CS60111: GEOGRAPHICAL INFORMATION SYSTEM

- Teacher: **Prof. Soumya K Ghosh**, CSE
- TA: **Ms. Riya Samanta, Mr. Susovan Halder, Mr. Manish Kumar Garg**

Mon (11:00 – 11:55)
Tue (08:00 – 09:55)

Course Page

http://www.facweb.iitkgp.ac.in/~skg/GIS22/

Books and References

- Spatial Databases: A Tour, by Shashi Shekhar, Sanjay Chawla, Prentice Hall
- Principles of geographical information systems, by P. A. Burrough, Oxford Press
- ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems
- Open Geospatial Consortium (OGC): http://www.opengeospatial.org/
- ACM Transactions on Spatial Algorithms and Systems
- *[DBMS] Database System Concepts, by Avi Silberschatz, Henry F. Korth, S. Sudarshan*

1

GIS – Geographic Information System

- *Spatial Database*
- *Spatial Data Analysis*
- *Spatial Data Science*

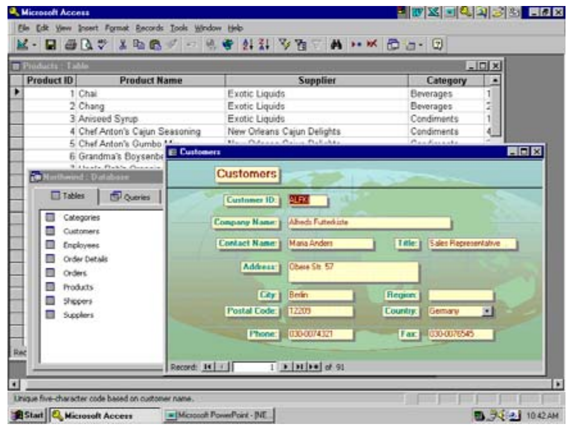
2

Information System?

In the digital environment we use software to create complex information systems.

D a t a b a s e

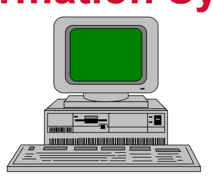
M a n a g e m e n t



3

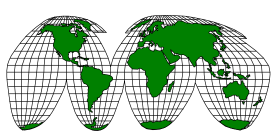
GIS?

Information System



+

Geographic Position

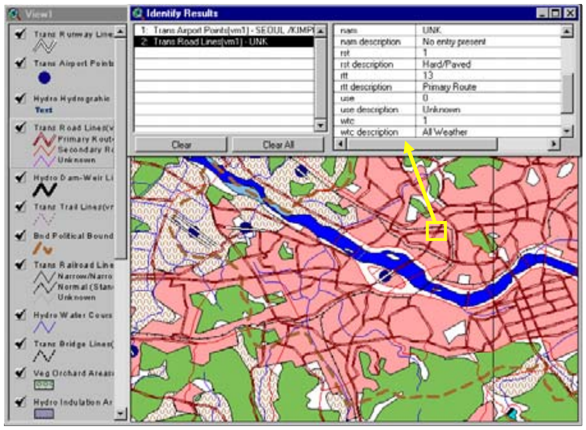


A means of storing, retrieving, sorting, and comparing *spatial data* to support some analytic process.

4

GIS?

GEOGRAPHIC Information System



GIS links graphical features (**entities**) to tabular data (**attributes**)

