Geographic Information Systems 101:

Understanding GIS

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Scholarly Commons

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Instructor: James Whitacre

- **GIS Specialist**

  Scholarly Commons, Main Library at the University of Illinois at Urbana-Champaign

Previously:

- **GIS Manager**

  Carnegie Museum of Natural History

- **Master of Science in Geography, concentration in GIS and Cartography**

  Indiana University of Pennsylvania

- **Bachelor of Arts in Zoology**

  Ohio Wesleyan University

GIS at Scholarly Commons

- **Provide GIS research services and consultation**
- **Provide GIS workshops and training**
- **Manage the University Library's geospatial data and GIS software resources**
- **Act as a central resource for the University's GIS community and promote the use of GIS in research**

Learning Objectives

- **Learn to think spatially about data and research**
- **Understand how to frame and ascertain research questions and methods using GIS**
- **Overview of different types of GIS software tools and data**
- **Overview of foundational geospatial concepts and analyses**
- **Familiarity with GIS resources available for further investigation**

GIS Workshops

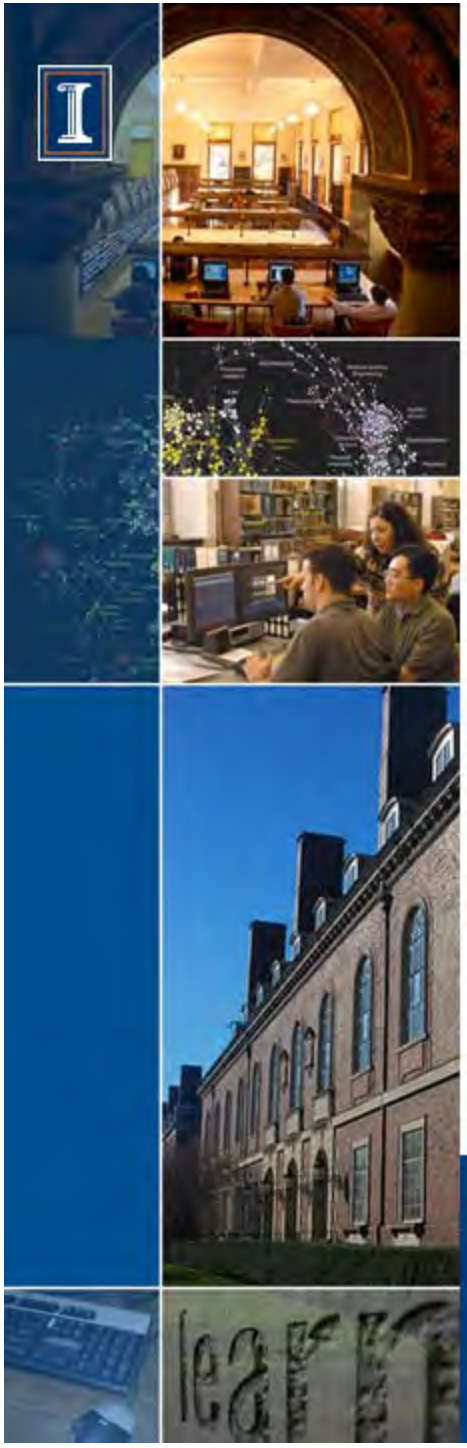
Core Workshops

- **Geographic Information Systems 101: Understanding GIS**
- **GIS for Research I: Tools, Concepts, and Geodata Management**
- **Discovering GIS Data**
- **GIS for Research II: Geoprocessing, Analysis, and Visualization**

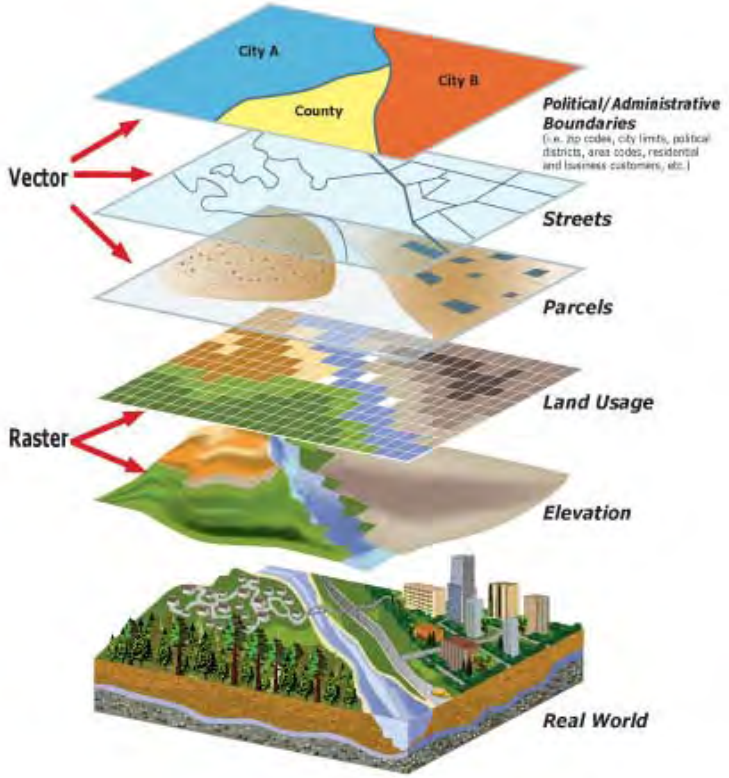
GIS Workshops

Special Topics

- ArcGIS Online and Story Maps
- ModelBuilder and Python in ArcGIS
- Field data collection techniques and Collector for ArcGIS
- Geocoding and georeferencing
- Spatial Analysis Techniques: Interpolation, Clusters, Statistics, and more
- Lidar and 3D mapping techniques



What is GIS?



Geographic Information System or Science

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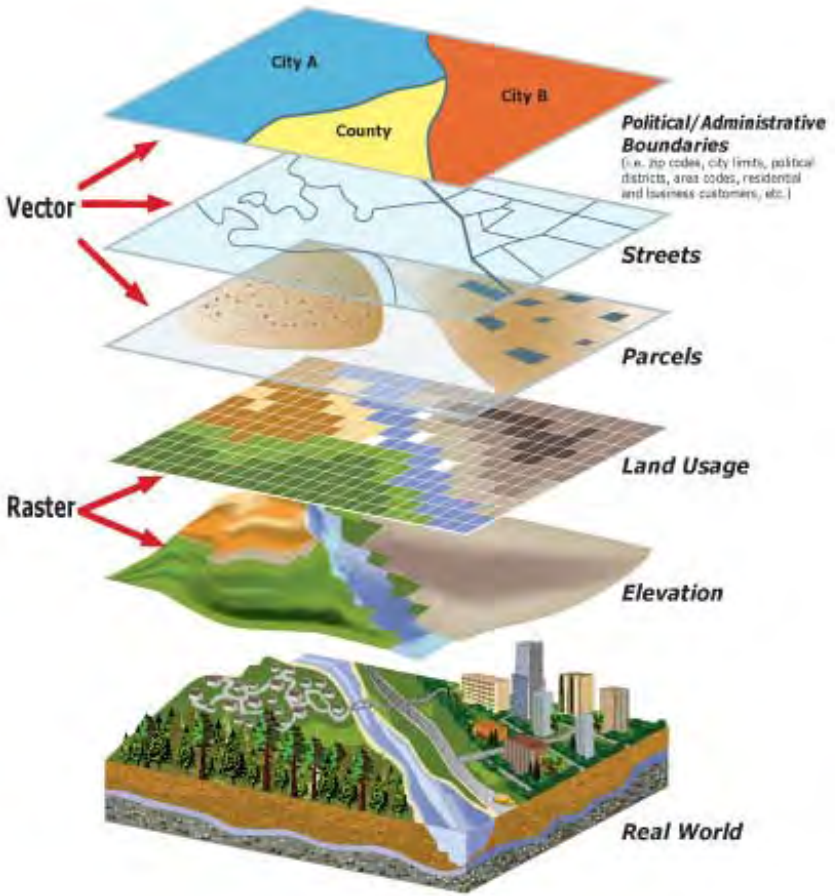
Geographic Information

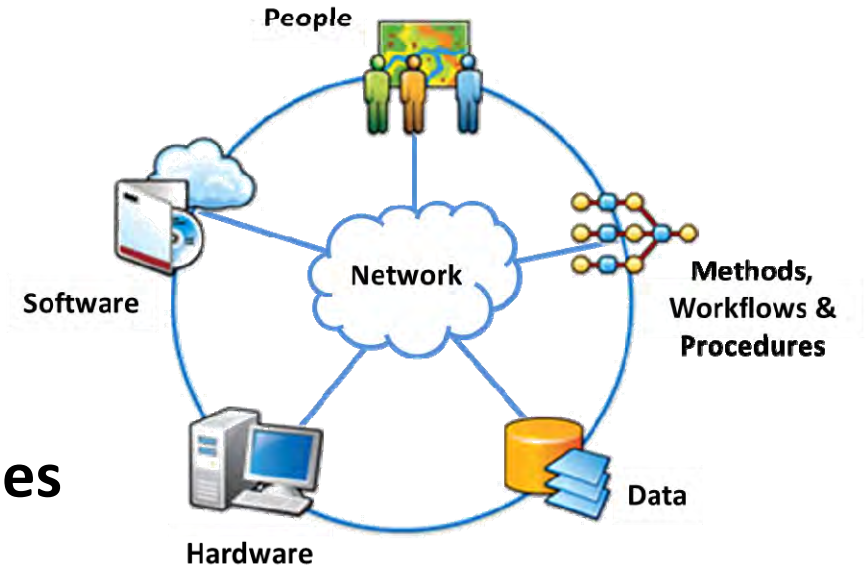
- **Information about places and features on the Earth's surface**
- **Knowledge about *where* something is**
- **Knowledge about *what* is at a given location**



Source: Goodchild, M. F. 1997. "What is Geographic Information Science?, NCGIA Core Curriculum in GIScience". Last modified October 7. http://www.ncgia.ucsb.edu/giscc/units/u002/u002.html.

Geographic Information System

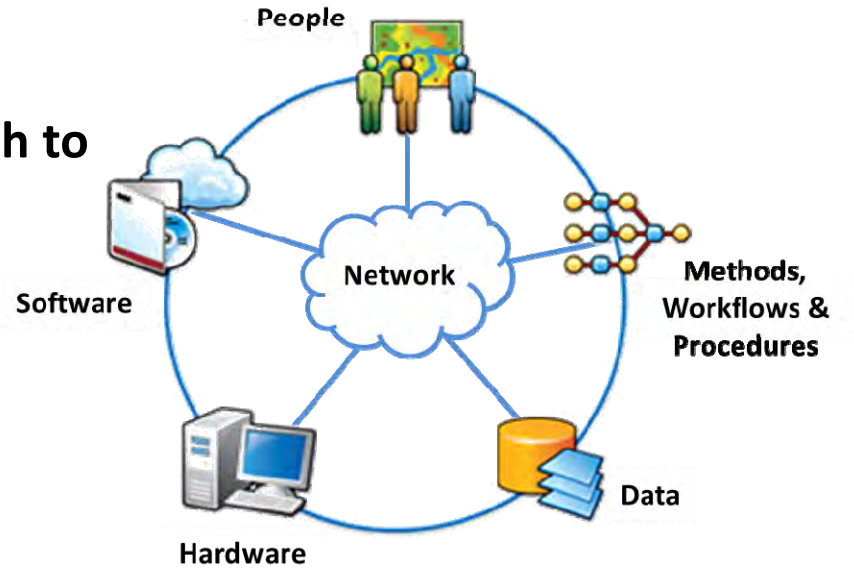
- **Computer hardware and software**
- **Spatial information and data(bases)**
- **Spatial and statistical analysis**
- **Geography and maps drive the underlying concepts and theories**
- **Powerful tool that must be handled with care to not misuse it**



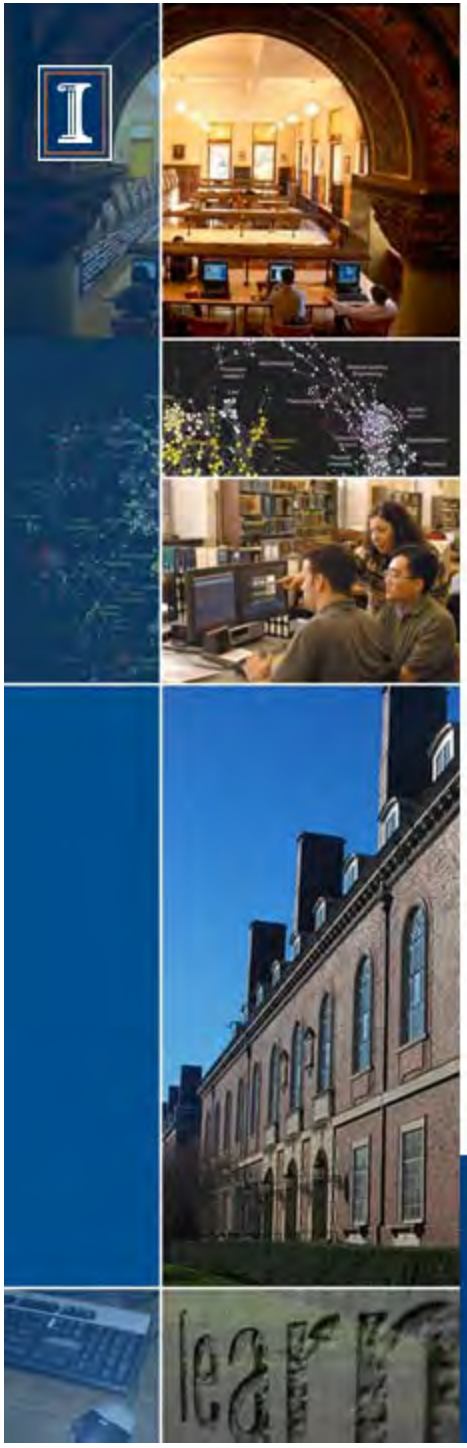
Sources: Steinberg, Sheila L., and Steven J. Steinberg. *GIS Research Methods: Incorporating Spatial Perspectives*. Redlands, CA: Esri, 2015.
Esri. 2014. "GIS - GIS Dictionary". Accessed August 4. http://support.esri.com/en/knowledgebase/GISDictionary/term/GIS.

Geographic Information Science

- **Research that studies the theory and concepts that underpin GIS**
- **Establishes a theoretical basis for the technology and use of GIS**
- **Commonly an interdisciplinary approach to research and investigation**
- **Two forms:**
  - Research about GIS that leads to improvements in the technology
  - Research that uses GIS as a technology tool for the advancement of science



Sources: Esri. 2014. "GIScience - GIS Dictionary". Accessed August 4. http://support.esri.com/en/knowledgebase/GISDictionary/term/GIScience
Goodchild, M. F. 1997. "What is Geographic Information Science?, NCGIA Core Curriculum in GIScience". Last modified October 7. http://www.ncgia.ucsb.edu/giscc/units/u002/u002.html
Goodchild, M.F. 2006. "Geographical information science: fifteen years later." In Classics from IJGIS: Twenty years of the International Journal of Geographical Information Science and Systems, edited by P.F. Fisher, 199–204. Boca Raton: CRC Press.



