GEOG 204

LECTURE 4
Spatial Analysis

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Spatial Analysis

- In a GIS,
  - Data are usually grouped into layers (or themes).
  - The analysis functions of a GIS use both spatial and non-spatial data
  - Analysis functions are used
    - for maintenance of the data
    - Computing new information from the data
- Spatial Analysis can be viewed as:
  - Operations that use spatial data to derive new spatial information.
  - The most distinguishing purpose of a GIS

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Topology

- Topology: The spatial relationships between adjacent or neighboring features.
  - Based on 3 basic elements, Adjacency, Containment and Connectivity
  - Allows analyses like as contiguity, containment, connectivity, overlap…
    - For example, it is used in routing through linear networks. Routes cannot be established through the network if the line features do not share nodes/vertices.

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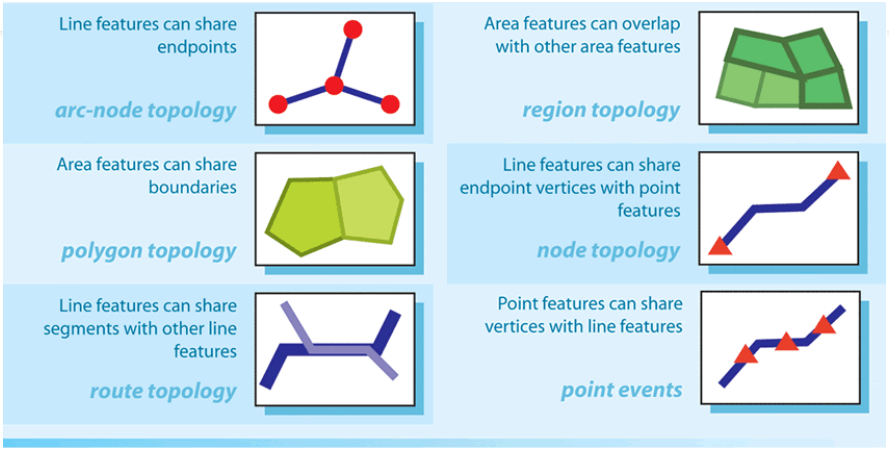
Topology



Source: ESRI

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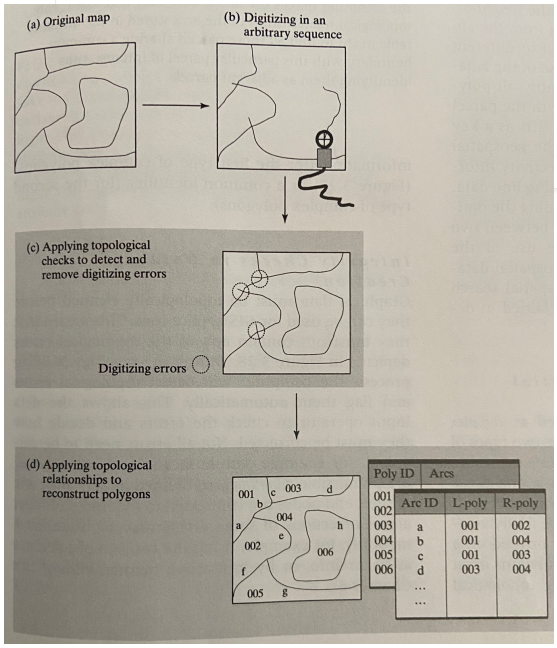

Topological Relationships: Areas of Usage

- Data input and representation
  - Identify and store adjacency, connectivity & containment information
    - field data collection, digitizing
    - E.g. Left/Right of polygon or line