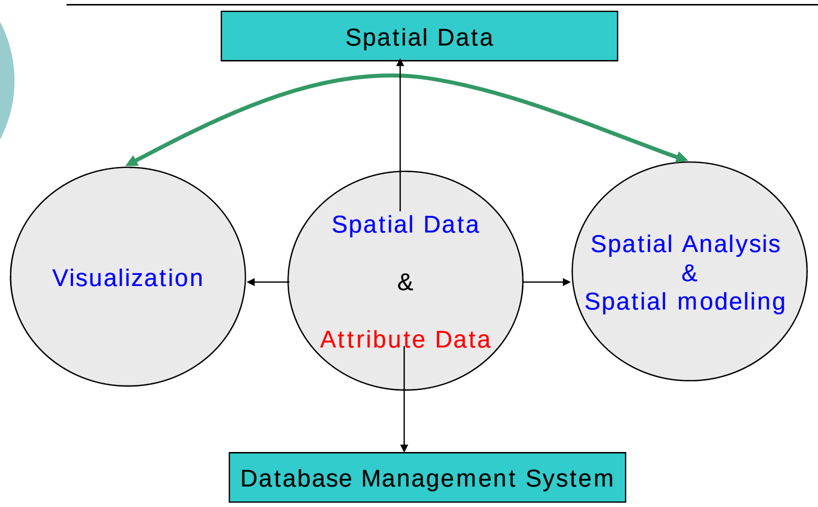
5

GIS Definition

- A GIS is a system (hardware + database engine) that is designed to efficiently, assemble, store, update, analyze, manipulate, and display **geographically referenced information** (data identified by their locations).
- *A GIS also includes the **people** operating the system and the **data** that go into the system.*

6

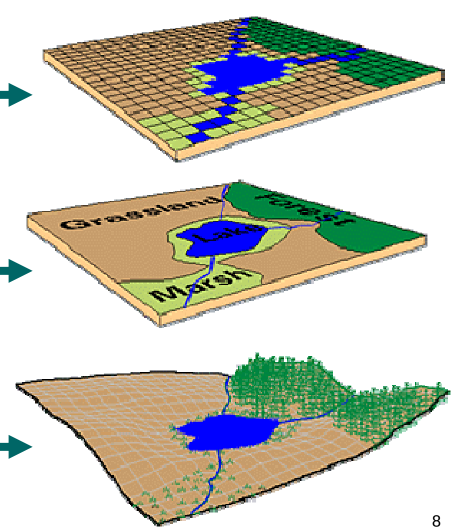
Key Components of GIS



7

Spatial Data Modeling

- RASTER →
- VECTOR →
- Real World →



8

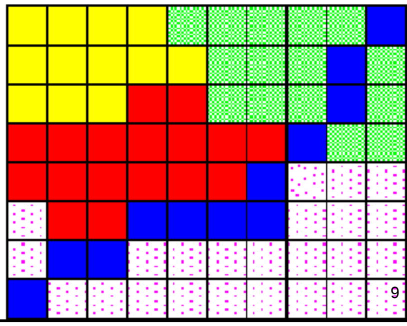
Representing Spatial Elements
Raster

Stores images as rows and columns of numbers with a Digital Value/Number (DN) for each cell.

Units are usually represented as square grid cells that are uniform in size.

Data is classified as "*continuous*" (such as in an image), or *"thematic"* (where each cell denotes a feature type).

Numerous data formats (TIFF, GIF, ERDAS.img etc)

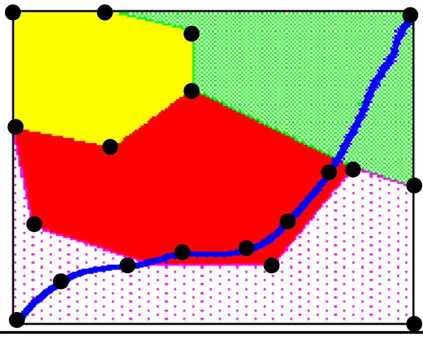


9

Representing Spatial Elements
Vector

Allows user to specify specific spatial locations and assumes that geographic space is continuous, not broken up into discrete grid squares

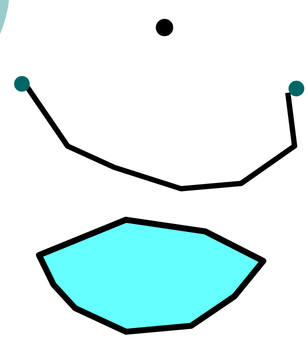
We store features as sets of X,Y coordinate pairs.



10

Entity Representations

We typically represent objects in space as three distinct spatial elements:



Points - simplest element

Lines (arcs) - set of connected points

Polygons - set of connected lines

We use these three spatial elements to represent real world features and attach locational information to them.

11

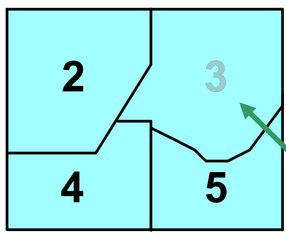
Attributes

- In the raster data model, the cell value (Digital Number) is the attribute. Examples: brightness, land-cover code, SST, etc.
- For vector data, attribute records are linked to point, line & polygon features. Can store *multiple* attributes per feature. Vector features are linked to attributes by a *unique feature number*.