Think: Spatially

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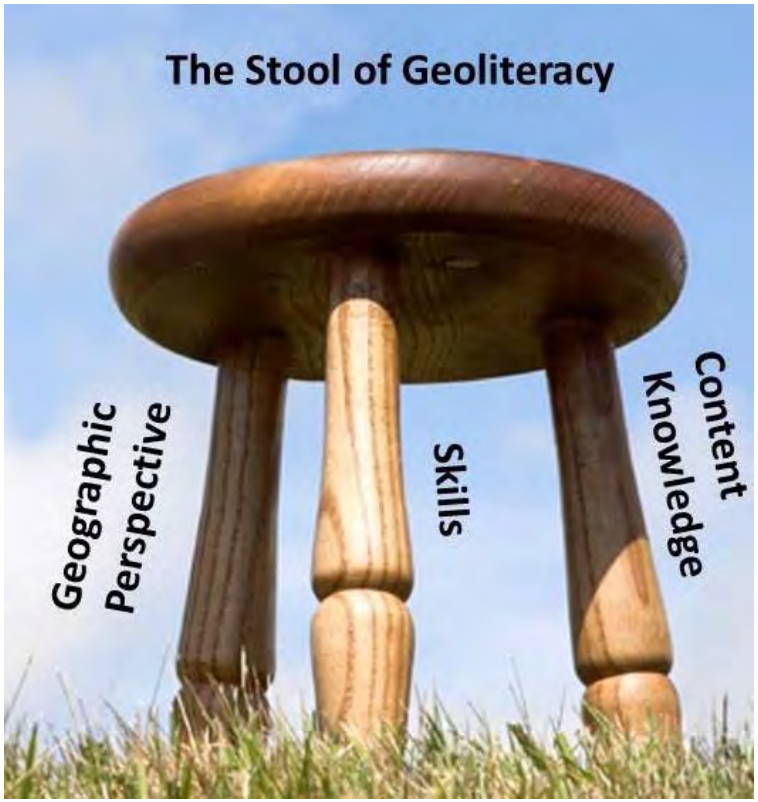
What is Spatial Thinking in Research?

- **Applying geographic principles of place, time, and distance**
- **Ability to conceptualize research questions and methods in light of place, distance, and time**
- **Ability to integrate different forms of spatial data and explore spatial patterns**



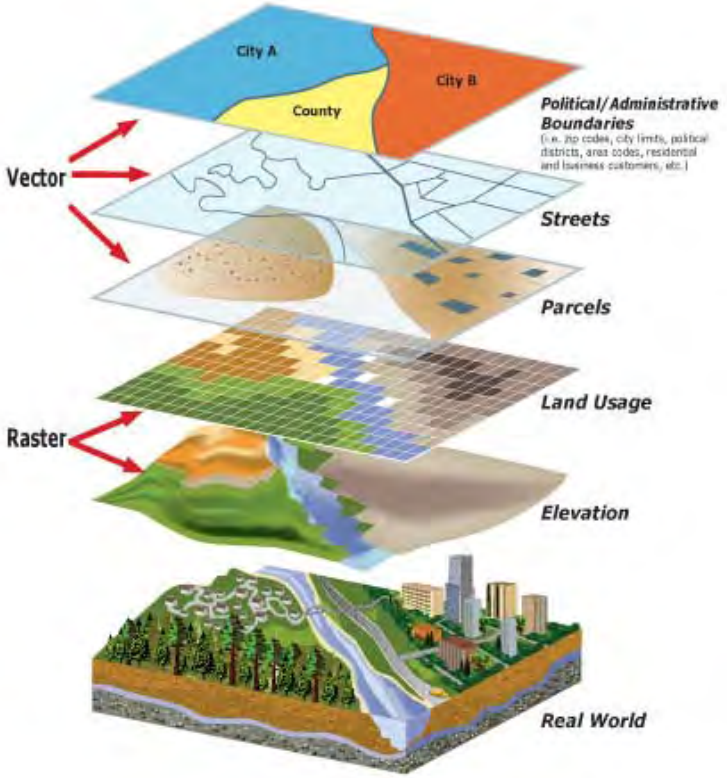
Why Think Spatially in Research?

- **Contextualizes relationships, patterns, and connections in space and time**
- **Results in more holistic and realistic picture of the data**
- **Enables better visualization, communication, and implementation of research**
- **Most data is spatial → it can be tied or linked to a specific location on the earth**

In Research…

Aren’t GPS Coordinates Good Enough?

GIS in Research



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Who uses GIS in Research?

Geography, Ecology, Environmental Sciences, Forest Science, Geology, Engineering, History, Archeology, Anthropology, Literature, Political Science, Business, Economics, Biology, Public Health, Medicine, Education, Public Administration, Agriculture, Urban Planning, Atmospheric Sciences, Library and Information Science, Journalism, Veterinary Medicine, Social Work, Criminology…

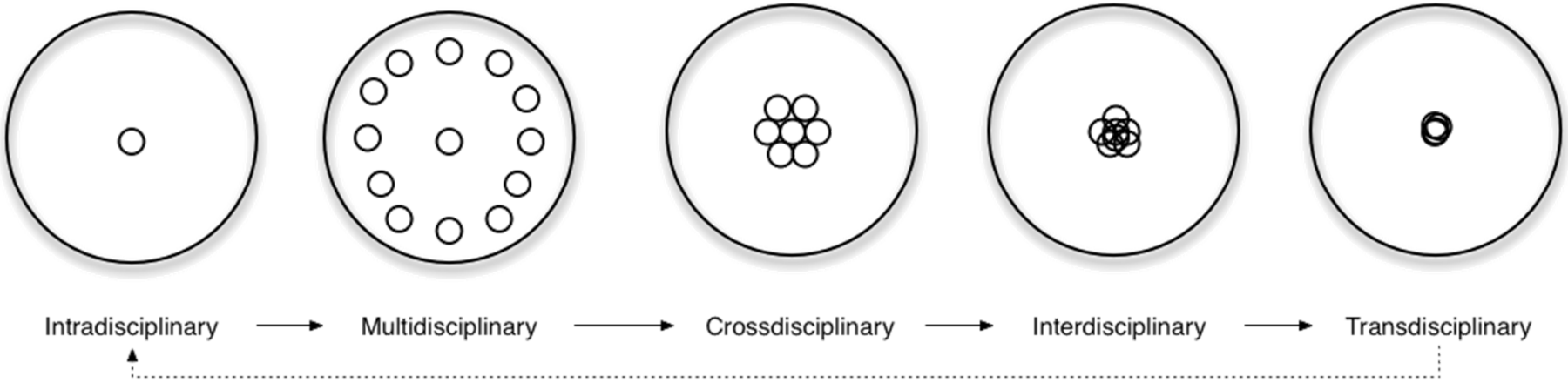


Image Source: Jensenius, Alexander Refsum. 2012. Disciplinarities: intra, cross, multi, inter, trans. Accesses 18 June 2015: http://www.arj.no/2012/03/12/disciplinarities-2/

Advantages of Using GIS in Research

- **Comprehensive approach to research problem solving**
  - Quantitative
  - Qualitative
- **Analyze large amounts of data in a spatial context and at different scales**
- **Data management, analysis, and visualization tool all in one**

GIS | Advantage

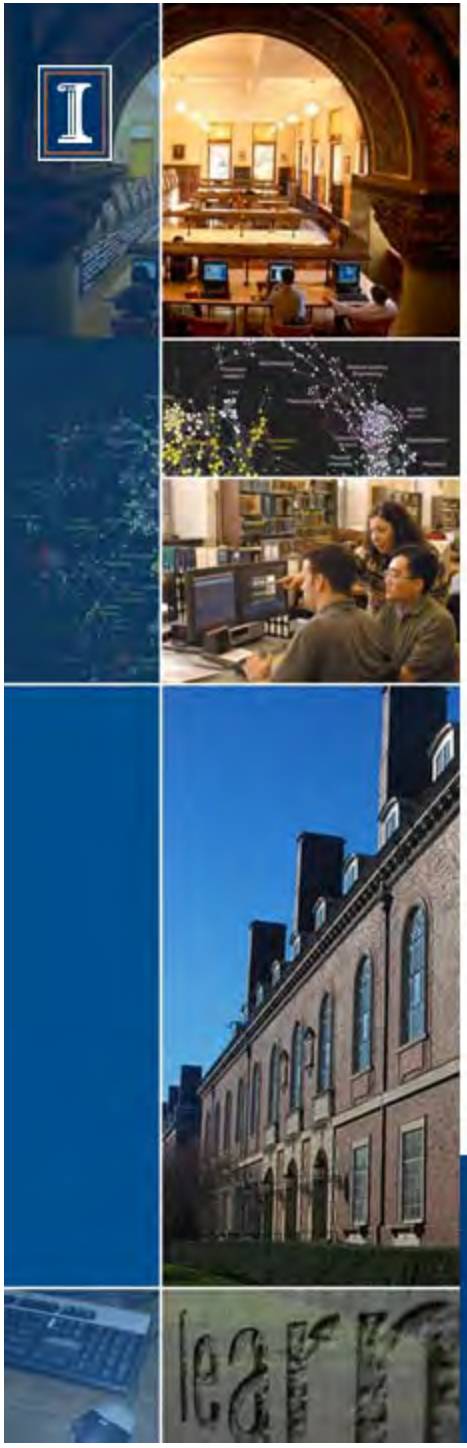
Framing Research for GIS

- **Key in determining how GIS can or will be used in your research**
- **Requires concise research questions for what you want to accomplish with GIS**
- **Analysis will influence research question(s)**
- **Results or final product will influence research question(s)**

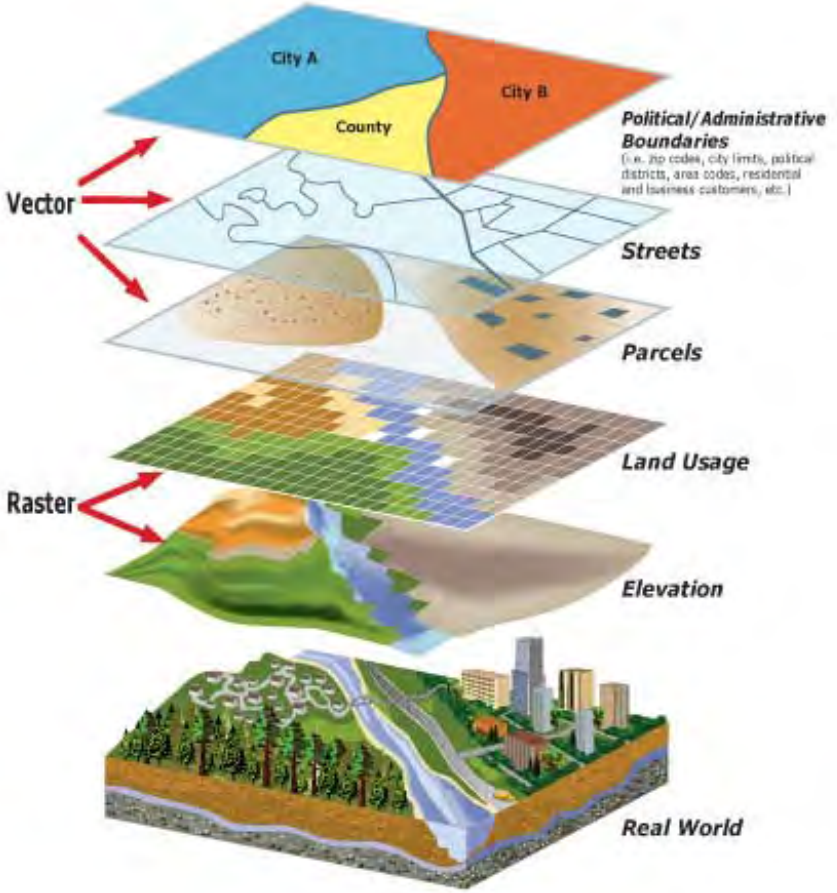
Acquire Geospatial Data

Analyze Geospatial Data

Present Geospatial Data



GIS Maps, Software, and Data



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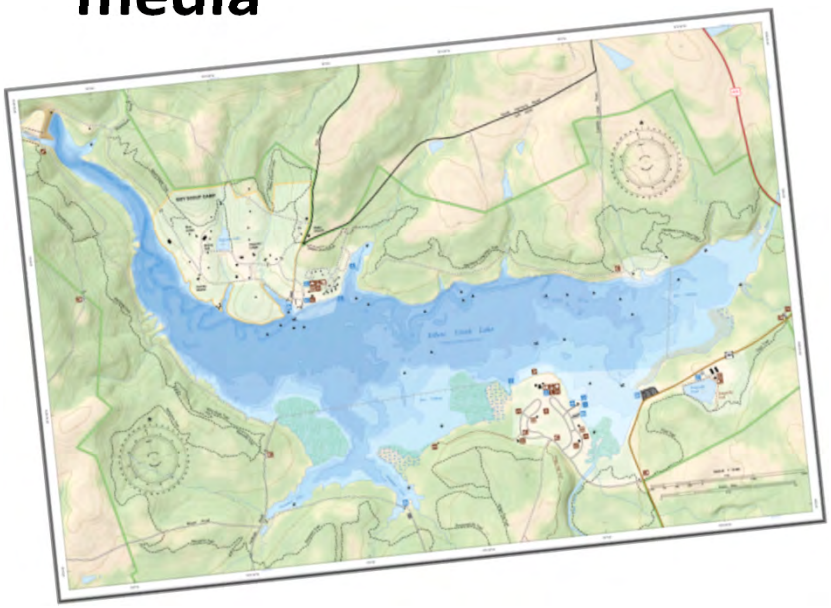
What is a map?

- **Symbolic and visual representation of a place**
- **Contains only selected characteristics or features**
- **Highlights spatial relationships of different features**
- **Usually drawn on a flat surface at a specific scale**

Print vs. Digital Maps

Print:

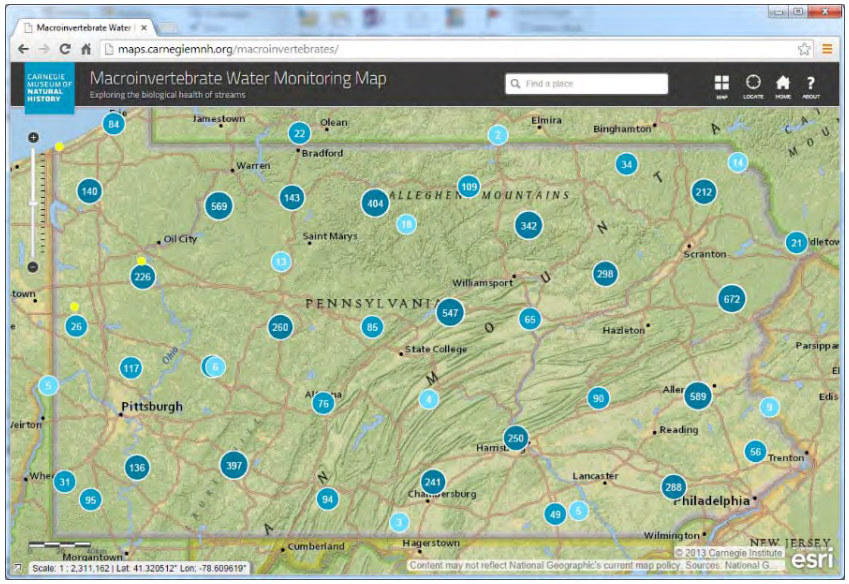
- **Printed and viewed on paper or other physical media**



- **Static view**

Digital:

- **Viewed on a computer or projected screen**

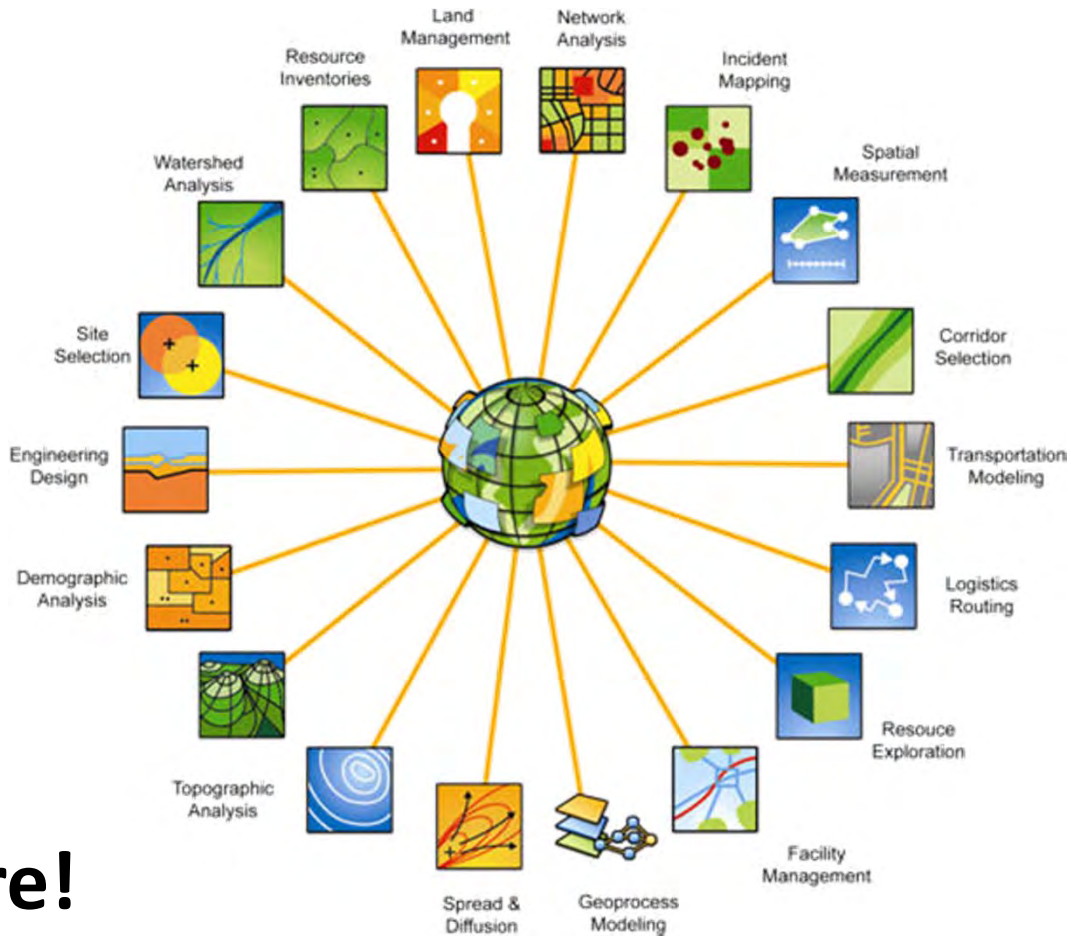


- **Dynamic and Static views**

Maps in GIS

Map :

- **Location**
  - **Quantities**
    - **Densities**
- **What is nearby**
  - **What overlaps**
    - **Change**
- **Map so much more!**



Desktop GIS Software

Traditional GIS Software

Proprietary (usually not free)

- ArcGIS for Desktop
- TerrSet/IDRISI
- ERDAS IMAGINE
- MapInfo
- MicroStation
- AutoCAD
- Google Earth Pro*

Free (usually open source)

- QGIS
- GRASS
- PostGIS
- MultiSpec **
- SAGA
- uDig
- GeoDa
- Google Earth**

*Recently became free!
**Not open source

Web GIS Software

The Future!

