points. Using methods of computational geometry, the points are connected into what is called a triangulation, forming a network of triangles. The lines of the triangles are called **edges**, and the interior area is called a face, or **facet**.
- While the TIN model is somewhat more complex than the simple point, line, and polygon vector model, or the raster model, it is actually quite useful for representing elevations. For example a raster grid would require grid cells to cover the entire surface of a geographic area. Also, if we wanted to show great detail we would have to have small grid cells. Now, if the land area is relatively flat, we would still need the small grid cells. However, with a TIN we would not have to include so many points on the flat areas, but could add more points on the steep areas where we want to show greater detail.
- The illustration shows how we can create a TIN of the terrain around Ithaca, NY.
  - First, a series of elevation points are created
  - Second, a TIN face is created with the elevation data
  - Third, the faces are shaded in to give the impression of a 3D surface



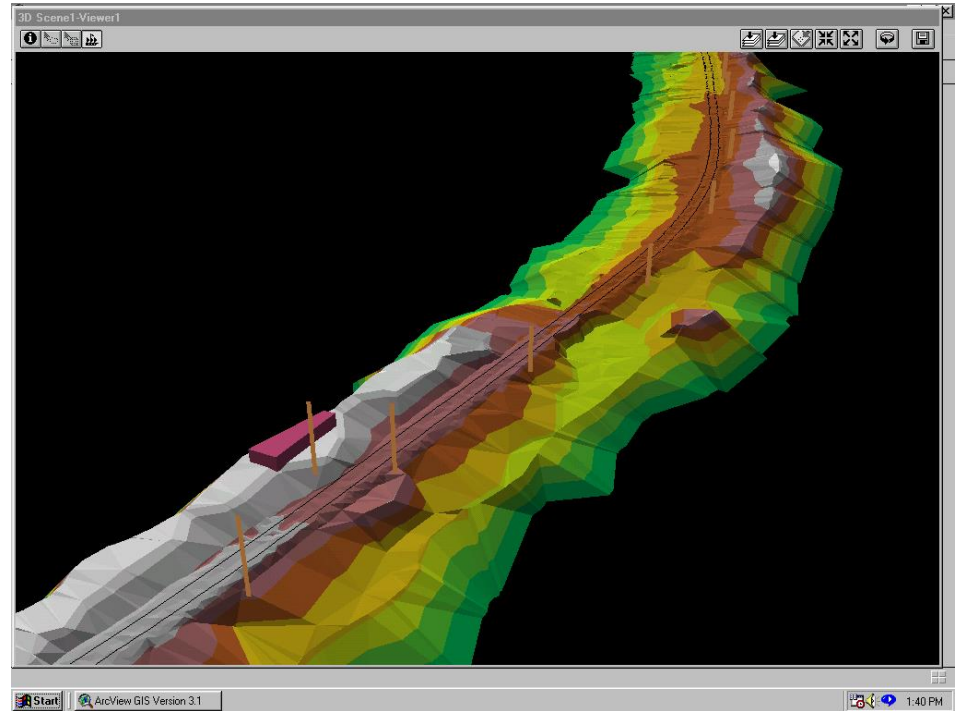
# TIN Data Structures

- The tin data structure is based on two basic elements:
  - points with x,y,z values, and a series of edges joining these points to form triangles.
  - This triangular mosaic forms a continuous faceted surface, much like a jewel.
  - TIN's triangulation method satisfies the Delaunay criterion



# Components of a TIN

- Nodes
- Edges
- Triangles
- Hull
- Topology



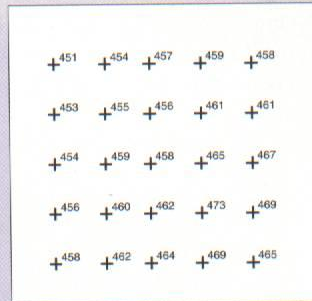
# Comparing rasters and TINs for representing surfaces

Surfaces can be modeled with rasters or TINs. Each model has advantages and limitations.