12

Linking Spatial Entity with Attributes

1 (Universe polygon)

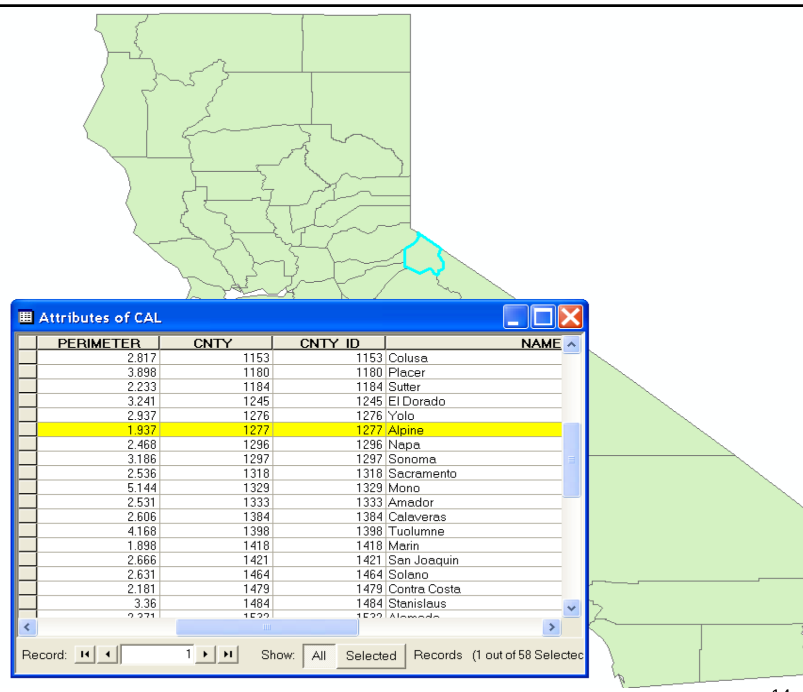


Spatial data
(ARC functions)

Attribute data
(INFO or TABLES functions)

COV#	ZONE	ZIP
1		0
2	C-19	22060
3	A-4	22061
4	C-22	22060
5	A-5	22057

13



Attributes of CAL

PERIMETER	CNTY	CNTY ID	NAME
2.817	1153	1153	Colusa
3.898	1180	1180	Placer
2.233	1184	1184	Sutter
3.241	1245	1245	El Dorado
2.937	1276	1276	Yolo
1.937	1277	1277	Alpine
2.468	1296	1296	Napa
3.186	1297	1297	Sonoma
2.536	1318	1318	Sacramento
5.144	1329	1329	Mono
2.531	1333	1333	Amador
2.606	1384	1384	Calaveras
4.168	1398	1398	Tuolumne
1.898	1418	1418	Marin
2.666	1421	1421	San Joaquin
2.631	1464	1464	Solano
2.181	1479	1479	Contra Costa
3.36	1484	1484	Stanislaus

Record: 1 Show: All Selected Records (1 out of 58 Selectec

14

Raster vs. Vector

Raster Advantages

The most common data format

Easy to perform mathematical and overlay operations

Satellite information is easily incorporated

Better represents "continuous"- type data

Vector Advantages

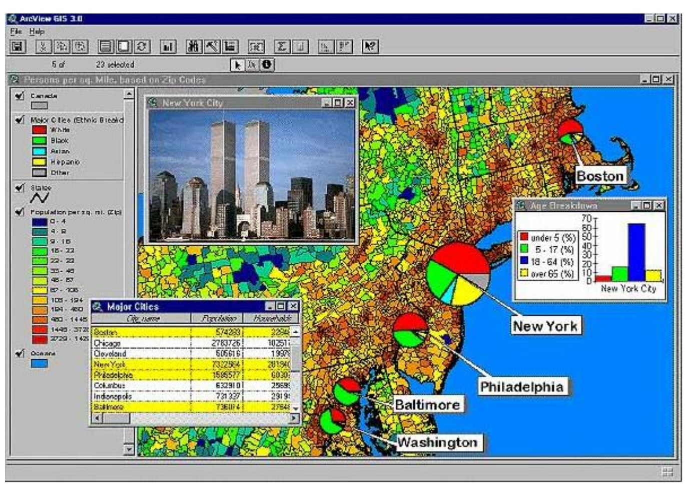
Accurate positional information that is best for storing discrete thematic features (e.g., roads, shorelines, sea-bed features.

