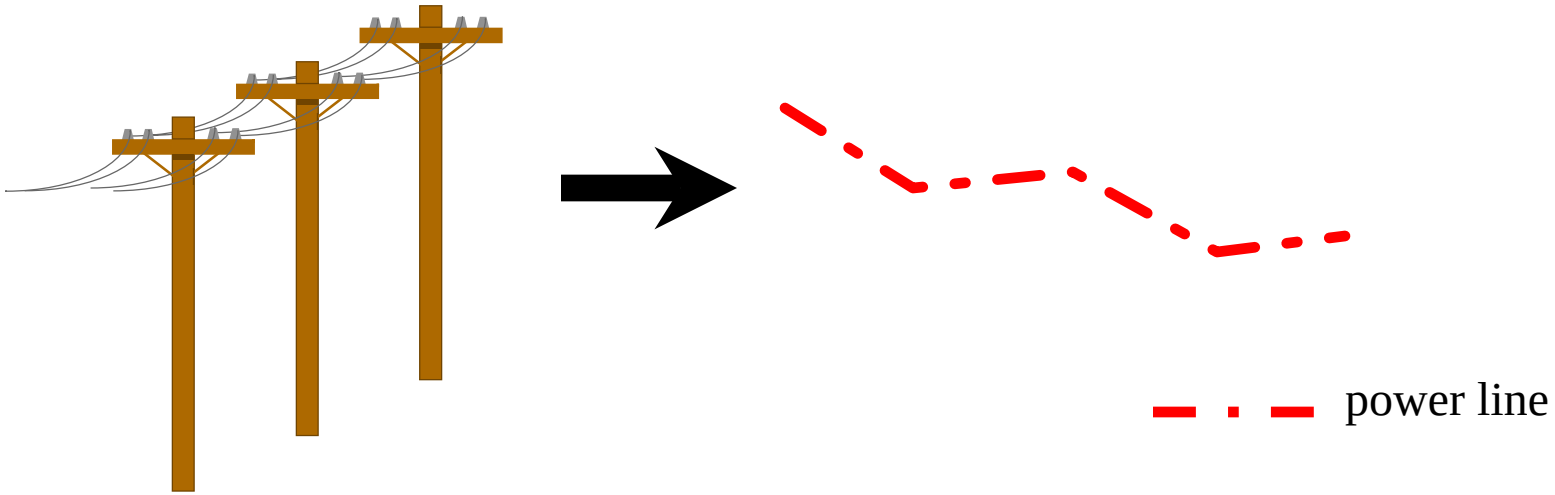
Chapter 7: Making Maps with GIS

- 7.1 The Parts of a Map
- 7.2 Choosing a Map Type
- 7.3 Designing the Map

What is a map?

- "A **graphic depiction** of all or part of a **geographic realm** in which the **real-world features** have been replaced by **symbols** in their **correct spatial location** at a **reduced scale**."



Map Function in GIS

- Storage - maps are a means of **data storage**
- Temporary communication – as an aid to an activity in progress e.g. **navigation**
- Intermediate check of data – **before** the task is done
- Final report - maps provide useful ways of **displaying data in a meaningful way** (→ information)

- To be effective, must be **correctly designed and constructed**.

Map Design Considerations

- Maps are a **means of communication** and **organization of thoughts**, they **transmit some spatial information** to the map reader
- Success or failure depends on whether or not the map **communicates** the intended information
- Cartography as a **communication system**:

  "How do I say what to whom?"

  - **cartographer** = I
  - **map reader/audience** = whom
  - **map design & production methods** = how
  - **subject & goals of map** = what

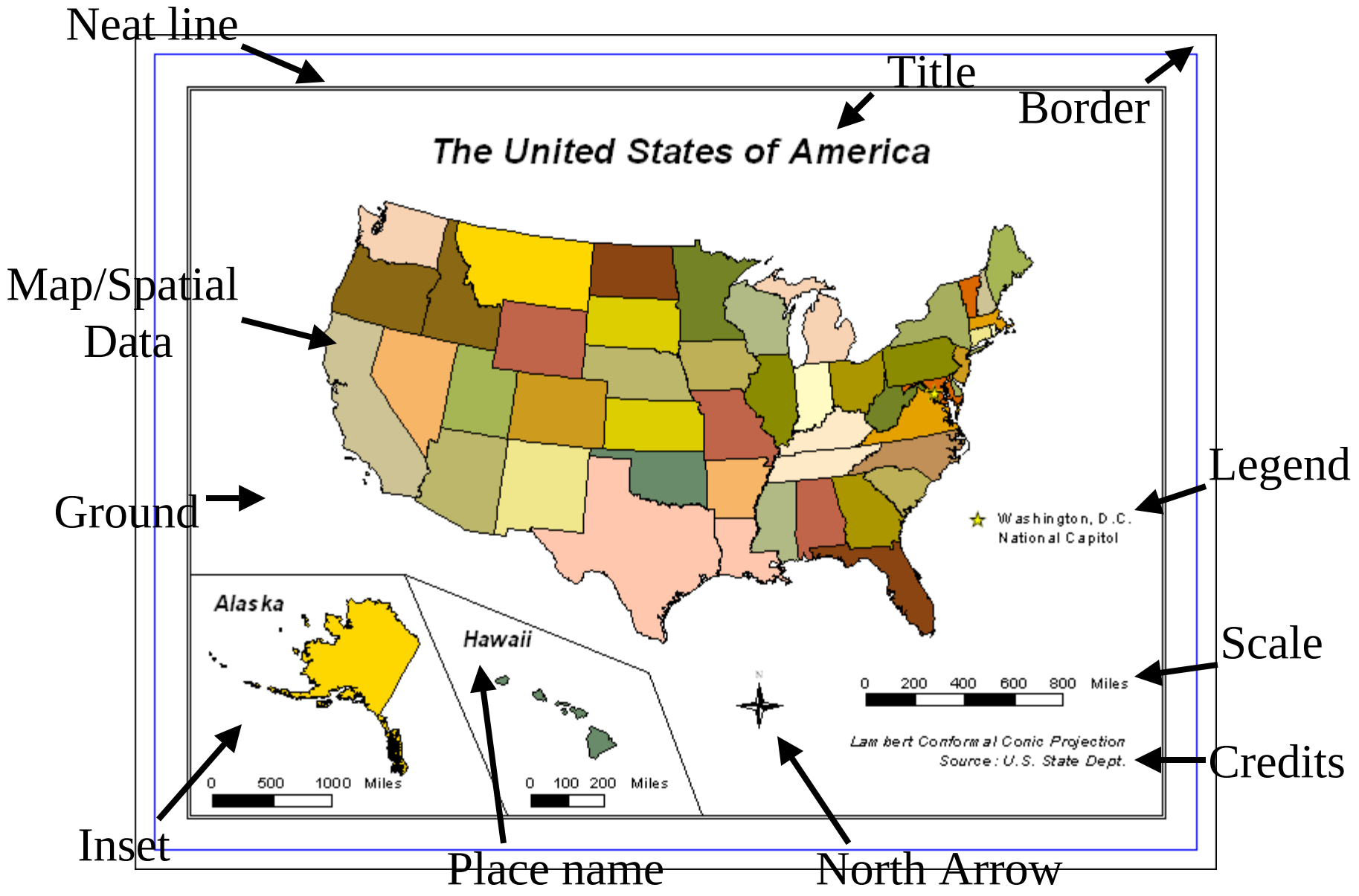
The medium is the message

- Paper
- Film
- Mylar
- Monitor
- Projection
- Broadcast TV
- The display is PART of the **symbolization**!

Cartographic Elements

- Most **common elements** include:
  - (Medium)
  - map/spatial data (figure & ground)
  - title
  - legend
  - scale
  - north arrow
  - inset(s)
  - textual information (reference information)
  - borders & neatlines
  - coordinate grid

Cartographic Elements



Cartographic Elements

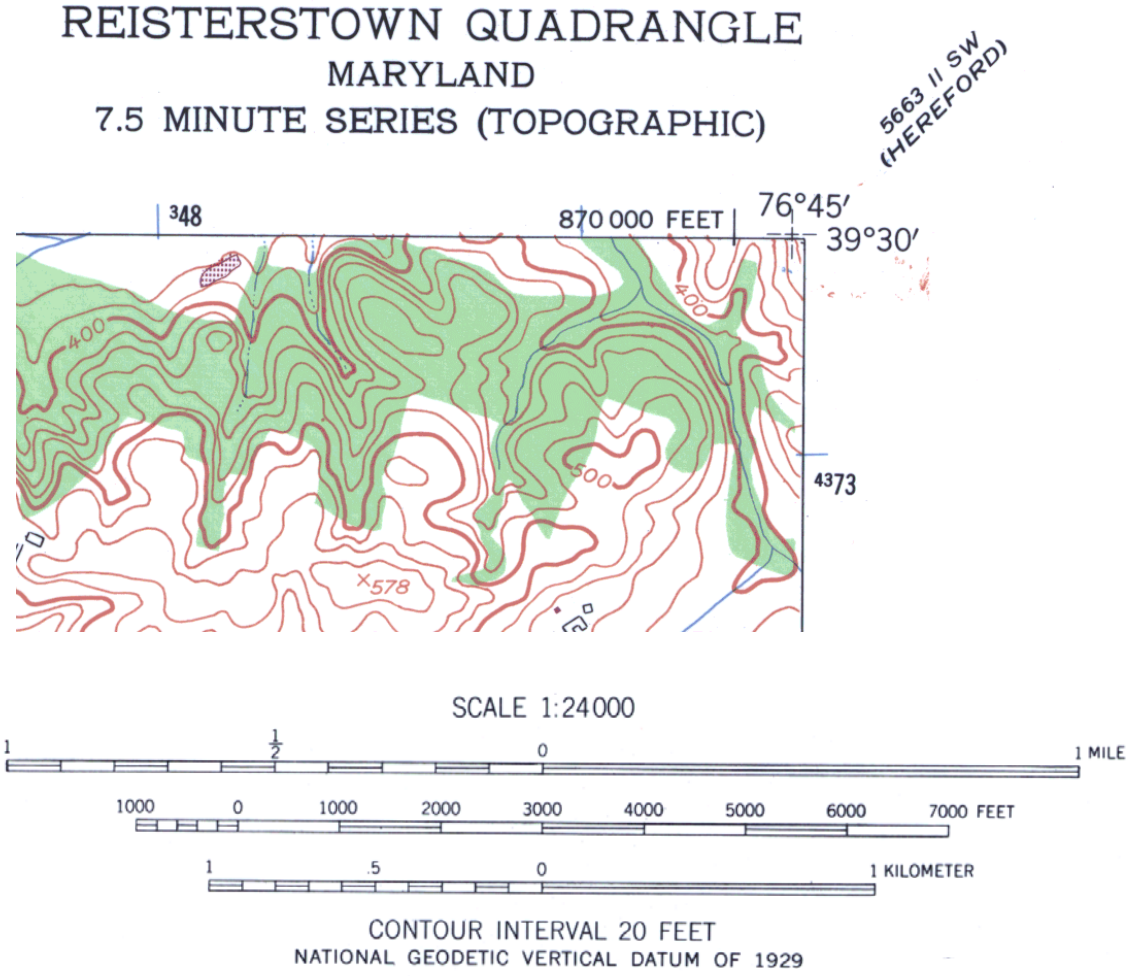
Title

- Should be the **largest and most noticeable** text on the map
- Be **precise**! No superfluous words
- No "Map of..." in the title -- **we know it's a map**

Scale

- **Only graphic scales** will survive enlargement or reduction during reproduction
- Some thematic maps **may not need** a scale bar