GIS and Map Servers

- ArcGIS for Server
- GeoServer
- MapServer
- OpenGeo Suite*
- Others

Cloud GIS and Map Services

- ArcGIS Online
- Mapbox
- CartoDB
- GIS Cloud
- GeoCloud2
- Others

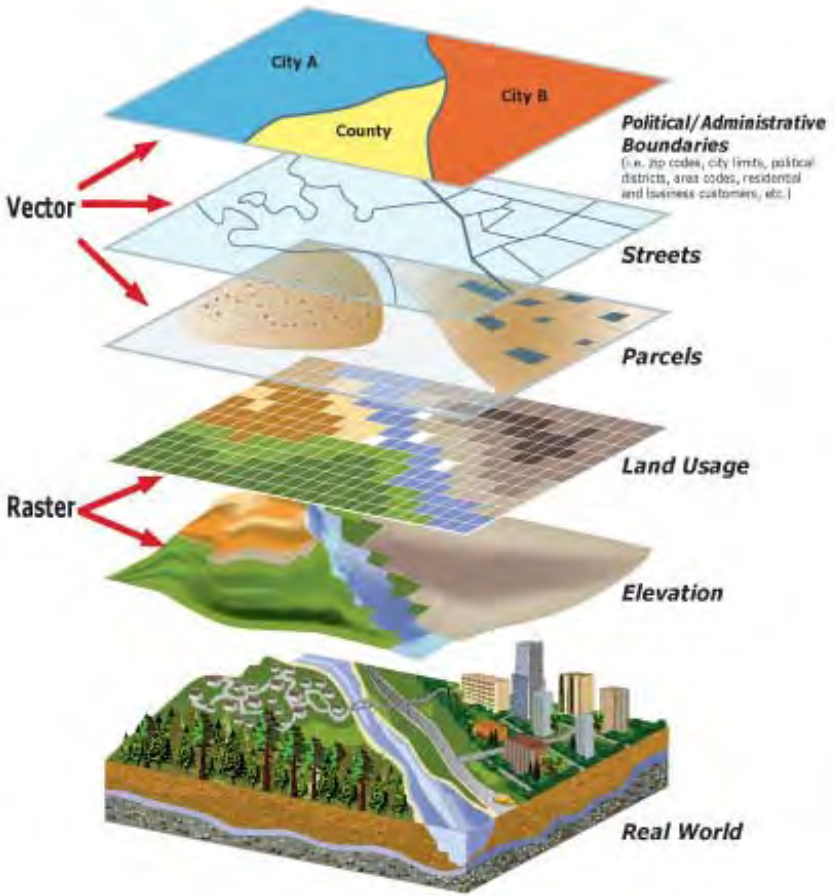
Web Mapping APIs

- ArcGIS API for JavaScript
- Google Maps API
- Leaflet
- OpenLayers
- Many others!

*Includes GeoServer

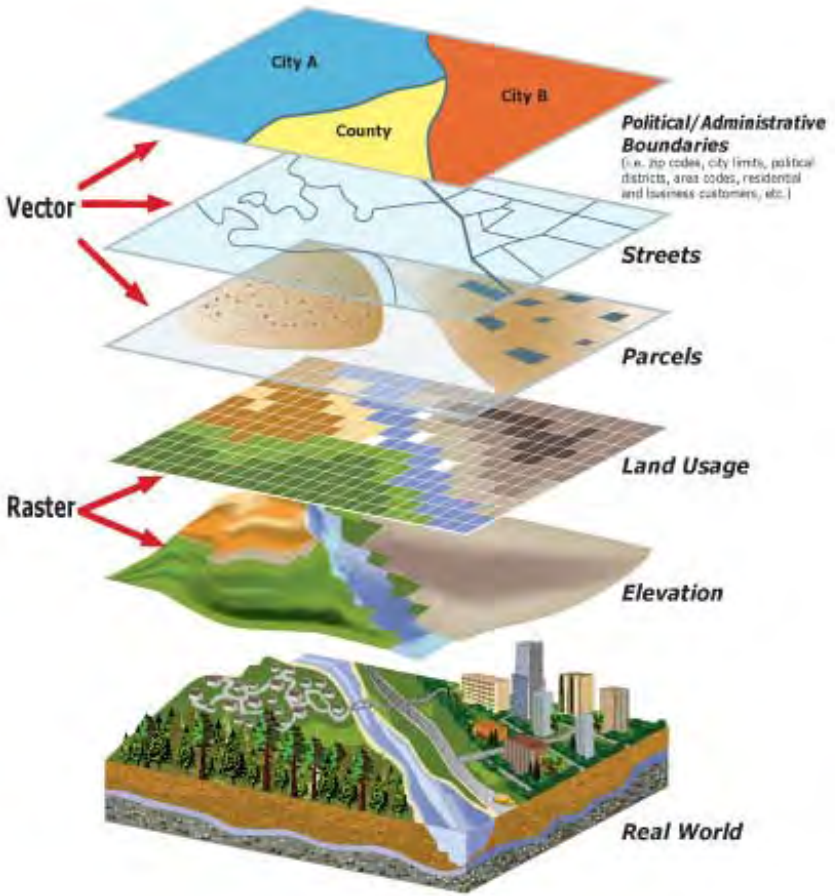
Geospatial Data

- **Where and what something is…**
- **Can be shown on a map**
- **If data has location info** (e.g. latitude and longitude, addresses, place names, etc.) **it is geospatial data**
- **Examples include counties, streams, nesting locations, hillshades**



Layers

- **Geospatial data is arranged by layers on a map in GIS**
- **Collection of similar or thematic geographic features**
- **All features must be the same type of data** (point, line, polygon, raster) **and share the same set of attribute types** (or fields)



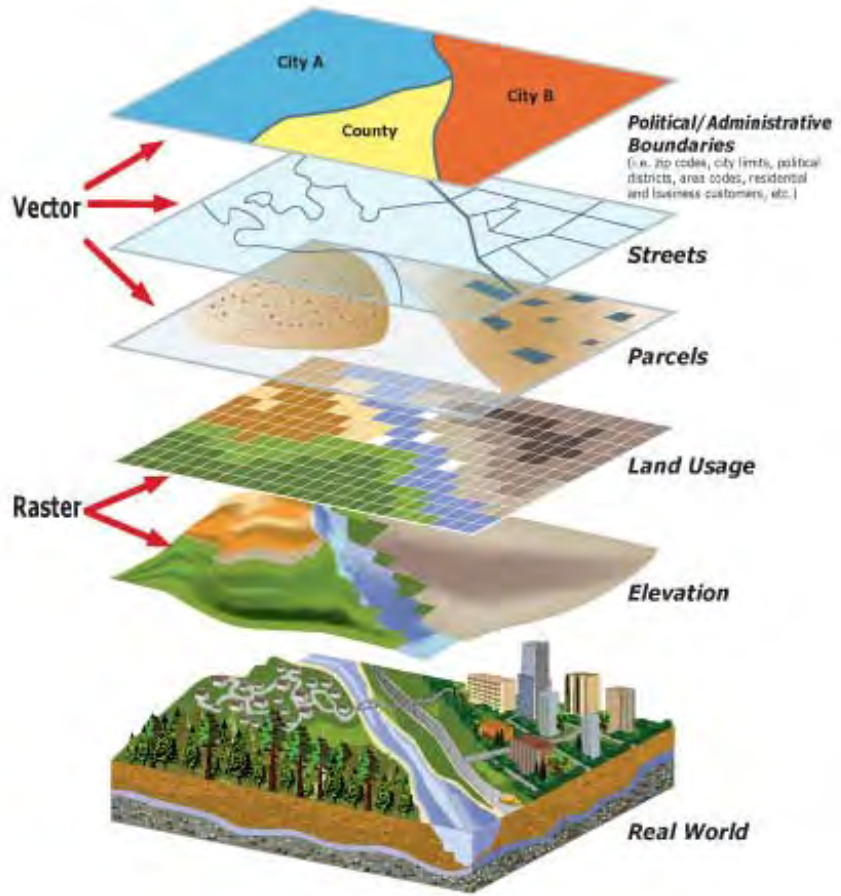
In GIS software, layers:

- **Define visualization or symbology and other essential properties**
- **Do not store data, but reference** (i.e. point to) **data sources**

Geospatial Data Models

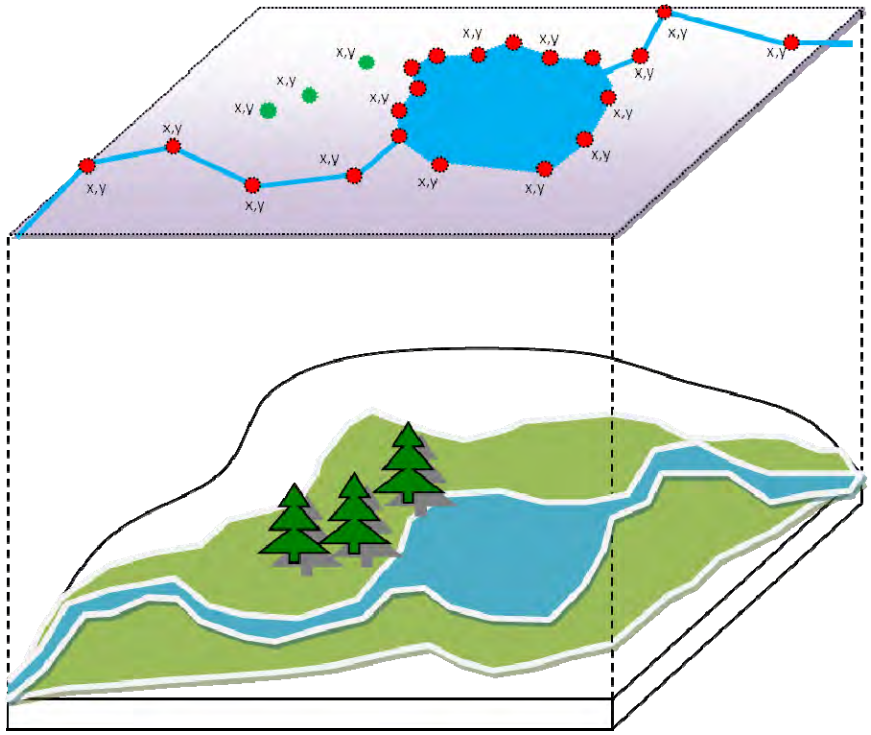
Two Basic Types:

- **Vector**
- **Raster**



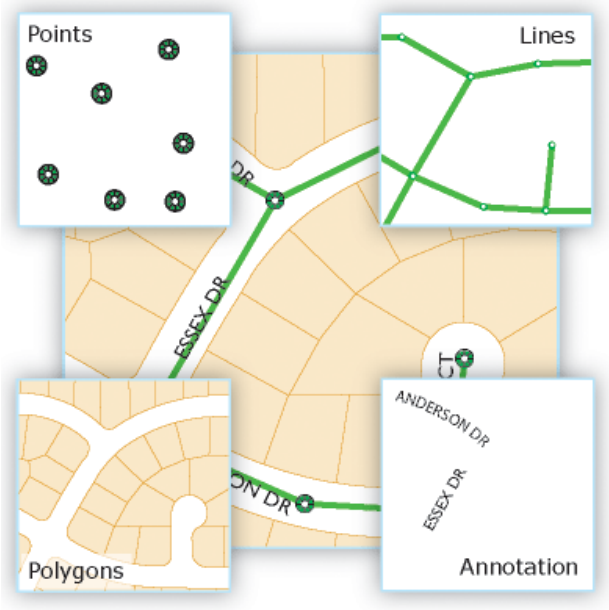
Vector Data

- A coordinate-based data model that represents geographic features as points, lines, and polygons
- Point features represented as a single coordinate pair
- Line and polygon features represented as ordered lists of vertices
- Attributes are associated with each vector feature



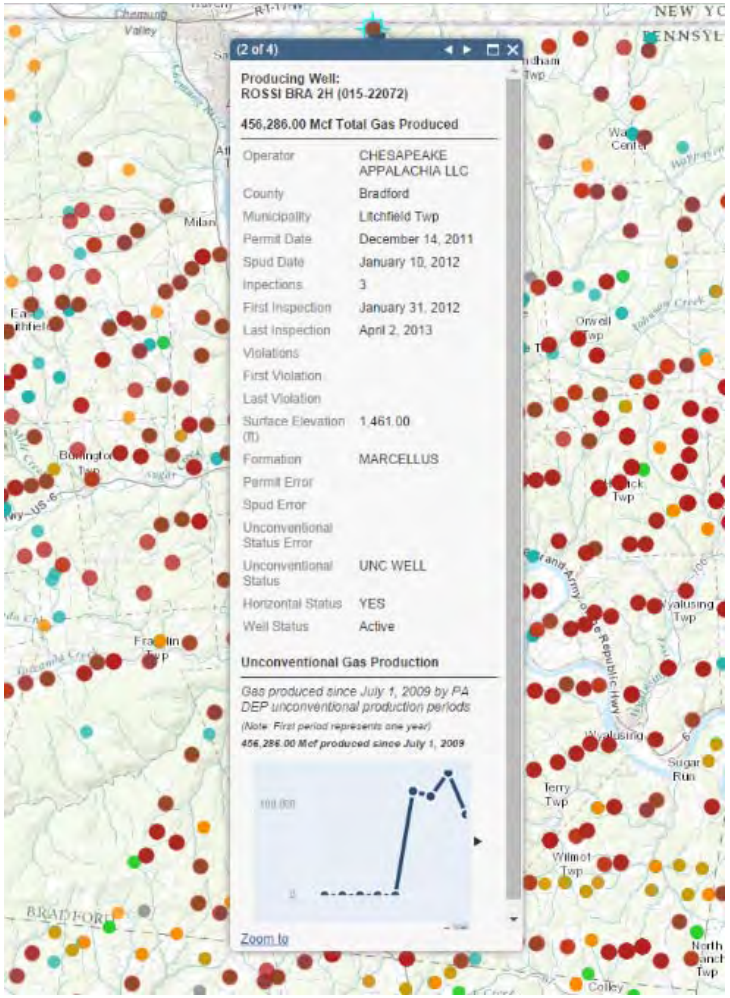
Features

- **Where something is…**
- **A representation of a real-world object on a map translated by a coordinate system**
- **Four main components**
  - Shape or geometry
    - Points → cities
    - Lines → rivers
    - Polygons (areas) → countries
  - Location: geographic coordinates
  - Symbol: shape, color, pattern, outline
  - Attributes: describes the feature