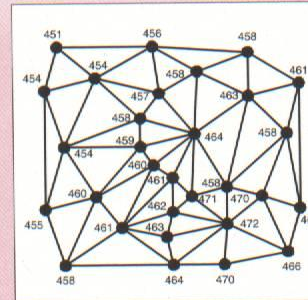
Rasters are a simpler model of a surface. Digital terrain data is widely accessible in raster format.

TINs can produce a more accurate representation of surfaces and features, but usually require a data collection effort.

**Raster representation of a surface**



**TIN representation of a surface**



## Accuracy of surface model

The precision of a raster surface model is determined by the cell dimensions. To increase the accuracy of a raster surface model, the entire raster must be resampled at a higher resolution.

A TIN surface model has a variable point density that varies on the degree of change of slope. To make a TIN more accurate, additional mass points, breaklines, and polygons can be added.

## Fidelity of surface features

Rasters sample the z-values of surface features on a regular grid. Features such as peaks and ridges cannot be located to a position more accurate than the grid resolution.

TINs are designed to capture and represent surface features such as streams, ridges, and peaks. These features are stored with precise coordinates, and slope discontinuities such as ridges are modeled with breaklines.

## Surface analysis

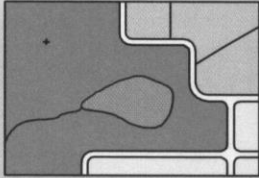
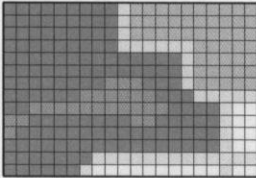
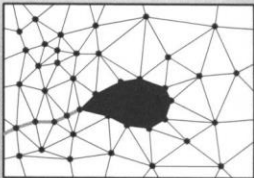
Spatial coincidence  
Proximity  
Dispersion  
Least-cost path

Elevation, slope, aspect calculations  
Contour derivation from surface  
Volume calculations  
Vertical profiles on alignments  
Line-of-sight analysis

## Sample applications

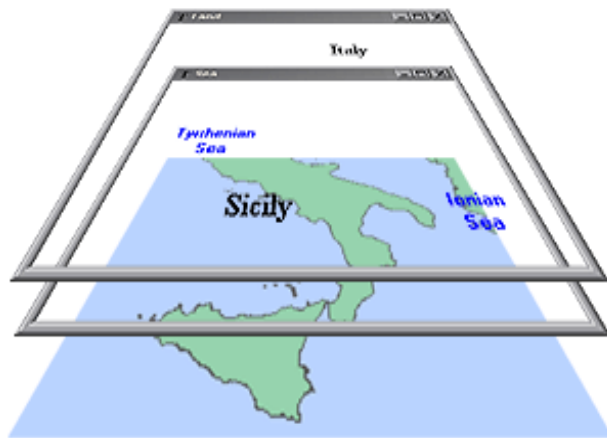
Small-scale surface display and modeling  
Modeling of pollutant dispersion  
Identification of watershed basins  
Hydrologic analysis of flood zones

Volumetric calculations for roadway design  
Drainage studies for land development  
Generation of high-quality elevation contours  
Perspective displays of buildings on a landscape

	<b>Vector data representation</b>	<b>Raster data representation</b>	<b>Triangulated data representation</b>
			