USGS Topo Map Title and Scale



Cartographic Elements

Legend

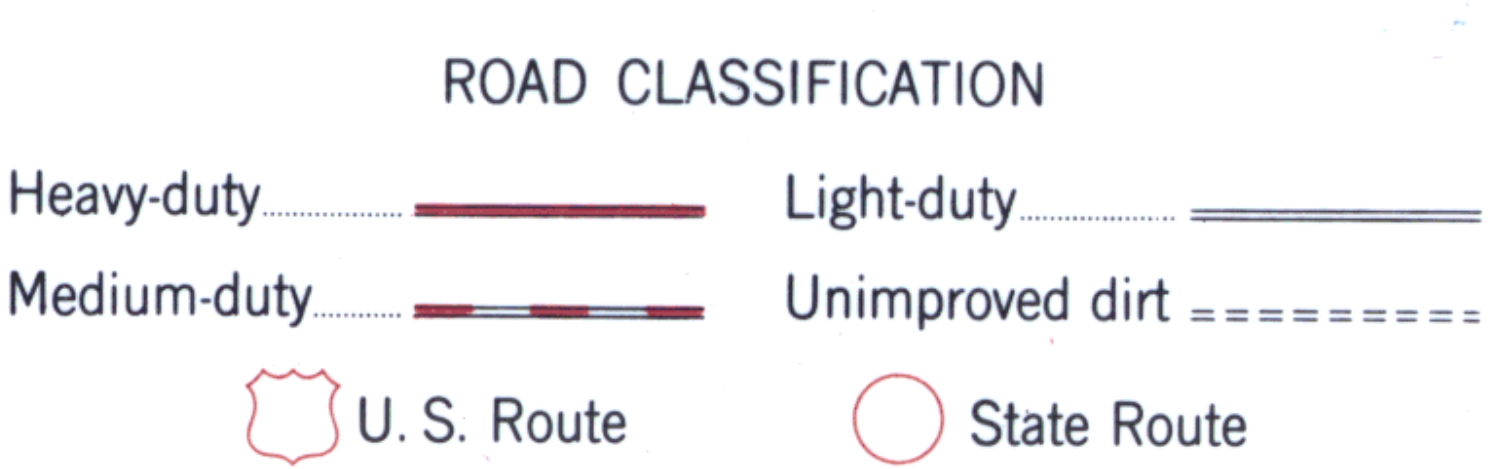
- Almost always **required** on thematic maps
- Symbolization in the legend **must exactly match** symbolization used on the map

Textual Information

Common uses include:

- author/publisher, date of production, date of map information, projection type and coordinate system information, data sources, brief information on how the map was produced

USGS Topo Map Legend



REISTERSTOWN, MD.

39076-D7-TF-024

1983, 1953

PHOTOREVISED 1966 AND 1974

DMA 5662 IV NE—SERIES V833

USGS Topo Map Textual Information

Mapped by the Army Map Service
Edited and published by the Geological Survey

Control by USGS and USC&GS

Topography from aerial photographs by stereophotogrammetric methods. Aerial photographs taken 1943. Field check 1944
Culture revised by the Geological Survey 1953

Polyconic projection. 1927 North American datum
10,000-foot grid based on Maryland coordinate system

Unchecked elevations are shown in brown

1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue

Revisions shown in purple compiled by the Geological Survey from aerial photographs taken 1966 and 1974. This information not field checked

Purple tint indicates extention of urban areas

Cartographic Elements

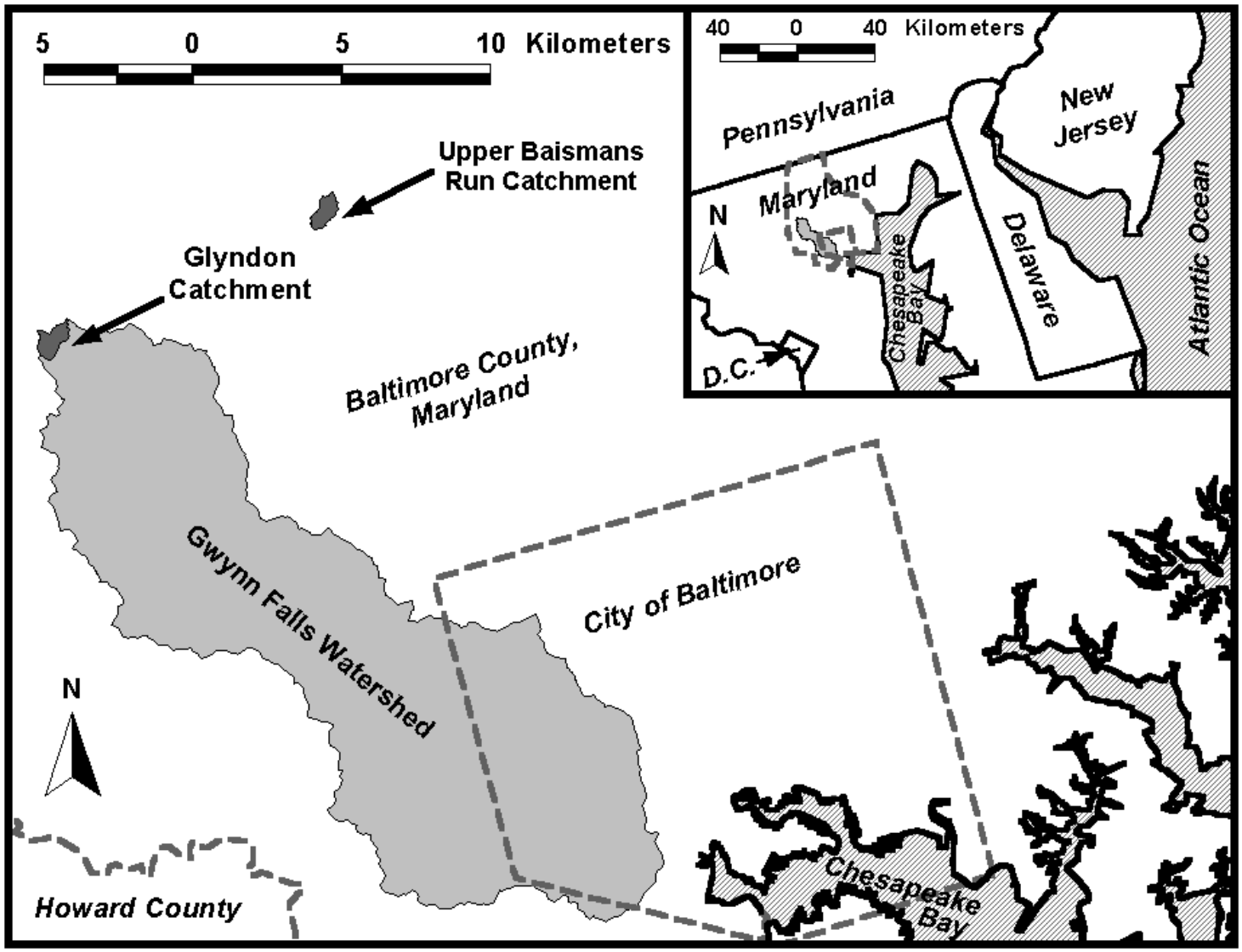
Insets

- Locator maps
- Detail maps
- Potentially **scaled up** or **scaled down**

Borders & Neatlines

- Provide a **graphic "container”**
- Almost essential when an **unclosed portion of a geographic area** is being shown