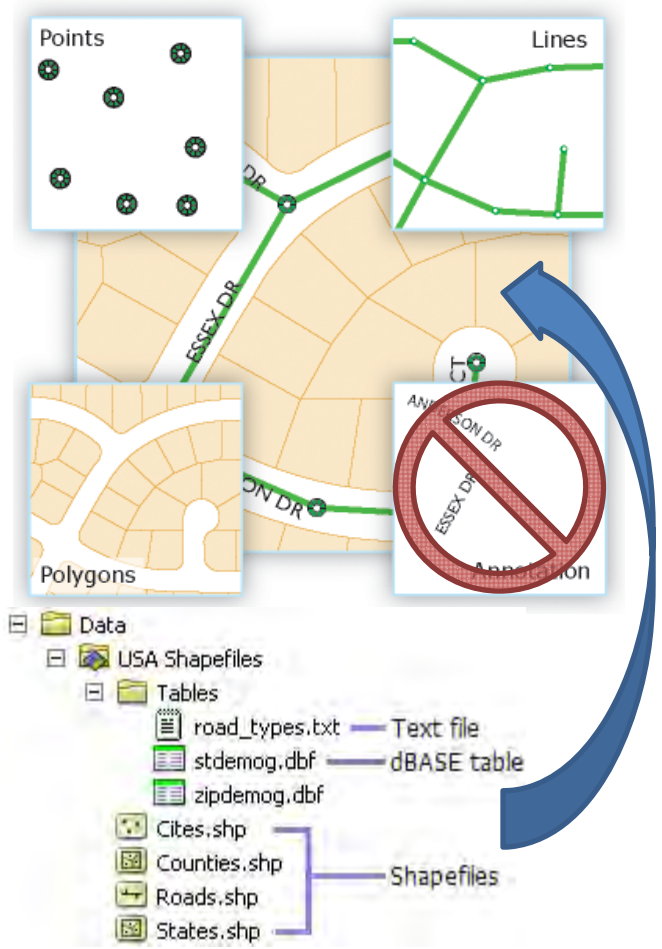
Attribute Information

- What something is…
- Describes features
- Stored as a data table connected to the features
- Examples include city names, stream length, or country population



Shapefile Feature Classes

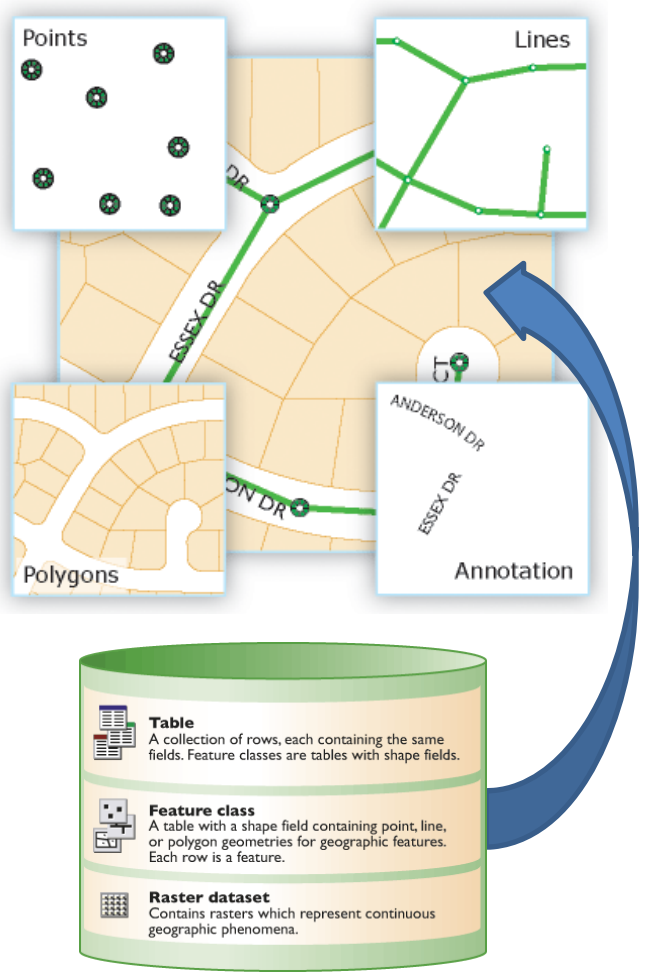
- **Simple vector format with features connected to dBASE format table**
- **Stores location, shape, and attributes of point, line, or polygon geographic features**
- **Requires at least three and up to 16 separate files stored in same workspace** (i.e. folder)



Sources: Esri. 2015. "What is a Shapefile". Accessed June 19. http://desktop.arcgis.com/en/desktop/latest/manage-data/shapefiles/what-is-a-shapefile.htm.
Wikipedia. 2015. "Shapefile" Accesed June 19. https://en.wikipedia.org/wiki/Shapefile.

Geodatabase Feature Class

- **Similar to a Shapefile, but with more functionality**
- **Four common types: points, lines, polygons, and annotations**
- **Optimized for analysis with better storage efficiency and capacity**
- **Stored in a Geodatabase**

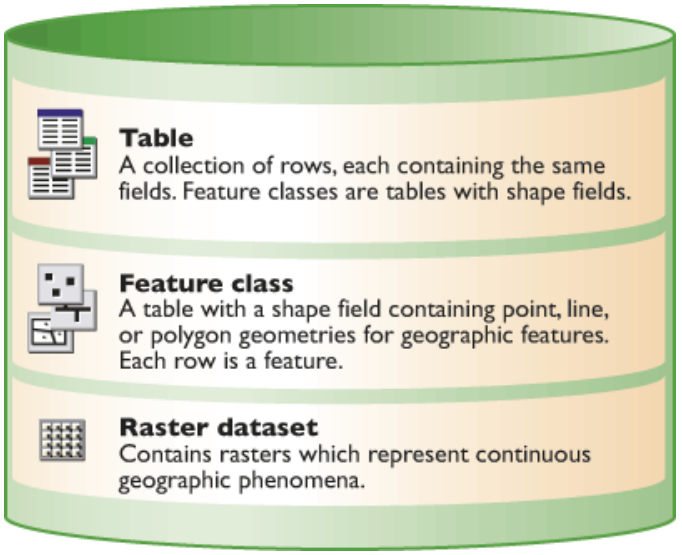


Geodatabases

- **Stores feature classes and various other GIS and non-GIS data types, including standalone tables, raster datasets, and many others**

- **Intended to replace Shapefiles as the primary native format for ArcGIS**

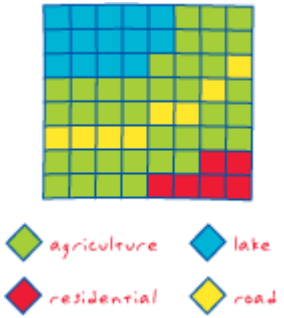
- **Three formats/types in ArcGIS**
  - **File Geodatabase** – stored in a files system folder
  - Personal Geodatabase – stored as Microsoft Access data files
  - Enterprise Geodatabase – stored in relational DBMS such as Microsoft SQL Server, Oracle, or PostgreSQL



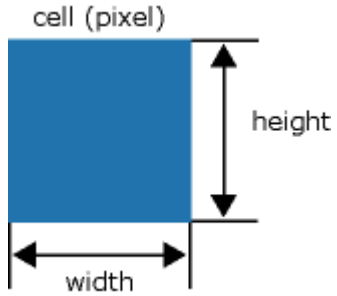
- **Generally readable in other GIS software and other formats/types exist in open-source sphere**

Raster Data

- A spatial data model that defines space as an array of equally sized cells arranged in rows and columns
- Can be composed of single or multiple bands
- Each cell contains an attribute value and location coordinates

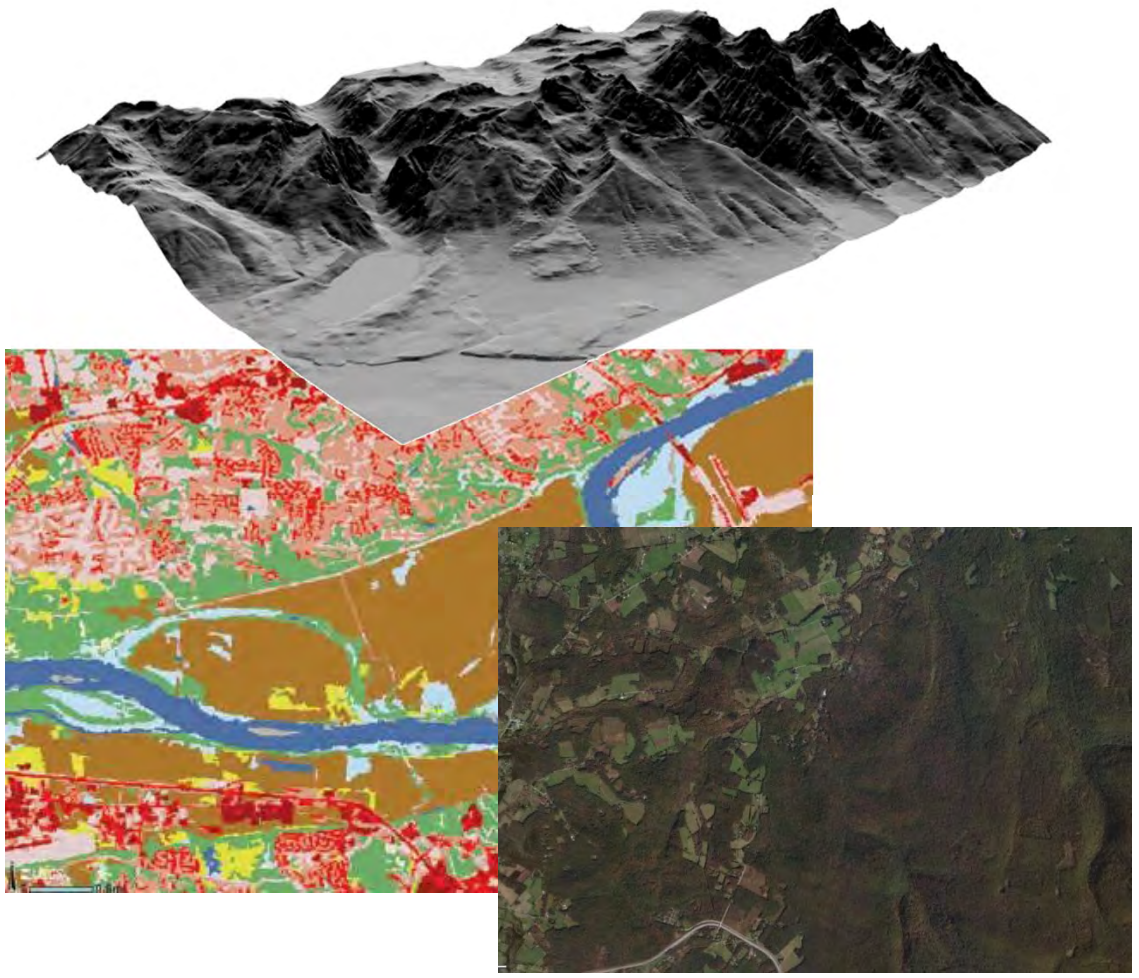


80	74	62	45	45	34	39	56
80	74	74	62	45	34	39	56
74	74	62	62	45	34	39	39
62	62	45	45	34	34	34	39
45	45	45	34	34	30	34	39



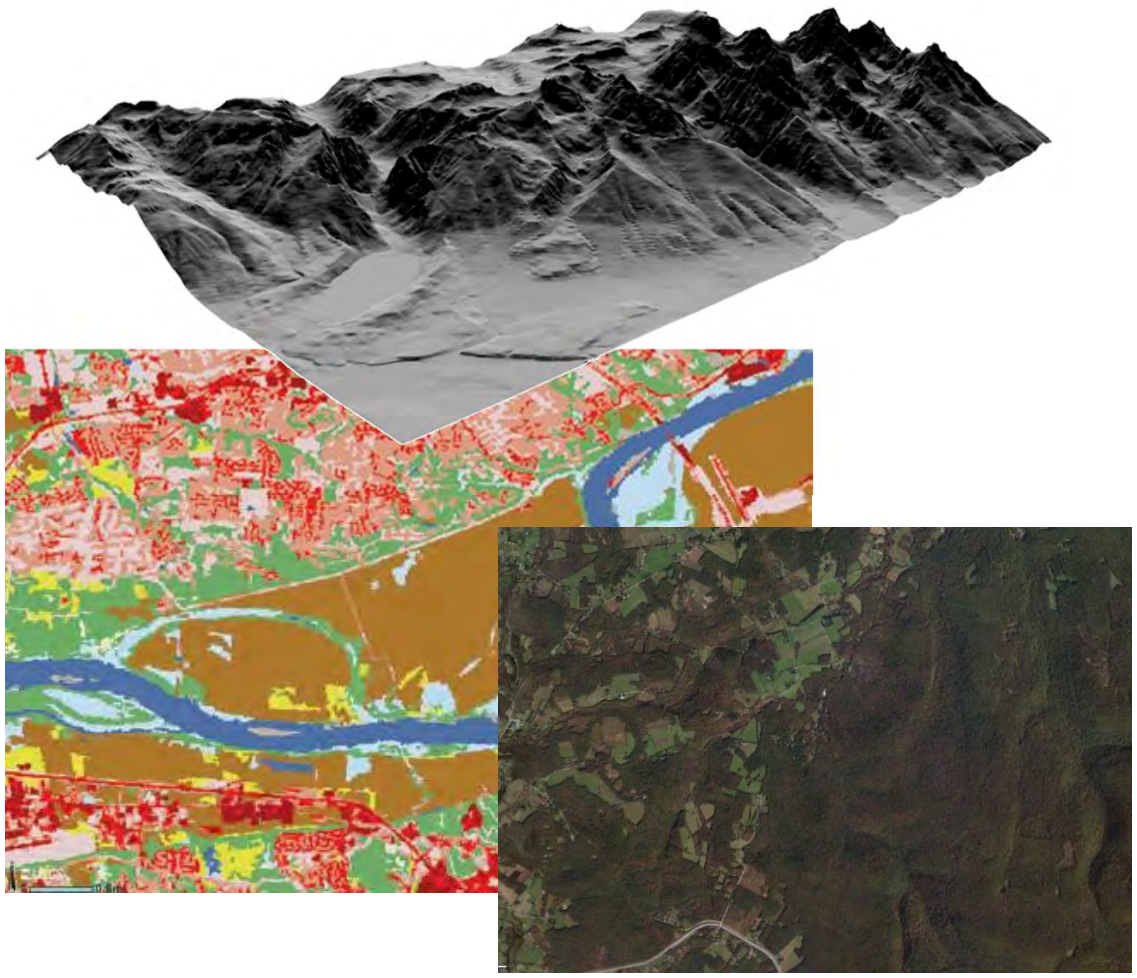
Raster Data Examples

- **Digital Elevation Models**
- **Land Cover**
- **Aerial Imagery**
- **Scanned Maps**



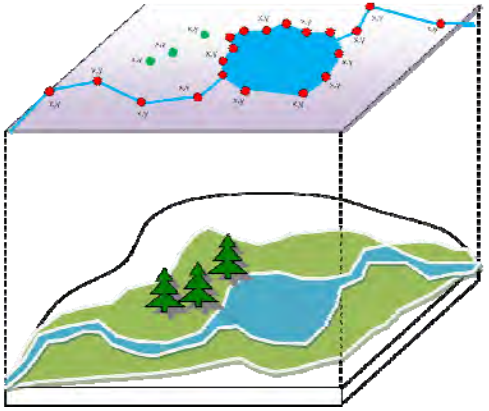
Raster Data Formats

- TIFF
- JPEG, JPEG2000
- MrSID
- ArcGIS GRID
- Geodatabase Raster
- Many others!



