Basic GIS Concepts and Processes

Mentoring Mondays
8 Jun 2026
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I. GIS Basics

A. What is GIS
B. Fundamental Elements
C. Data Management
D. Spatial Reference
E. Project Flow

A. What is GIS?

1. Definition

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.

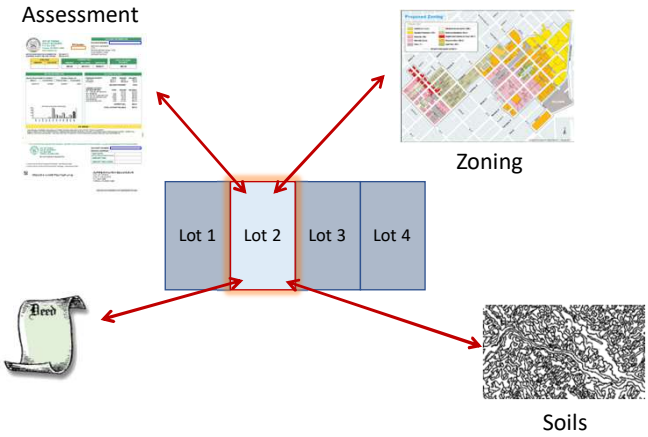
It's a technology and a process (or concept).

GIS technology allows us to more efficiently perform GIS processes.

A. What is GIS?

2. Process

Collecting and collating data about a specific location.

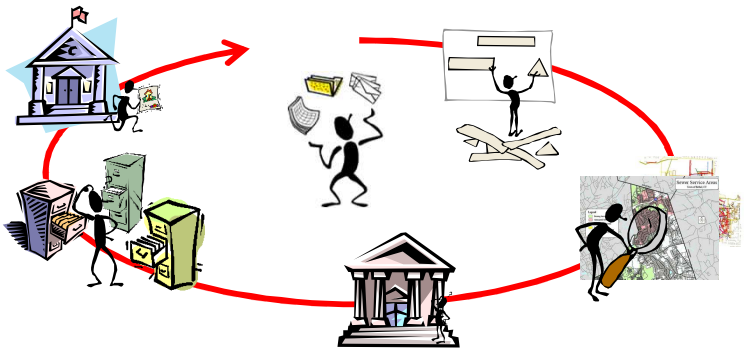


A. What is GIS?

3. Technology

Pre-computer integration.

Data collection, integration, and analysis performed by user. Slow, error-prone.

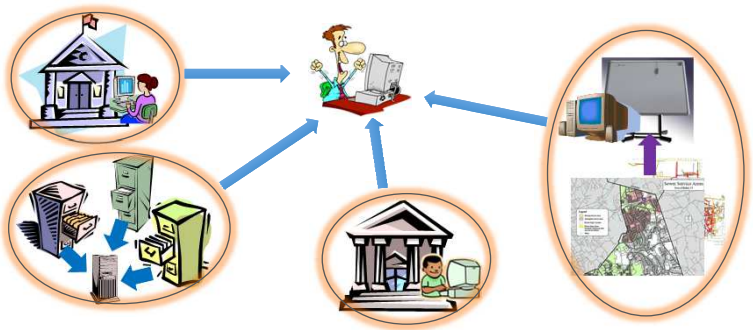


A. What is GIS?

3. Technology

Computer integration.

Digital data remotely accessible to users. Data collection, integration, and analysis is done with software, often in real time.

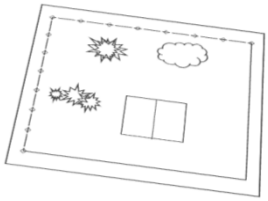


B. Fundamental Elements

1. Feature

An object that has a spatial location
Can be graphically depicted, mapped.

Graphic type
- Vector
  - Point (node)
  - Line (arc)
  - Polygon
- Raster
  - Image



B. Fundamental Elements

2. Attribute

Information about a feature.
May or may not be spatial

Examples
- Feature: Lot 8 of SweetWater Subdivision
- Attributes:
  - Parcel owner, Zoning district, Soil types, Assessment

- Feature: Street
- Attributes: Type, Pavement, Width

B. Fundamental Elements

3. Theme

A collection of like features

Theme examples

- Parcels
- Buildings
- Streets
- Curb lines
- Sidewalks
- Street lights
- Trees
- Access points

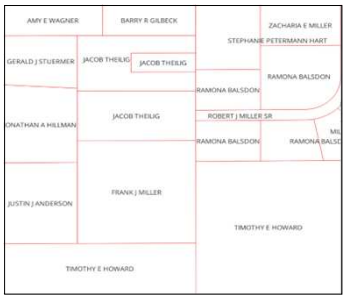
B. Fundamental Elements

4. Layer

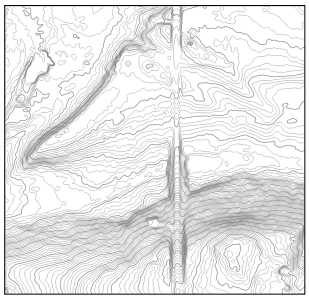
A set of features grouped by a theme.

Uniform feature type & graphic & attributes

Feature: Parcels
Graphic: polygons



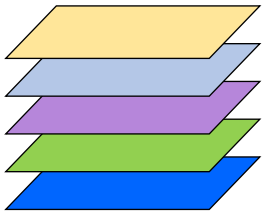
Feature: Contours
Graphic: lines



B. Fundamental Elements

4. Layer

A GIS layer is similar to a CAD layer except:



	CAD	GIS
Content	Can be a mixture of features	Only one type of feature
Graphic representation	Can be a mixture of graphic types	Single type of graphic
Attribute information	Not linked (generally)	Linked
Occurrence	Can generally only appear once*	Can appear multiple times

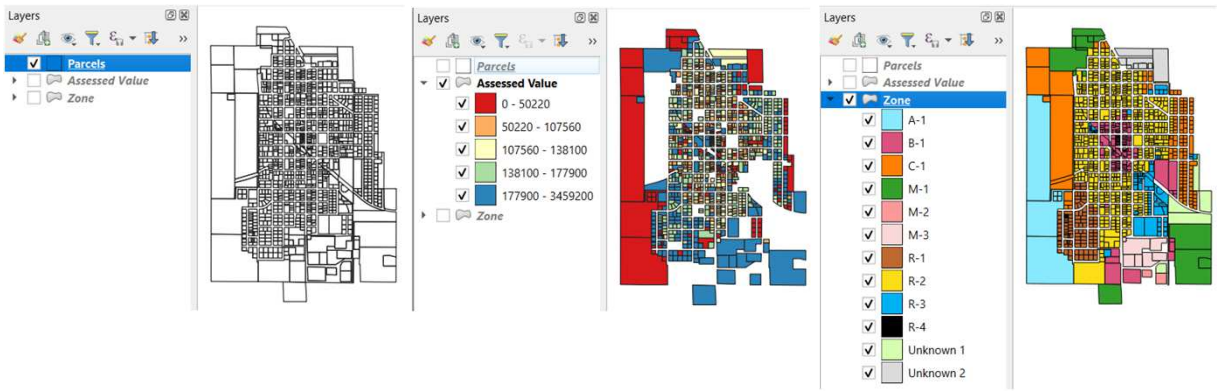
*Without self-referencing the drawing within itself

B. Fundamental Elements

4. Layer

Unlike CAD, a particular GIS layer can be used in a project more than once.