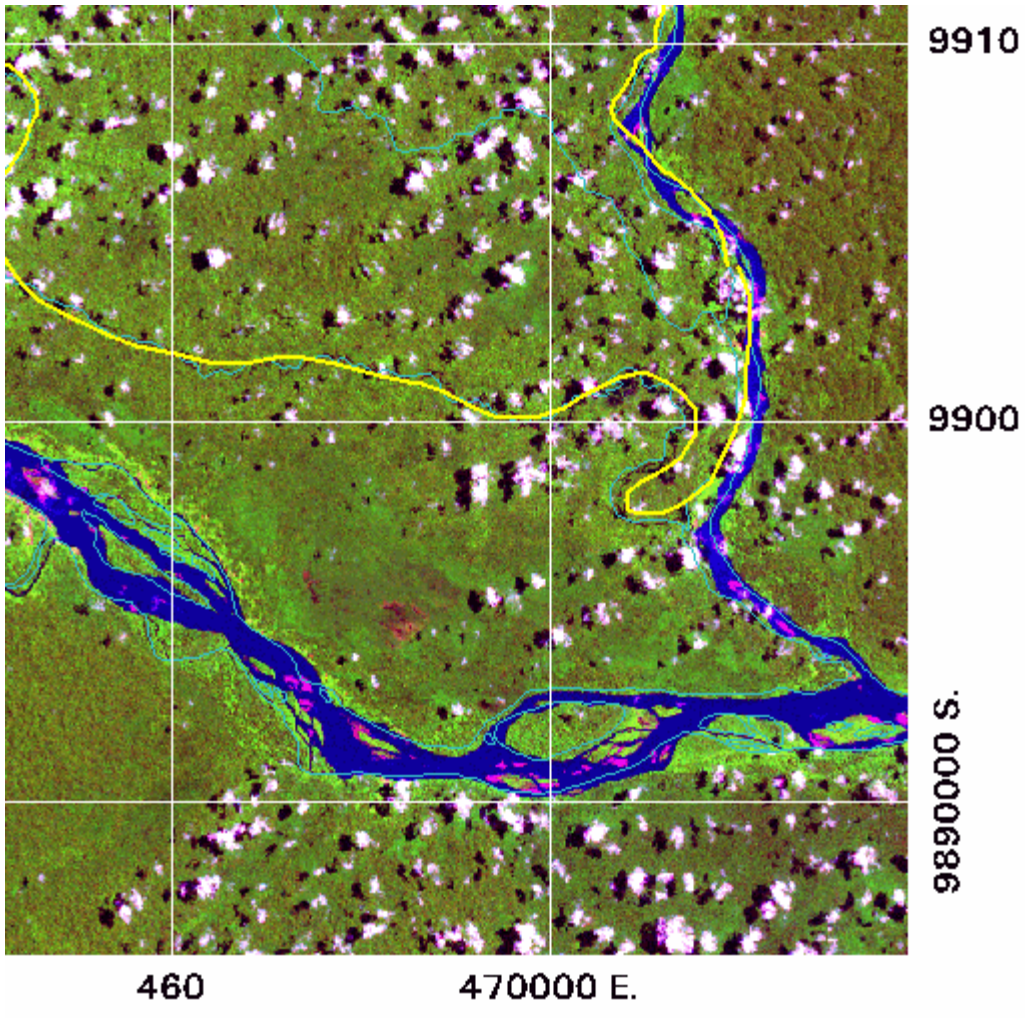
Study Catchments in Suburban Maryland



Cartographic Elements

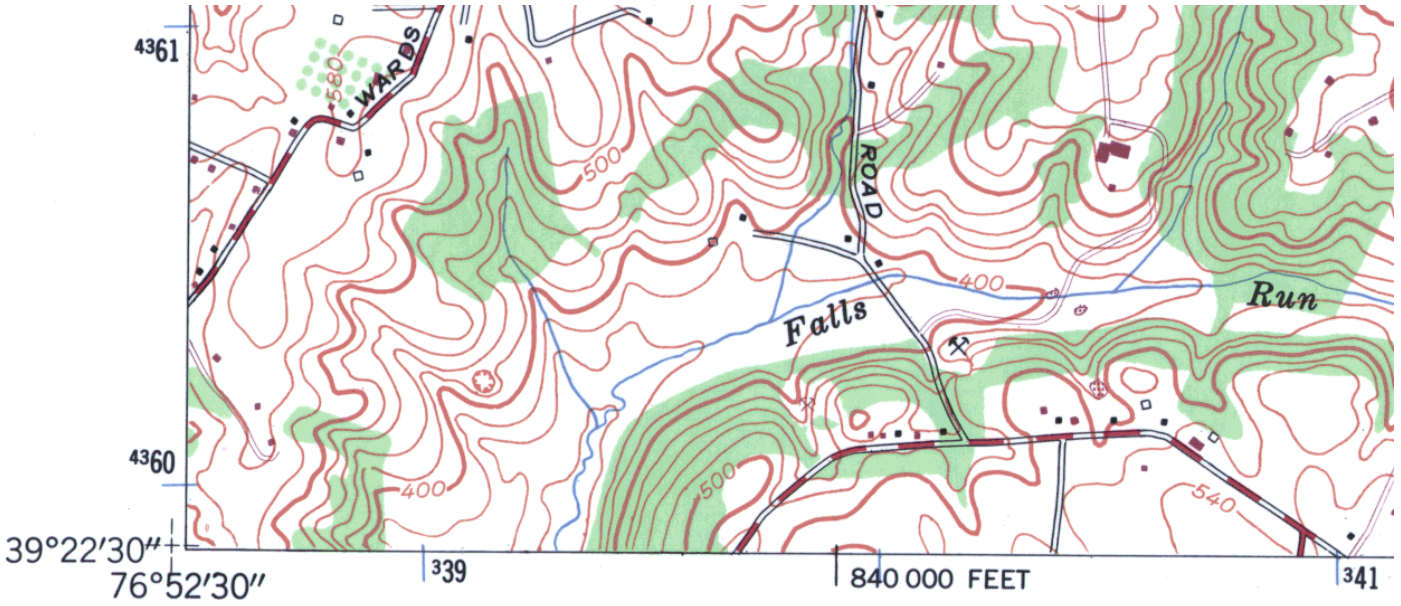
- Page coordinates
- Ground elements
- Graticule/Grid
- North arrow

Graticule/Grid



- Map should also state coordinate system used

USGS Topo Map Coordinate Grid



Polyconic projection. 1927 North American datum
10,000-foot grid based on Maryland coordinate system

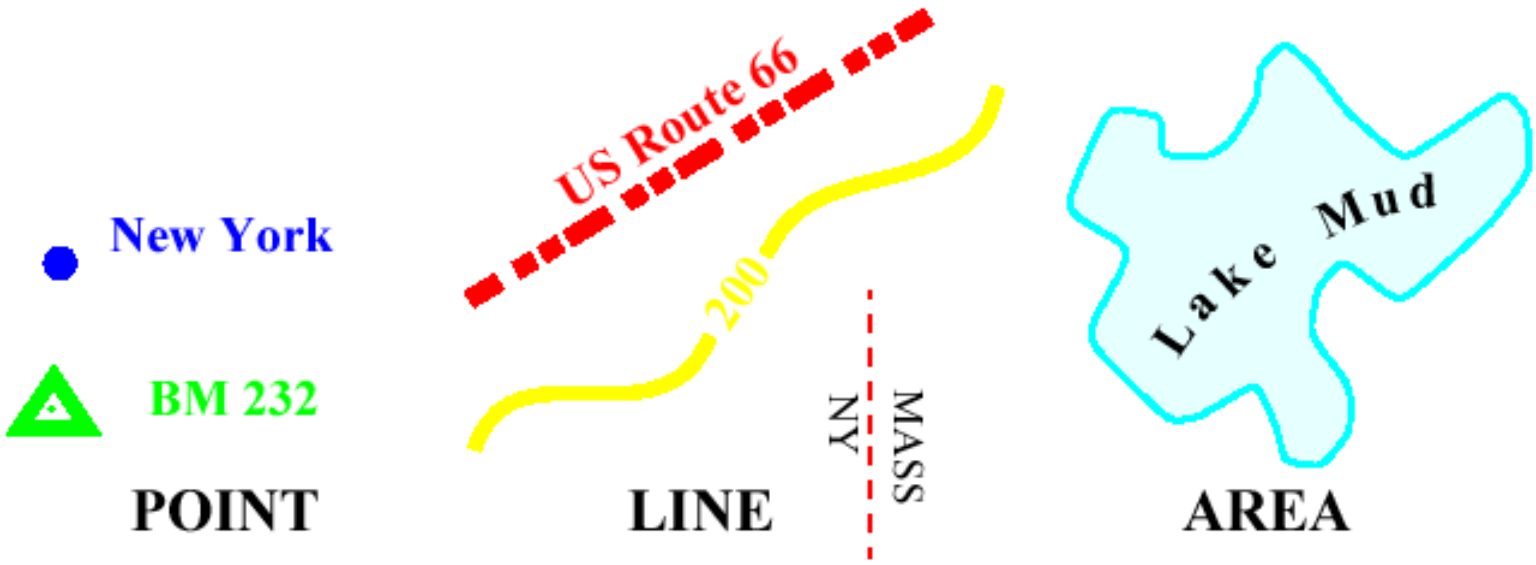
Unchecked elevations are shown in brown

1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue

Cartographic Elements

- Figure
- Point/Line/Area symbols
- Text
- Place Names

Text: Selection and Placement



Map “impact” – Choosing a Title

- Distribution of Employment by State 1996
- USA: Employment Distribution 1996
- **U.S. Employment: 1996 Distribution**
- America at Work
- Where the Jobs are Today

Choosing Elements

- Map research
- Map compilation
- Worksheet
- Selection
- Placement
- Layout
- Tools in GIS not ideal

Choosing a Map Type

- Cartographers have designed **hundreds of map types**: methods of cartographic representation.
- Not all GISs **allow** all types.
- Most have a set of **basic** types
- Depends heavily on the **dimension of the data** to be shown in the map figure.

Map Types: Point Data

- Reference
- Topographic
- Dot
- Picture Symbol
- Graduated Symbol

Map Types: Line Data

- Network
- Flow
- Isopleth
- Reference

Map Types: Area Data

- Choropleth
- Area qualitative
- Stepped surface
- Hypsometric
- Dasymetric
- Reference

Map Types: Volume Data

- [Isopleth, Stepped Surface, Hypsometric]
- Gridded fishnet
- Realistic perspective
- Hill-shaded
- Image map

Map Types: Time

- Multiple views
- Animation
  - Moving map
  - Fly thru
  - Fly by

Choosing the Wrong Type

- **Fairly common** GIS error.
- Due to **lack of knowledge** about cartographic options.
- Can still have **perfect symbolization**.
- Possibility of **misinformation**
- Definite reduction in **communication effectiveness**.

Choosing Map Types

- **Check** the data
  - Continuous vs. Discrete
  - Accuracy & Precision
  - Reliability
- **Dimension** (Point, Line, Area, Volume)
- **Scale of Measurement** (Nominal etc.)
- What types is your GIS **capable** of creating
- May need to **supplement** GIS software

Scales of Measurement

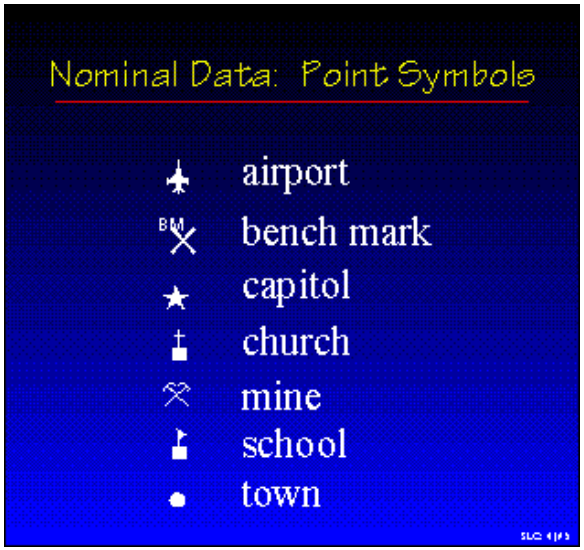
- **Thematic data** can be divided into four types

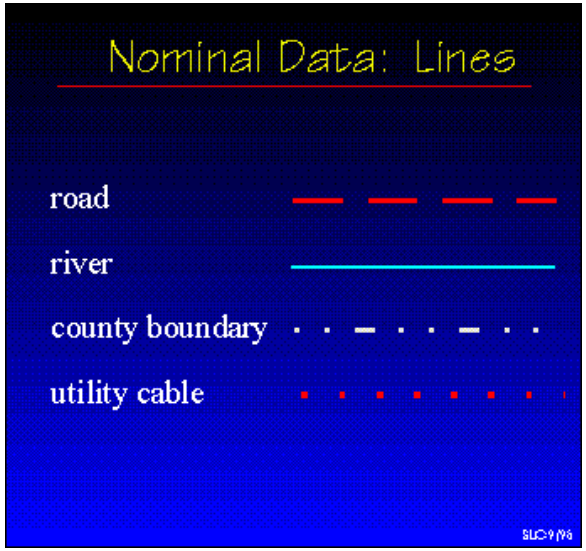
1. The Nominal Scale
2. The Ordinal Scale
3. The Interval Scale
4. The Ratio Scale

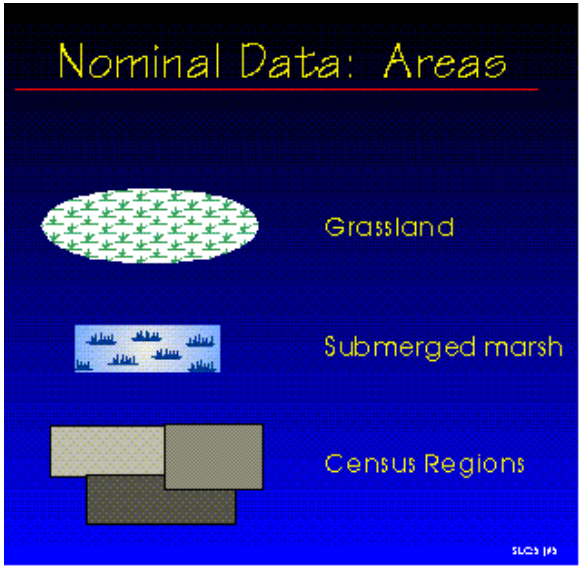
As we progress through these scales, the types of data they describe have increasing information content

The Nominal Scale

- **Nominal data** - information that is simply grouped into categories on the basis of qualitative considerations
  - Example: Place names