<b>Focus of model</b>	Vector data is focused on modeling discrete features with precise shapes and boundaries.	Raster data is focused on modeling continuous phenomena and images of the earth.	Triangulated data is focused on an efficient representation of a surface that can represent elevation or other quality, such as concentration.
<b>Sources of data</b>	Compiled from aerial photography Collected from GPS receivers Digitized from map manuscripts Sketched on top of raster display Vectorized from raster data Contours from triangulation Reduced from survey field data Imported from CAD drawings	Photographed from an airplane Imaged from a satellite Converted from a triangulation Rasterized from vector data Scanned blueprints, photographs	Compiled from aerial photography Collected from GPS receivers Imported points with elevations Converted from vector contours
<b>Spatial storage</b>	Points stored as x,y coordinates. Lines stored as paths of connected x,y coordinates. Polygons stored as closed paths.	From a coordinate in the lower-left corner of the raster and cell height and width, each cell is located by its row and column position.	Each node in a triangle face has an x,y coordinate value.
<b>Feature representation</b>	Points represent small features. Lines represent features with a length but small width. Polygons represent features that span an area.	Point features are represented by a single cell. Line features are represented by a series of adjacent cells with common value. Polygon features are represented by a region of cells with common value.	Point z values determine the shape of a surface. Breaklines define changes in the surface such as ridges or streams. Areas of exclusion define polygons with the same elevation.
<b>Topological associations</b>	Line topology keeps track of which lines are connected to a node. Polygon topology keeps track of which polygons are to the right and left sides of a line.	Neighboring cells can be quickly located by incrementing and decrementing row and column values.	Each triangle is associated with its neighboring triangles.
<b>Geographic analysis</b>	Topological map overlay Buffer generation and proximity Polygon dissolve and overlay Spatial and logical query Address geocoding Network analysis	Spatial coincidence Proximity Surface analysis Dispersion Least-cost path	Elevation, slope, aspect calculations Contour derivation from surface Volume calculations Vertical profiles on alignments Viewshed analysis
<b>Cartographic output</b>	Vector data is best for drawing the precise shape and position of features. It is not well suited for continuous phenomena or features with indistinct boundaries.	Raster data is best for presenting images and continuous features with gradually varying attributes. It is not generally well suited for drawing point and line features.	Triangulated data is best for rich presentation of surfaces. This data can be viewed by using color to show elevation, slope, or aspect or in a three-dimensional perspective.

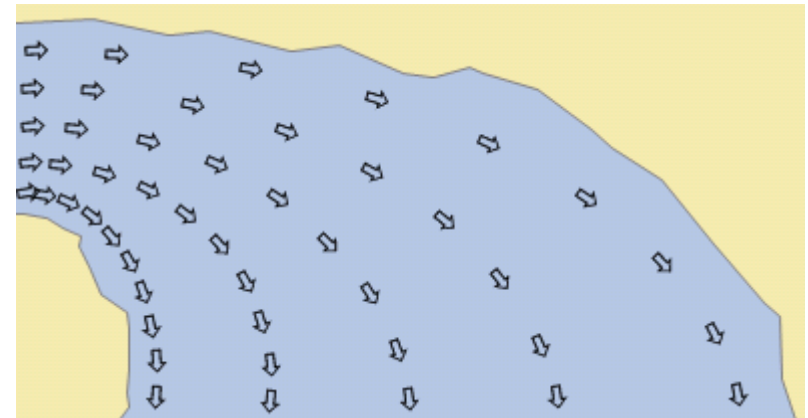
# Annotation / Labels

Text or labels plotted on a map which describe or identify a feature or add other information to the map.