View data from different perspectives or different combos with other layers.



B. Fundamental Elements

5. Attribute Table

Attributes of layer's features organized into a table

Each table row is a *record*.

A record has one or more *fields*

Each field is an attribute

Field formats can be:

- Numeric
- Text
- Links
- Images

Field/Attribute

Record

OBJECTID	PARCELID	OWNERNME1	PSTLADRESS
36410	211-00089-0...	J & M BUILDINGS LLC	11114 MINE RD CUBA CITY WI 53807
36411	211-00091-0...	QYBCYB LLC	105 1/2 S MAIN ST CUBA CITY WI 53807
36412	211-00093-0...	THEODORE J & AMY E SAMPSON	502 COUNTY ROAD H CUBA CITY WI 53807
36413	211-00095-0...	KAJEN MAIN ST PROPERTIES LLC	113 S MAIN ST CUBA CITY WI 53807
36414	211-00096-0...	JUNQUE STOPS HERE, LLC	117 S MAIN ST CUBA CITY WI 53807
36415	211-00098-0...	SHABANI LLC	119 S MAIN ST CUBA CITY WI 53807
36416	211-00100-0...	EASTLICK PROPERTIES LLC	107 W WEBSTER ST CUBA CITY WI 53807

B. Fundamental Elements

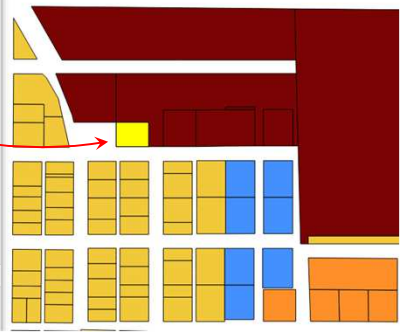
5. Attribute Table

Each record is linked to a specific feature.

Picking a record selects the feature.

Picking a feature selects its record

	PARCELID	OWNERNME1	PSTLADRESS	SITEADRESS	ADDNUMPREFIX	ADDNUM
843	211-00742-0000	MELVIN J DONAR	415 E ROOSEVELT ST CUBA CITY...	415 ROOSEVEL...	NULL	415
844	211-00743-0000	NORTHVIEW TERRACE APARTMENTS LLC	405 SUNSET DR CUBA CITY WI 5...	409 E ROOSEVE...	NULL	409
845	211-00746-0000	JEROME & KIMBERLY ADAMS	26021 DEER RIDGE TRL WATERF...	714 MAIN ST	NULL	714
846	211-00746-0010	PATRICK J ADAMS	205 E BRYAN ST CUBA CITY WI 5...	205 BRYAN ST	NULL	205
847	211-00746-0020	GERALD W. & RACHEL J. MAHUN	115 E BRYAN ST CUBA CITY WI 5...	115 BRYAN ST	NULL	115
848	211-00746-0050	LEONARD L & JANET C HAMILTON	213 E ROOSEVELT ST CUBA CITY...	NULL	NULL	NULL
849	211-00746-0060	ROGER A & DEBRA A HOPPENJAN	214 E PALMER ST CUBA CITY WI...	NULL	NULL	NULL
850	211-00746-0070	DROESSLER CONSTRUCTION INC	219 E BRYAN ST CUBA CITY WI 5...	NULL	NULL	NULL
851	211-00746-0080	KEVIN R GALLAGHER	313 E PALMER ST CUBA CITY WI...	313 E PALMER ST	NULL	313
852	211-00746-0090	RONALD G & PATRICIA A SCHUELLER	301 E PALMER ST CUBA CITY WI...	301 E PALMER ST	NULL	301
853	211-00746-0100	JOSEPH D & HOLLY J NILES	324 E BRYAN ST CUBA CITY WI 5...	324 E BRYAN ST	NULL	324
854	211-00746-0110	RONALD G & PATRICIA A SCHUELLER	301 E PALMER ST CUBA CITY WI...	NULL	NULL	NULL
855	211-00746-0120	FRANCIS J RAUPP & LORI A DROESSLER-RA...	323 E BRYAN ST CUBA CITY WI 5...	323 E BRYAN ST	NULL	323
856	211-00749-0000	KENNETH E. KREUL	413 S WASHINGTON ST CUBA C...	413 S WASHIN...	NULL	413
857	211-00750-0000	MARK S SMITH	417 S WASHINGTON ST CUBA C...	417 WASHINGT...	NULL	417



B. Fundamental Elements

6. Non-Spatial data

Information not tied to a singular location.

Examples include:

- Zoning districts
- Pipe material
- Soil types
- Pavement age
- Income levels

More than one location can include non-spatial data as an attribute.

Generally organized into tables of records and fields.

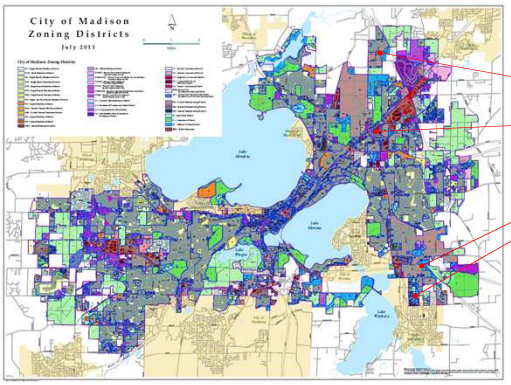
- Those tables must be connected to features

B. Fundamental Elements

6. Non-Spatial data

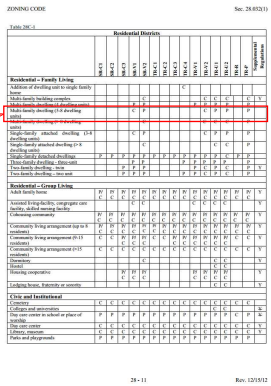
Example

Madison Zoning Map



Connections

Madison Zoning Districts



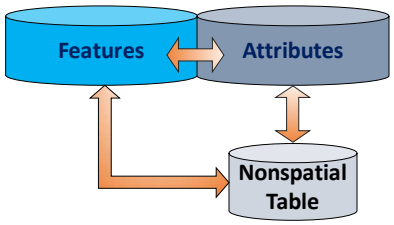
C. Data Management

1. Features and Attributes

In a GIS, each feature has attributes.