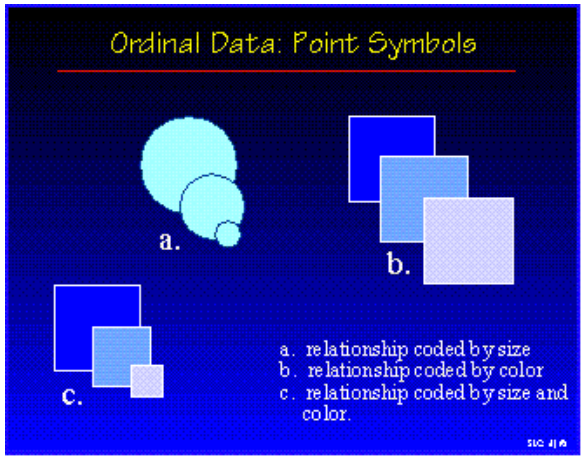


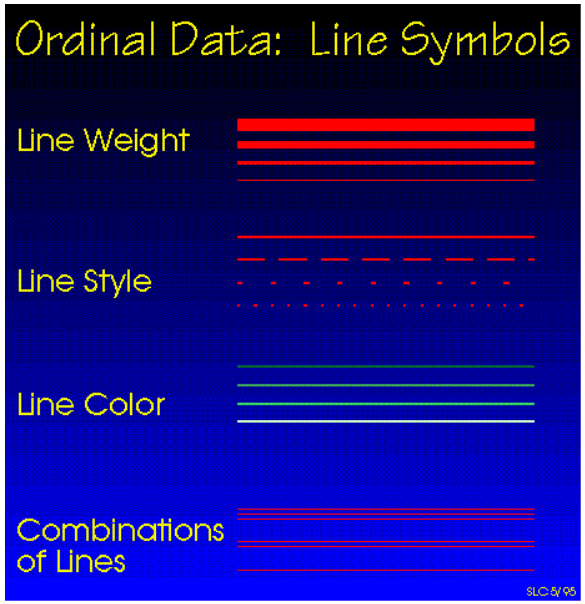


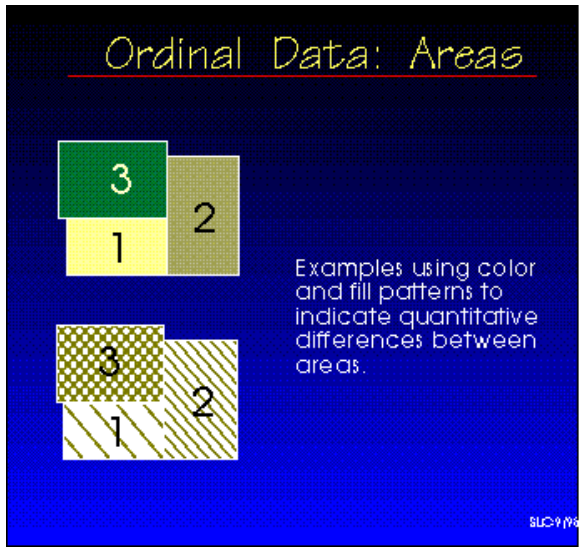


The Ordinal Scale

- **Ordinal data** - grouped by rank on the basis of some quantitative measure
  - Example: Small, medium and large towns







The Interval Scale

- **Interval data** - information that can be arranged using a standard scale along which operations of addition and subtraction have meaning
  - Example: Temperature is an interval measure

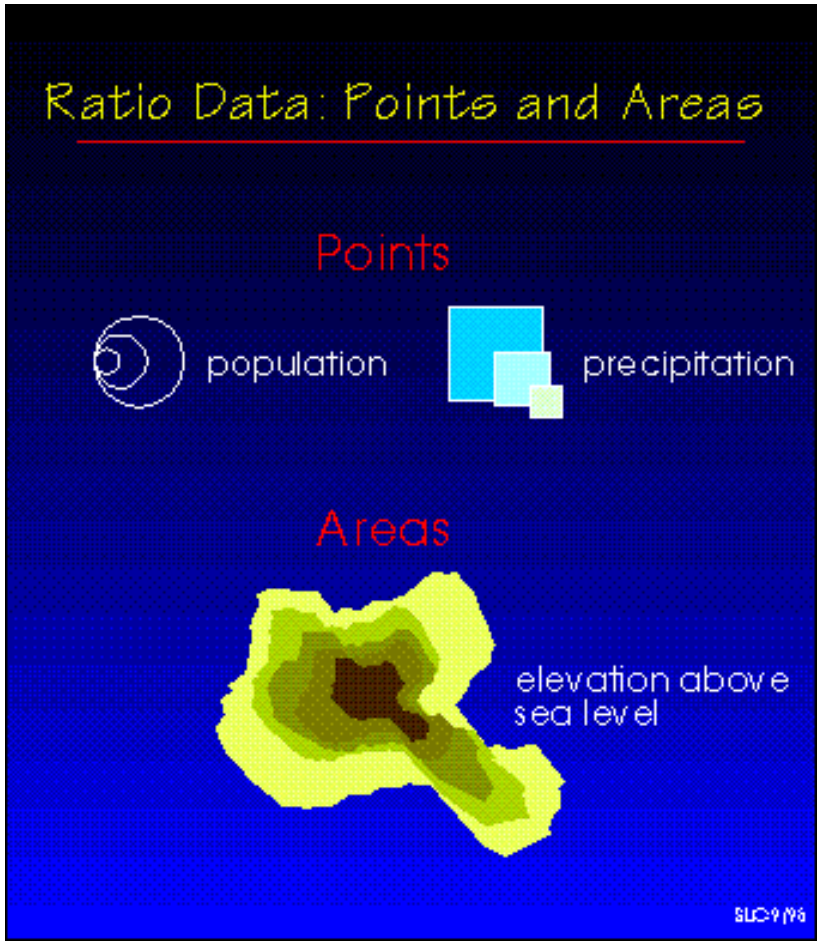
- Interval data is one type of continuous data

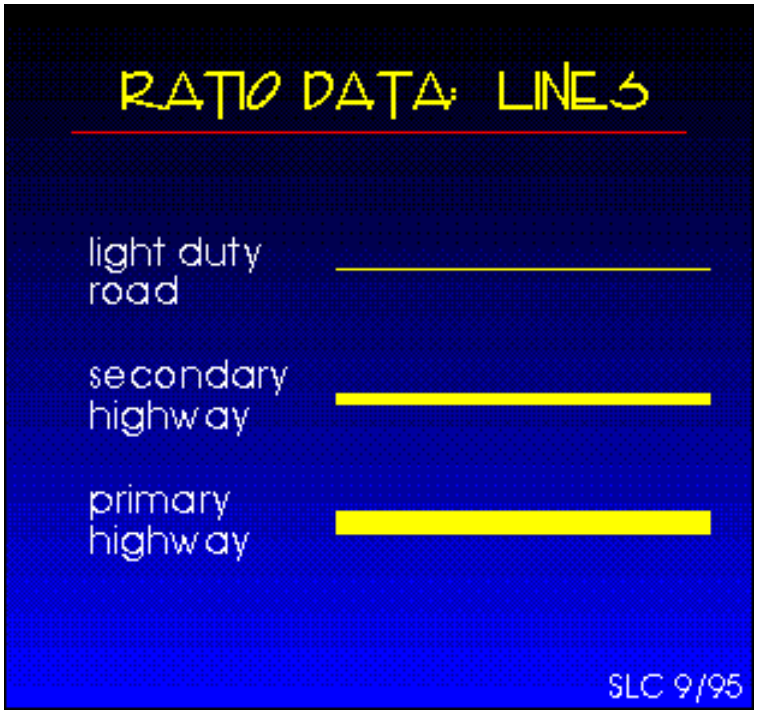
The Ratio Scale

- **Ratio data** - other type of continuous data that can be arranged along a scale but, in addition, the scale begins at a non-arbitrary zero point
  - At the zero point, no features are present
  - Multiplication and division can be employed with ratio data to consider proportions and magnitudes
  - Examples: Elevation above sea level, precipitation, population

The Ratio Scale

- **Ratio data**





Data Symbolization

•There are a number of characteristics of symbols that we can use of to make **visual distinctions** in **thematic information** (Jacques Bertin's **Visual Variables**):

- Size
- Shape
- Color Hue (color)
- Color Value (intensity)
- Texture
- Orientation
- Arrangement

Data Symbolization

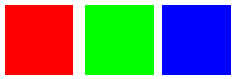
Size

- difference in geometric dimensions (e.g. length, height, diameter) of symbols
- useful for ordinal, interval, & ratio data; bad for nominal
- convention: larger size = greater quantity

Shape

- differences in forms of symbols can be abstract and "geometric", or iconographic
- useful for nominal data; bad for for ordinal, interval, & ratio
- too many shapes = cluttered & difficult for map reader to discriminate

Data Symbolization



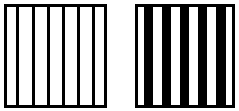
Color Hue (color)

- differences in wavelengths of light reflected (or emitted, in the case of computer monitors)
- useful for nominal data, can be used for ordinal & interval/ratio data but is tricky
- perceptual difficulties for some map readers is a problem (e.g. 6-8% males color-blind)

Color Value (intensity)

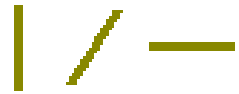
- relative lightness or darkness of symbols
- useful for ordinal, interval, & ratio data
- convention: darker = higher numerical values
- difficult for map readers to perceive more than four or five values

Data Symbolization



Texture

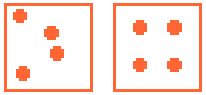
- size and spacing of elements that make up a single symbol
- dense vs. sparse
- can be used for all data scales
- danger of aesthetically unpleasing appearance



Orientation

- direction of symbols
- useful for nominal (e.g. wind direction)

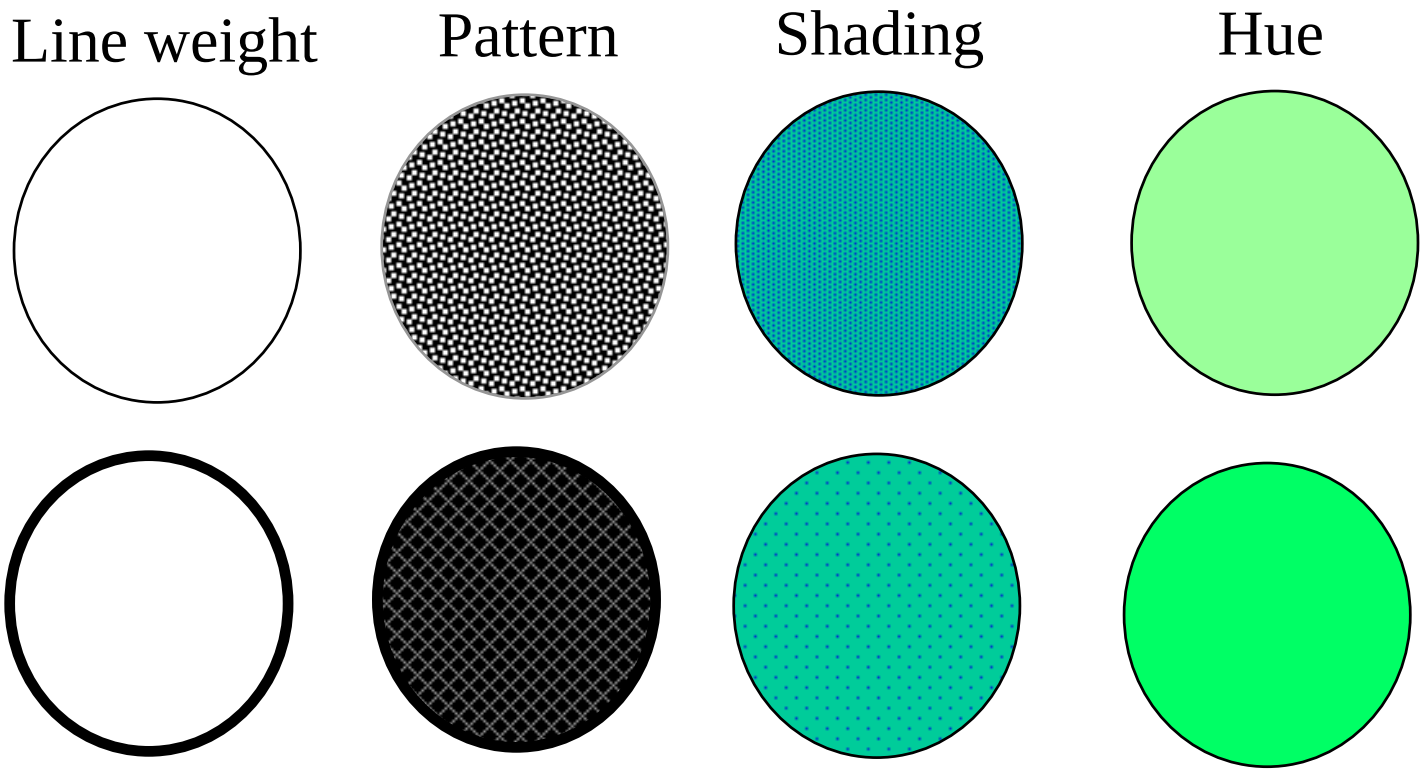
Data Symbolization



Arrangement

- configuration (random vs. organized or systematic patterns) of symbols
- useful for nominal, less so for ordinal, interval, & ratio data
- convention: random arrangements are often used to symbolize natural phenomena, systematic used to symbolize human-made phenomena