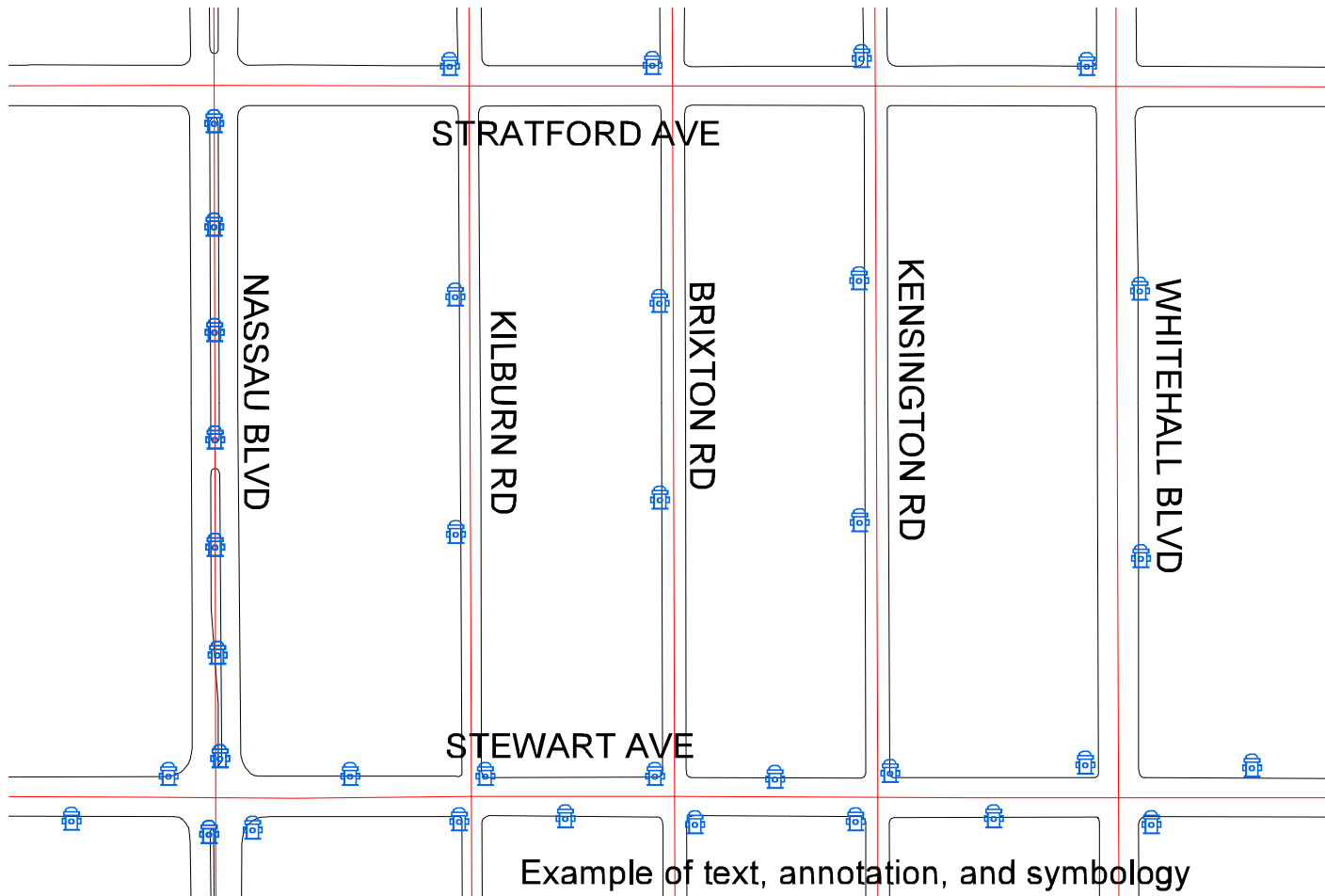


# Annotation

- Text
  - Information placed on a map to provide additional information about a graphic feature.
- Symbols
  - The means by which graphic features are displayed in a GIS.



# Annotation, Symbology, and Text



Example of text, annotation, and symbology

Courtesy Village of Garden City  
**Salisbury**  
UNIVERSITY

# Issues of Scale in Feature Representation

- Depending upon the presentation scale, a feature may take on different forms
  - Buildings
    - Engineering drawing – building outline
    - USGS Quad Sheet – point location
  - City
    - USGS Quad Sheet – Polygon of city boundary
    - Rand McNally Map – Point representing city location

# Issue of Discreteness

- Some feature types (especially in environmental science) do not have discrete boundaries
  - Soil zone
  - Plant community
  - Wetland

# Classifying Features

- Classification is a means of grouping entities into categories or sets with unifying attributes
- Classification Requirements
  - Relevant (does it make sense?)
  - Comprehensive (does it include all the data?)
  - Repeatable (can we recreate it?)
  - Achievable, given technology (can we develop it?)
  - Discrete (can we separate the classes?)