The number and content of the attributes depend on the data's purpose.

GIS also allows external tables to be connected to features

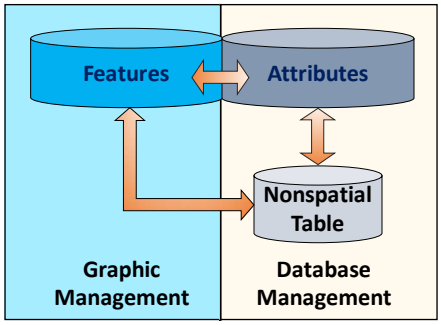


C. Data Management

1. Features and Attributes

This means GIS software has two built in "sides"

- Graphic (feature) manipulation: Layers
- Database (attribute) management: Attribute tables



D. Spatial Reference

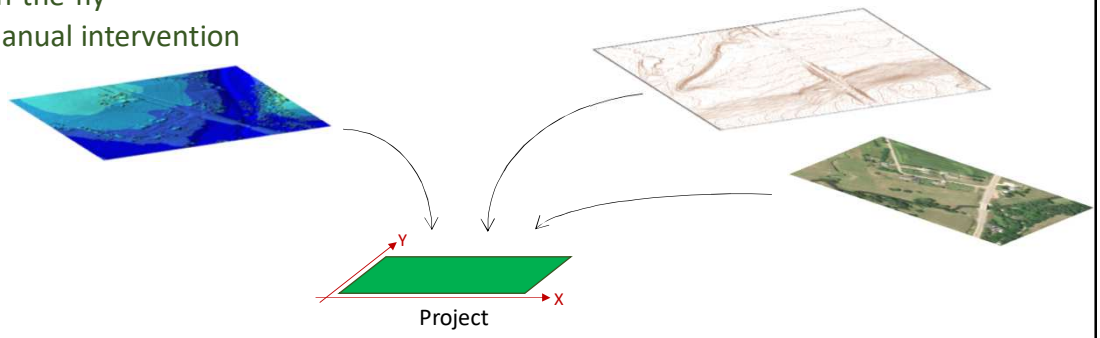
1. Data Integration

GIS allows combining feature data from different sources.

Coordinate system is defined for the project.

Data coordinates must be converted and/or transformed to the project system

- On-the-fly
- Manual intervention



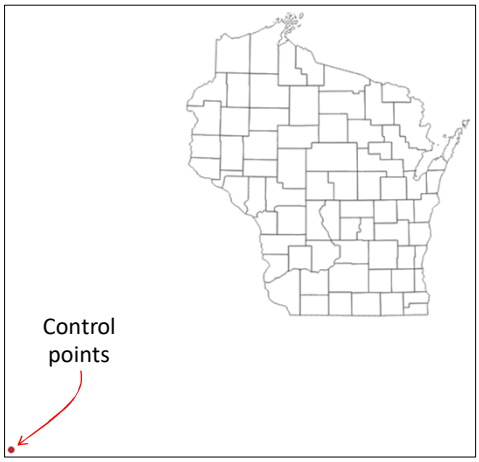
D. Spatial Reference

1. Data Integration

Example of a common problem

- Two data layers
  - County boundaries
  - Control points

When combined, the counties look OK, but the control points appear as a "dot".



D. Spatial Reference

1. Data Integration

Example of a common problem

Both layers were on different coordinate systems.

After Control points layer coordinate system was converted to Counties layer system, everything registered correctly.

Must know:

a. data coordinate systems

b. relationship between them

E. Project Flow

1. Identify needs

Design, data, & analysis tools are defined by questions to be answered.

2. Create a project basemap

This defines the spatial reference system and provides a framework to which other data is added.

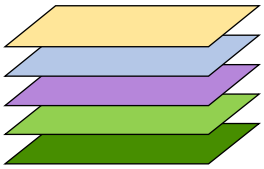
Basemap

E. Project Flow

3. Data collection & integration
   Consider availability, accuracy, acquisition costs, etc.

4. Analysis
   Perform necessary operations & processes to address the questions.

5. Reporting results
   Either in graphic and/or report form.



Basemap

II. GIS Data

A. Data Acquisition
B. Graphic Data Format
C. Accuracy
D. Data Custodian
E. Metadata

A. Data Acquisition

1. Existing

Free or nominal cost

- Federal Agencies
  - Individual agencies
    - GeoPlatform.gov: cross agency data access; other GIS resources
- State Agencies
  - Individual agencies
    - State may or may not have a central data access site
- Local governments

Format
- Digital
- Paper-based

A. Data Acquisition

2. Collect

If required data does not exist or meet project needs, go collect it.

Advantages
- Quality control: accuracy and density
- Capture important attributes
- Collect only what's needed

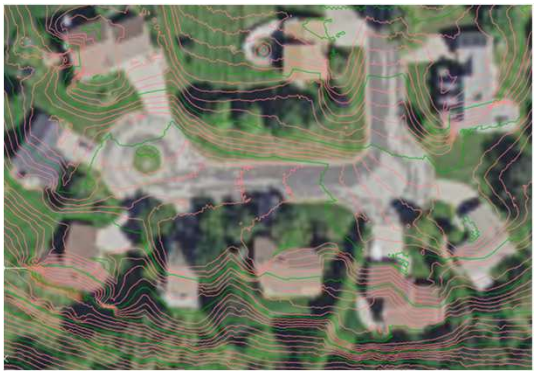
Disadvantages
- Cost: equipment, personnel, etc
- Time

B. Graphic Data Format

1. Types

Two different graphic categories depending on feature

- Vector: points, lines, polygons
- Raster: image



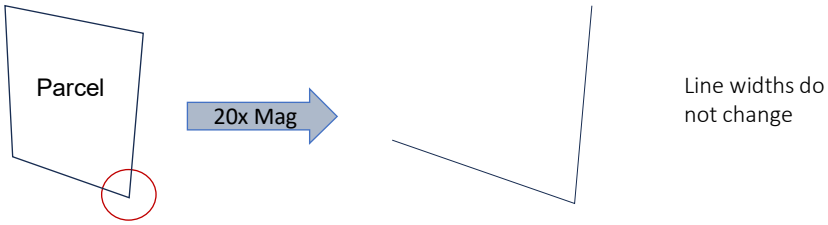
B. Graphic Data Format

2. Vector

Graphic representations

- Point – Has location, no dimension
- Line – Has length and path/direction, no width
- Polygon – Has perimeter and area; boundary lines have no width.