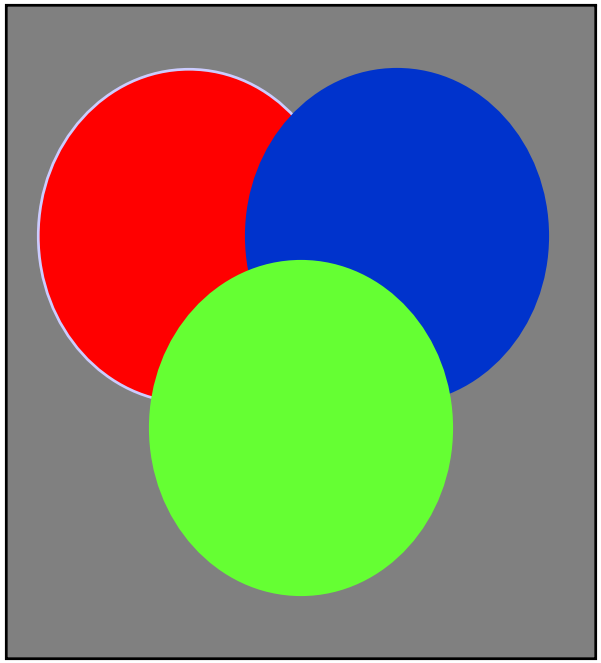
Symbol “weight”



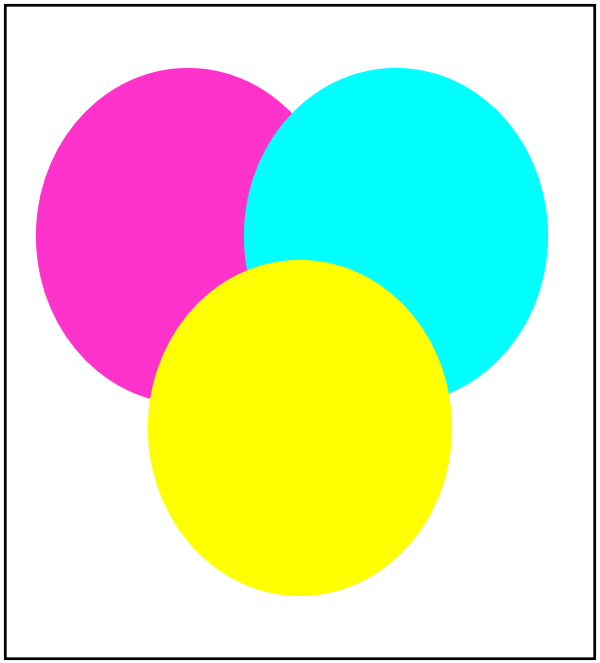
Color and Map Design

- Color is a **complex visual variable** and in a GIS is specified by RGB or HSI values.
- Red, Green, Blue are **additive** primaries.
- Magenta, Cyan and Yellow are **subtractive** primaries.
- Intensity maps **better** onto values than hue.

Color Primaries



Subtractive color



Additive color

Example: Choropleth Mapping

- Data should be **Areas** (e.g. States)
- Data should not suffer from **'area effect'**.
  - Population?
  - Per capita Income?
  - Elevation?
  - Temperature?
- Boundaries **unambiguous**.
- Areas **non-overlapping**.

Choropleth Maps

- Greek: choros (place) + plethos (filled)
- These are used to map categorical and quantitative data over defined areas
  - **polygonal enumeration units**

    e.g. census tract, counties, watersheds, etc.
- Data values are generally **classified** into ranges
  - allow map reader to readily interpret the map
- Polygons can produce **misleading** impressions
  - area/size of polygon vs. quantity of thematic data value

Thematic Mapping Issue: Modifiable Area Unit Problem

- Assumption:
  - Mapped phenomena are **uniformly** spatially distributed within each polygon unit
  - This is usually not true!
- **Boundaries** of enumeration units are frequently **unrelated** to the spatial distribution of the phenomena being mapped
- This issue is **always present** when dealing with data collected or aggregated by polygon units

Classifying Thematic Data

- Data values are **classified into ranges** for many thematic maps (especially choropleth)
  - This aids the reader's **interpretation** of map
- Trade-off:
  - presenting the underlying data **accurately**

    VS.
  - **generalizing** data using classes
- Goal is to **meaningfully classify** the data
  - **group features** with similar values
  - assign them the **same symbol**
- But how to **meaningfully** classify the data?

Creating Classes

- **How many** classes should we use?
  - too few - **obscures** patterns
  - too many - **confuses** map reader
    - difficult to recognize more than **seven** classes
- How do we **create** the classes?
  - assign classes **manually**: create meaningful classes, such as population above / below poverty level
  - **equal intervals**: This ignores the data distribution, which can be misleading too!

Creating Classes

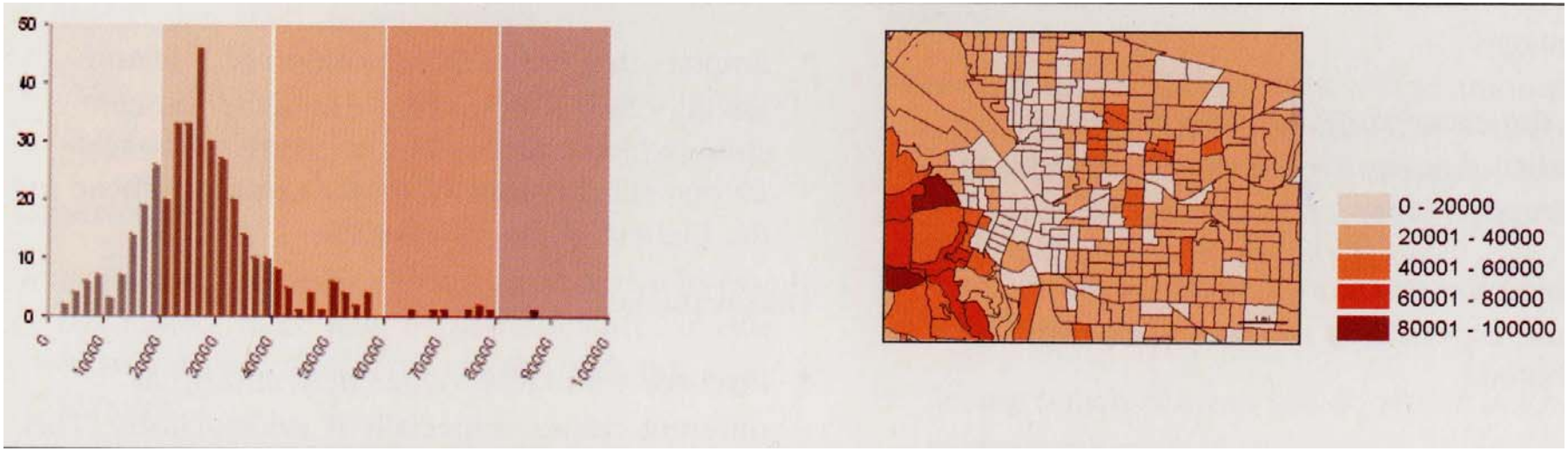
- How do we create the classes (cont.)
  - **"natural" breaks** based on data distribution: minimize within-class variation and maximize between-class variation
  - **quartiles**: top 25%, 25% above middle, 25% below middle, bottom 25% (quintiles uses 20%)
  - **standard deviation**: mean+1s, mean-1s, mean+2s, mean-2s, …

The Effect of Classification

- **Four common ways** to display continuous data in ArcGIS (i.e. these are options in Symbolization):
  - Equal Interval
  - Quantiles
  - Natural Breaks
  - Standard Deviation

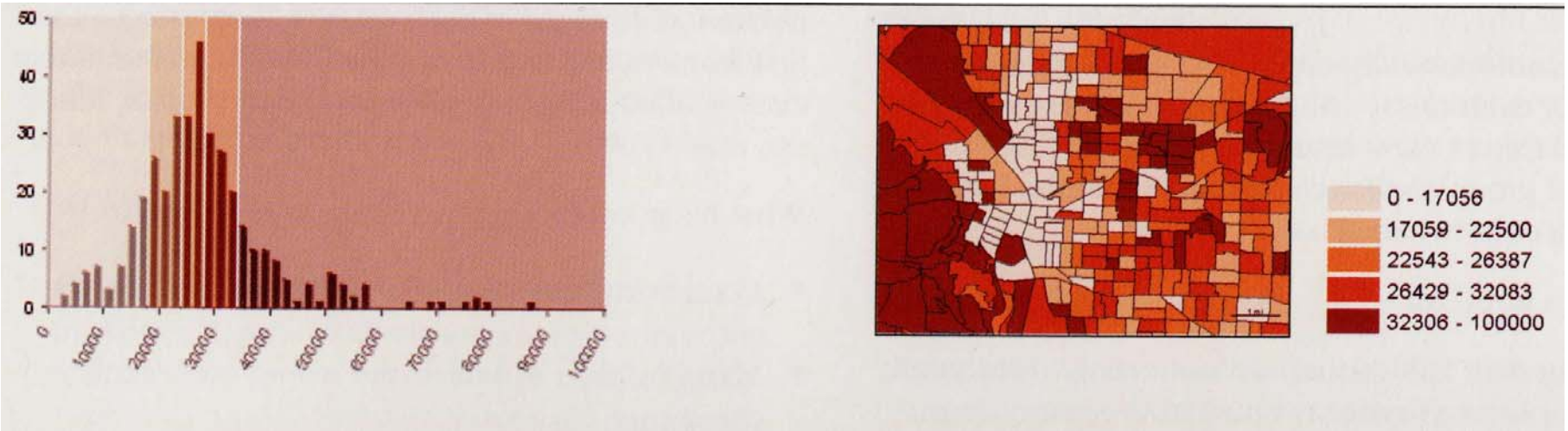
The Effect of Classification

- **Equal Interval**
  - Splits data into user-specified number of classes of **equal width**
  - Each class has a **different** number of observations



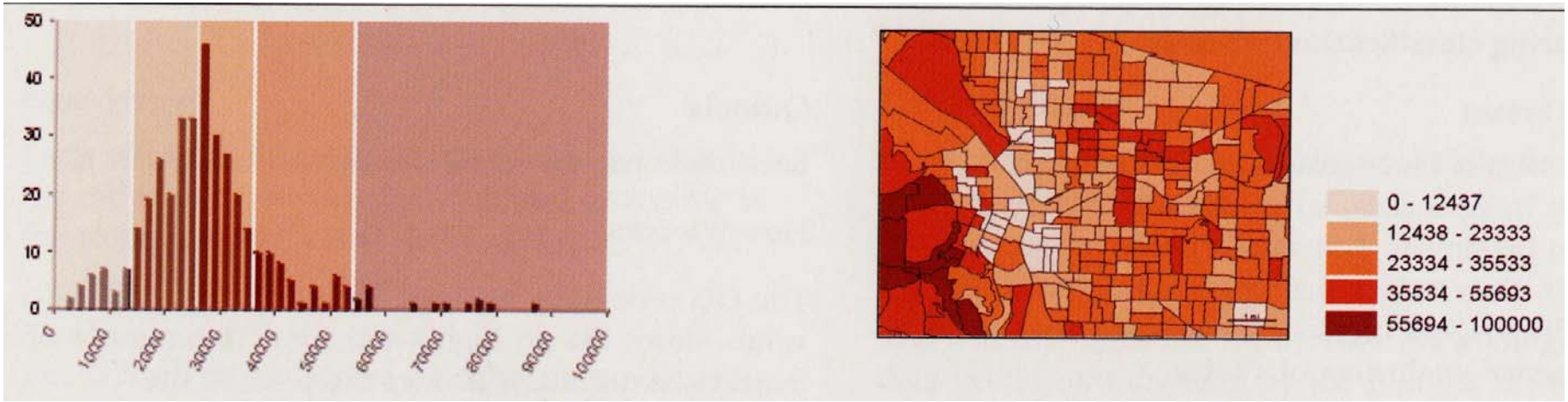
The Effect of Classification

- **Quantiles**
  - Data divided so that there are an **equal number of observations** are in each class
  - Some classes can have quite **narrow** intervals