Should I Use Vector or Raster Data?

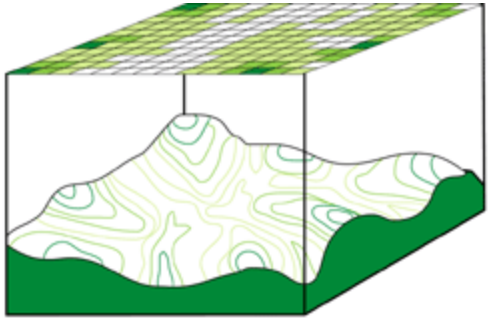
Is your data Discrete or Continuous?



- **Discrete**
  - Individually distinguishable
  - Phenomenon does not exist between observations

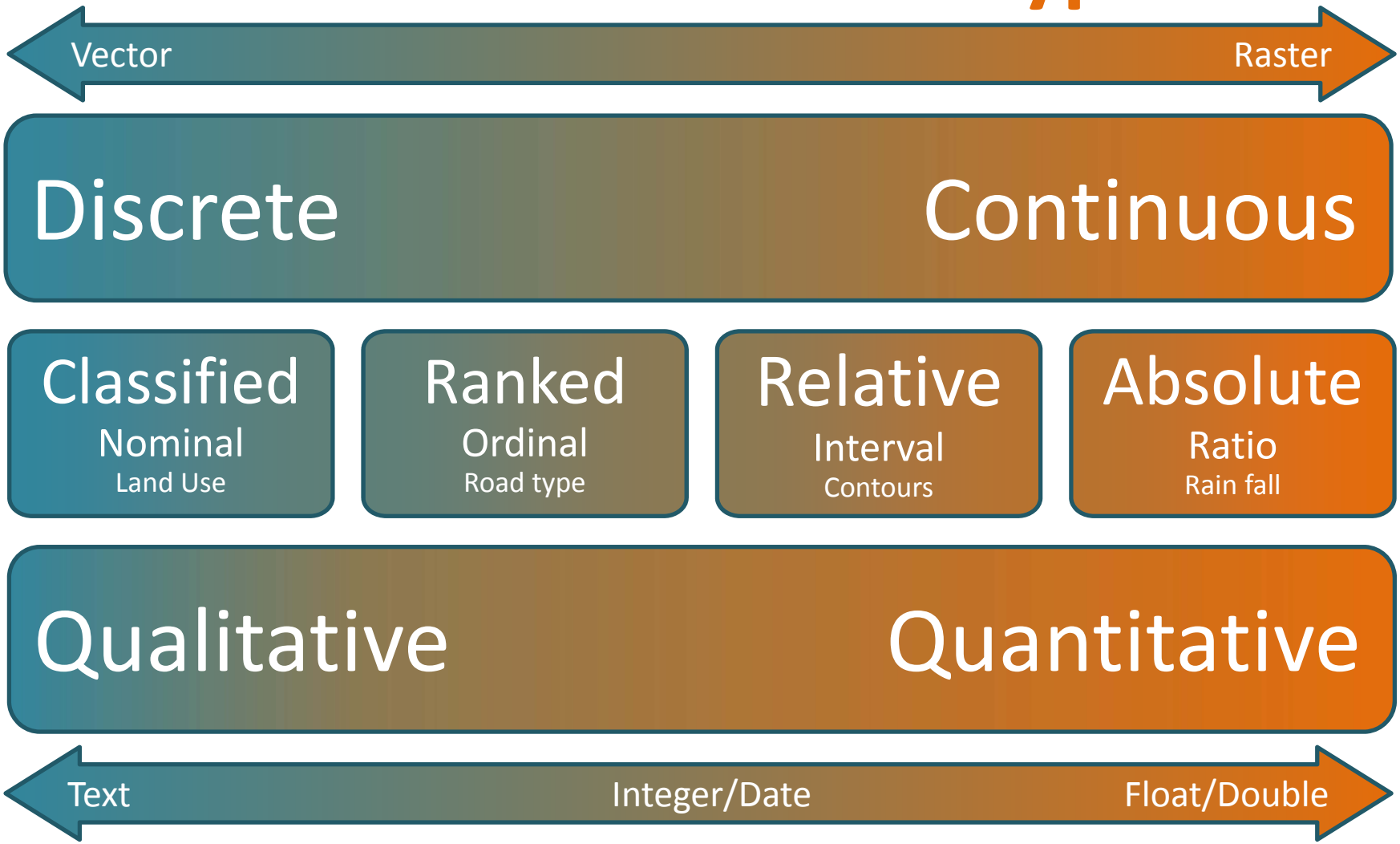
    ex. lakes and roads
- **Continuous**
  - Gradual variation across a range of values
  - Values exists between observations, but maybe not always measurable

    ex. temperature and elevation



- **Both Vector and Raster data can model discrete and continuous data, but…**
  - Vector data → better for discrete data
  - Raster data → better for continuous data
- **Decision also depends on the scale or resolution of data, analysis workflow, and tools available**

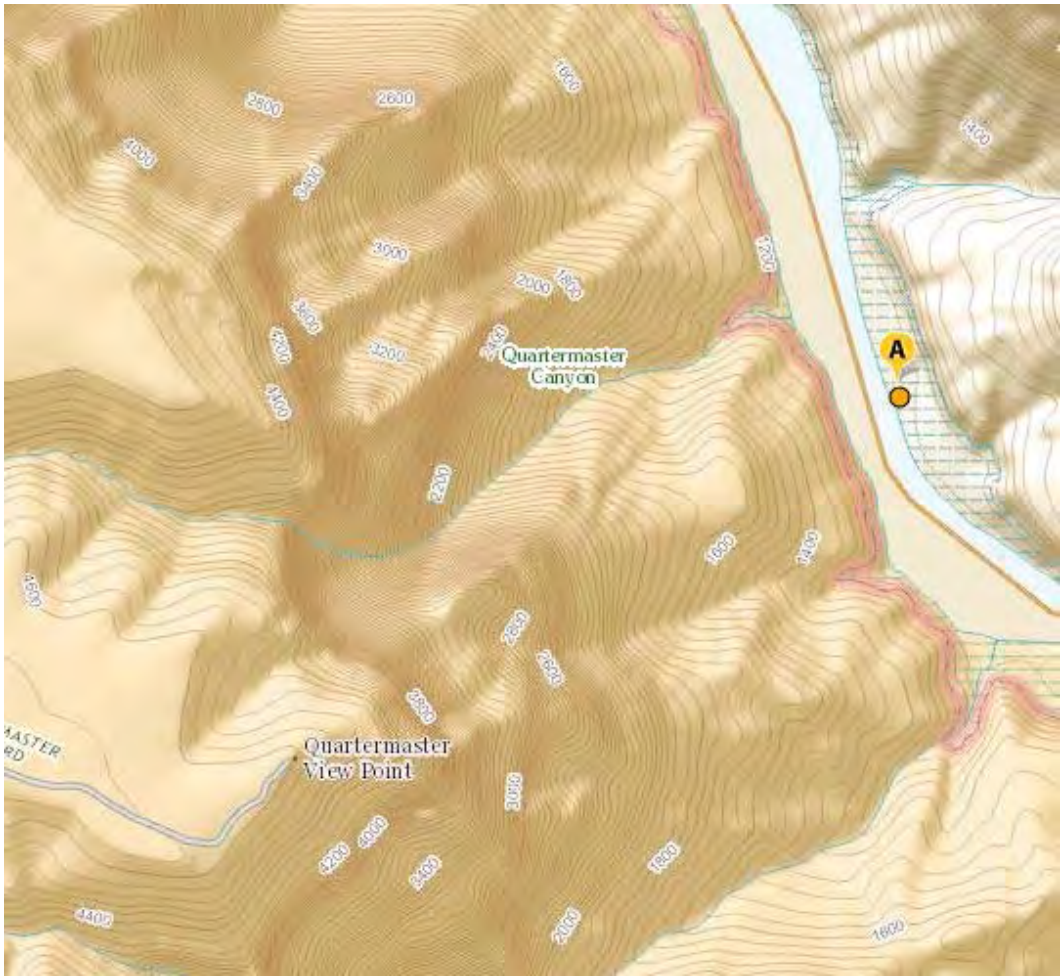
Data Measurement Types



Helpful resources: http://www.socialresearchmethods.net/kb/measlevl.php and https://en.wikipedia.org/wiki/Level_of_measurement

Adapted from: Zeiler, M. and J. Murphy. 2010. *Modeling Our World: The Esri Guide to Geodatabase Concepts*. Redlands, CA: ESRI Press.

Is Contour Data Discrete or Continuous?



Elevation Contours

- **What is being visualized?**
- **Are Contours vector or raster data?**

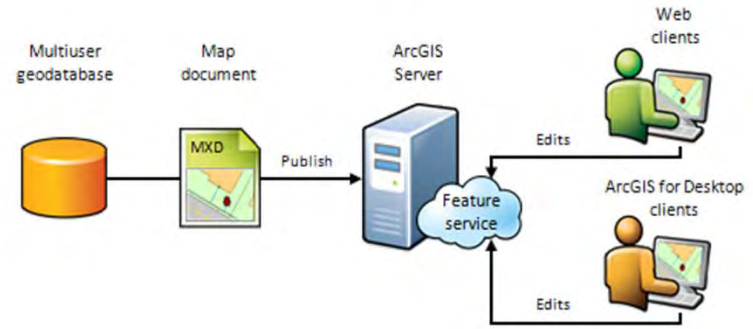
Web Map/Layer Services

Two basic types of web map services

- Allows GIS data to be served to the internet and viewed in a web browser
- Typically published from traditional GIS formats to the web

Feature Layers → Vector

- Published from vector datasets
- Individual feature attribute information is always accessible
- Can be used for GIS analysis on the web

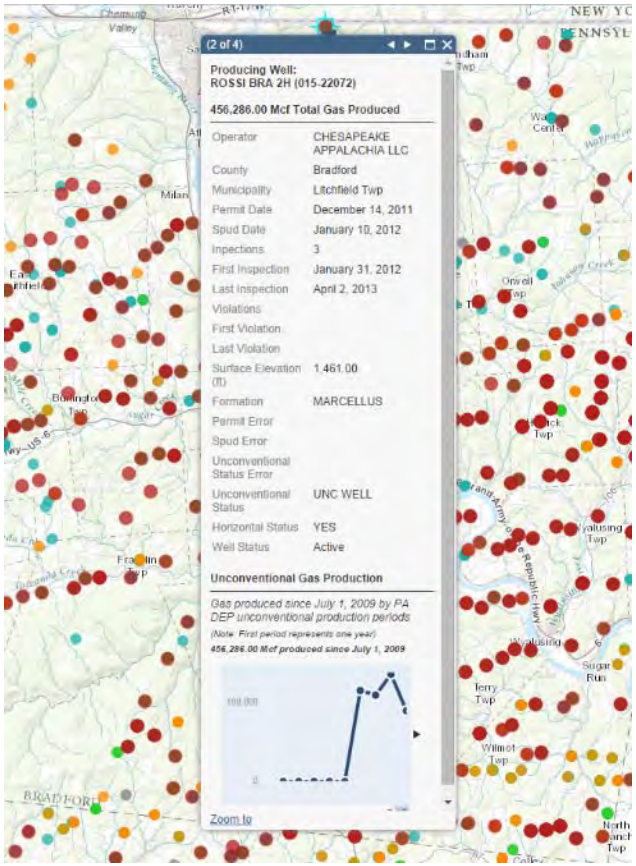


Tile Layers → Raster (or Raster-like)

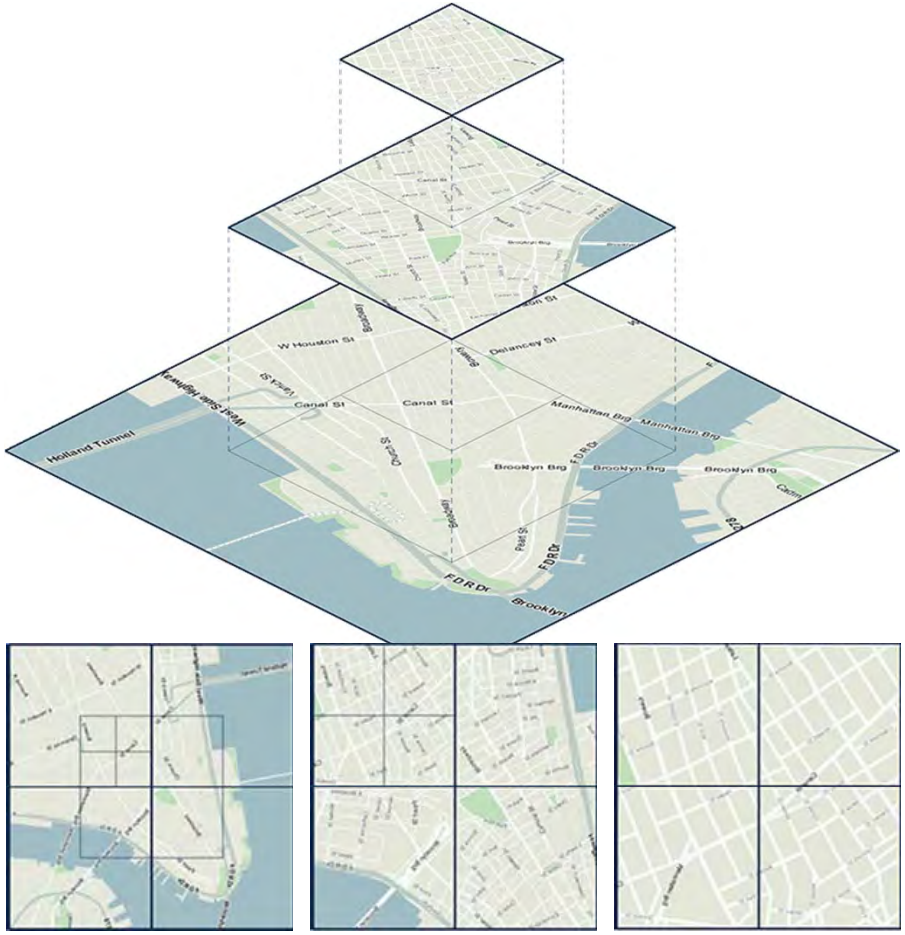
- Pre-drawn map images tiled to appear seamless
- Good for fast map visualization over the web
- Good as basemaps to give geographic context
- Individual feature attribute information NOT ALWAYS accessible