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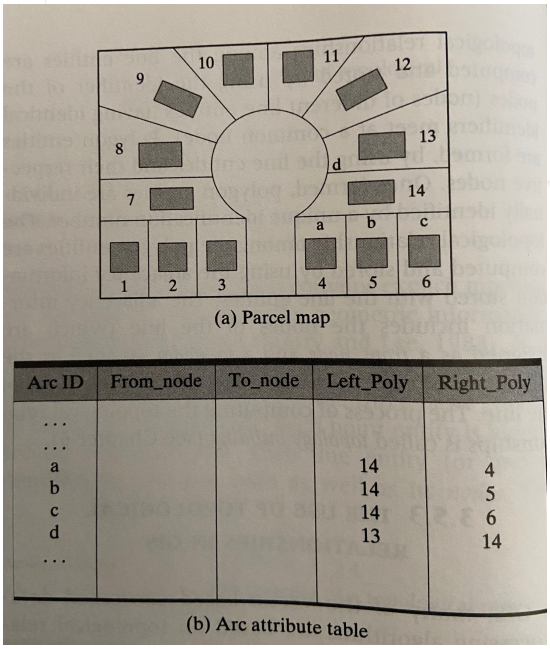

Topological Relationships: Areas of Usage

- Spatial Search by Topological Relationships
  - Find features by adjacency, containment and connectivity

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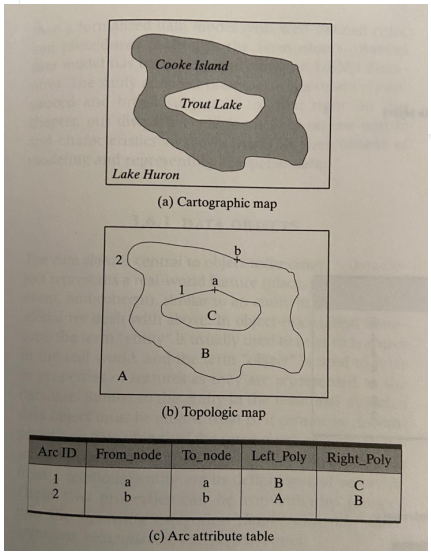

Topological Relationships: Areas of Usage

- Construction of Complex Spatial Relationships
  - E.g. Holes on polygons
  - Multipart polygons

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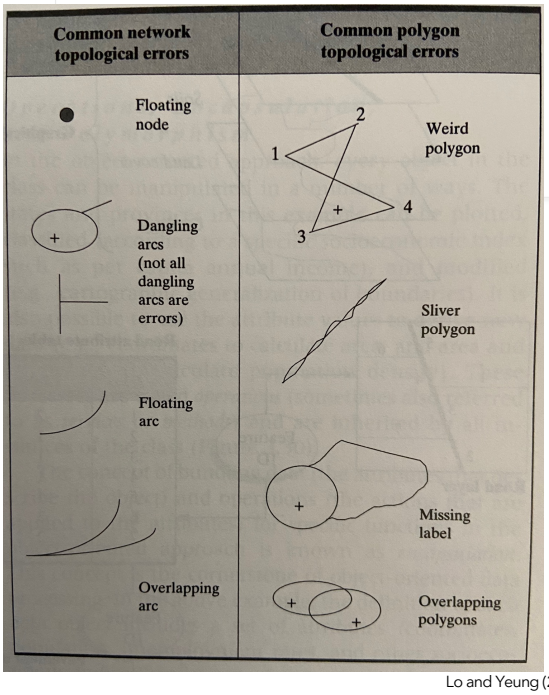

Topological Relationships: Areas of Usage

- Integrity checks and balances
  - Essentially the removal topological errors
    - E.g. No dangling arcs or overlapping polygons

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Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
  - Raster Model: phenomena that exhibit spatial variability
    - Temperature, topography
    - Environmental aspects at a regional or national scale
      - Habitat, biodiversity analysis

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Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
  - Vector Model: phenomena necessitates the need for location and individuality of spatial objects
    - Land title management, transportation management and planning, facilities management
    - Environmental aspects at a local scale (as opposed to a regional or national scale)

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Spatial Analysis

- Analysis occurs using either:
  - **Spatial location** e.g. wetlands near a pipeline; houses within 5km
    - Distinguishes GIS from a non-spatial analysis
  - **Data attributes** e.g. wetlands with black spruce; houses in a given price range
    - Distinguishes GIS from 'non-GIS' mapping software
  - **Comparative spatial statistics**
    - e.g. the correlation of variables across space
    - e.g. wetlands clustered at local scale, uniform at regional scale
    - Statistical Spatial Data Analysis with ArcGIS, QGIS,….