Used for distinct locations and/or boundaries

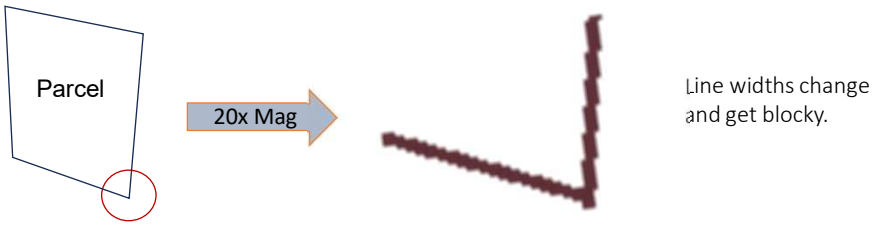


B. Graphic Data Format

3. Raster

Graphic elements made up of individual pixels.
- Each pixel has a color.
- The smaller the pixel the better the resolution.

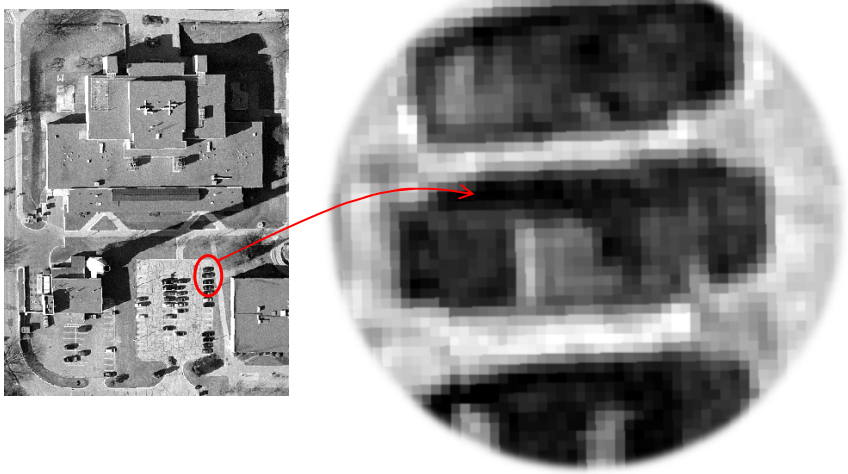
Used for "fuzzy" boundaries and images, eg, wetlands, soils areas, etc



B. Graphic Data Format

3. Raster

Images



B. Graphic Data Format

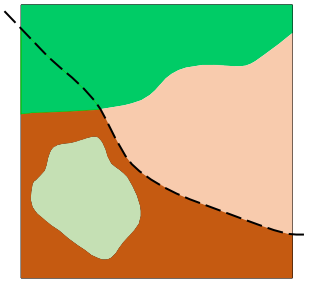
4. Vector <> Raster

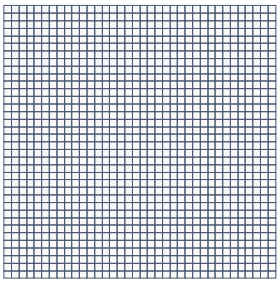
Sometimes it's necessary to convert data between vector and raster.

Because they are two different graphic formats, some accuracy loss will occur.

Vector to Raster

Vector representation





Grid cells

B. Graphic Data Format

4. Vector <> Raster

Sometimes it's necessary to convert data between vector and raster.

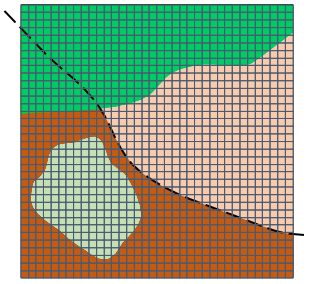
Because they are two different graphic formats, some accuracy loss will occur.

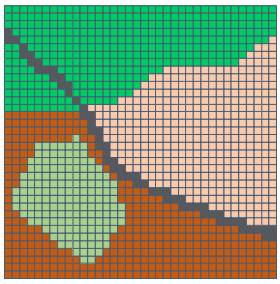
Vector to Raster

Overlay grid cells.

Each cell assigned prevalent color.

Dashed feature line has priority





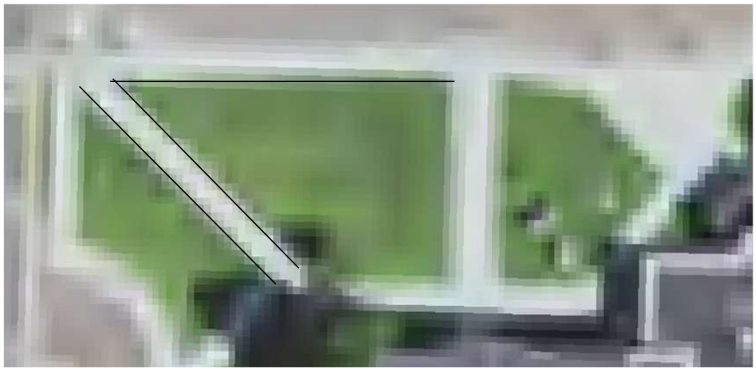
Raster representations are blocky, not smooth like vector

B. Graphic Data Format

4. Vector <> Raster

Raster to Vector

Image magnified 10X



C. Accuracy

How does user determine data accuracy?

- Traditional paper map:
  - National Map Accuracy Standards (NMAS)
  - Scale; control interval
  - Level of detail

- Digital GIS data?
  - *Geographic Information Framework Data Standard* FGDC-STD-014-2008, Parts 0-7
    - Accuracy independent of scale.
    - Accuracy thresholds are the responsibility of data generating entity.
    - The standard concentrates on testing and reporting digital data accuracy.

C. Accuracy

How does user determine data accuracy?

- Traditional paper map:
  - National Map Accuracy Standards (NMAS)
  - Scale; c
  - Level o

Combining less accurate data with more accurate data **does not** improve overall accuracy.

- Digital GIS
  - *Geographic Information Framework Data Standard* FGDC-STD-014-2008, Parts 0-7
    - Accuracy independent of scale.
    - Accuracy thresholds are the responsibility of data generating entity.
    - The standard concentrates on testing and reporting digital data accuracy.

D. Data Custodian

Data custodian:

- Entity responsible for data collecting, organization, updating, quality assessment, and dissemination in support of its agency's responsibilities.

Determines:

- Appropriate feature representation
- Attribute table contents
- Data accuracy assessment.

Distributes projects or individual layers.

Contact for internal and external data users.