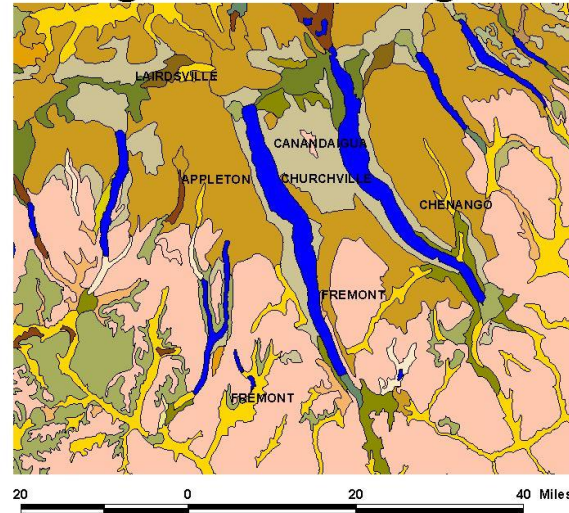
# Measurement Levels

- Once again, in GIS we are interested in geography as information. Therefore, when we describe the attributes of geography, we need to have an understanding of how this information is measured or categorized. All of the data that is used in GIS can be categorized as:
  - Nominal
  - Ordinal
  - Interval
  - Ratio
- Although this can be a rather “dry” topic, it is important for us to understand the differences in these measurement levels. Just as we need to understand the importance of datums and projections, so as to not risk making significant GIS blunders, understanding the appropriateness of the four measurement levels is equally important. Without a proper understanding of the measurement levels, it is easy to misapply the data to specific GIS processes.

# Measurement Levels

- **Nominal Data:** The first measurement level to consider is nominal data. Nominal data is simply a label or name used to describe a feature. With nominal data there is no assumption of ordering. The data is described as qualitative and categorical, and would include descriptions such as national origin, hair color, birthplace, or school district.
- Suppose we have a map of two zones: zone 1, and zone 2. When using nominal data, we must understand:
  - Zone “1” is not necessarily less than Zone “2”, even though the number “1” is less than the number “2”.
  - Combining Zone “1” and Zone “2” does not equal Zone “3”, even though  $1 + 2$  equals 3.
- A GIS does not care if you add these data together, or make Zone 1 less than Zone 2. But, if we have two soils: Mardin and Valois, should we assume that Valois is better than Mardin because it's higher in the alphabet? No. But, computers are often blind to logic. Therefore, you the geospatial analyst, must make the proper assumptions.

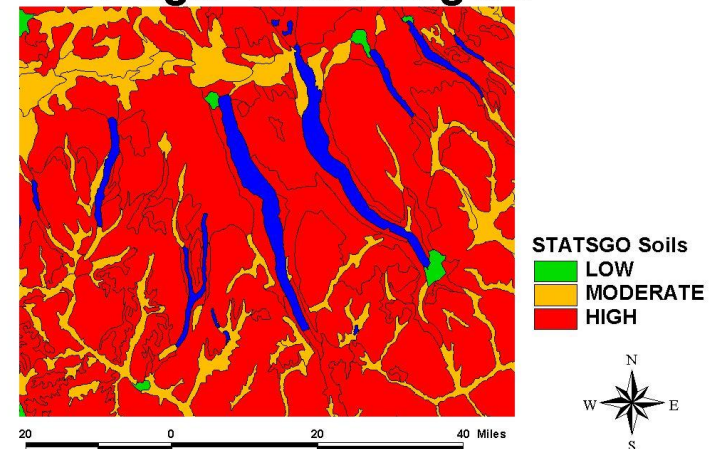
## STATSGO Soils in the Finger Lakes Region



# Measurement Levels

- **Ordinal Data:** While nominal data does not imply any specific order or rank, ordinal data is meaningful in terms of rank order in each category relative to other items in the category. For example, we can rank social class such as working, middle, and upper. *Upper class* is assumed to rank higher than *middle* or *working*. For geographic data, we can return to our previous example of soils. Soils can be considered *poorly drained*, *moderately drained*, and *highly drained*.
- Once again, we should understand for ordinal data:
  - The degree of difference is not known. For example, *upper class* is not two better than *working class*. Also, even though *highly drained* soil may be more desirable than *poorly drained* soil, it is not twice as better drained.
- But again, GIS software doesn't care what you do with the data. Therefore, you must be the police your own use of the data.

