Spatial Data Modelling

Spatial Data Models

The construction of models of spatial form can be thought of as a series of stages of data abstraction.

By applying these abstraction techniques, the GIS designer moves from the position of observing the geographical complexities of the real world to one of simulating them in the computer .

This involves:

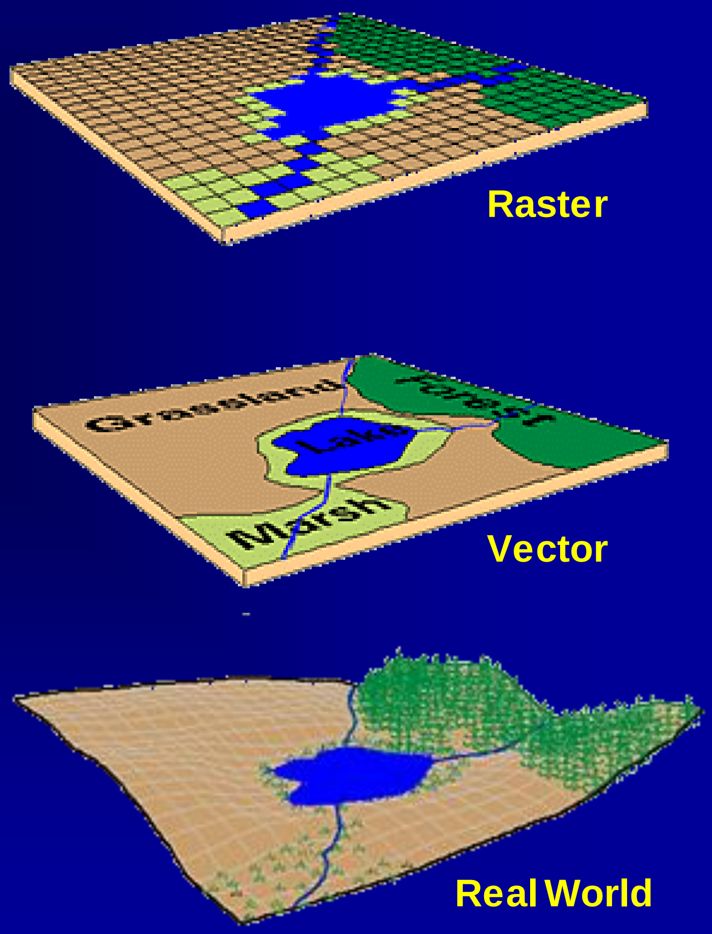
- **identifying the spatial features in the real world and choosing how to represent them in a conceptual model (points, lines, area);**

- **representing the conceptual model by an appropriate spatial data model; and**

- **Selecting an appropriate spatial data structure to store the model within the computer.**

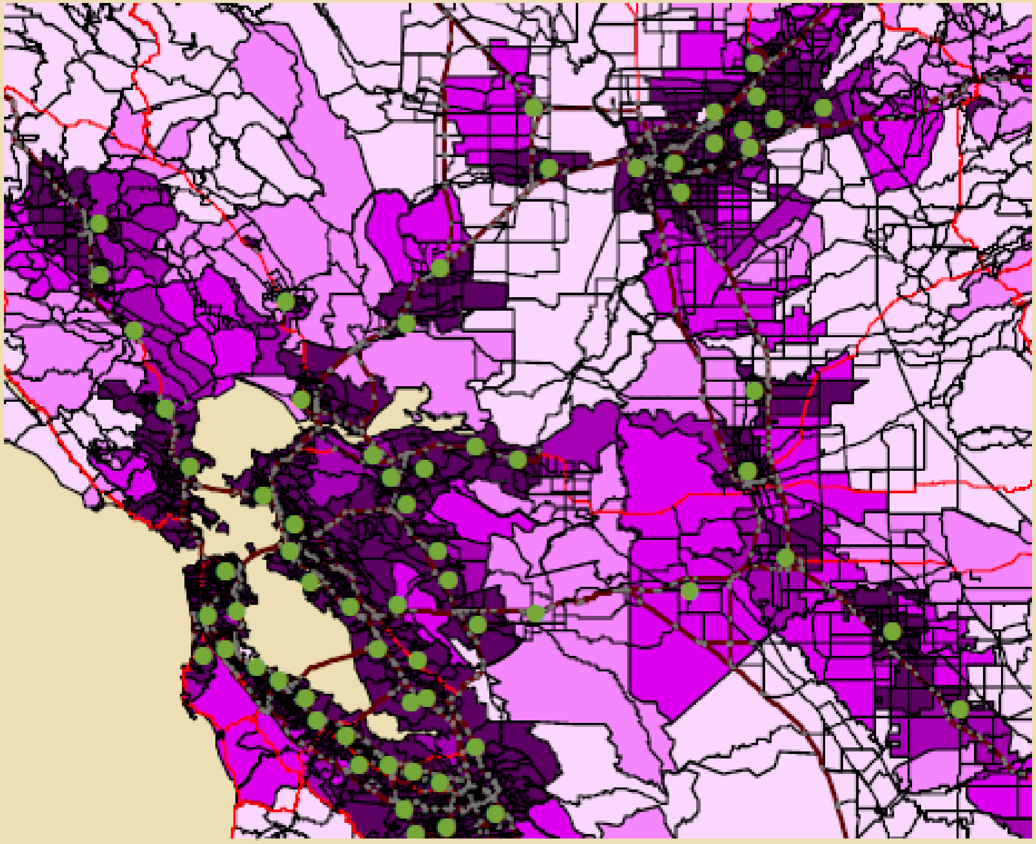
Raster vs. Vector: types of GIS map representation

- Vector vs. Raster
- Two basic ways that spatial data can be represented
- Raster:
  - Data represented by pixels with values, creating a grid
  - Allows certain types of operations not possible with vector data
  - Map algebra is possible with multiple data layers – creating index maps
- Vector:
  - Data stored as points, lines, and polygons
  - Uses less memory than raster format
  - Does not loose positional accuracy