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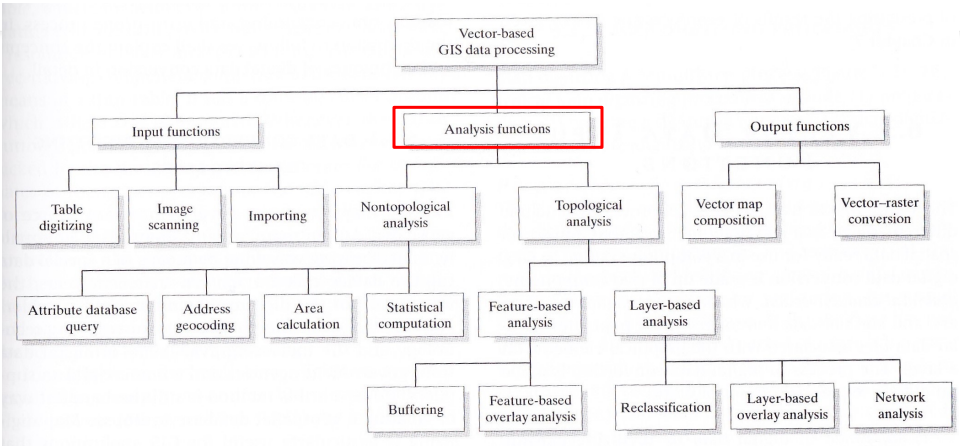
Spatial Analysis



Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

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Spatial Analysis

- Analysis functions
  - Non-topological functions
    - Attribute values of spatial data
  - Topological functions
    - Individual data objects
      - Feature-based
        - individual data objects
      - Layer-based
        - all objects in a layer

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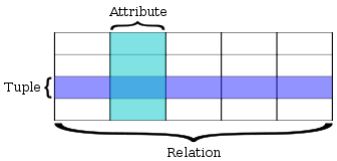
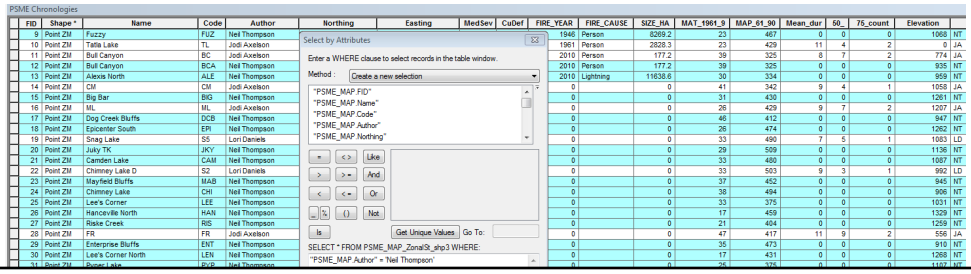
Nontopological Analysis

- SQL: Structured Query Language
- Goal: select only the features with (or without) particular values
- Relational table





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Nontopological Analysis

- Attribute Database Query Operations
  - **SELECT**: Extract data items in specified rows of a table

    SELECT <attribute_name> FROM <table> WHERE <condition_statement>

  - **JOIN (RELATIONAL JOIN):** Merges two tables based on the values in the columns of the tables

    [a select statement] *<table_1> JOIN <table_2> ON table_1.attribute= table_2.attribute*
    [a condition statement]

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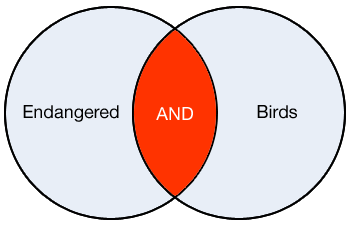
Nontopological Analysis