Compact data storage requirements

Can associate unlimited numbers of attributes with specific features

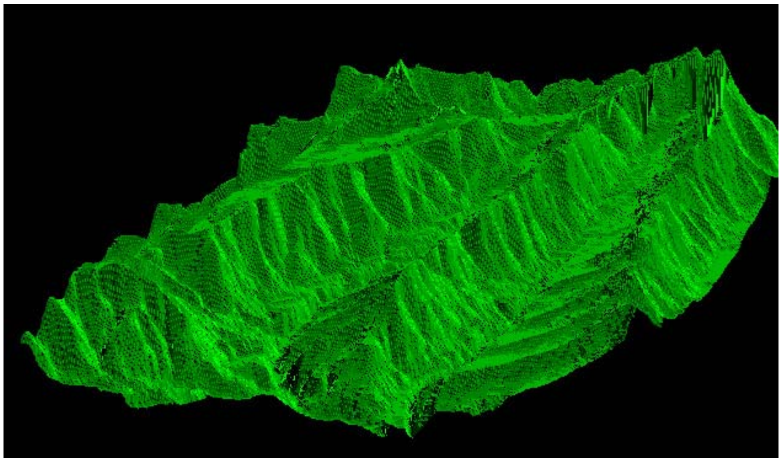
15

Visualization



16

Visualization



17

Spatial Analysis/Modeling

Spatial Operation

- Buffering
- Overlay

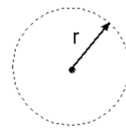
Spatial Statistics

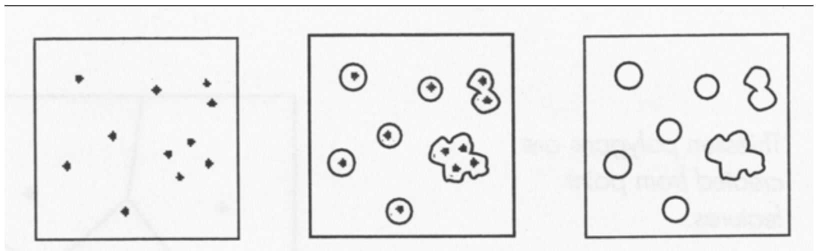
Spatial Data Mining

18

Proximity Analysis

Buffer: Delineation of a zone around the feature of interest within a given distance. For a point feature, it is simply a circle with its radius equal to the buffer distance.

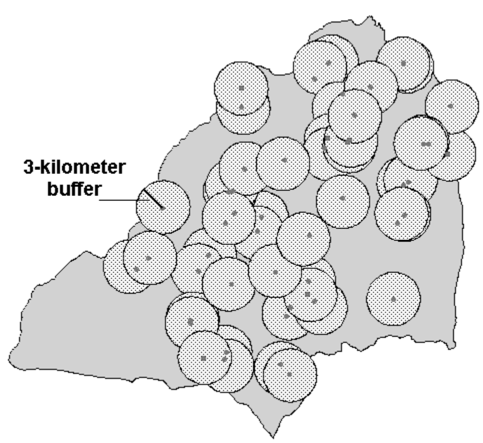




19

Buffer Example

- Rural district in N.E. Thailand
- 51 study villages:
- Evaluate land use in the district relative to population change
- Need to determine types & quantities of land use surrounding each village:
  - generate 3-km buffers around village centroids
  - overlay buffers on land-cover classification generated from satellite imagery
  - use buffers to “cut out” land near each village and summarize land uses within “cut out” area

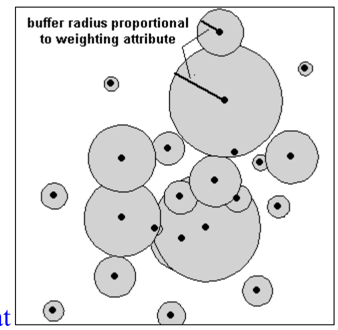


20

Variable Distance Buffer

Buffer zone can be made variable according to certain attributes.

Suppose we have a point pollution source, such as a power plant. We certainly want to keep our residential area away a distance from it. However, this distance can be made variable according to the amount of pollution that a power plant produces. For small power plant, the distance can be short, while for large power plant that generate a lot of pollutant, we should keep a longer distance from it. As we is shown on the right.