Web Map/Layer Services

Feature Service

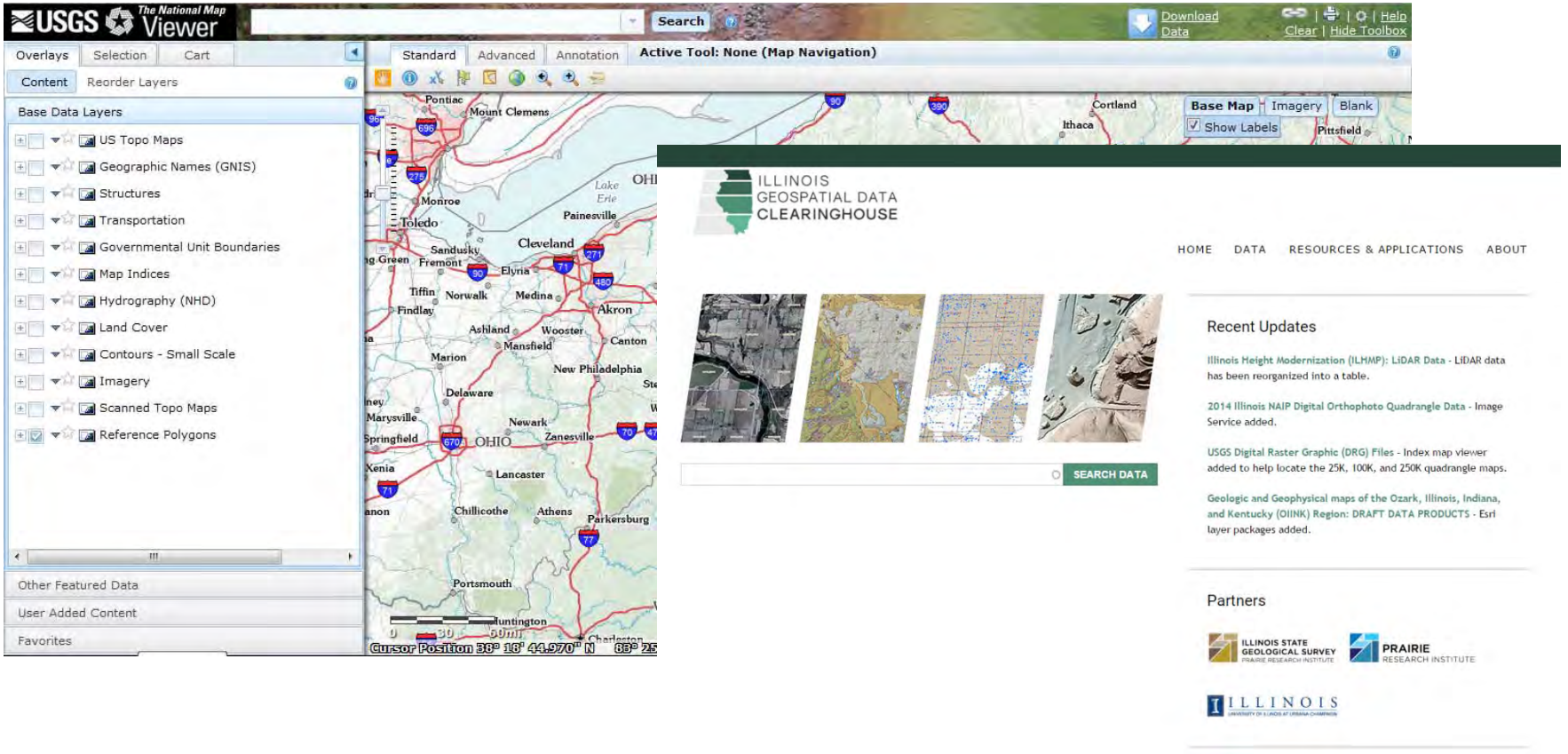


Tile Service



Acquiring Spatial Data

Download or access data from the internet



Acquiring Spatial Data

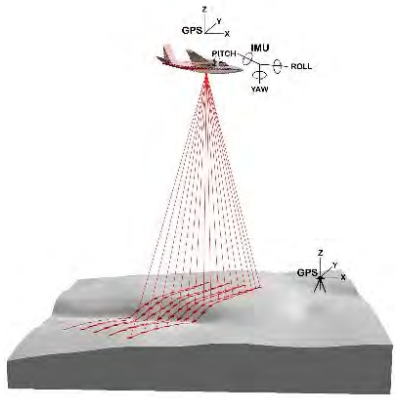
Geocoding

Process of transforming a description of a location—such as a pair of coordinates, an address, or a name of a place—to a location on the earth's surface

Acquiring Spatial Data

Data Collection

GPS or surveying techniques

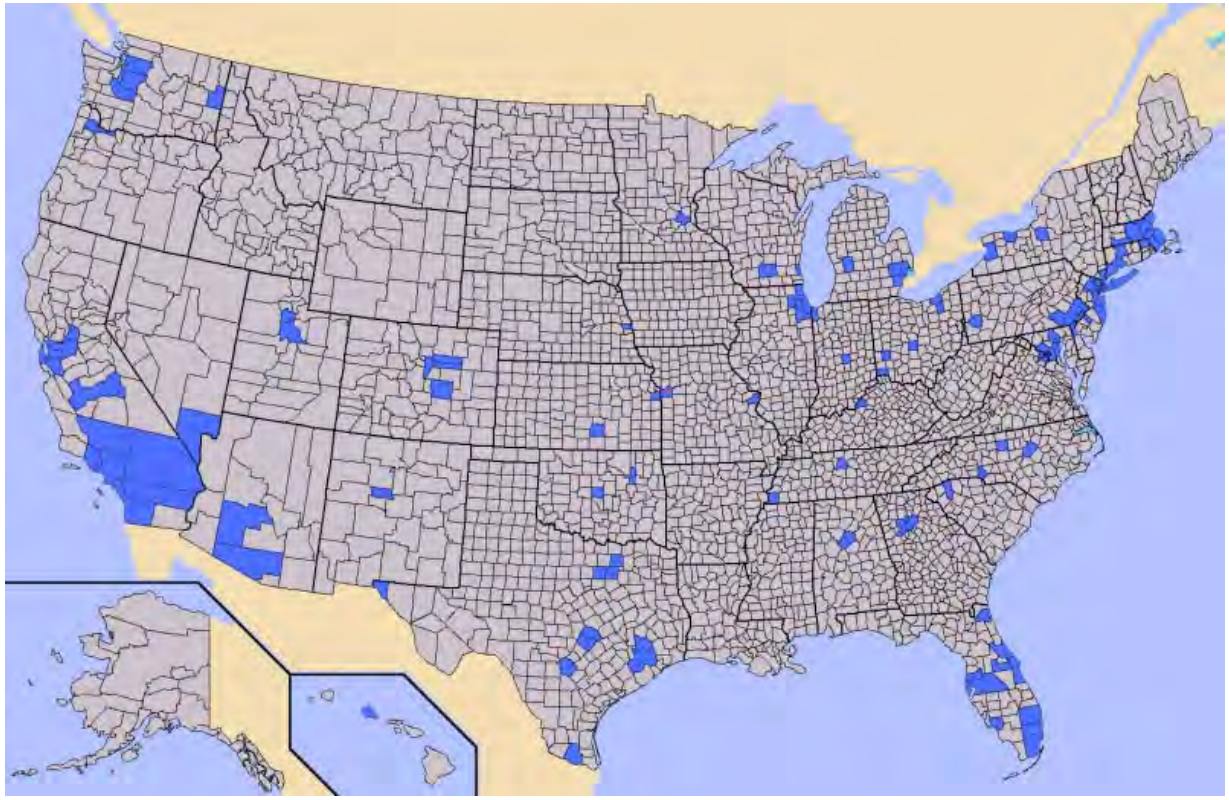


Acquiring Spatial Data

Digitizing

- Using GIS software to create vector data
- Trace features from aerial images and scanned based maps that have been georeferenced

Geography and Cartography Concepts



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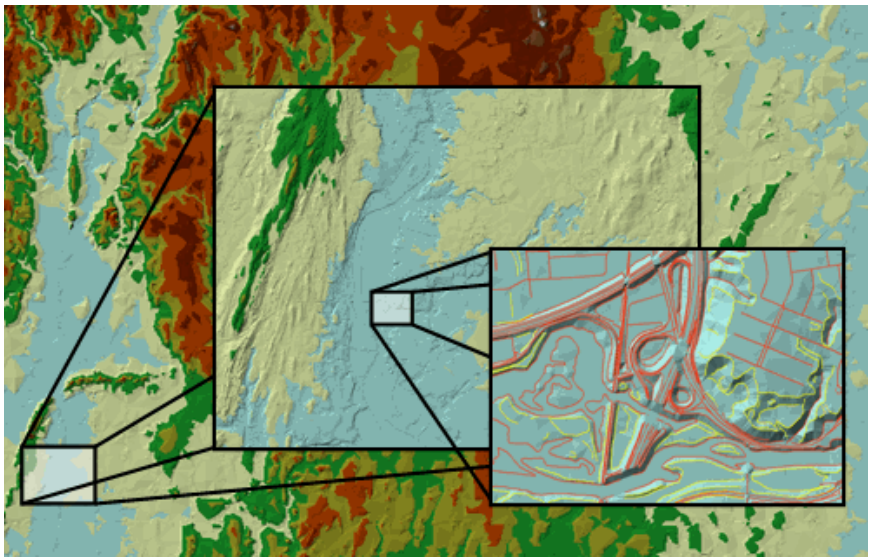
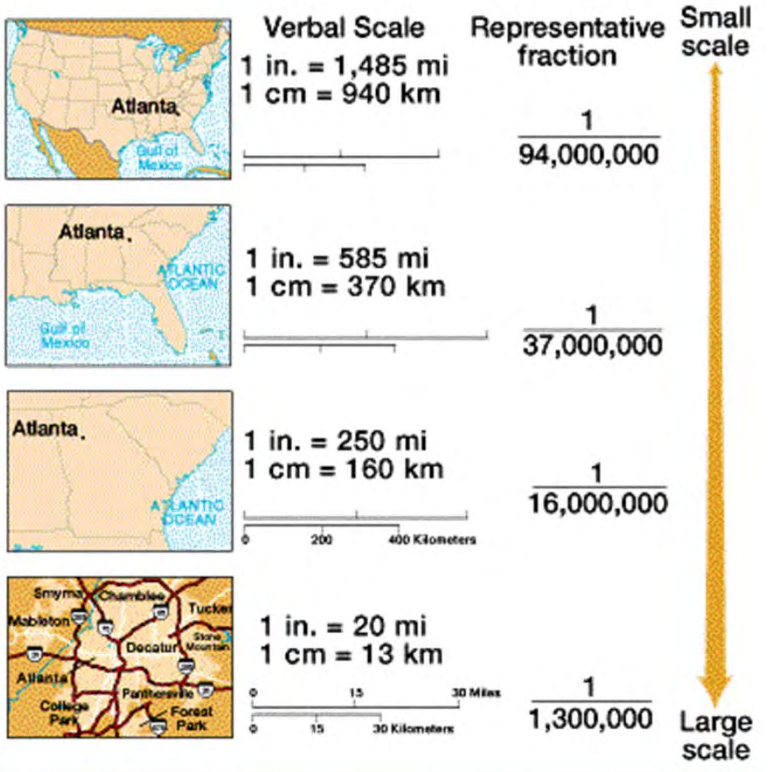
Space vs. Place

- **Place** – meaningful or important location; can be conceptual or real
- **Space** – distance between places
- **Spatial** – Related to or existing within space
- **Geographic** – Of or relating to earth space
- **Geospatial** – Catch all term that refers to everything above; usually used in the context of analysis or technology

Scale

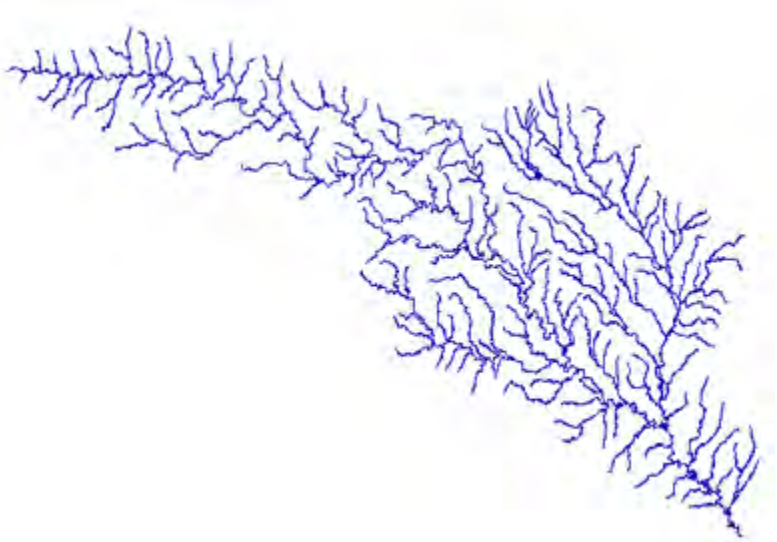
- **Maps cannot show features at their actual size**
- **Scale represents the reduction between the map and the real world**



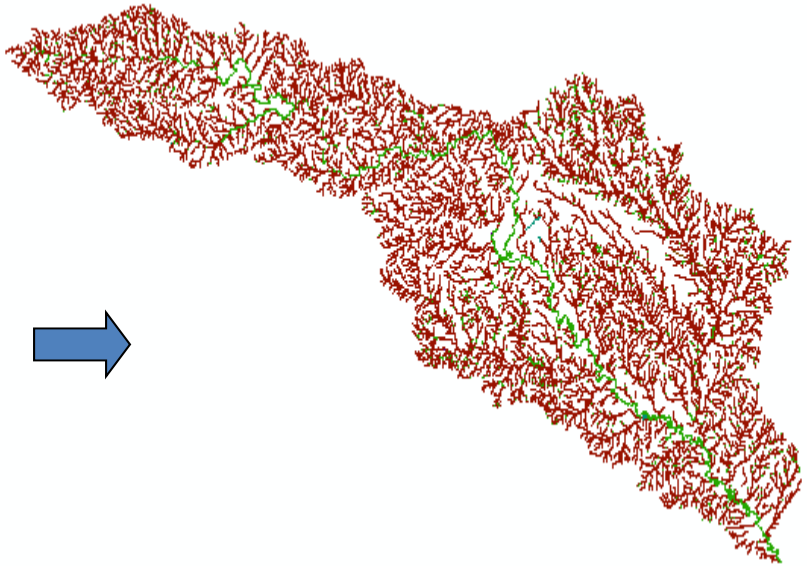


Small vs. Large Scale

1:100,000 scale (small scale)



1:24,000 scale (large scale)



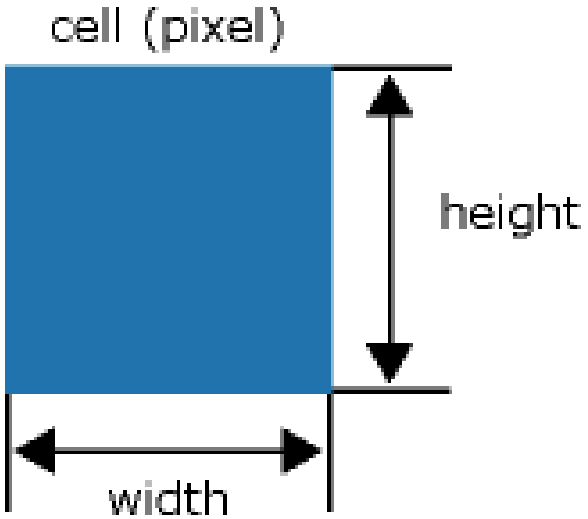
20 times no. of lines
3 times total length of lines

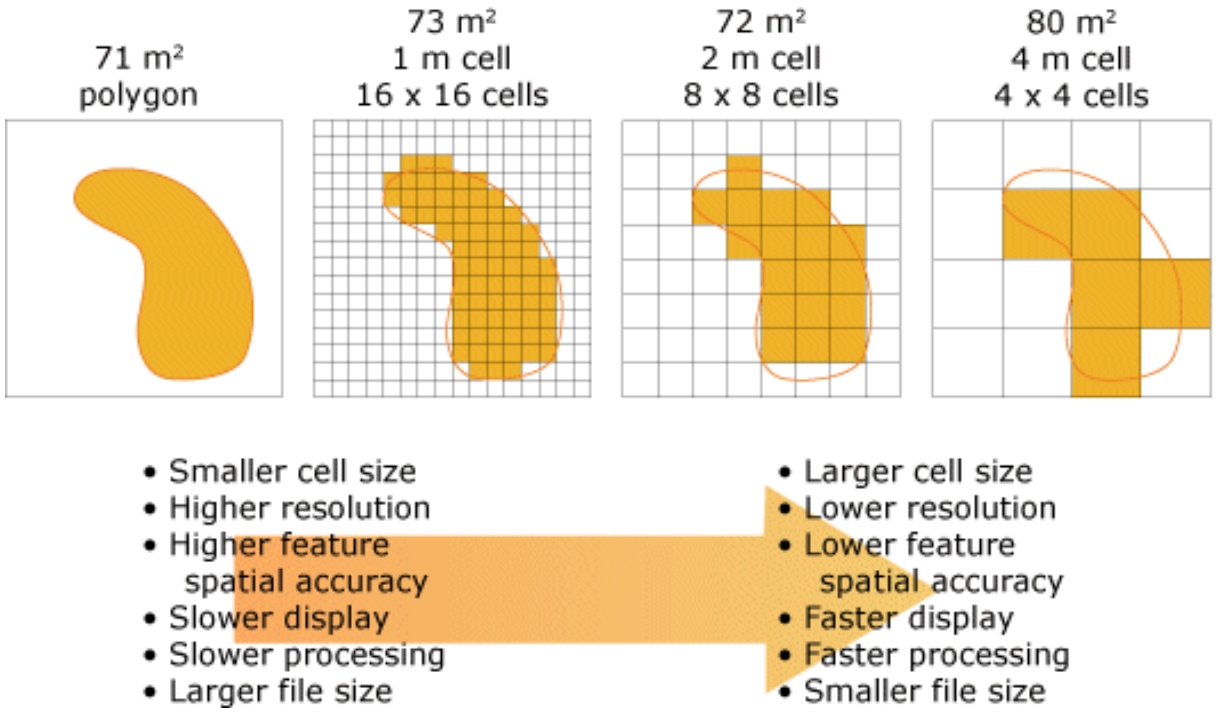
1:100,000 scale – 557 lines,
Total length 1890 km