- **Boolean Logic** (after George Boole, a 19th century mathematician)
  - "Create an expression reducible to a true or false condition".
- **SQL can use:**
  - **Boolean Operators**
    - **And** (narrows the selection)
    - **Or** (expands the selection)
    - **Not** (excludes/reduces results)
    - **XOR** (A or B, but not both)
    - **Like (Similarity)**
      - **% is wildcard**
  - Relational Operators (=, >, <, >=, <=)
  - Arithmetic Operators (+, - *, /)



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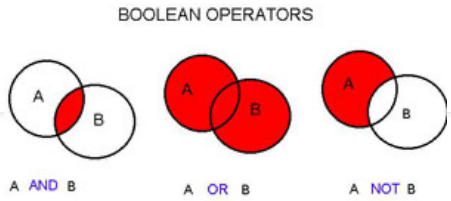
Boolean Operators (to combine conditions)



Selection by attribute

type = pine AND age > 100 ... selects all old growth pine

type = pine OR age > 100 selects all pine and any type older than 100

These may require the use of brackets to avoid ambiguity in complex queries e.g.

type = pine OR type = fir AND age > 100 selects any pine plus old growth fir

type = (pine OR type = fir) AND age > 100 selects old growth (pine and fir)

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Nontopological Analysis

- Statistical Computation
  - Extension of attribute data query
  - Conventional statistical measures such as:
    - mean, maximum, minimum, range, standard deviation, frequency
    - Note: These are aspatial (non-spatial) statistics
    - Note: Can't do statistics on text field

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Nontopological Analysis

- Spatial Calculation
  - Spatial calculation of position, area, perimeter, distance, proximity
    - Algorithms are well known
  - An intermediate step to obtain new attribute data to support specific spatial analyses
  - Be sure that data are preprocessed
    - projection, coordinate transformation, measurement unit conversion

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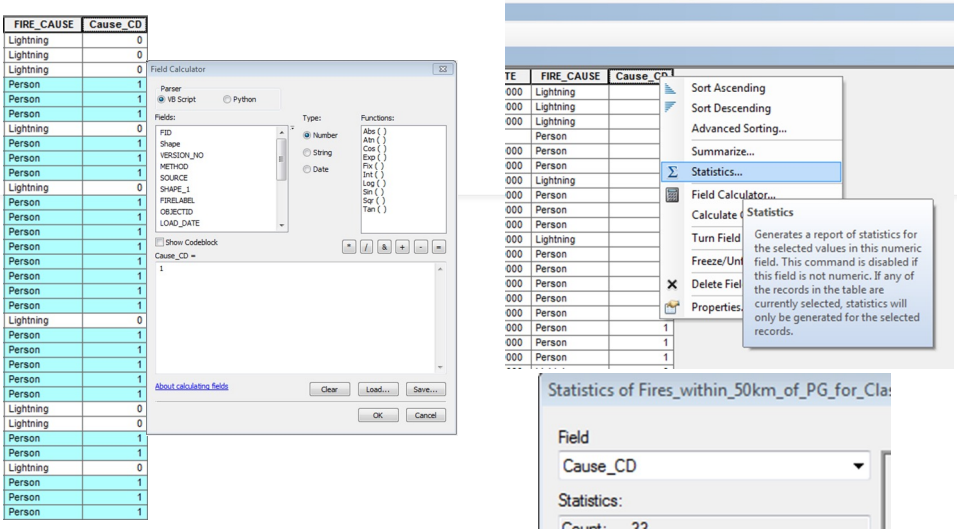