Vector Layers

Points, Lines, Polygons



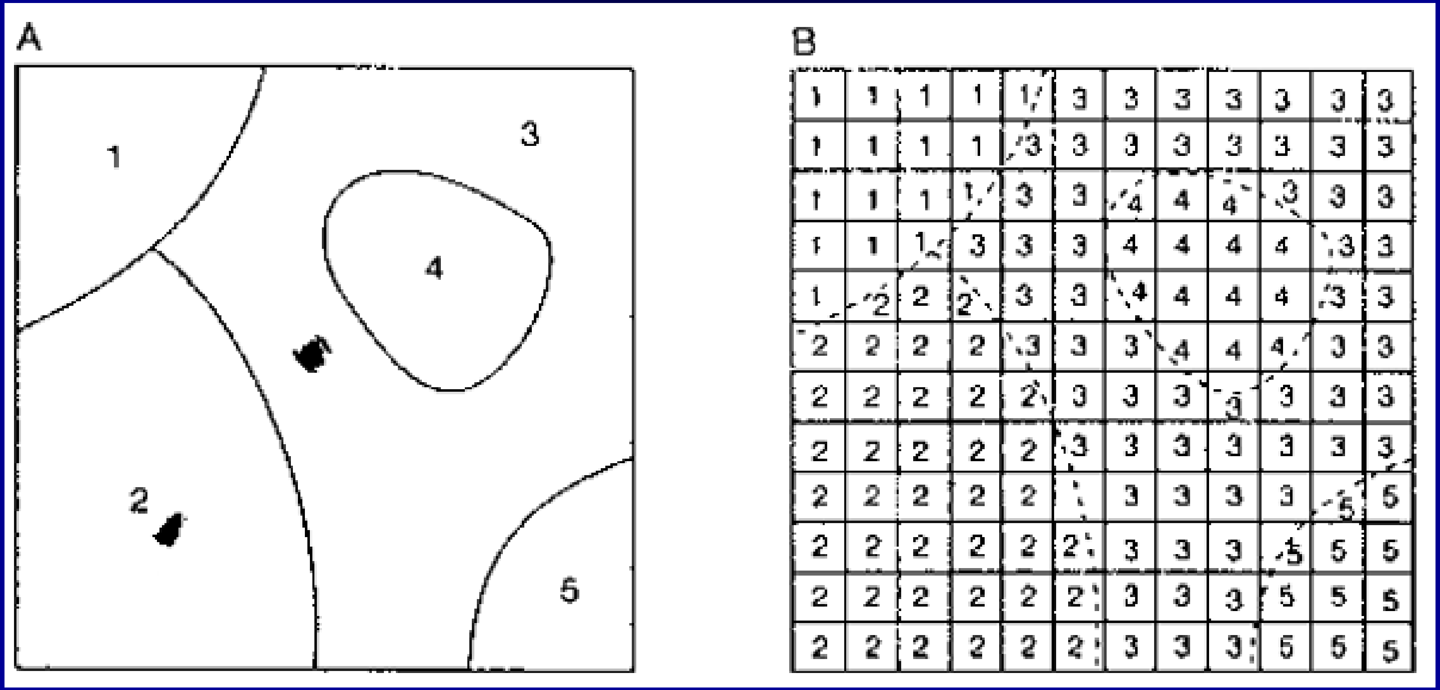
Some possible layers:

- Political Boundaries
- Linguistic Regions
- Streets
- Trade Routes
- Addresses
- Churches
- Census Blocks

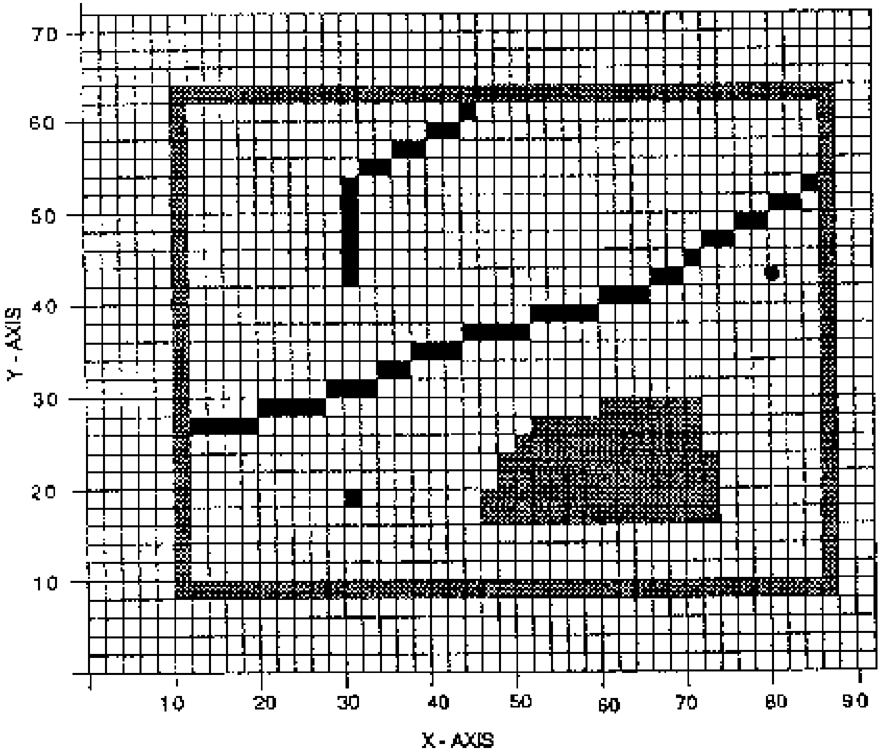
Spatial Data Structures

Data structures provide the information that the computer requires to reconstruct the spatial data model in digital form.

These can be classified according to whether they are used to structure raster or vector data.