1:24,000 scale – 11,338 lines,
Total length 5559 km

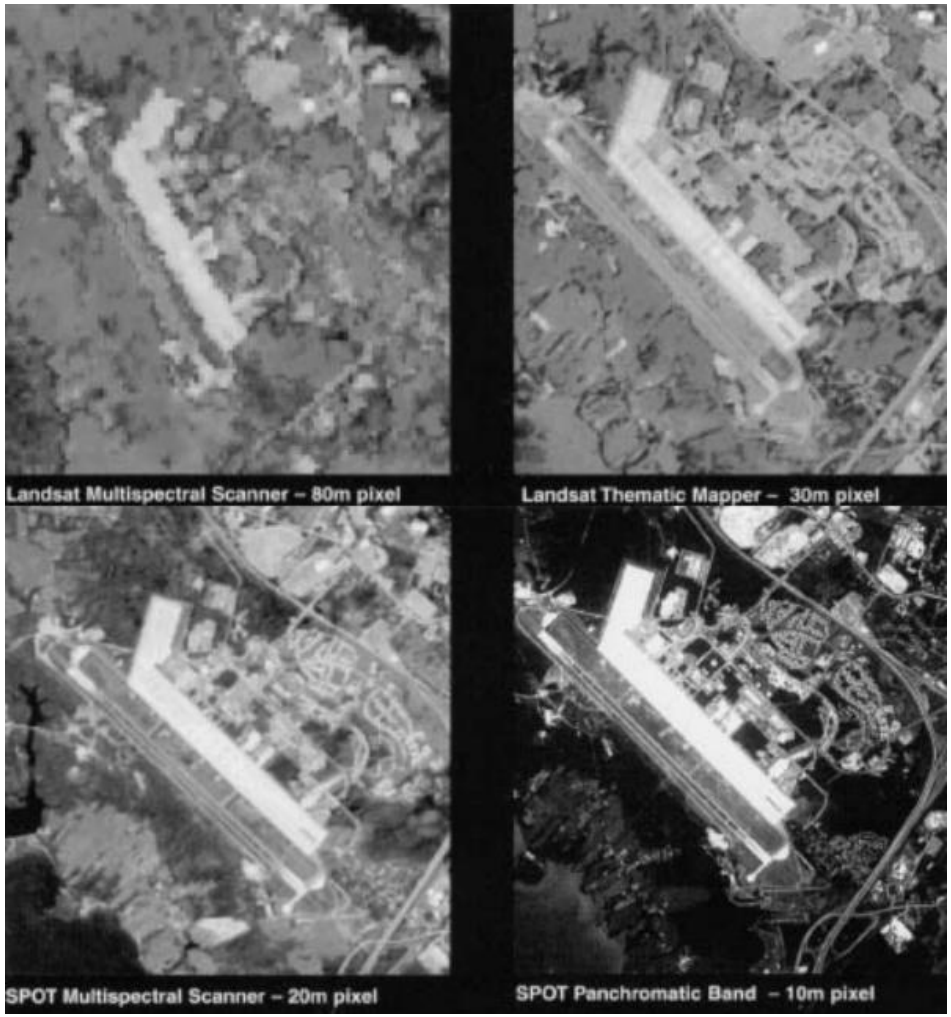
Resolution

- **In GIS and Remote Sensing: The real-world dimensions represented by each cell or pixel in a raster**
- **Example: 10 meters, 30 meters, 90 meters, etc.**





Resolution



Source: http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/scaleandresolution.html

Scale vs. Resolution

Scale → Vector

Resolution → Raster

- **In general:**

Map Scale Denominator =
Raster resolution (in meters) * 2 * 1000

Map scale	Detectable size (in meters)	Raster resolution (in meters)
1:1,000	1	0.5
1:5,000	5	2.5
1:10,000	10	5
1:50,000	50	25
1:100,000	100	50
1:250,000	250	125
1:500,000	500	250
1:1,000,000	1,000	500

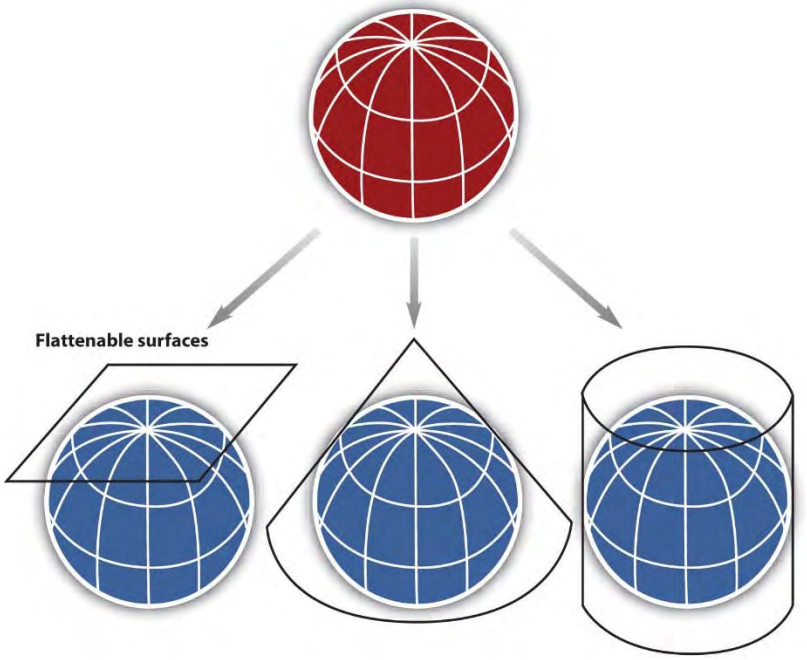
- **It is not good practice to perform analyses on data intended for different scales/resolution**

Source: Nagi, R. 2010. "On map scale and raster resolution". Accessed September 25, 2015. http://blogs.esri.com/esri/arcgis/2010/12/12/on-map-scale-and-raster-resolution/.

Coordinate Systems in GIS

Two types in GIS:

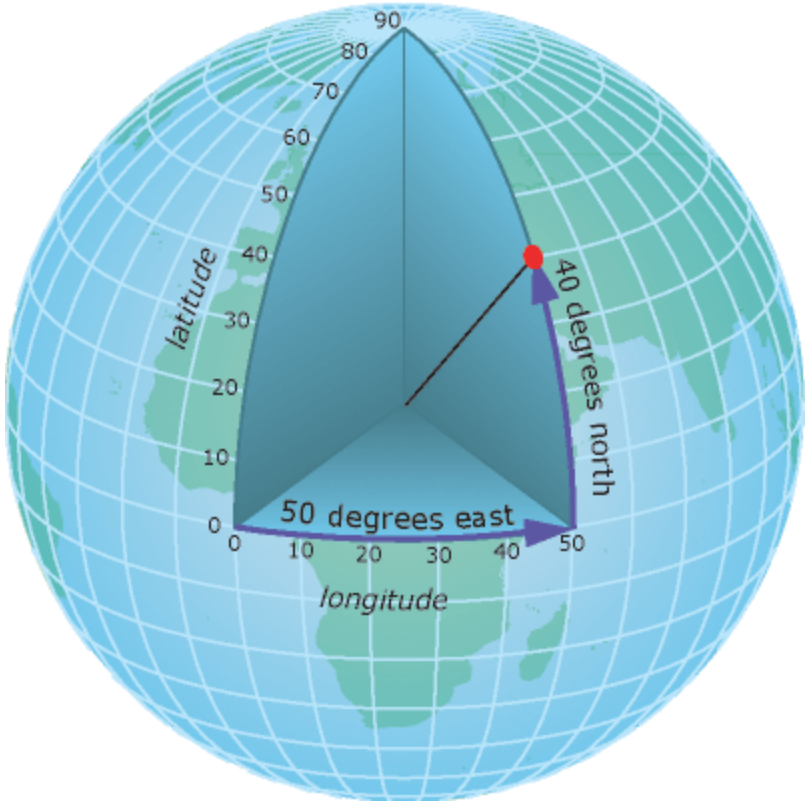
- **Geographic Coordinate Systems (GCS)**



- **Projected Coordinate Systems (PCS)**

Geographic Coordinate Systems

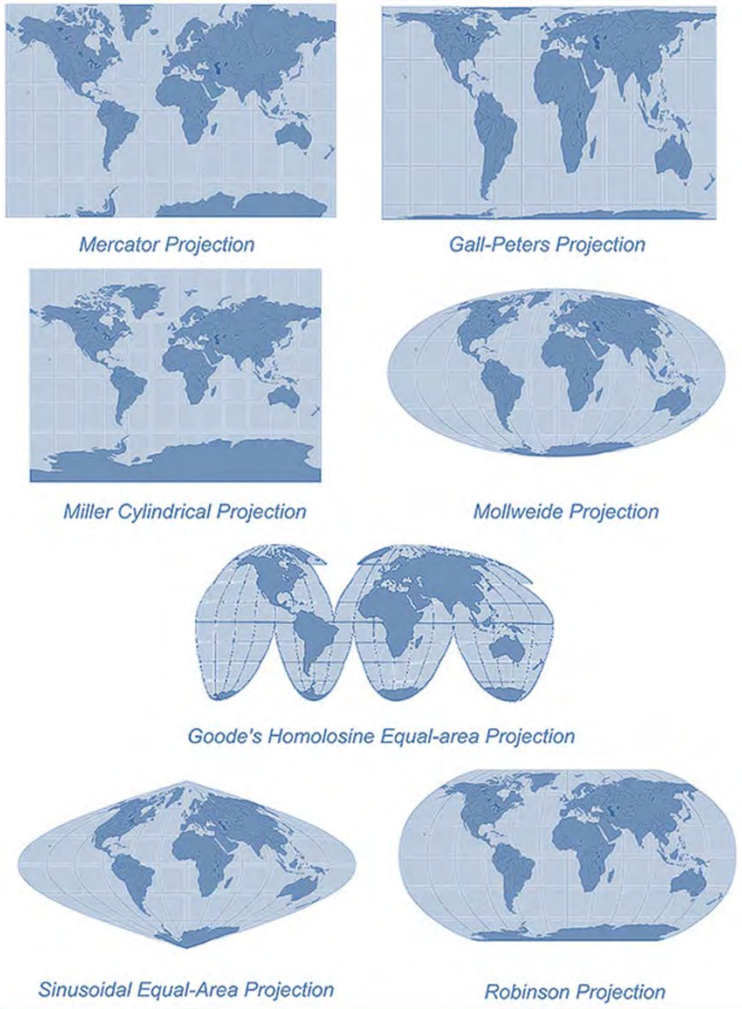
- Based on a ***spheroidal*** model of the earth
- Reference lines are parallels (latitude) and meridians (longitude)
- Uses geographic coordinates and angular measurements (x,y – where x is lon., y is lat) to define unique positions on the earth
- Defined primarily by a geographic datum



Projected Coordinate Systems

- **Portrays curved/spherical surface of the earth to planar or flat surface**
  - Systematic mathematical transformation of the earth's lines of longitude and latitude onto a plane
  - Uses length-based units (m and ft)

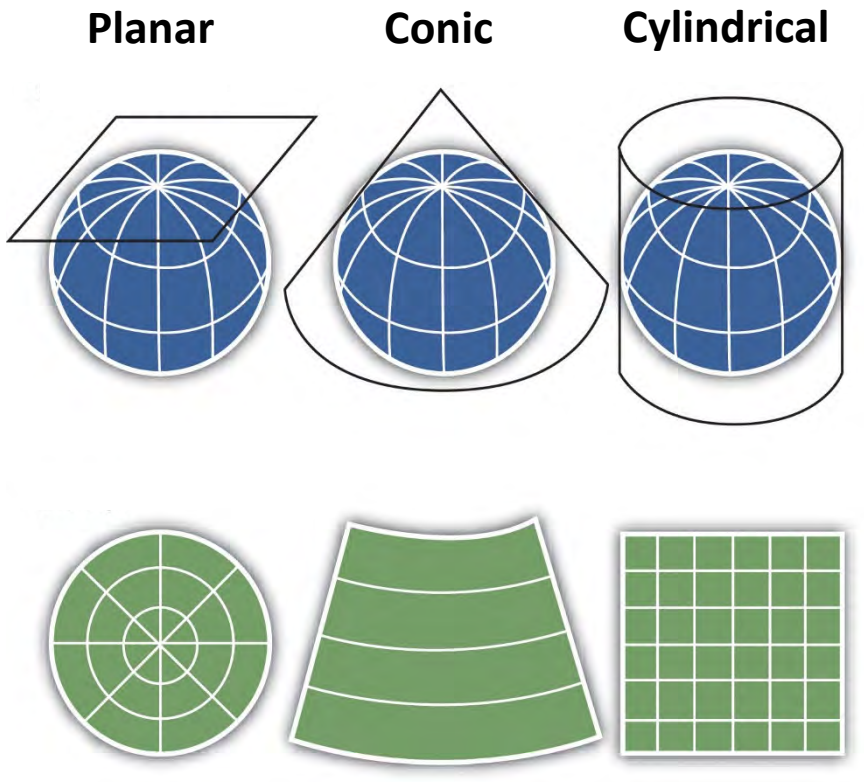
- **Introduces distortion of the map data, but designed to minimize:**
  - Distance → Equidistant
  - Area → Equal area
  - Shape → Conformal
  - Direction → Azimuthal