Statistics and the Field Calculator

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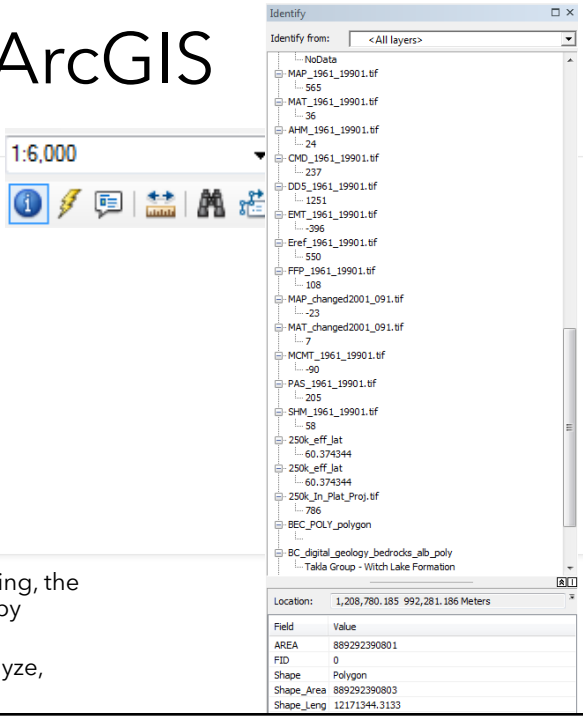
Selection in ArcGIS



- Manual selection
- By Location
- By Attributes

- Show attributes from
  - All layers
  - Selected layer
  - Visible layers
  - Top-most layer

Once you have selected something, the selection will be all ArcGIS sees by default.
CAUTION when you export, analyze, compare

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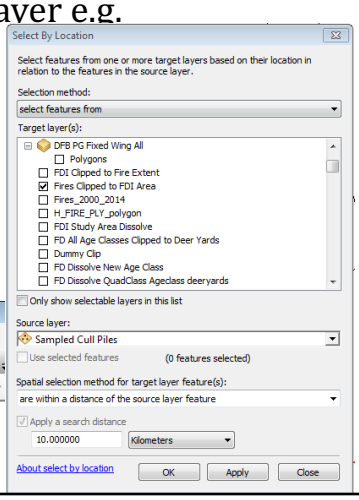
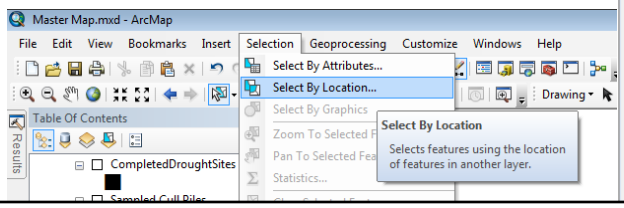
Select by Location

- Selects features from one data set based on their spatial relationship with another layer e.g.
  - Are within a distance of
  - Are within
  - Are completely within
  - Share a line segment with
  - Intersect





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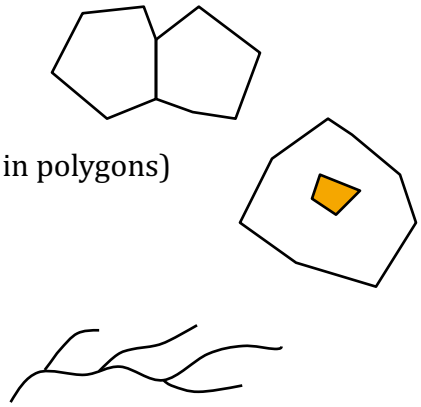
Topological Functions

- Topology: spatial relationship between entities
  - Adjacency (polygons)
  - Containment (e.g. points in polygons)
  - Connectivity (lines)



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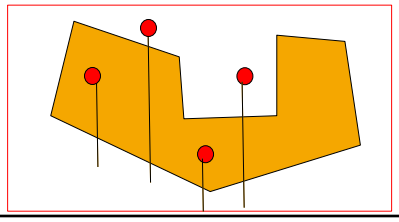
Topological Functions

- Feature-Based Analysis: Find relationships between features of one layer and those of another
  - Common functions: Point in polygon, adjacency, connectivity, buffering
    - Point in polygon matching: whether a given point feature falls inside a polygon