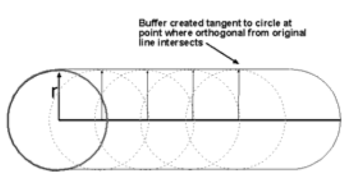
21

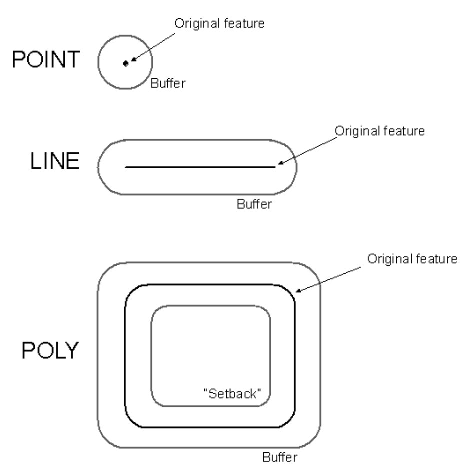
Buffers for lines and Polygons

Move circle of specified radius along lie (or lines forming polygon)

Draw orthogonal from line to edge of circle

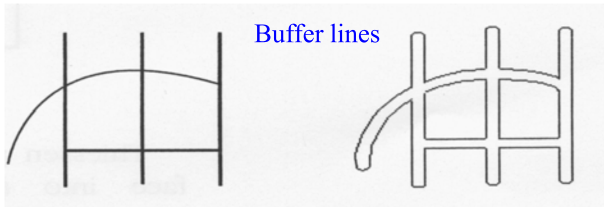
Buffer line is tangent to circle where the orthogonal intersects it.



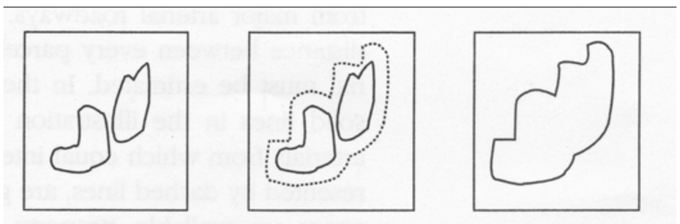


22

Lines and Polygons Buffer Example

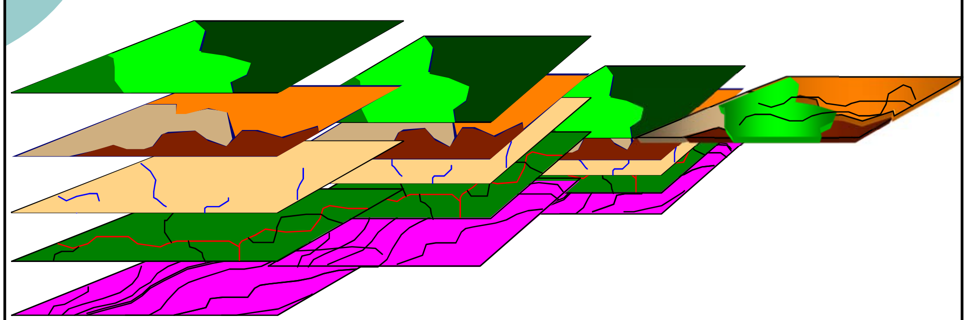


Buffer polygons



Spatial Analysis

- Overlay function creates new “layers” to solve spatial problems



Spatial Operation with Multiple Vector Layers

- ***Overlay*** analyses
  - Operate on spatial entities from two or more maps to determine spatial *overlap*, *combination*, *containment*, *intersection*…*etc.*
  - one of the most "fundamental" of GIS operations
  - formalized in 1960s by landscape architects who used acetate map overlays
  - now a basic part of the GIS toolbox
- Vector overlays-
  - combine point, line, and polygon features
  - computationally complex
- Raster overlays-
  - cell-by-cell comparison, combination, or operation
  - computationally less demanding

25

Spatial Operation with Multiple Vector Layers

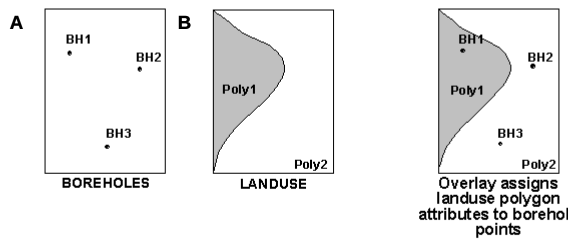
- Basic idea:
  - spatially combine/compare two data layers to:
    - (a) generate new output data layer, or
    - (b) assign attributes of one data layer to another
  - most cases: one of the data layers will contain polygon entities
- Point-in-polygon overlay →
  - increasing conceptual and computational complexity

26

Point-in-polygon vector overlay

- Overlay point layer (A) with polygon layer (B)
  - in which B polygon are A points spatially located?
    - » assign polygon attributes from B to points in A

Example: comparing soil mineral content at sample borehole locations (points) with landuse (polys)...