A Simple Raster Map Plus the Encoding Structure Used for data Storage



RASTER RUN LENGTH CODE STRUCTURE

Row	Run length encoding
66	0, 90, 0
64	0, 90, 0
62	0, 8, 0; 10, 86, 1; 88, 90, 0
60	0, 8, 0; 10, 1; 12, 42, 0; 44, 2; 46, 84, 0; 86, 1; 88, 90, 0
58	0, 8, 0; 10, 1; 12, 38, 0; 40, 42, 2; 44, 84, 0; 86, 1; 88, 90, 0
56	0, 8, 0; 10, 1; 12, 34, 0; 36, 38, 2; 40, 84, 0; 86, 1; 88, 90, 0
54	0, 8, 0; 10, 1; 12, 30, 0; 32, 34, 2; 36, 84, 0; 86, 1; 88, 90, 0
52	0, 8, 0, 10, 1; 12, 28, 0; 30, 2; 32, 82, 0; 84, 2; 86, 1; 88, 90, 0
50	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 78, 0; 80, 82, 2; 84, 0; 86, 1; 88, 90, 0
48	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 74, 0; 76, 78, 2; 80, 84, 0; 86, 1; 88, 90, 0
46	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 70, 0; 72, 74, 2; 76, 84, 0; 86, 1; 88, 90, 0
44	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 68, 0; 70, 2; 72, 84, 0; 86, 1; 88, 90, 0
42	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 64, 0; 66, 68, 2; 70, 84, 0; 86, 1; 88, 90, 0
40	0, 8, 0; 10, 1; 12, 58, 0; 60, 64, 2; 66, 84, 0; 86, 1; 88, 90, 0
38	0, 8, 0; 10, 1; 12, 50, 0; 52, 58, 2; 60, 84, 0; 86, 1; 88, 90, 0
36	0, 8, 0; 10, 1; 12, 42, 0; 44, 50, 2; 52, 84, 0; 86, 1; 88, 90, 0
34	0, 8, 0; 10, 1; 12, 36, 0; 38, 42, 2; 44, 84, 0; 86, 1; 88, 90, 0
32	0, 8, 0; 10, 1; 12, 32, 0; 34, 36, 2; 38, 84, 0; 86, 1; 88, 90, 0
30	0, 8, 0; 10, 1; 12, 26, 0; 28, 32, 2; 34, 84, 0; 86, 1; 88, 90, 0
28	0, 8, 0; 10, 1; 12, 18, 0; 20, 26, 2; 28, 58, 0; 60, 70, 1; 72, 84, 0; 86, 1; 88, 90, 0
26	0, 8, 0; 10, 1; 12, 18, 2; 20, 50, 0; 52, 70, 1; 72, 84, 0; 86, 1; 88, 90, 0
24	0, 8, 0; 10, 1; 12, 48, 0; 50, 70, 1; 72, 84, 0; 86, 1; 88, 90, 0
22	0, 8, 0; 10, 1; 12, 46, 0; 48, 72, 1; 74, 84, 0; 86, 1; 88, 90, 0
20	0, 8, 0; 10, 1; 12, 46, 0; 48, 72, 1; 74, 84, 0; 86, 1; 88, 90, 0
18	0, 8, 0; 10, 1; 12, 28, 0; 30, 2; 32, 44, 0; 46, 72, 1; 74, 84, 0; 86, 1; 88, 90, 0
16	0, 8, 0; 10, 1; 12, 44, 0; 46, 72, 1; 74, 84, 0; 86, 1; 88, 90, 0
14	0, 8, 0; 10, 1; 12, 84, 0; 86, 1; 88, 90, 0
12	0, 8, 0; 10, 1; 12, 84, 0; 86, 1; 88, 90, 0
10	0, 8, 0; 10, 1; 12, 84, 0; 86, 1; 88, 90, 0
8	0, 8, 0; 10, 86, 1; 88, 90, 0
6	0, 90, 0
4	0, 90, 0
2	0, 90, 0

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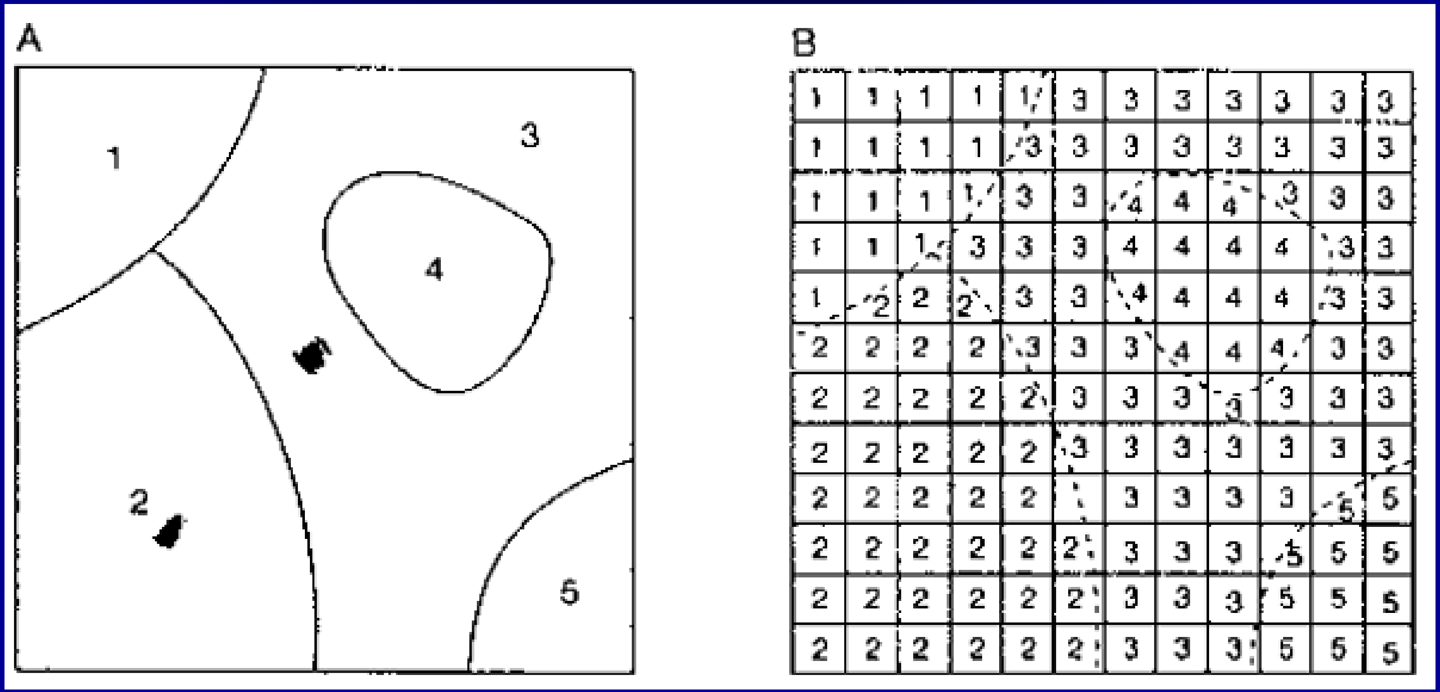