Plumb-line algorithm

Odd number of intersections: **In**
Even number of intersections: **Out**

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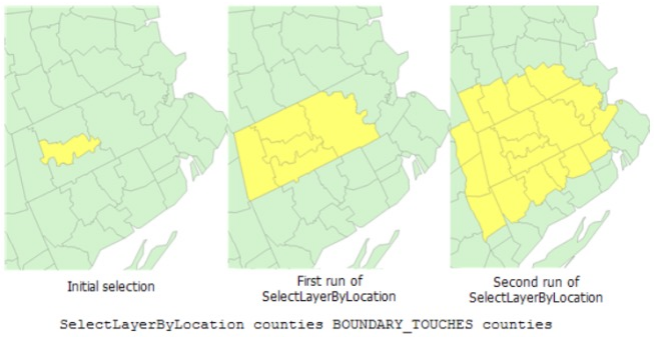
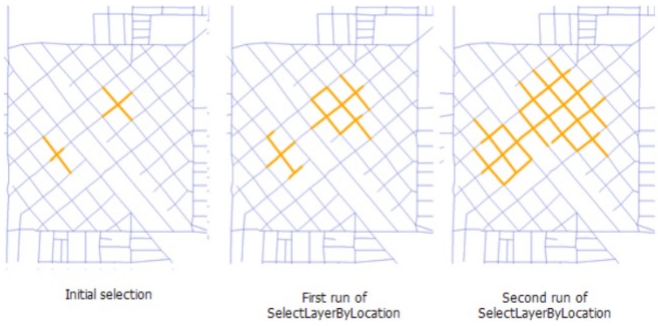
Touch = adjacency




```
SelectLayerByLocation counties BOUNDARY_TOUCHES counties
```

Are connected with



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Topological Functions

- Buffering
  - A buffer is a zone covering a specified distance around a spatial feature
    - Buffer zones are polygons.
    - Buffer distance is usually user defined
    - Boundaries of overlapping buffer zones are automatically dissolved to give a single coherent buffer polygon

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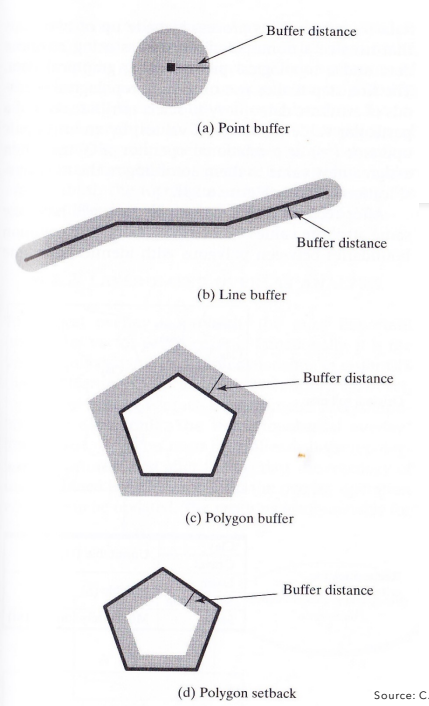

Useful when evaluating charactering of an area surrounding a feature.

- properties/population with walking distance of a bus stop
- delineation of restricted zones around sensitive sites

Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

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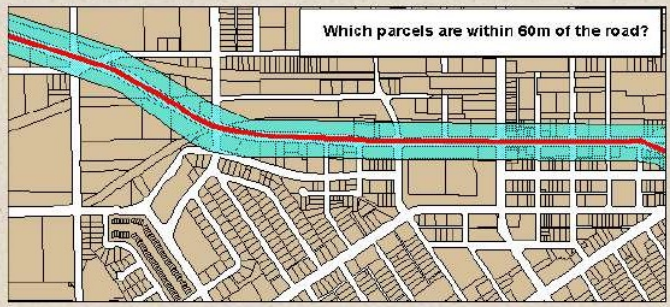
Applications of BUFFER



For example: consideration of widening of existing roadway, to identify parcels affected by underground utility line additions, etc.