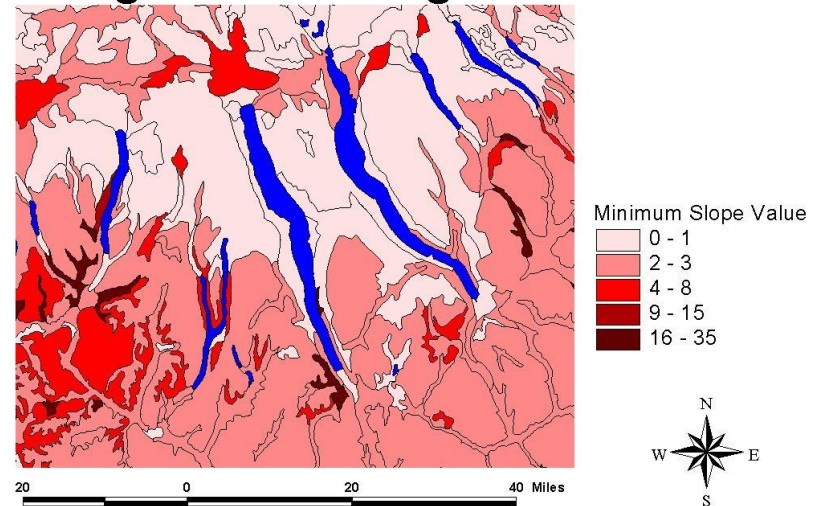
## Potential Frost Action for the Finger Lakes Region



# Measurement Levels

- **Interval and Ratio:** While ordinal data did give us some useful methods to rank data we saw that it was limited in its ability to provide us with any real differences between the objects under study. Interval data is useful for both ordering and illustrating differences between categories. However, interval data does not have an absolute zero starting point, while ratio data does. For example, when measuring temperature, the Kelvin scale has an absolute zero value, while Celsius assigns zero to the freezing point of water. So, while it is true that the difference in temperature between 20 and 40 degrees Celsius is 20 degrees, it is not true to say that 40 degrees Celsius is twice as hot as 20 degrees.
- Ratio data actually does measure magnitude. So, attributes such as distance, area, weight, or value can be measured and ranked. Therefore, you can say that 10 km is twice as far as 5 km.

## STATSGO Soils in the Finger Lakes Region



# Data Layers

## Environmental Attributes

## Map Layer

Parcels

Hazard Areas

Existing Land Use

Contours

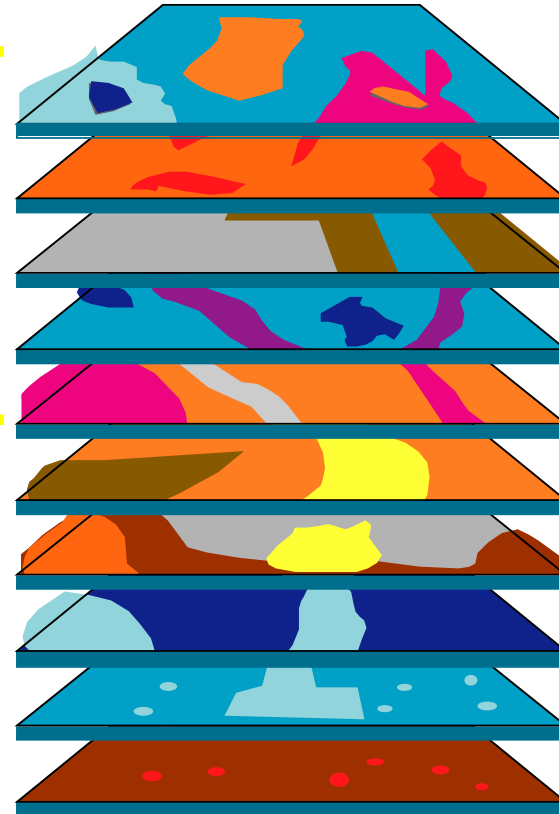
FEMA Floodplain

Soils

Vegetation

Water

Study Areas



© ESRI

# Themes

- Examples of Common Themes:
  - Roads
  - Parks
  - Buildings
  - Soils
  - Habitat Zone

# Data Formats

- ARC/INFO Coverage
- ArcView Shape
- Geodatabase Layer
- AutoCAD DWG/DXF
- MapINFO
- Other