Modelling Surfaces

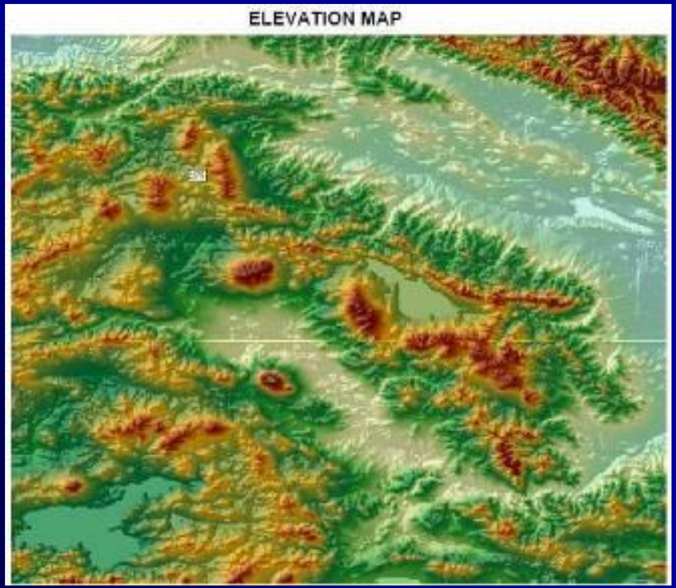
Maps of continuous data

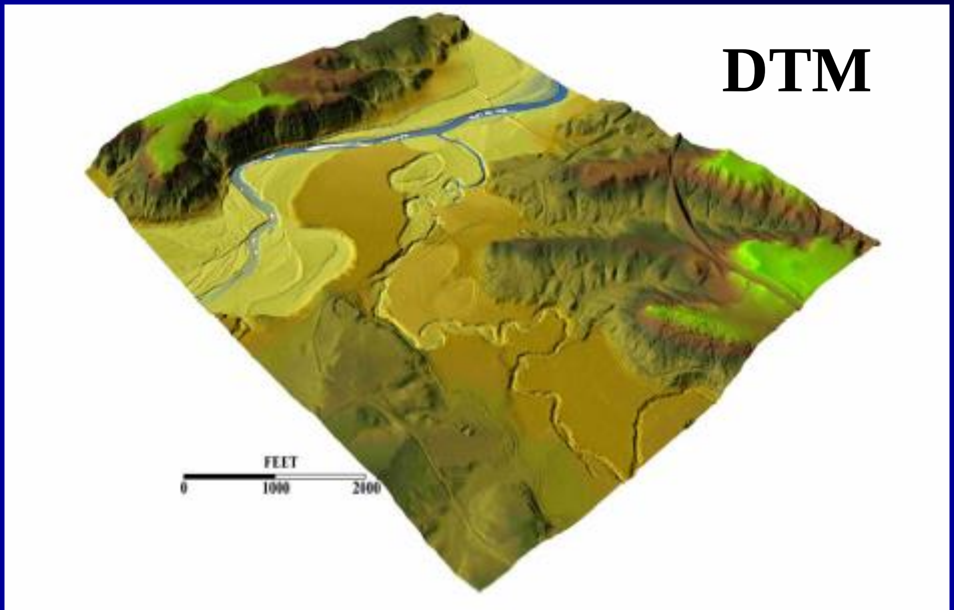
Elevation

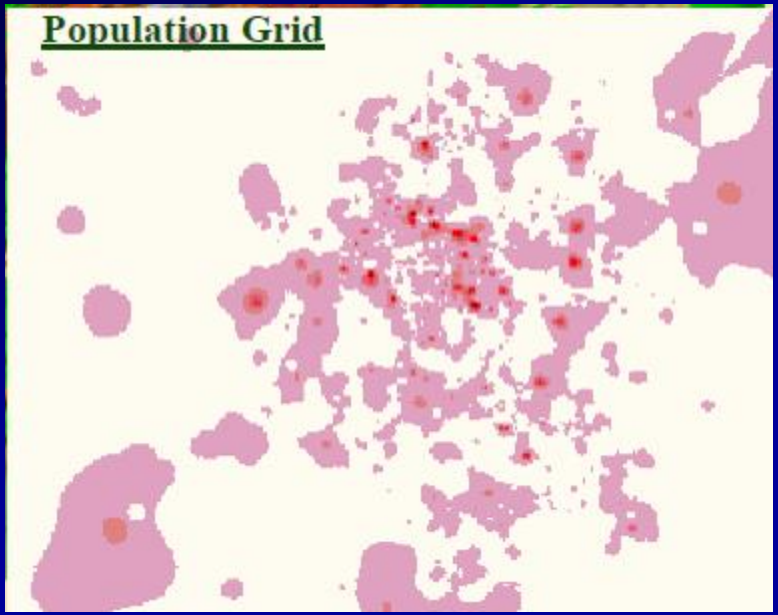
Temperature

Rainfall

Population, etc.