E. Metadata

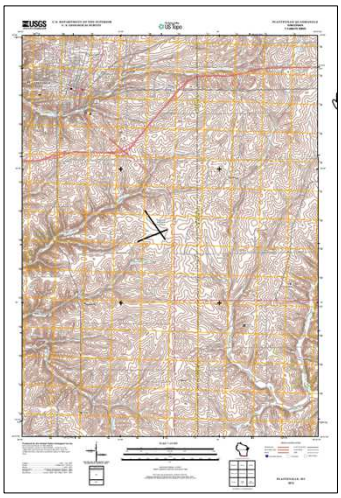
Data content and quality is communicated via *metadata*.

- Metadata is data about the data.

Provides user information to:

- Determine custodian
- Understand contents
- Identify reference system
- Make judgement about accuracy
- etc.

Metadata is not a GIS-only concept.



Consider a 7.5’ Topoquad.

E. Metadata

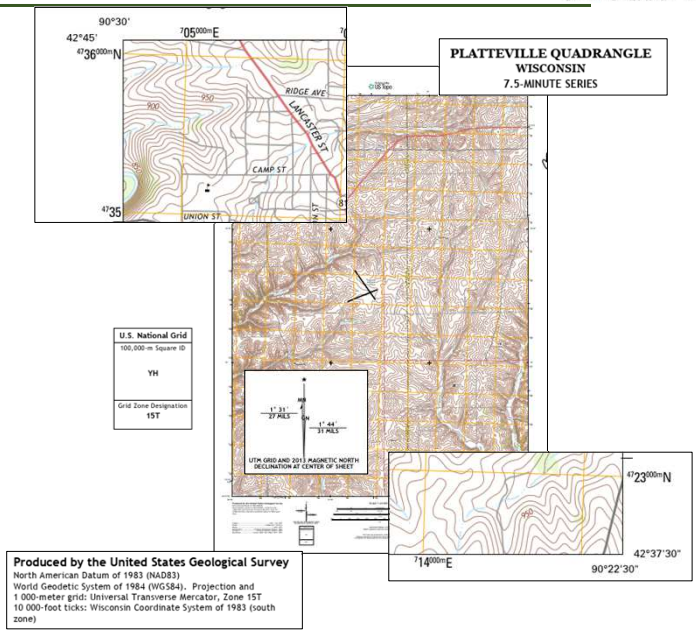
Multiple themes

Custodian: USGS

Margin information

- Title
- Compilation method(s)
- H & V datums
- Mag-True-Grid meridians
- Quality statement
- Coordinate systems
- etc.

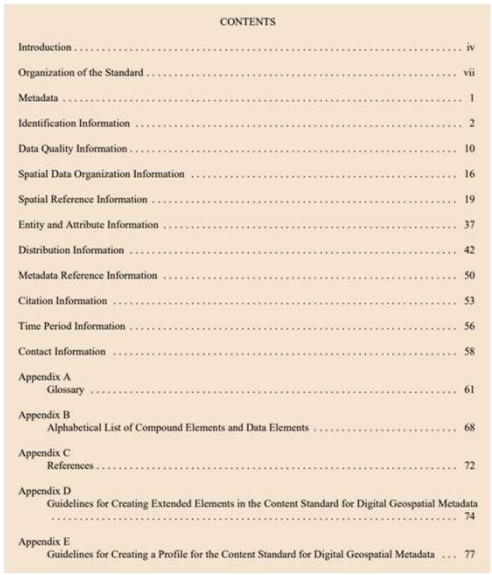
That’s metadata: data about data.



E. Metadata

Content Standard for Digital Geospatial Metadata,

FGDC-STD-001-1998



CONTENTS

E. Metadata

Example

Information from provider

Storage ESRI Shapefile
Encoding UTF-8
Geometry Polygon (MultiPolygon)
Extent 294875.6610158025287092,225325.1648442705627531 : 770165.1867714223917574,734439.5197338045109063
Feature count 11,134

Coordinate Reference System (CRS)

Name EPSG:3071 - NAD83(HARN) / Wisconsin Transverse Mercator
Units meters
Type Projected
Method Transverse Mercator
Celestial Body Earth
Reference Static (relies on a datum which is plate-fixed)

Identification

Identifier
Parent Identifier
Title
Type dataset
Language
Abstract
Categories
Keywords

Extent

CRS EPSG:3071 - NAD83(HARN) / Wisconsin Transverse Mercator - Projected
Spatial Extent
Temporal Extent

Access

Fees
Licenses
Rights
Constraints

Fields

Count 5

Field	Type	Length	Precision	Comment
OBJECTID	Integer	5	0	
VEG_TYPE_C	Integer	2	0	
LUC_LEVEL_	Integer	2	0	
SHAPEAREA	Real	23	15	
SHAPELEN	Real	23	15	

III. GIS Analysis & Presentation

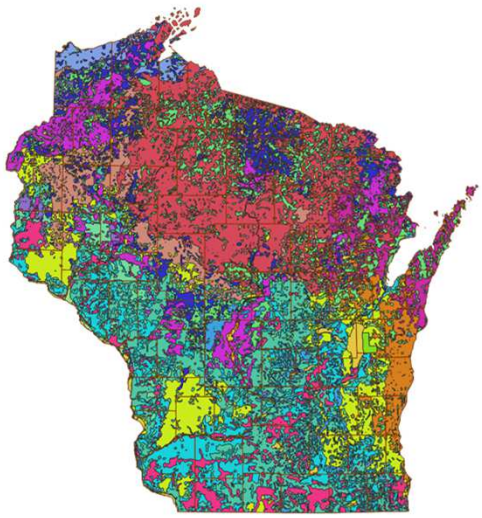
A. Introduction
B. Classification
C. Spatial Query
D. Geoprocessing

A. Introduction

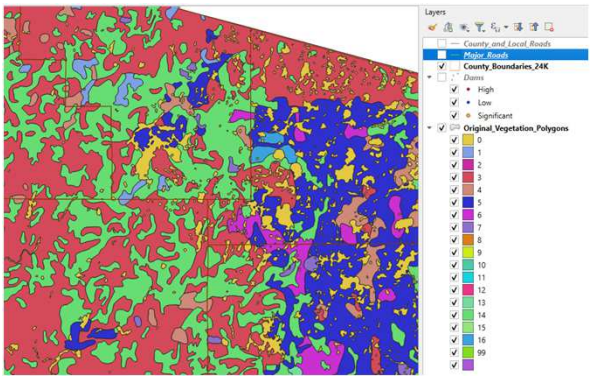
Mentoring MONDAYS

Strengths of GIS are:
- Data integration
- Classification
- Geoprocessing
- Maps and Reports

These characteristics set GIS apart from CAD.
- CAD has some of these tools but they are not as spatially optimized as in GIS.