The Effect of Classification

- **Natural Breaks**
  - Splits data into classes based on **natural breaks** represented in the data histogram



The Effect of Classification

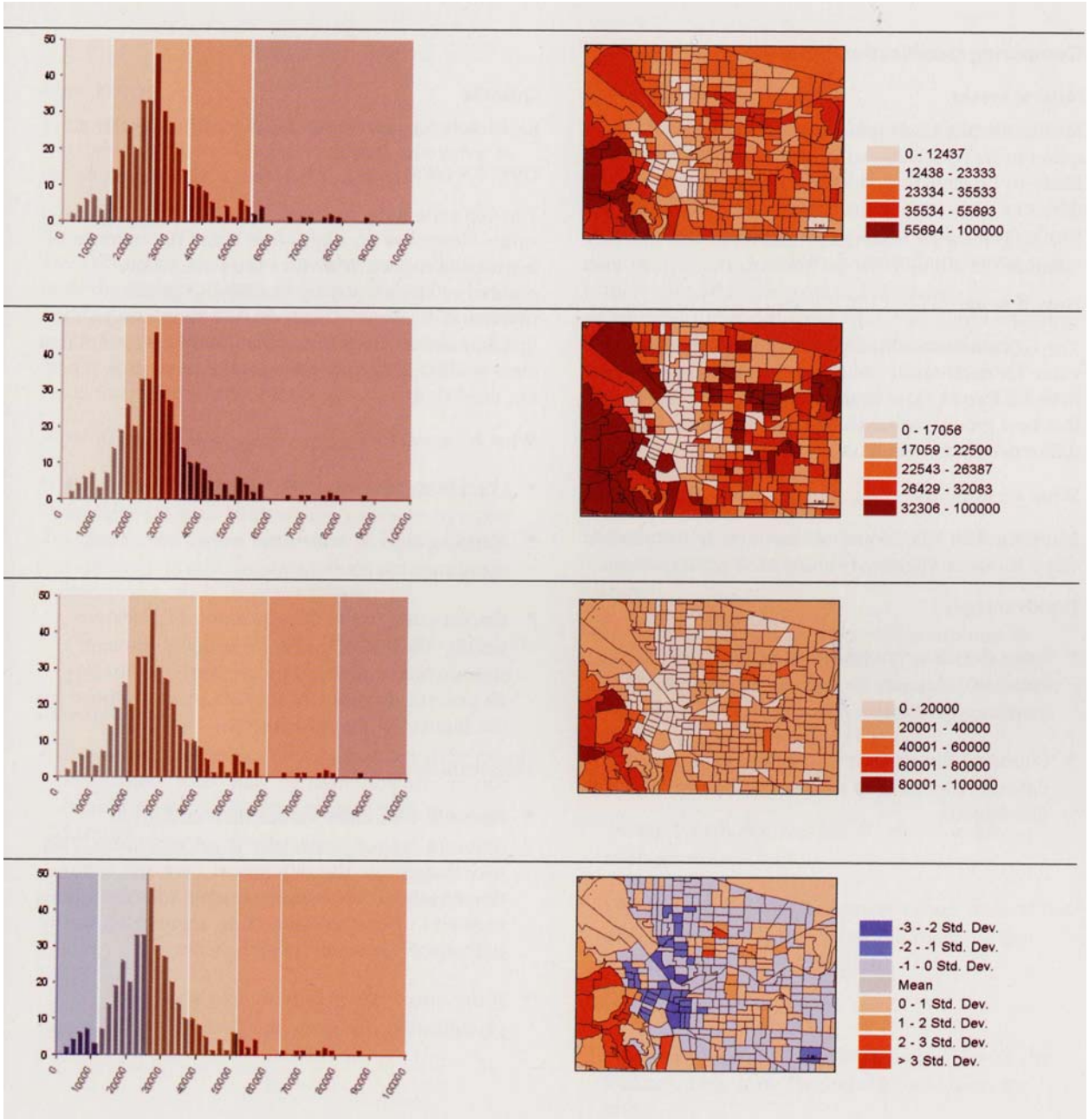
- **Standard Deviation**
  - Splits data into classes that represent values close to the mean and **increments of standard deviations** above and below the mean

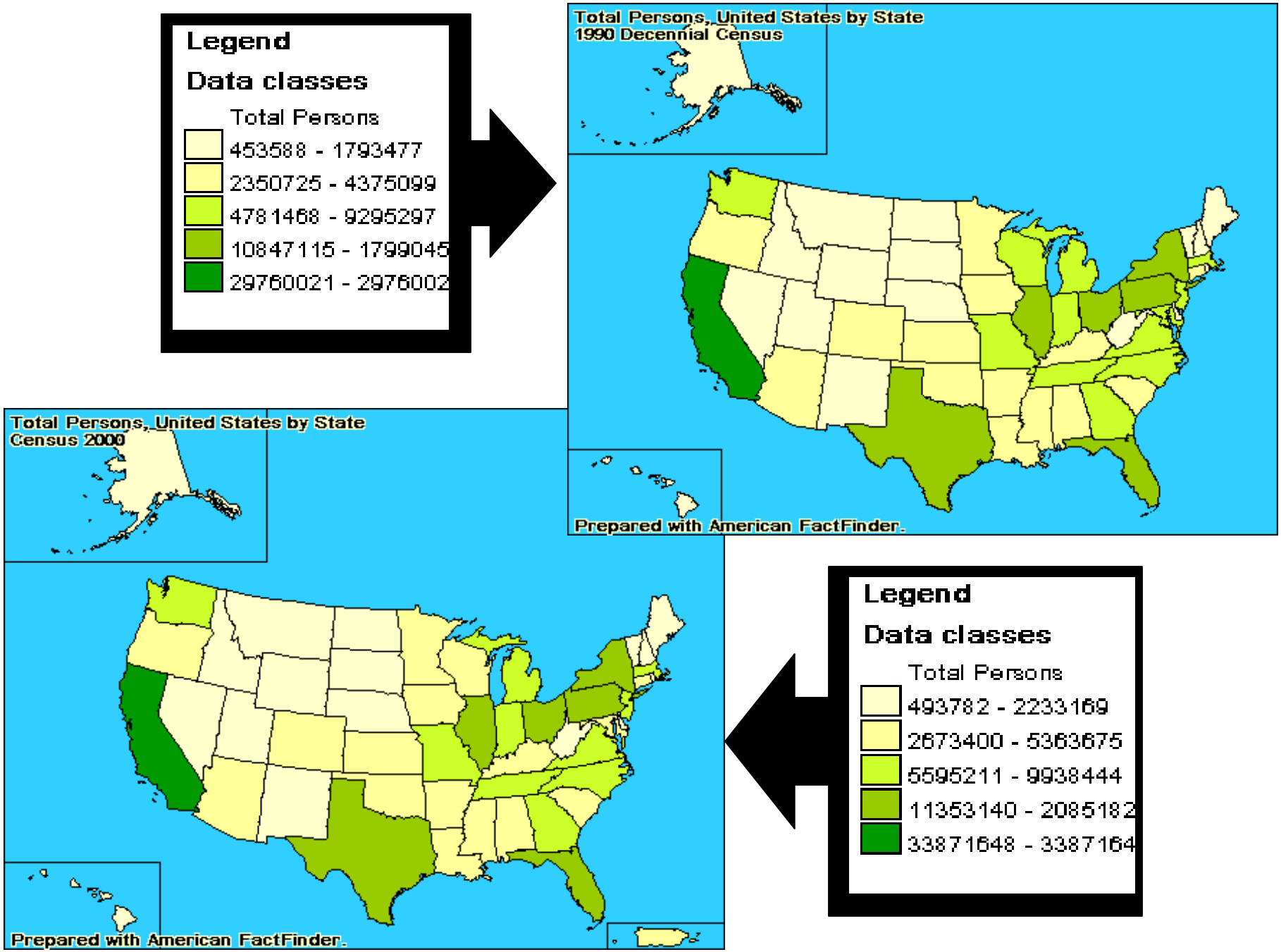
Natural Breaks

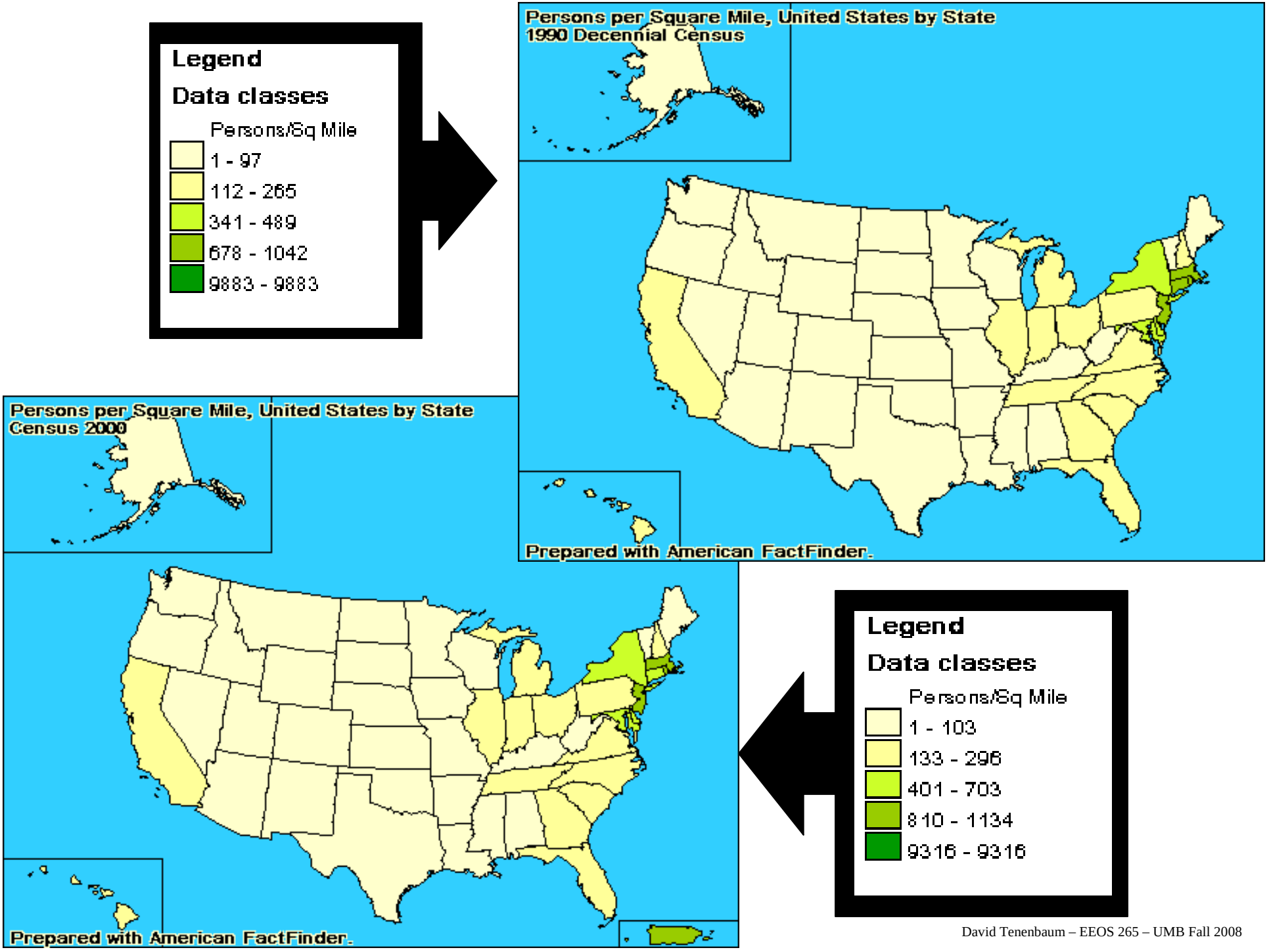
Quantiles

Equal Interval

Standard Deviation




Legend
Data classes
Total Persons
453588 - 1793477
2350725 - 4375099
4781468 - 9295297
10847115 - 1799045
29760021 - 2976002
Total Persons, United States by State
1990 Decennial Census
Prepared with American FactFinder.
Total Persons, United States by State
Census 2000
Prepared with American FactFinder.
Legend
Data classes
Total Persons
493782 - 2233169
2673400 - 5363675
5595211 - 9938444
11353140 - 2085182
33871648 - 3387164