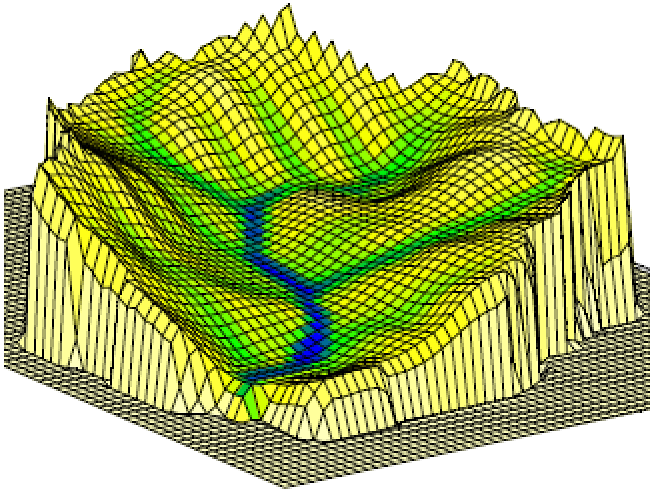




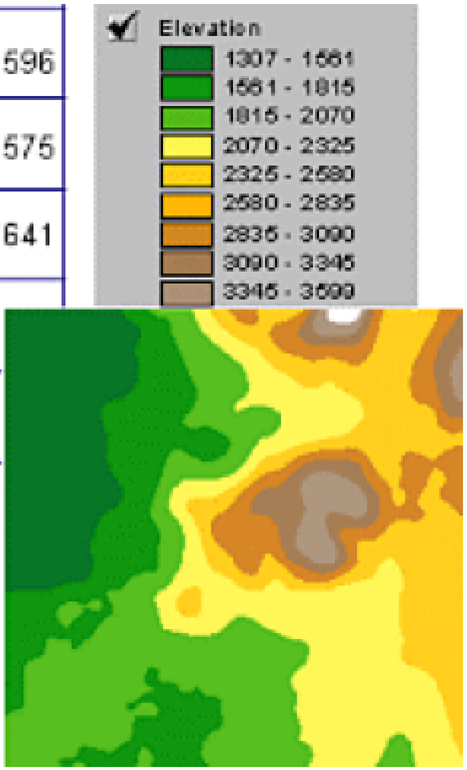


3D Modelling

Digital Elevation Models



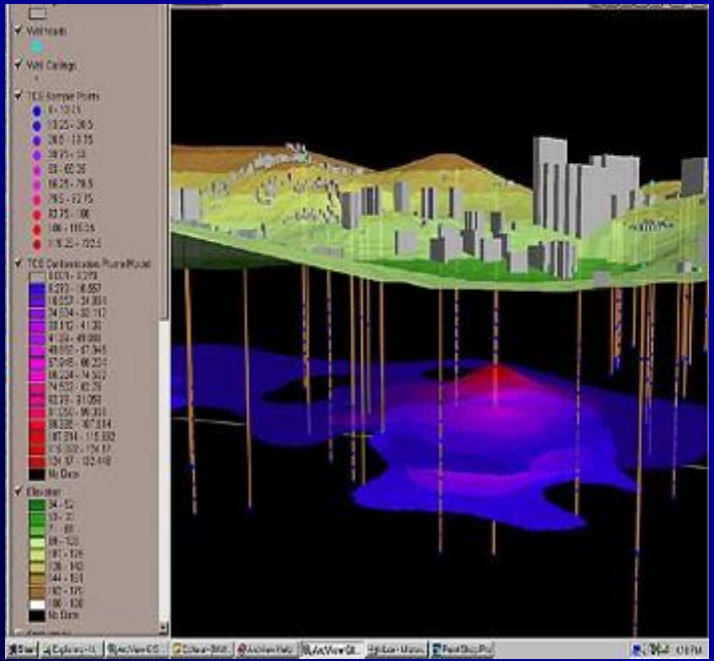
1654	1606	1555	1546	1596
1686	1658	1597	1557	1575
1594	1618	1621	1648	1641
1562	1598	1586	1547	[illegible]
1473	1422	1430	1459	[illegible]

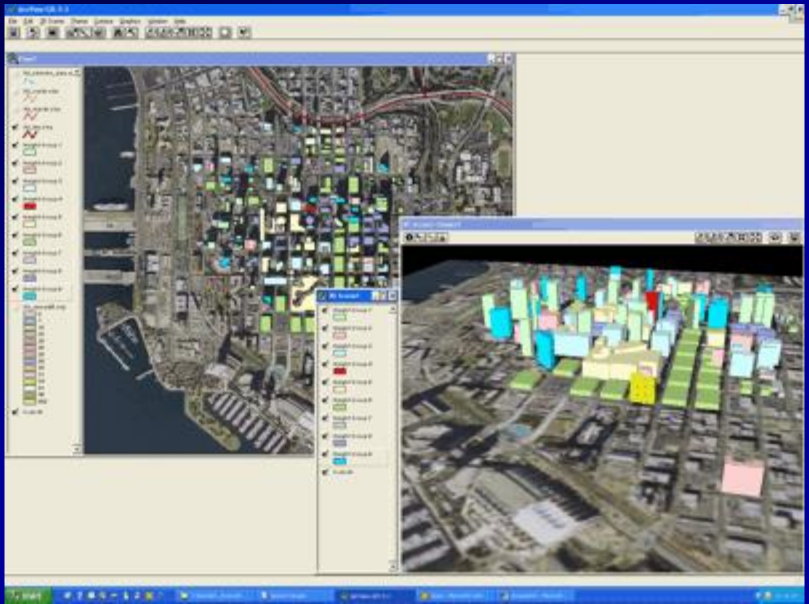


A grid where the centre of every cell has a elevation value as an attribute. Elevation information is usually captured from topographic maps or retrieved photogrametrically. The cell size determine the resolution of a DEM.

High End 3-D Representation

- Surfaces are made from Triangular Irregular Networks (TIN) that interpolate 3-D surfaces from 2-D contour values.
- Uses:
  - Hydrology: surface and underground flows
  - Line-of-Sight analysis
  - Pollution Plume tracking
  - Customer analysis
  - Soil erosion potential



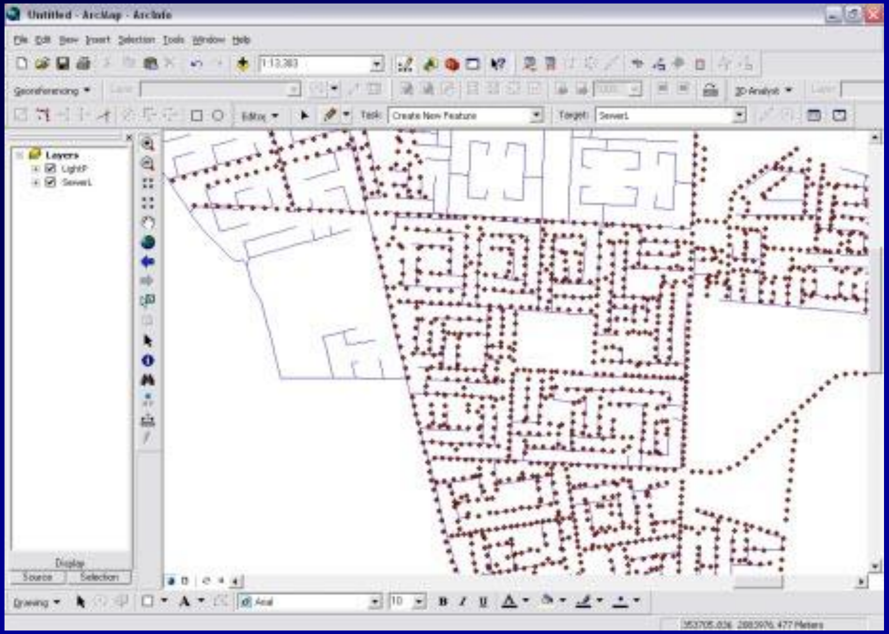


Modelling Networks

A network is a set of interconnected lines making up a set of features

Network modelling applications

- Rail transport
- Road transport
- Water
- Waste water
- Transport
- Electricity
- Natural gas



Data Capture, Storage and Management

Methods of Data Input

A GIS without data can be likened to a car without fuel - without fuel you cannot go anywhere; without data a GIS will not produce output.

Whereas fuel can only be obtained from only one place - a fuel station,

Spatial data on the other hand can be obtained from many different sources, in different formats, and can be input to GIS using a number of different methods.