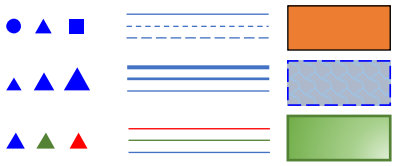
B. Classification



Visual depiction of features based on attributes.

Applicable to vector data.

Symbol types, symbol sizes, colors, line types, line weights:

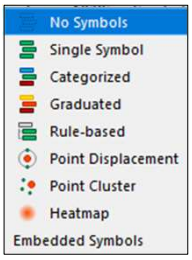


Visually communicate a theme or attribute(s).

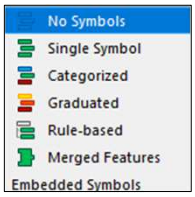
B. Classification

Classification options:

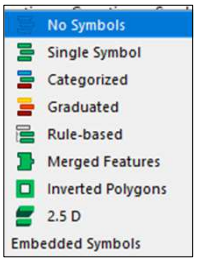
Point



Line



Polygon



C. Spatial Query

A spatial query is a question whose answer is at least partially dependent on some location criteria.

Query may be based on an attribute

Find all gate-type water valves that are more than twenty years old.

Features: Valves; points
Attributes: ID, Material, **Type**, **Inst_date**, Last_insp

Type="Gate" AND Inst_date ≤ 2006

C. Spatial Query

A spatial query is a question whose answer is at least partially dependent on some location criteria.

It could also be relationship to other feature(s)

Find all gate-type water valves that are more than twenty years old on 8 inch dia or smaller waterline.

Features: Valves; points
Attributes: ID, Material, **Type**, **Inst_date**, Last_insp

Type="Gate" AND Inst_date ≤ 2006

Features: Waterlines; lines
Attributes: ID, Material, **Diameter**, Length, Inst_date, Last_insp

Diameter ≤ 8

C. Spatial Query

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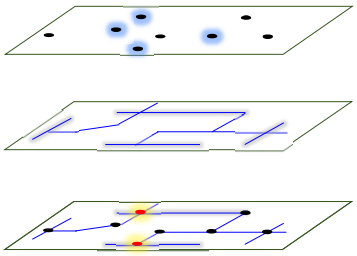
Attributes: ID, Material, **Diameter**, Length, Inst_date, Last_insp



Type="Gate" AND Inst_date ≤ 2006

AND

Diameter ≤ 8

SQL- Structured Query Language.
Questions using Boolean operands:
AND, OR, NOT, =, ≠, >, ≥, <, ≤

D. Geoprocessing

Graphic or mathematic computations:

- within a single layer
- between multiple layers
- between layers and linked non-spatial data

Simple or complex:

Identify vacant parcels zoned R1 or R2 located entirely outside the Brule River FEMA designated floodplain but within 1000 feet of the river and at least 500 feet from an existing County Highway intersection.

Also known as Spatial Analysis.

D. Geoprocessing

1. Join

Connecting a non-spatial table to a layer through the layer's attribute table.

Parcel layer attribute table

PID	*Owner*	*Zone*
345.88	Jones	A1
432.90	Asimov	A1
654.34	Tyler	R2
789.12	Smith	C1

JOIN

Zones and allowable uses

Code	*Primary Use*	*Res Allowed*
A1	Agricultural-1	No
A2	Agricultural-2	Yes
C1	Commercial, medium	No
R1	Residential, single family	Yes
R2	Residential, multi-family	Yes

PID	*Owner*	*Zone*	*Primary Use*	*Res Allowed*
345.88	Jones	A1	Agricultural-1	No
432.90	Asimov	A1	Agricultural-1	No
654.34	Tyler	R2	Residential, multi-family	Yes
789.12	Smith	C1	Commercial, light	No

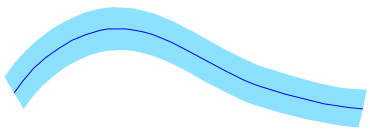
Non-spatial records joined to attribute table

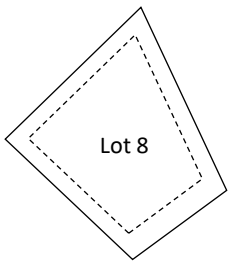
D. Geoprocessing

2. Buffer

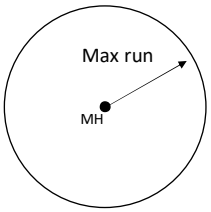
Proximity; distance from a feature.

- Point: Radial distance
- Line: Parallel offset
- Polygon: Radial distance from centroid or corners; parallel offset





Setback lines



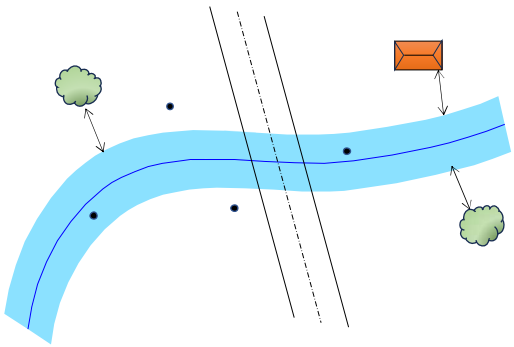
D. Geoprocessing

2. Buffer

Select features that are...
- Completely inside
- Partially inside
- Partially outside
- Completely outside

the buffer.

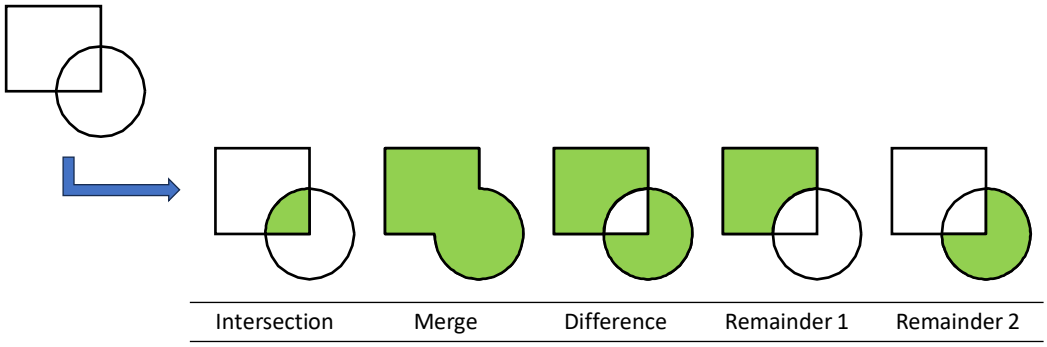
Where are other features with respect to the buffer?