Point	Zn	Pb
BH1	140	65
BH2	178	54
BH3	101	87

Poly	Landuse
1	Agriculture
2	Urban

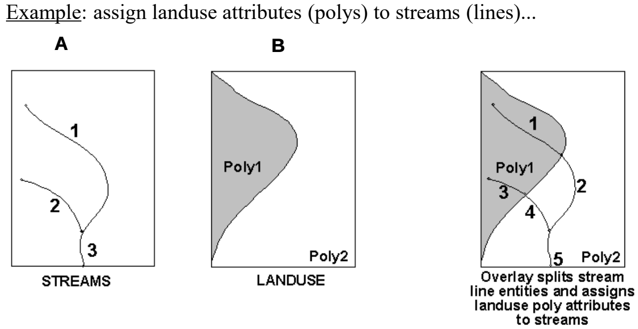
Point	Zn	Pb	Landuse
BH1	140	65	Agriculture
BH2	178	54	Urban
BH3	101	87	Urban

27

Line-in-polygon vector overlay

- Overlay line layer (A) with polygon layer (B)
  - in which B polygons are A lines spatially located?
    - » assign polygon attributes from B to lines in A

Example: assign landuse attributes (polys) to streams (lines)...



Line	Length
1	780
2	520
3	225

Poly	Landuse
1	Agriculture
2	Urban

Line	Length	Landuse
1	440	Agriculture
2	340	Urban
3	220	Agriculture
4	300	Urban
5	225	Urban

28

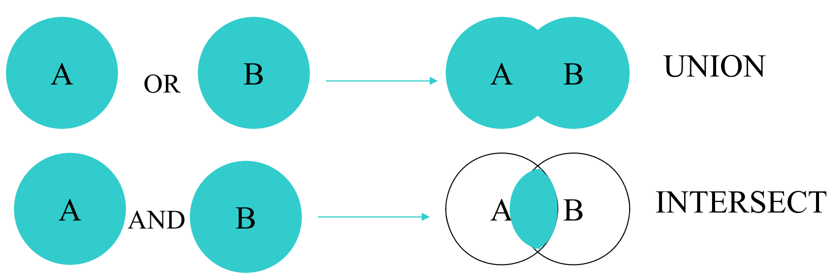
Polygon-Polygon vector overlay

- Overlay polygon layer (A) with polygon layer (B)
  - result: what are the spatial polygon combinations of A and B?
  - » generate new data layer with combined polygons
    - attributes from both polygon layers are included in output
- How are polygons combined?
  (i.e. what geometric rules are used for combination?)
  - UNION (Boolean OR)
  - INTERSECTION (Boolean AND)
  - IDENTITY
- Polygon overlay will generally result in a significant increase in the number of spatial entities in the output
  - can result in output that is too complex too interpret

29

Boolean Operations

Some of the fundamental overlay analysis for vector data are UNION, and INTERSECT corresponding to Boolean operations of OR, AND



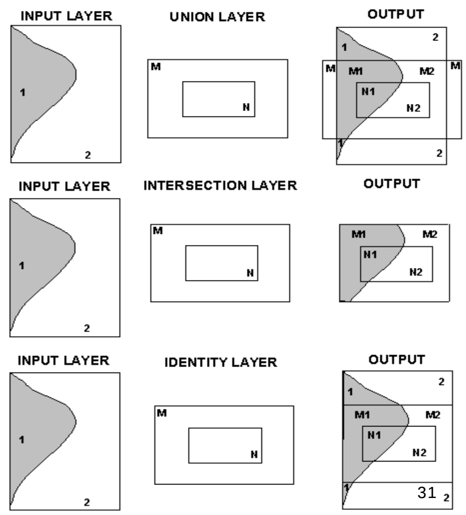
30

Polygon-polygon vector overlay (cont'd.)