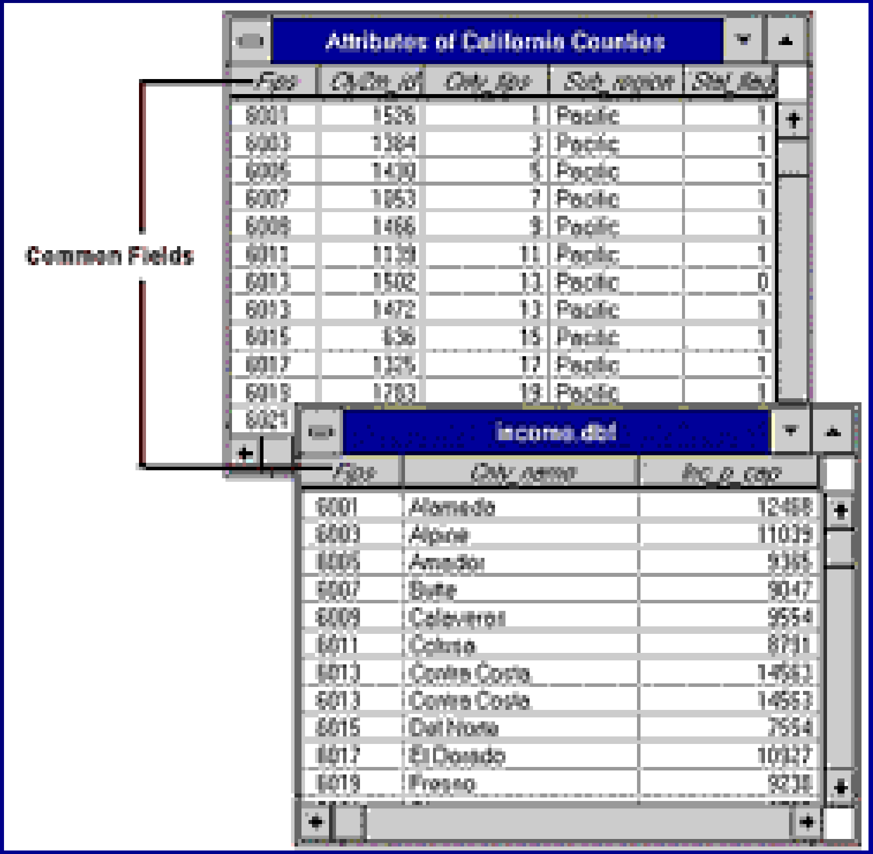
Methods of Data Input

Data Source	Analogue/Digital	Encoding Methods	Examples
Tabular Data	Analogue	• Keyboard entry • Text scanning	• Census data • Survey data • Address list
Aerial photographs	Analogue	• Manual digitizing • Automatic digitizing • Scanning	• Extent of floods • Ski Piste location
Map data	Analogue	• Manual digitizing • Automatic digitizing • Scanning	• Admin maps • Infrastructure Map
Tabular data	Digital	• Digital file transfer	• Census data • Survey data • Address list
Map data	Digital	• Digital file transfer	• DTM data • Topographic data
Aerial photographs	Digital	• Digital file transfer	• Background data • Ski Piste location
Satellite Imagery	Digital	• Digital file transfer • Image processing and reformatting	• Land use data •Forest condition

The Database Approach

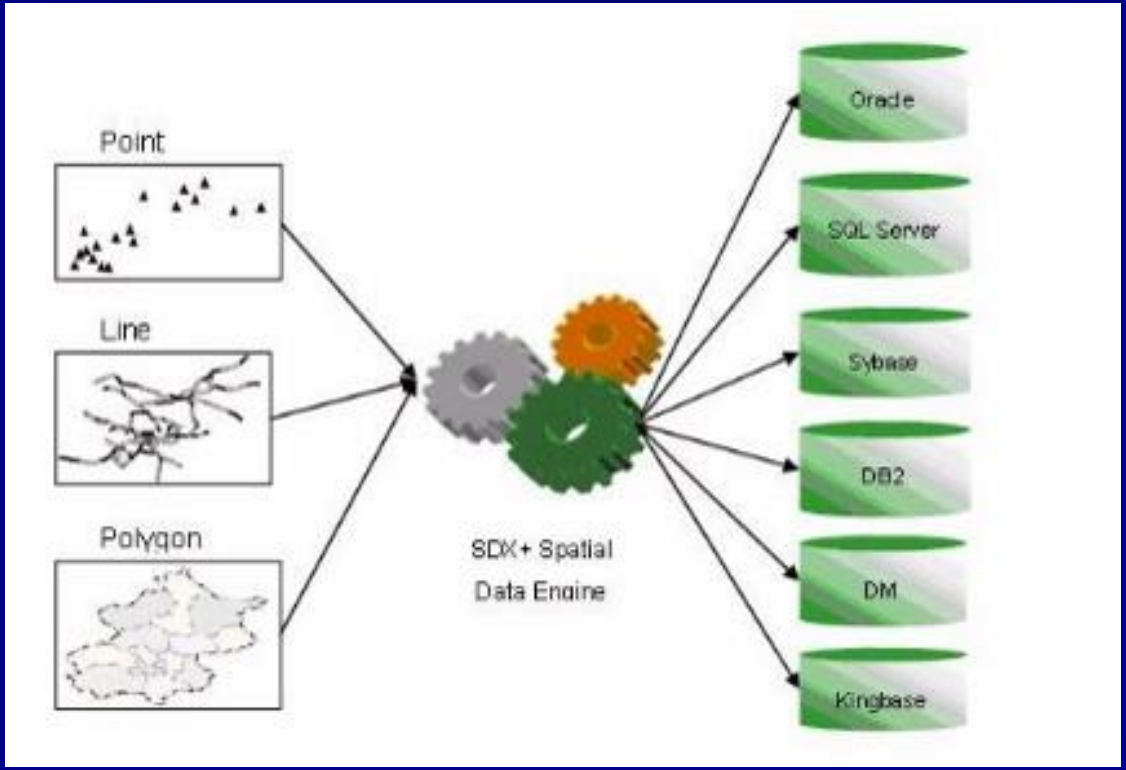
A database is a collection of related data

- **GIS stores data in a relational database structure ('3-D spreadsheets')**
  - e.g. employee names linked to store number, store number linked to shipment arrival
  - any data can be linked by a common attribute to any other data
    - Example shown here is a list of counties (geographic data) by income code (demographic data)



Database Management System

The data in a computer database are managed and accessed through a database management system (DBMS)



A DBMS is a computer program to control the storage, retrieval and modification of data **(in a database).**