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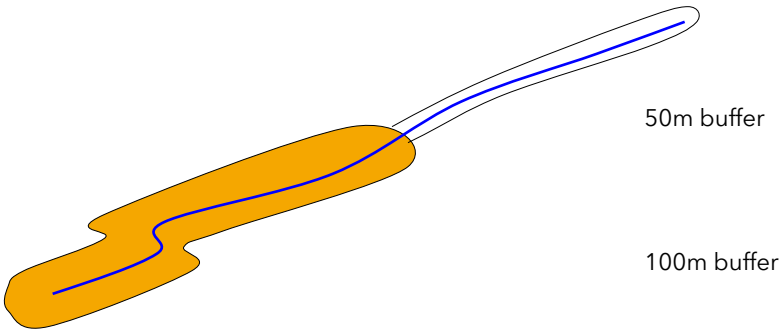
Topological Functions

- *Variable buffer distances* (assigned by attribute)
  - Different buffer size depending on stream attribute
  - e.g. stream protection status



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Topological Functions

- Reclassification
  - Database simplification process
    - reduces (modifies) the categories in attribute data
  - Two step process
    - Nontopological: select attribute e.g. a range of values and assign them a new class
    - Topological: dissolve according to new classification scheme

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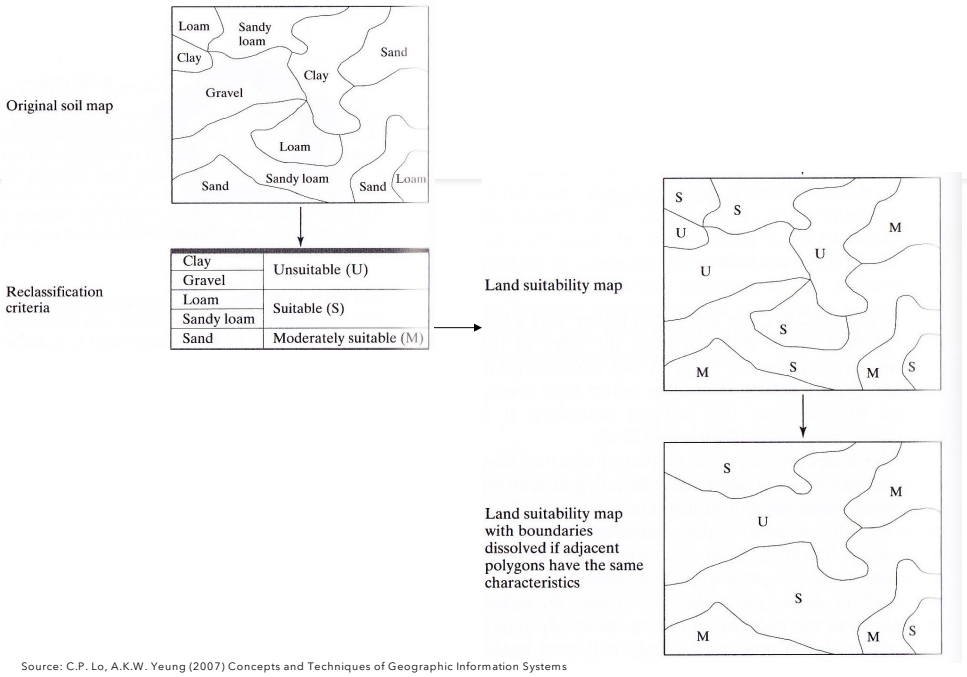

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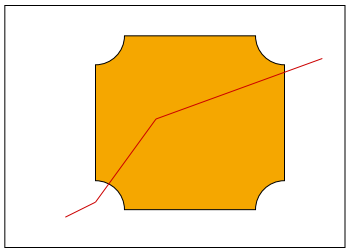
The Concept of GIS Overlay

- Overlay addresses the relationship of the overlap between spatial features.
- Overlay combines the spatial *and* attribute data of two input themes.