UNION
overlay polygons and keep areas from both layers

INTERSECTION
overlay polygons and keep only areas in the input layer that fall within the intersection layer

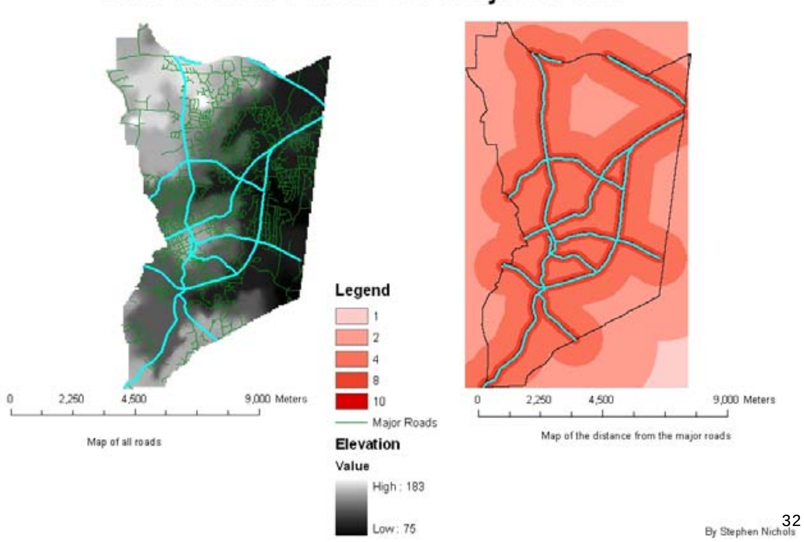
IDENTITY
overlay polygons and keep areas from input layer