D. Geoprocessing

3. Overlaps

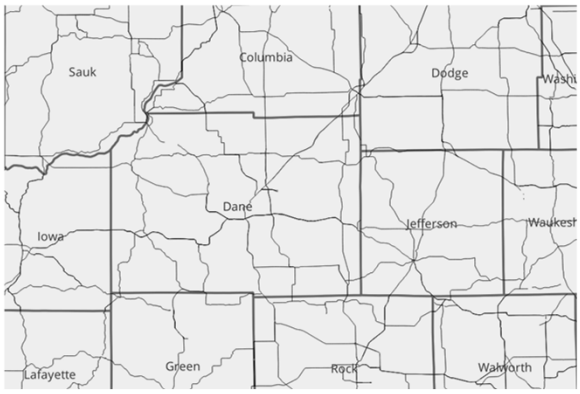
Overlap features on two layers to create a third layer.



D. Geoprocessing

3. Overlaps

Example



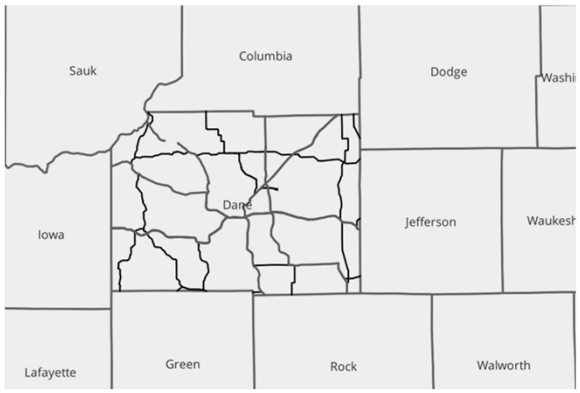
Two layers:
- County boundaries – polygon
- Major roads – line

Want Major roads in Dane County

D. Geoprocessing

3. Overlaps

Example



Two layers:
- County boundaries – polygon
- Major roads – line

Want Major roads in Dane County

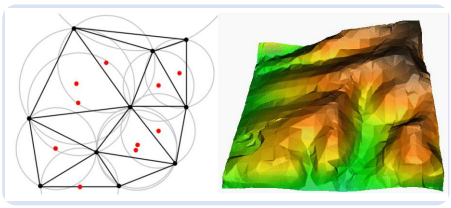
Intersect Dane county in *County* layer with the *Major roads* layer.

New layer

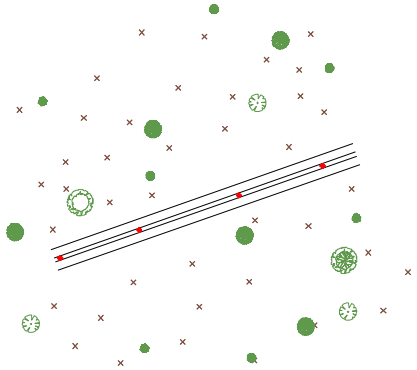
D. Geoprocessing

4. Interpolation

Using point attributes, spatial interpolation can estimate intermediate values to create a new layer or surface: a statistical surface.



A TIN and grade analysis are surfaces interpolated from spot elevations.



Layers
- Highway
- Sound Monitors
- Trees
- Spot Elevs

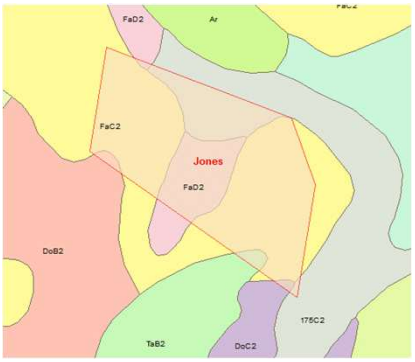
Create
- Sound contours

D. Geoprocessing

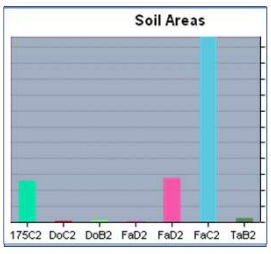
5. Resolution

a. Combining vector and raster data.

Example: Property boundary (vector) with soils (raster) to determine soil areas.



Generate Soils Cover graph:



D. Geoprocessing

5. Resolution

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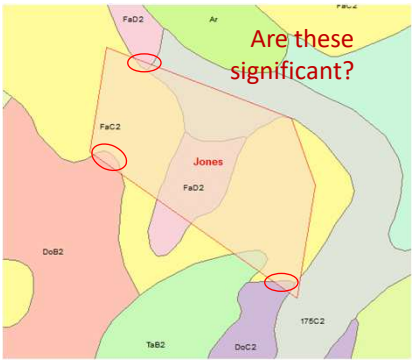
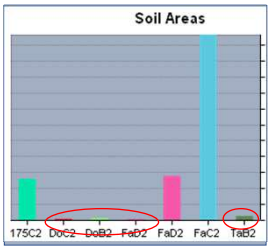


Generate Soils Cover graph:



Are these significant?
Fuzzy boundaries are, well, *fuzzy*.

D. Geoprocessing

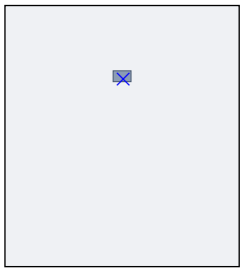
5. Resolution

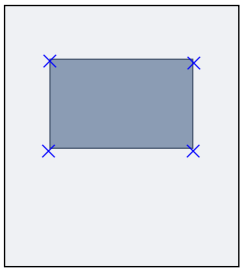
b. Generalization

Less data needed at smaller scale than at larger scale

Example: Building representation

Small scale
Single data point
Lower accuracy
Point feature





Large scale
Four data points
Higher accuracy
Polygon feature

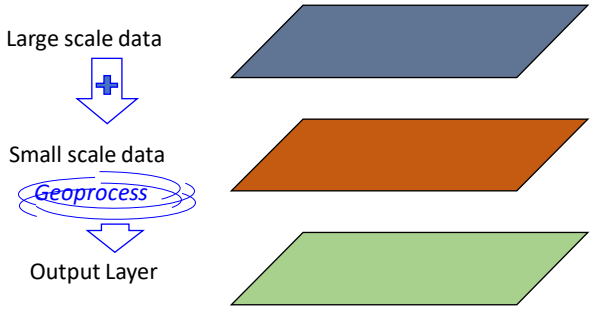
D. Geoprocessing

5. Resolution

b. Generalization

GIS allows combining data from different sources and scales.

Geoprocessing results are only as accurate as least accurate data.