Data Analysis

Queries and Analysis

Once you have a functioning GIS containing your geographic information, you can begin to ask simple questions such as:

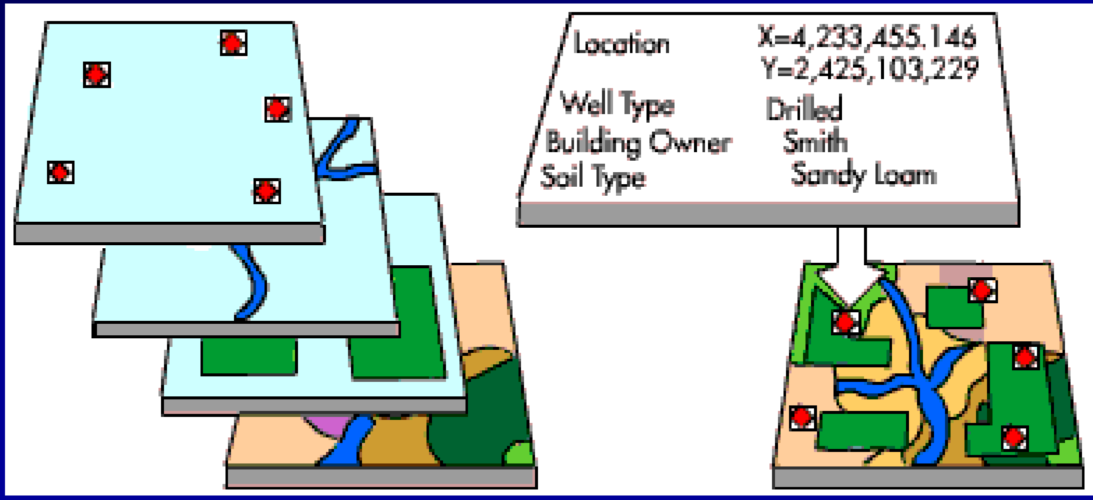
- Who owns the land parcel on the corner?
- How far is it between two places?
- Where is land zoned for industrial use?

And analytical questions such as:

- Where are all the sites suitable for building new houses?
- What is the dominant soil type for oak forest?
- If I build a new highway here, how will traffic be affected?

Queries and Analysis

- Query building is a data exploration operation
  - Example statement: ‘([acres] > 500 AND [age] > 55)’
  - This would highlight all land parcels of greater than 500 acres owned by people older than 55 years old in a data set loaded into the GIS.
- Map algebra with raster data, in this type of operation mathematical operations are done on each pixel of multiple data layers. This results in a new data layer that is calculated from all the input layers.



Proximity Analysis
(Buffering and Neighbourhood Functions)

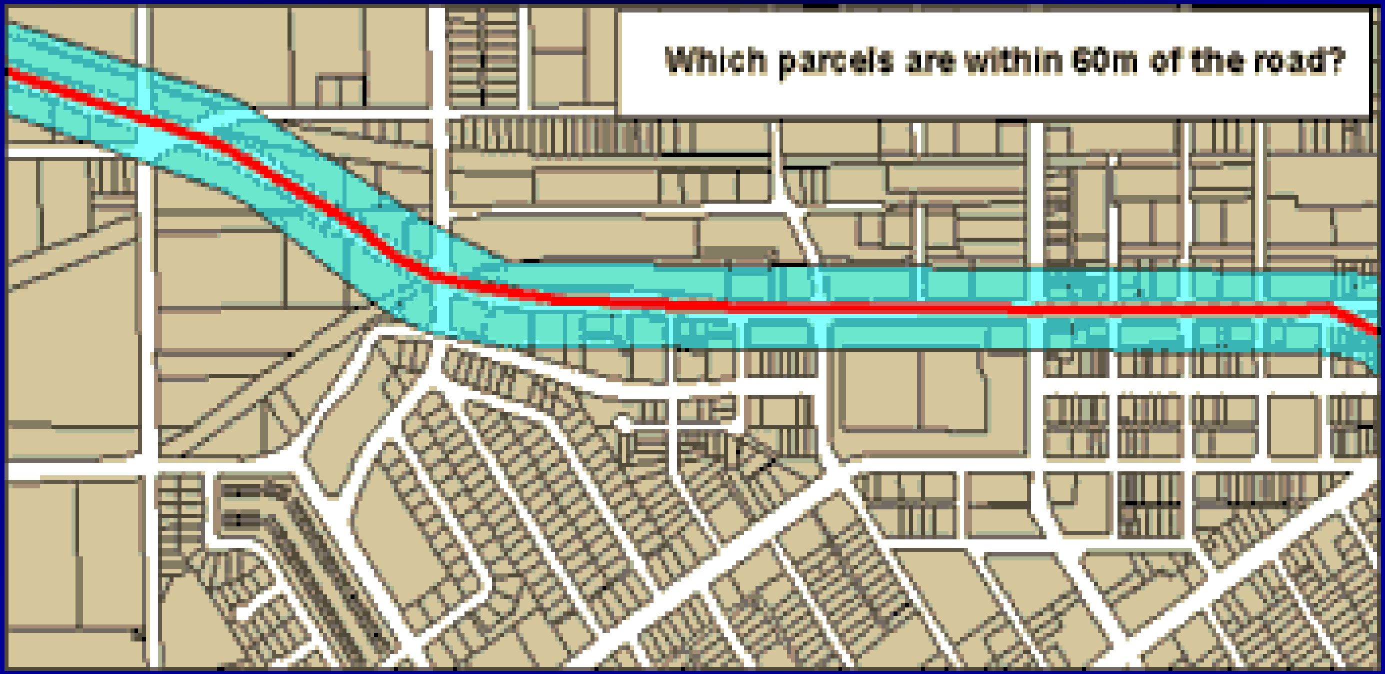
Proximity Analysis

- How many houses lie within 100 m of this water main?
- What is the total number of customers within 10 km of this store?
- What proportion of the alfalfa crop is within 500 m of the well?

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.