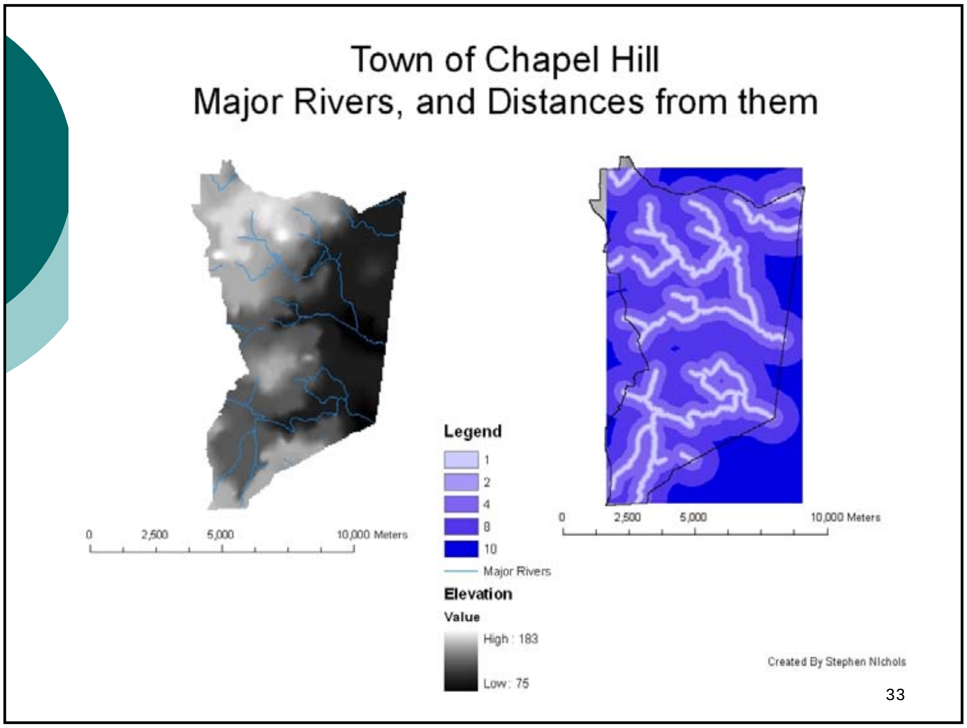
31

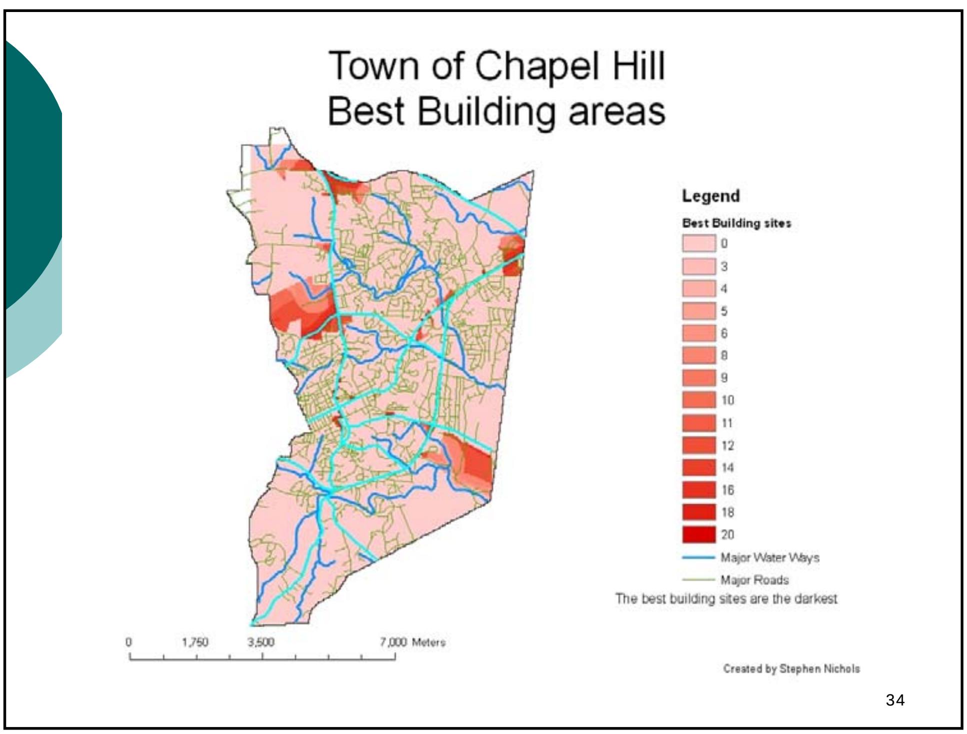
GIS Application – *Region-of-Interest*

Town of Chapel Hill Major Roads
and distance from the major roads



32


Town of Chapel Hill
Major Rivers, and Distances from them
0 2,500 5,000 10,000 Meters
Legend
1
2
4
8
10
Major Rivers
Elevation
Value
High : 183
Low : 75
0 2,500 5,000 10,000 Meters
Created By Stephen Nichols
33


Town of Chapel Hill
Best Building areas
Legend
Best Building sites
0
3
4
5
6
8
9
10
11
12
14
16
18
20
Major Water Ways
Major Roads
The best building sites are the darkest
0 1,750 3,500 7,000 Meters
Created by Stephen Nichols
34

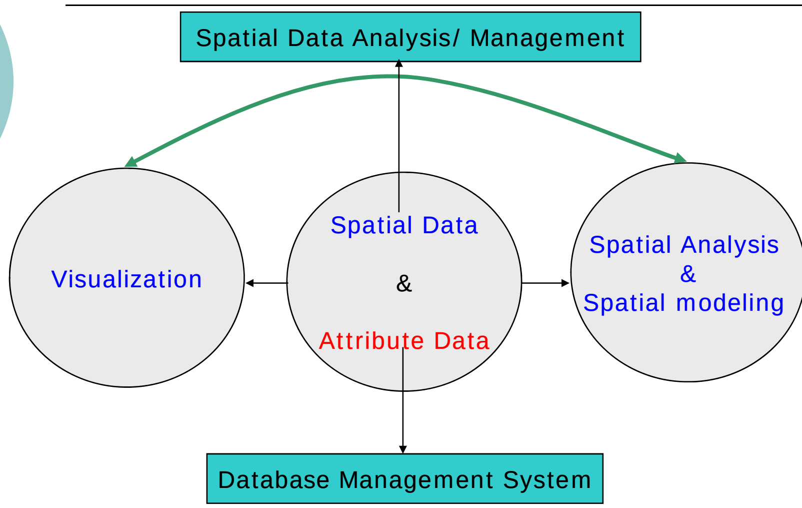
GIS software

- ESRI products: ArcGIS, Arc/Info …
- MapInfo
- AutoDesk products: AutoCAD

- Clark University: IDRISI
- GRASS

35

Summary



36