Legend
Data classes
Persons/Sq Mile
1 - 97
112 - 265
341 - 489
678 - 1042
9883 - 9883
Persons per Square Mile, United States by State
1990 Decennial Census
Prepared with American FactFinder.
Persons per Square Mile, United States by State
Census 2000
Prepared with American FactFinder.
Legend
Data classes
Persons/Sq Mile
1 - 103
133 - 296
401 - 703
810 - 1134
9316 - 9316

The Need for Design

- To appear professional and avoid errors, GIS maps should **reflect cartographic knowledge** about map design.
- A map has a **visual grammar** or structure that must be understood and used if the **best map design** is desired.
- **Cartographic conventions** must be obeyed (e.g. forests should be green).

Map Design

- A GIS map is designed in a process called the **design loop**.
- **Good map design** requires that map elements be placed in a **balanced arrangement** within the neat line.

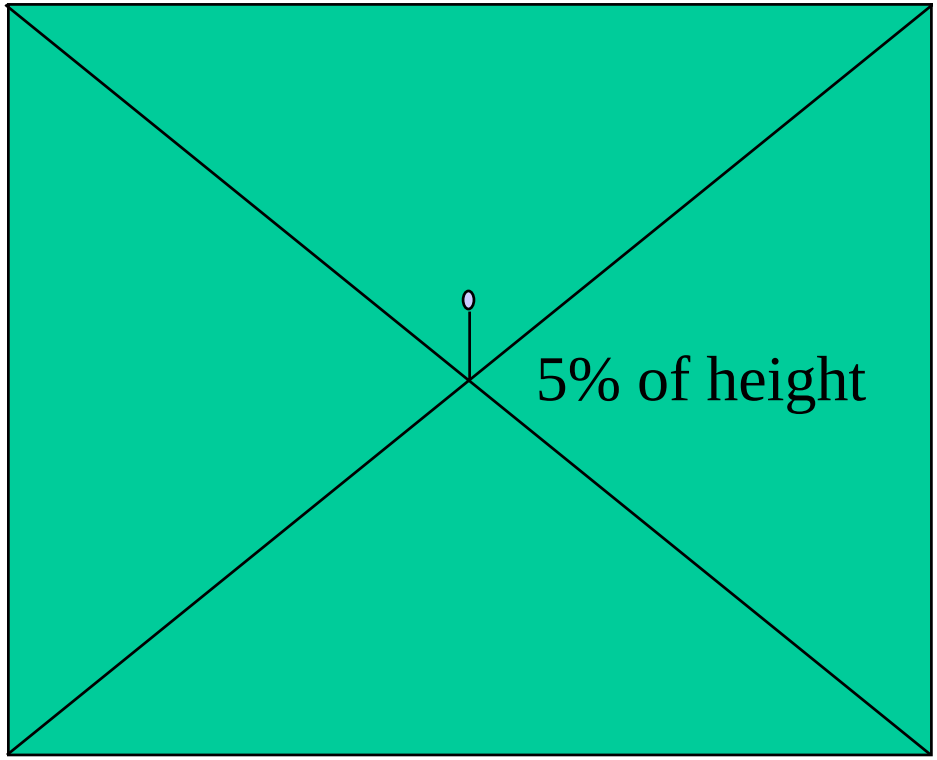
The Design Loop

- **Create** map layout / **draw** on screen
- **Look**
- **Edit** map layout
- Look **again**
- **Repeat** until happy
- Make **final** plot

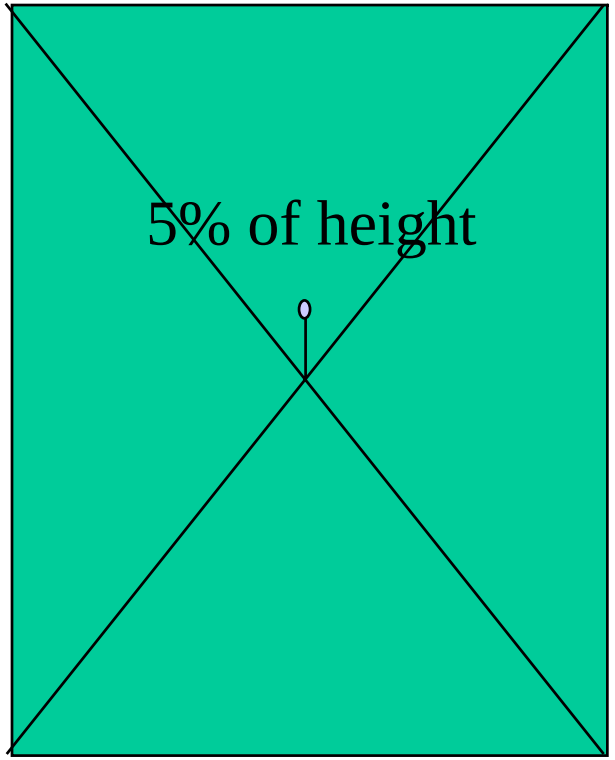
Map Design

- **Visual balance** is affected by:
  - the **"weight"** of the symbols
  - the **visual hierarchy** of the symbols and elements
  - the **location** of the elements with **respect to each other** and the **visual center** of the map.