IV. Reporting Results

A. Maps

B. Reports

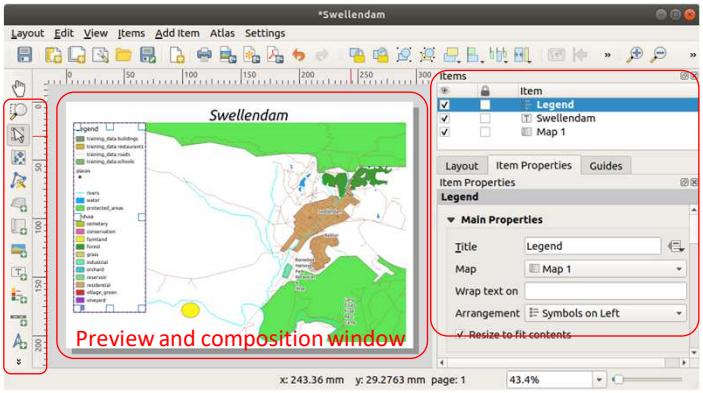
A. Maps

GIS is Map Ready

Graphic depiction of features is primary map component.

GIS provides tools to add map elements dynamically linked to the features and attributes.

Map element tools



Map element properties

B. Reports

Geoprocessing Outputs Can Vary

Geoprocessing generally results in another layer which can be added to the project or shared externally.

Sometimes, it's better to show results in a table or a structured report.

Examples:

What is the percentage of area that exceeds 12% slope per lot in the SweetWater Subdivision?

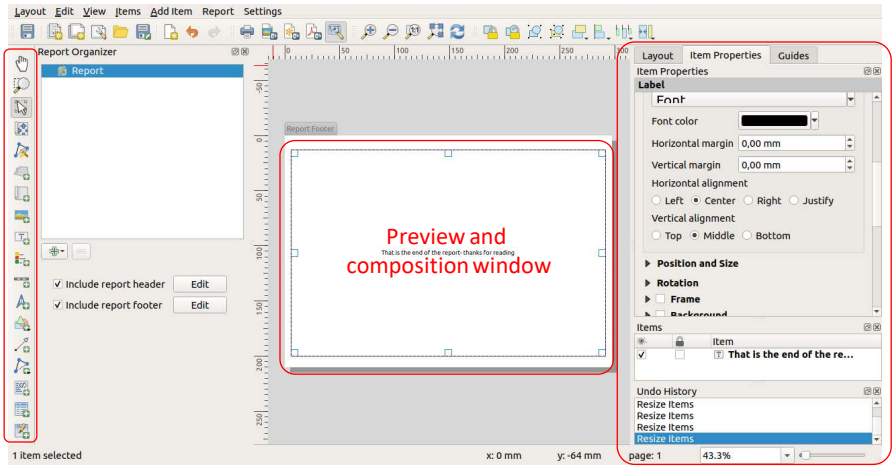
What is the total mileage breakdown, and percentage they represent, by pavement type for County roads?

Some geoprocessing operations can report results in tables.

Most GIS software have report generation tools.

B. Reports

Report element tools



Map element properties

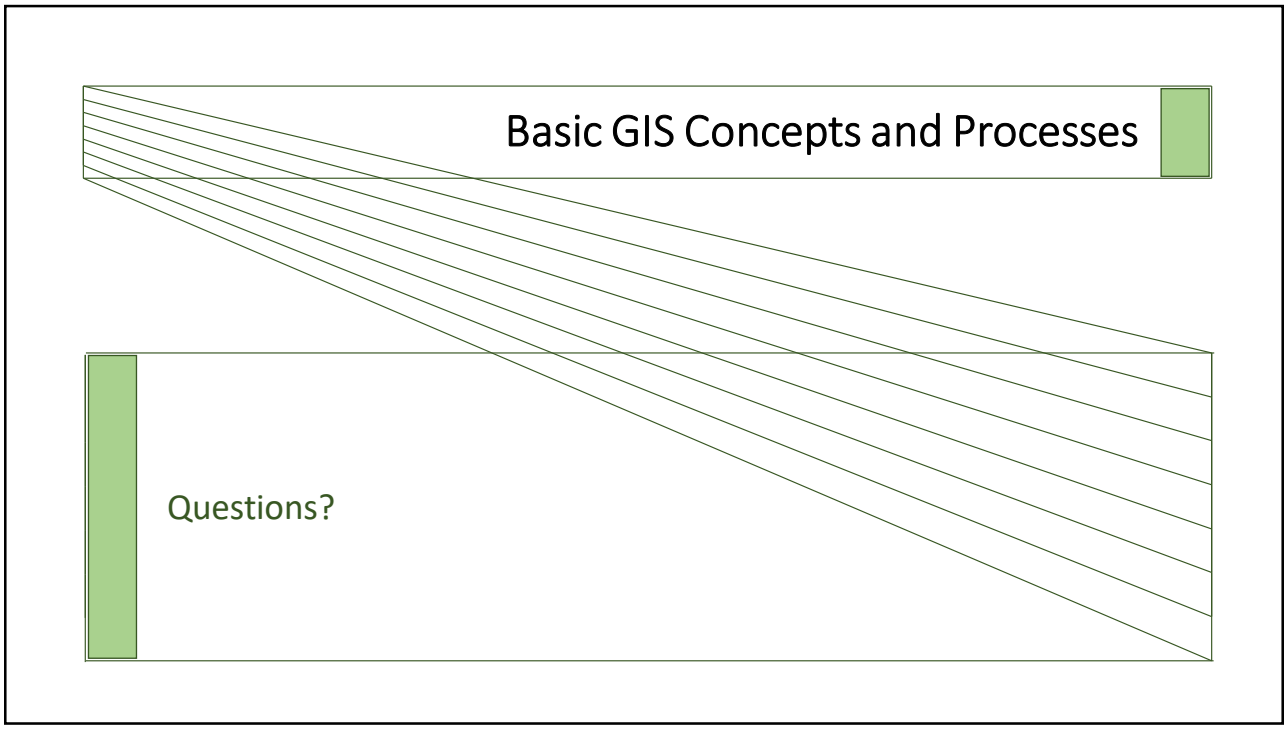
Summary

I. GIS Basics
- A. What is GIS
- B. Fundamental Elements
- C. Data Management
- D. Spatial Reference
- E. Project Flow

II. GIS Data
- A. Data Acquisition
- B. Graphic Data Format
- C. Accuracy
- D. Data Custodian
- E. Metadata

III. GIS Analysis
- A. Introduction
- B. Classification
- C. Spatial Query
- D. Geoprocessing

IV. Reporting Results
- A. Maps
- B. Reports


Basic GIS Concepts and Processes
Questions?