Three input feature types, overlay cover is always polygon:

1) point-in-polygon, → points are output
2) line-in-polygon, → lines are output
3) polygon-in-polygon → polygons are output

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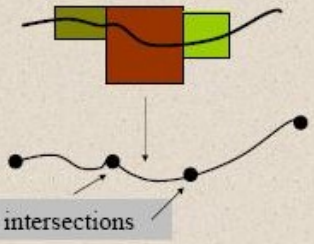
Line Feature Types and Map Overlay

- Line - in - Polygon
  - Input Theme
  - Overlay Theme



- Attach attributes of polygon to line that traverses through polygon
- Example - What types of soils does a proposed road cross?
- Line is actually broken into different line segments at polygon boundaries. Each line segment takes on attributes for the polygon it overlays.

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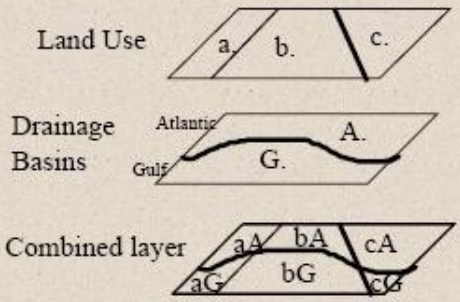
Example: Spatial Matching via *Polygon-on-Polygon Overlay*



The two themes (land use & drainage basins) do not have common boundaries. GIS creates combined layer permitting calculation of land use by drainage basin.

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Topological Functions

- Topological Overlay Operators
  - UNION: Overlays polygons and keeps all areas in both layers. Never clips data
  - INTERSECT: Keeps portions of the first input layer that fall within the second input layer
  - IDENTITY: Overlays polygons and keeps all input features. The input features that overlap identity features will get the attributes of the identity features.
  - CLIP: Cuts out the first input layer using the second input layer as a cookie cutter
  - ERASE: Erases part of the first input layer using the second input layer
  - SPLIT: Divide the polygons in the first input layer into a number of smaller polygons based on the second input layer

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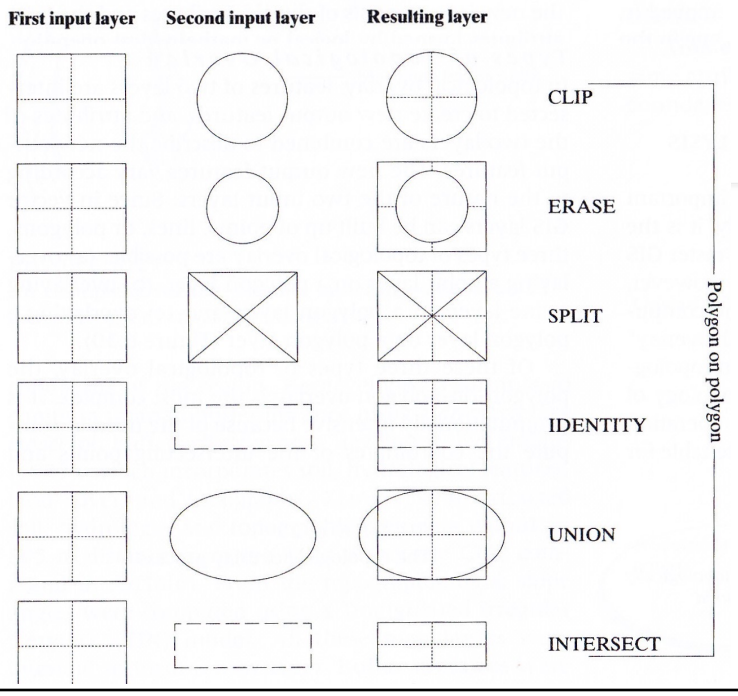

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