Visual center

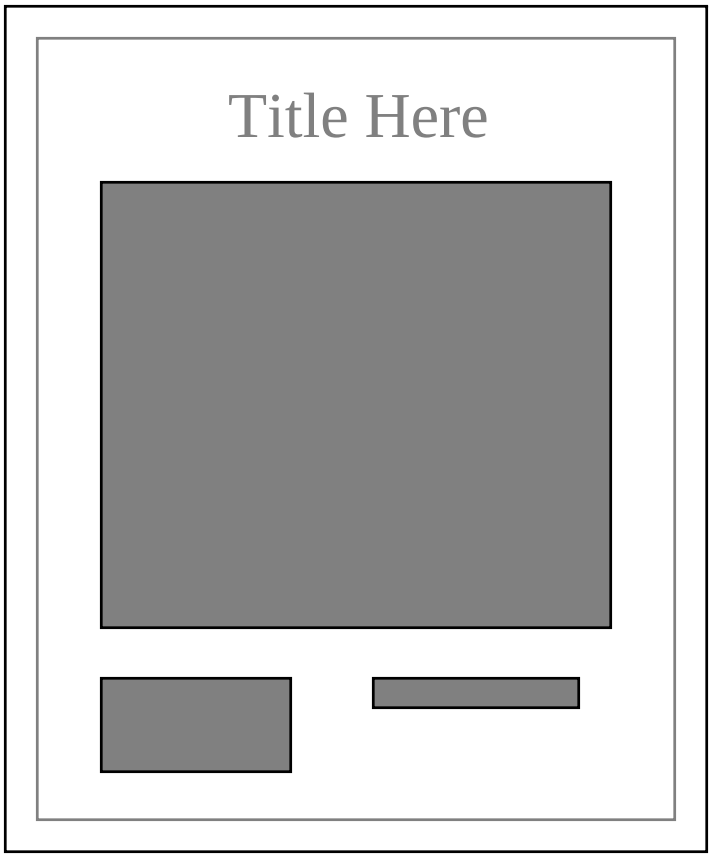


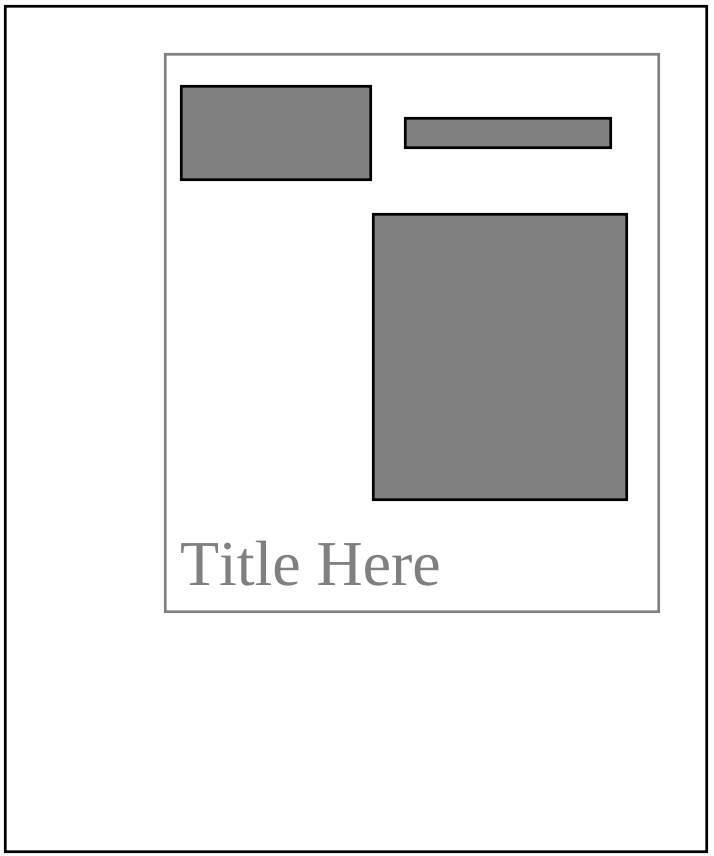
Landscape



Portrait

Visual Layout

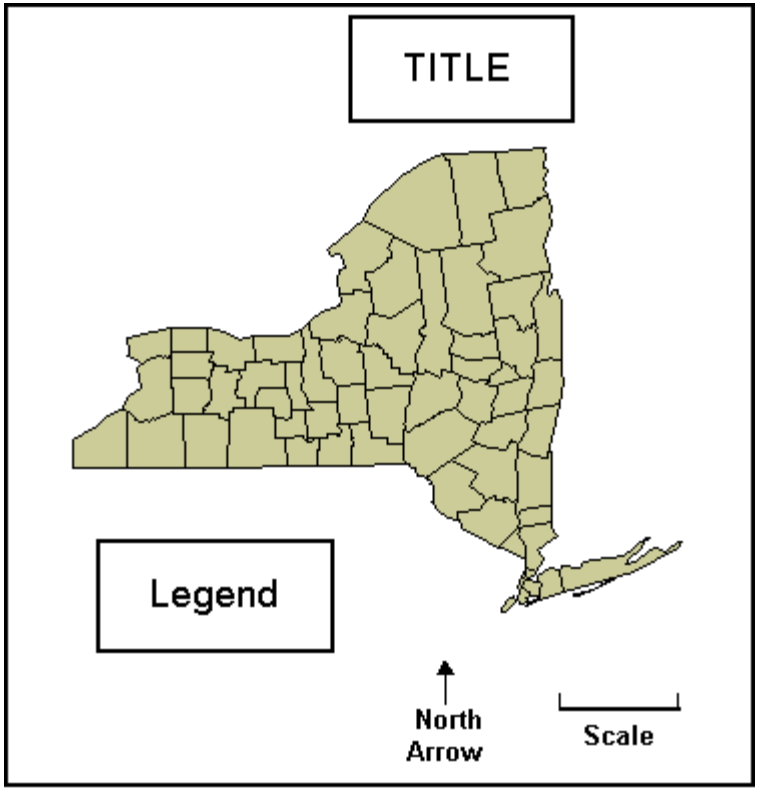




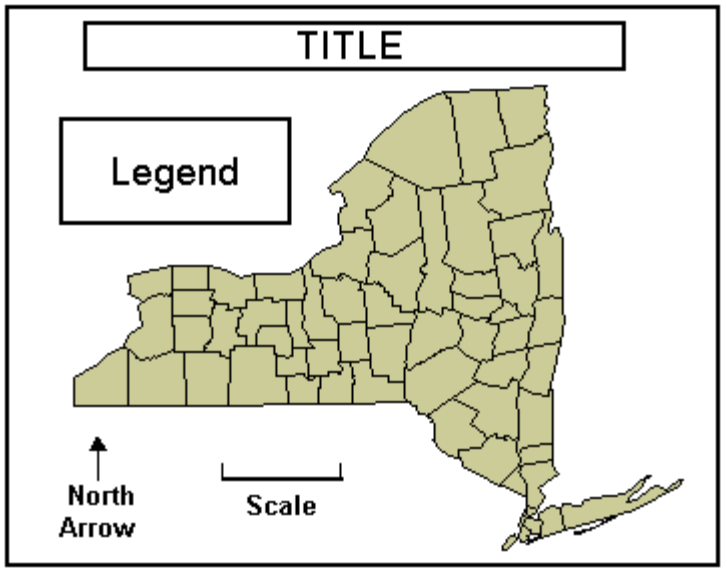
Eye expects (1) balance and (2) alignment

Design Guidelines

Map layout - visual balance



Poor visual balance

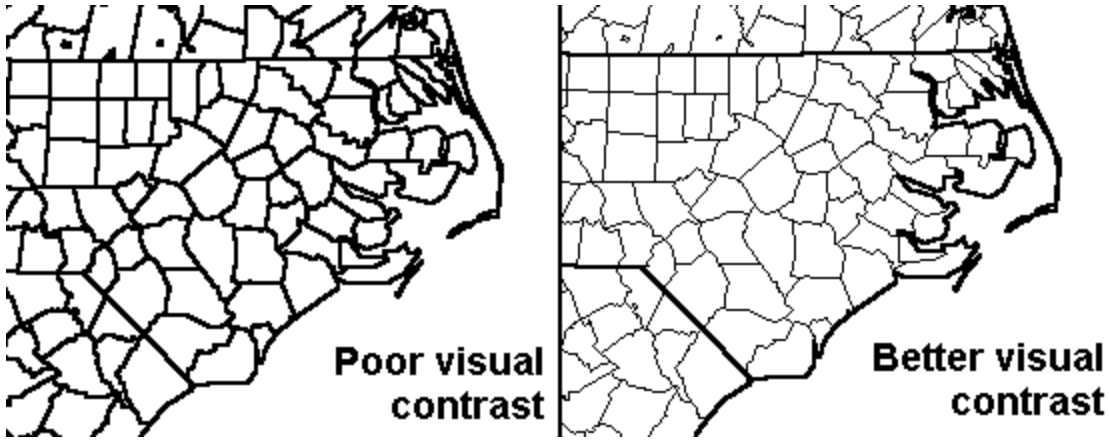


Better visual balance

- Based on the **graphic weight** (or visual weight) of the map elements relative to the **visual center**

Design Guidelines

Visual contrast



- **Variation** and **contrast** will improve legibility
- Can be **expressed** with size, intensity, and shape of map elements and symbolization.

Design Guidelines

Figure-Ground Relationships

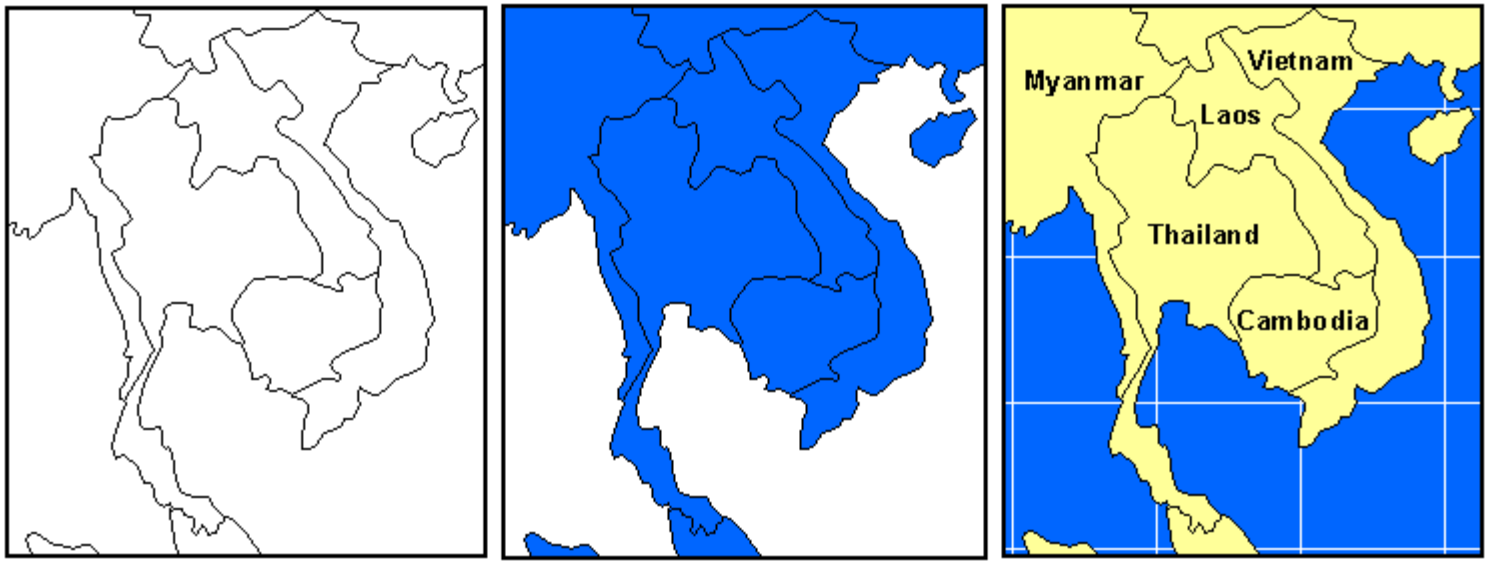
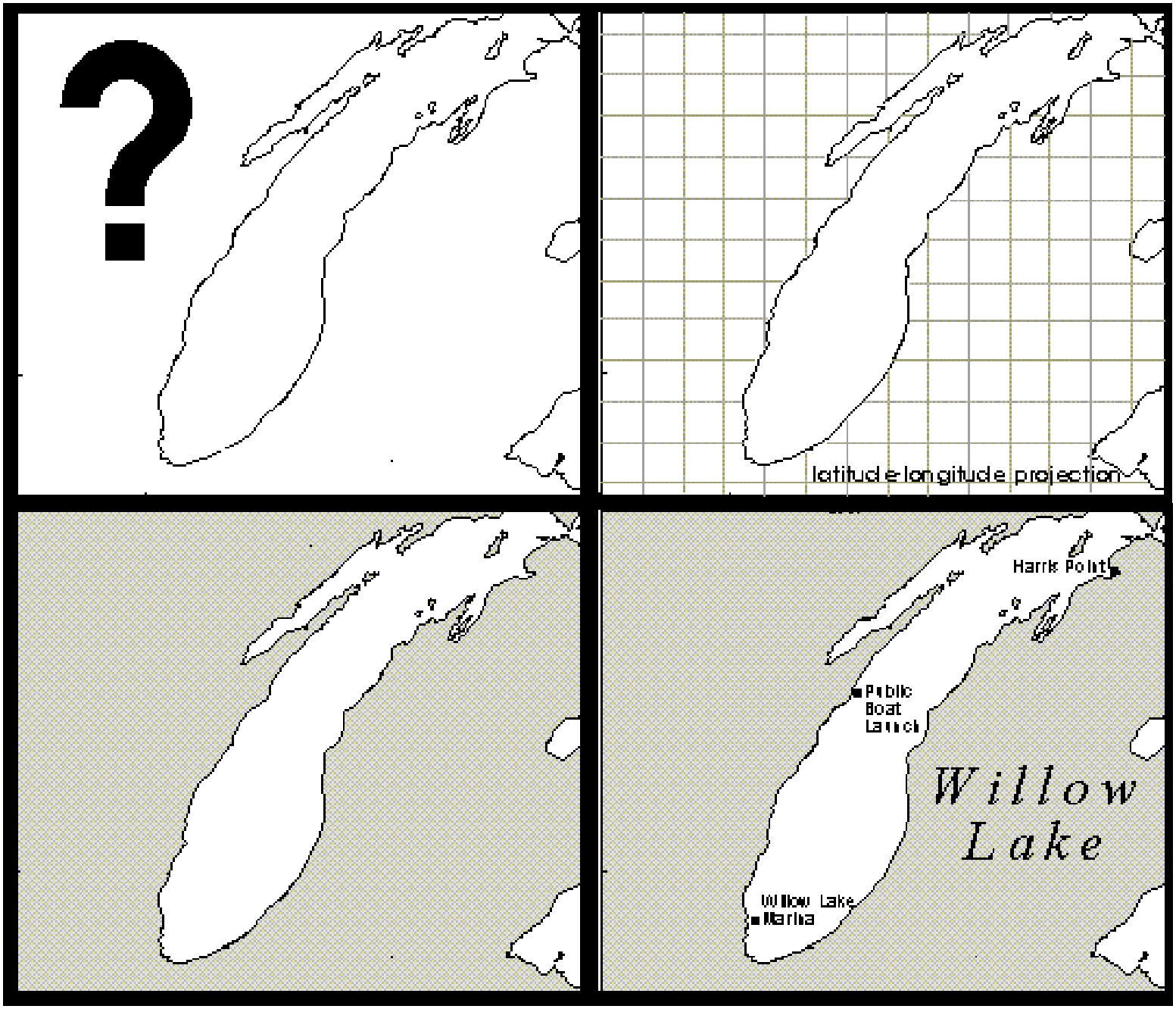


Figure-Ground Relationships

- **Figure**: eye settles on and sees clearly
- **Ground**: amorphous area around the figure that map readers will not perceive as readily
- Relationships used to **focus** reader's attention


?
latitude longitude projection
Harris Point
Public Boat Launch
Willow Lake
Willow Lake Marina

Design Guidelines

Legibility/Clarity

•Must consider the **final production medium!**

–book, poster-sized map, computer display, web page

•Reduction factor:

–will the map be **reduced** for the final version?

Simplicity

•**Economy of expression** - less is frequently more

•only include elements for which you have a **defensible reason** for their presence

•compose maps as if they were essays in freshman composition course

Map Design and GIS

- When a GIS map is the result of a complex analytical or modeling process, **good design is essential** for understanding.
- The map is what **distinguishes** GIS as a different approach to the management of information, so **extra care should be taken** to improve the final maps that a GIS generates in a GIS task.

Chapter 7: Making Maps with GIS

- 7.1 The Parts of a Map
- 7.2 Choosing a Map Type
- 7.3 Designing the Map

Next Topic:

How to Pick a GIS