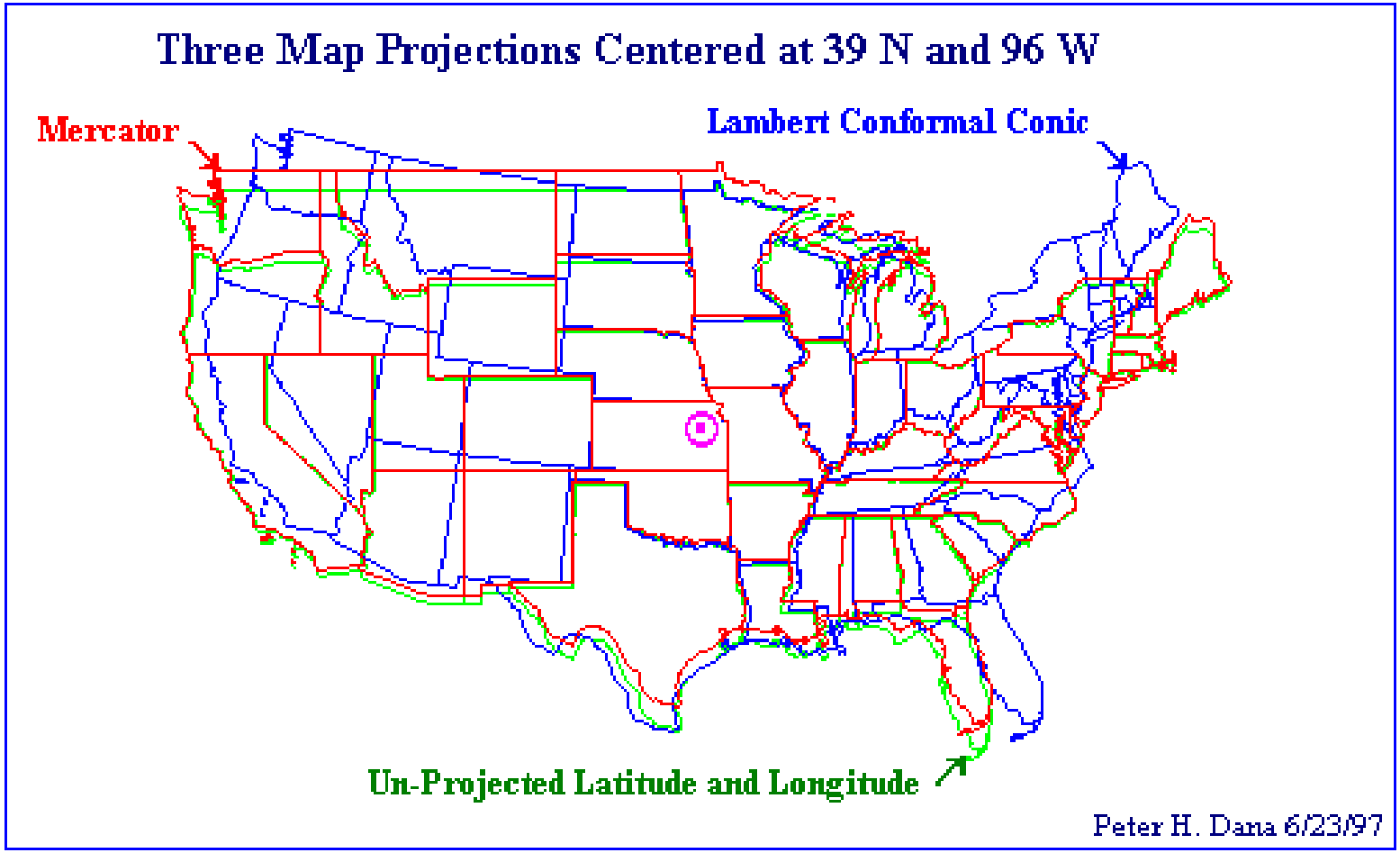
Projected Coordinate Systems

Three primary types:

- **Planar – surface is tangent to the globe**
- **Conical – surface formed into a cone**
- **Cylindrical – surface is formed into a cylinder**



Why Coordinate Systems are Important

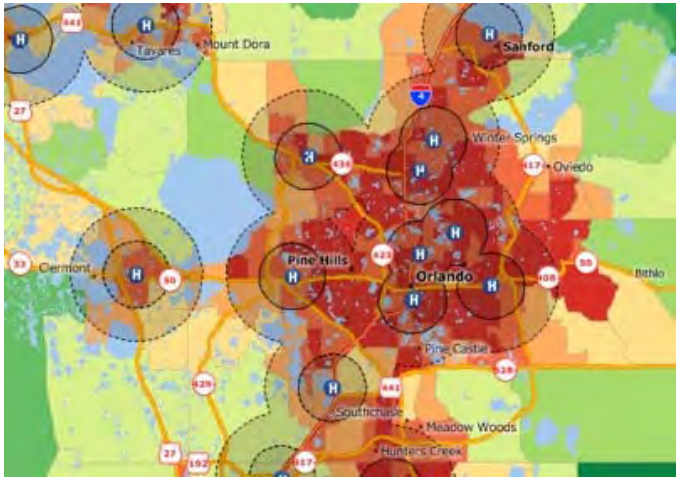


Spatial Analysis and Geoprocessing

Spatial Analysis

- Process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques

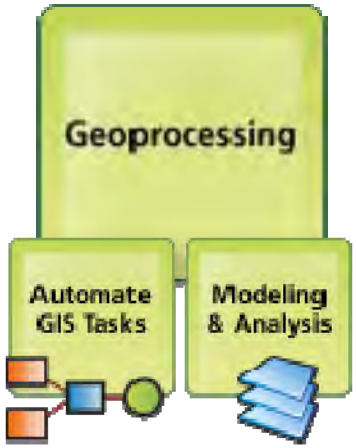
- Addresses questions to gain useful knowledge by extracting or creating new information from spatial data



Geoprocessing

- Provide tools and framework for performing spatial analysis and managing geospatial data

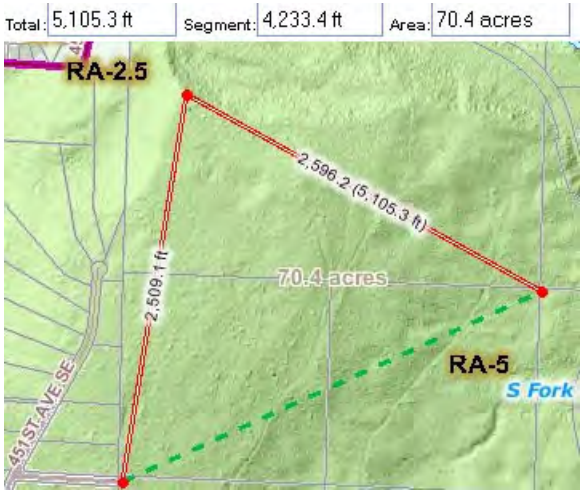
- Allows for analysis workflows to be automated

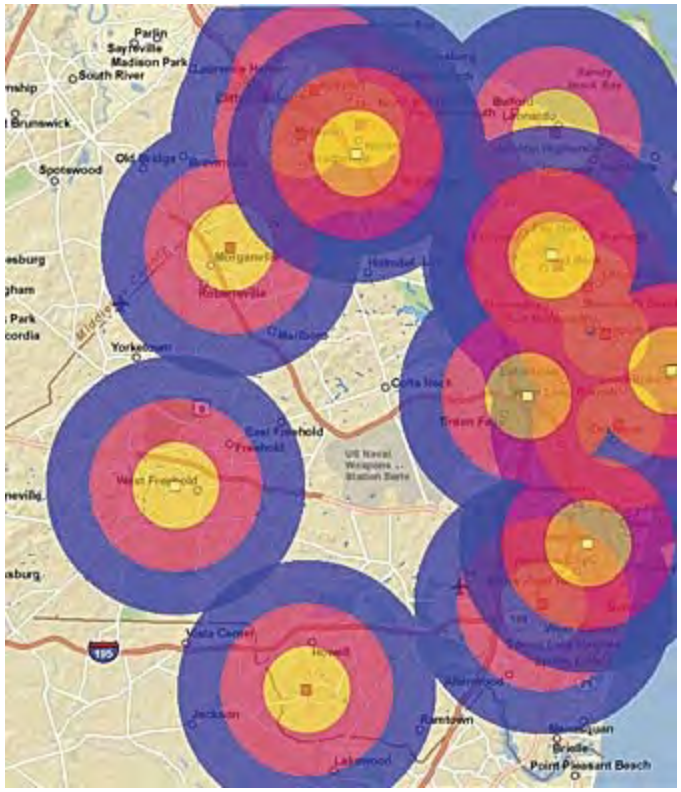


Spatial Analysis and Geoprocessing

Spatial Measurements

- Coordinates
- Distance and Buffers
- Area

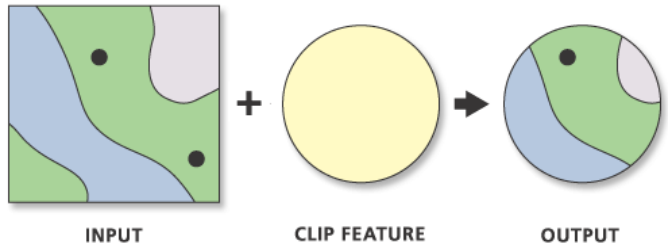


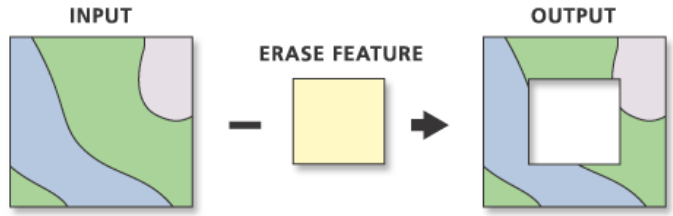


Spatial Analysis and Geoprocessing

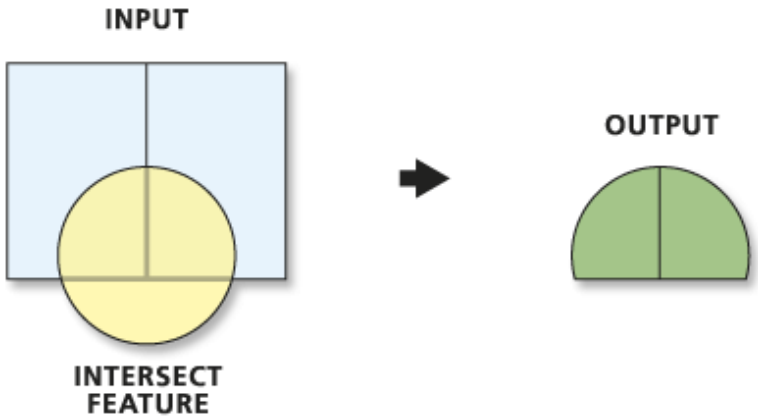
Overlays

- Intersect, Union, and Spatial Joins
- Clipping and Erasing

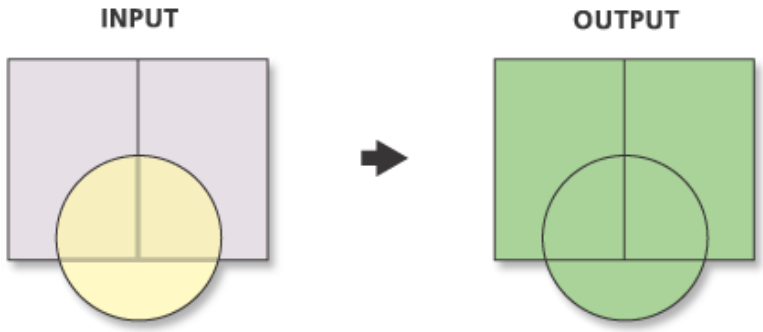




Intersect



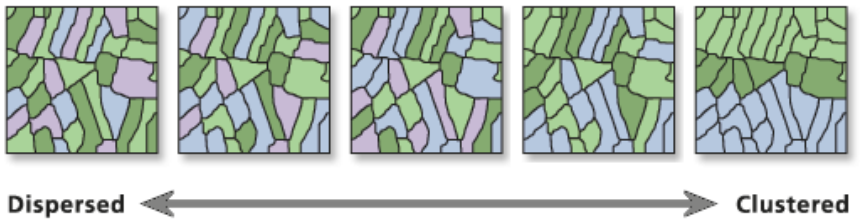
Union



Spatial Analysis and Geoprocessing

Spatial Patterns

- Geographic Distribution
- Density and Cluster Analysis
- Nearest Neighbor Analysis



Library GIS Workshops

Core GIS Workshops

- **Geographic Information Systems 101: Understanding GIS**
  - Thurs. Feb. 4 and Fri. April 1, 2 – 3 pm, room 314
- **GIS for Research I: Tools, Concepts, and Geodata Management**
  - Thurs. Feb. 11 and Fri. April 8, 2 – 4 pm, room 314
- **Discovering GIS Data**
  - Thurs. Feb. 18 and Fri. April 15, 2 – 3 pm, room 314
- **GIS for Research II: Geoprocessing, Analysis, and Visualization**
  - Thurs. Feb. 25 and Fri. April 22, 2 – 4 pm, room 314

Special Topic GIS Workshops

- **Forthcoming…**

Introductory Classes

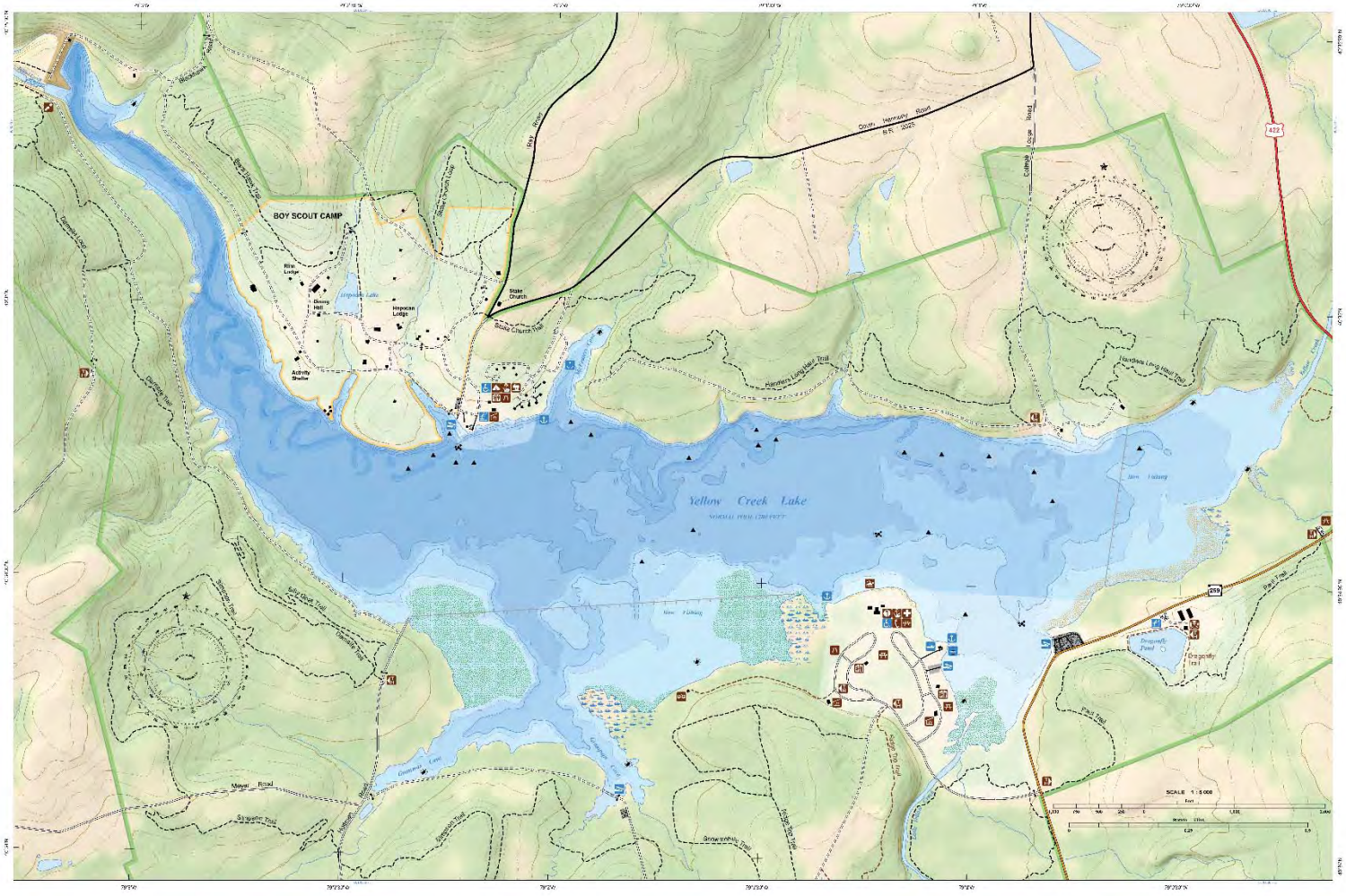
- **Geography and GIS Department**
  - GEOG 371: Spatial Analysis
  - GEOG 379: Introduction to GIS
  - GEOG 380: GIS II: Spatial Problem Solving
  - Many more…
- **Urban Planning**
  - UP 418: GIS for Planners
  - UP 519: Advanced Applications of GIS
- **Natural Resources and Environmental Sciences**
  - NRES 454: GIS in Natural Resource Management
  - NRES 455: Advanced GIS for Natural Resource Planning

Library Resources

- **Scholarly Commons Data Services:**
  - GIS data discovery and research services
  - GIS consultations by appointment
  - http://www.library.illinois.edu/sc/datagis

- **Map Library:**
  - Geospatial datasets, GIS reference books and journals, aerial photos, paper maps, etc.
  - www.library.illinois.edu/max

Questions?



Thank You!