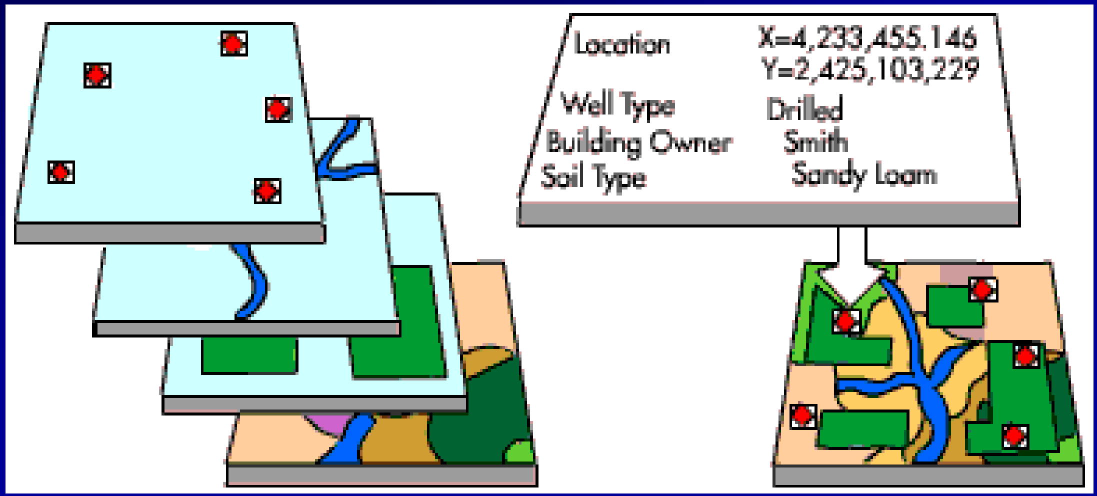
Proximity Analysis
(Buffering and Neighbourhood Functions)

- Two or more data layers are overlaid
- GIS creates buffers around features on a particular layer
- This allows analyses such as flood zone delineation and features near a route such as hotels along a bike route.



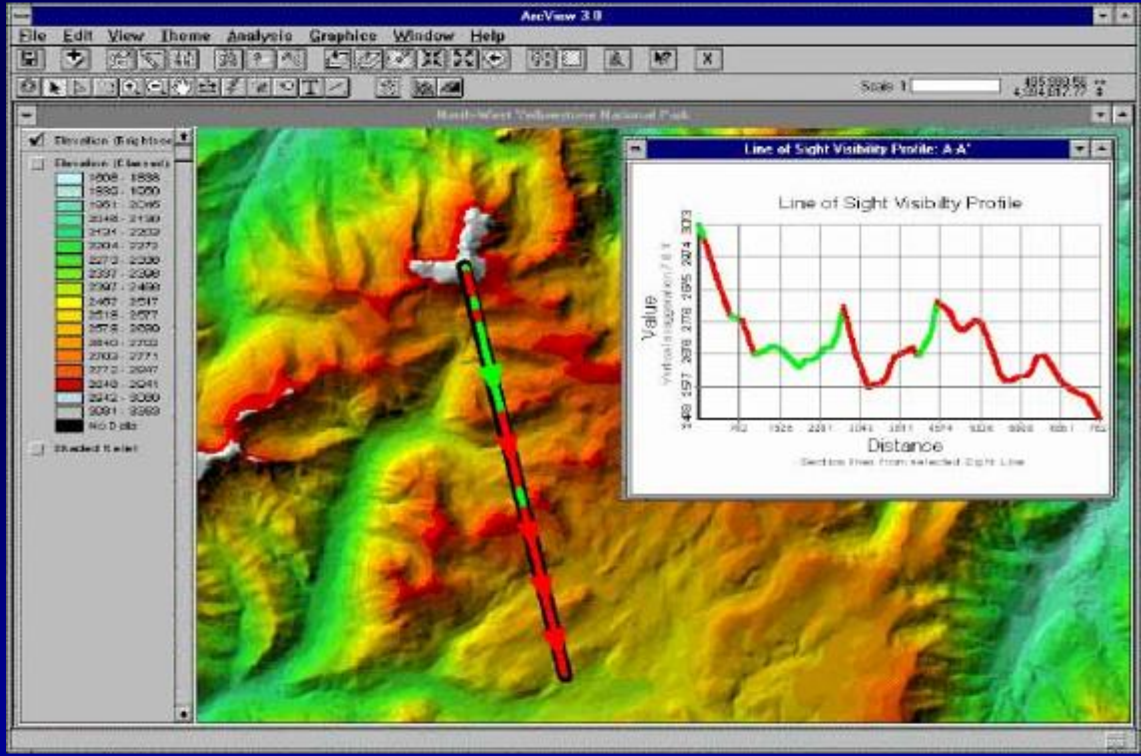
Integrating Data - Map Overlay

The integration of different data layers involves a process called overlay. Analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, drainage, and vegetation, or property ownership.



Analysis of Surfaces

- Raster data can also be used to create surfaces
- Other raster data uses:
  - Density analysis
  - Proximity analysis
  - Least-cost paths
  - Line-of-sight
  - Hydrology analysis



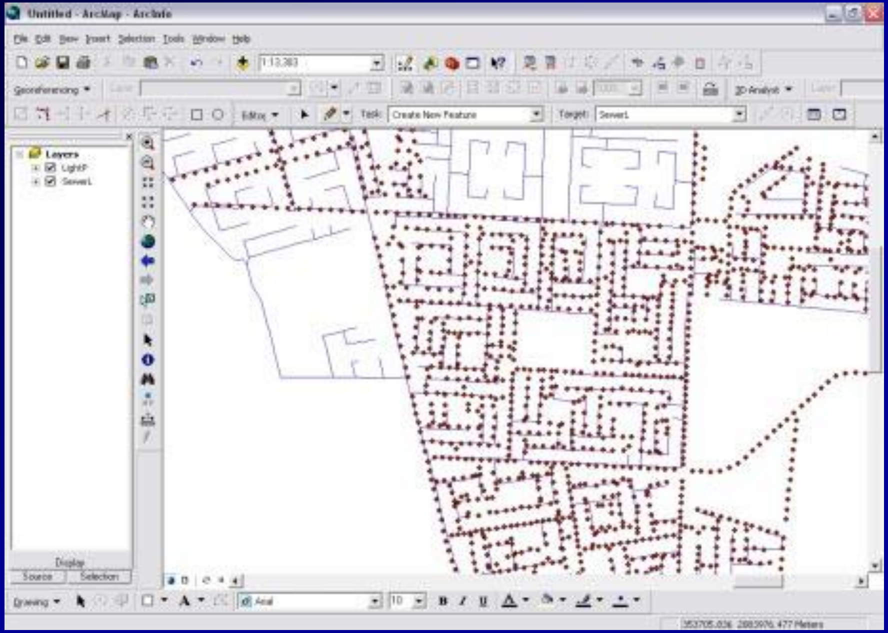
Network Analysis

Shortest Path Problem

Travelling Salesman Problem

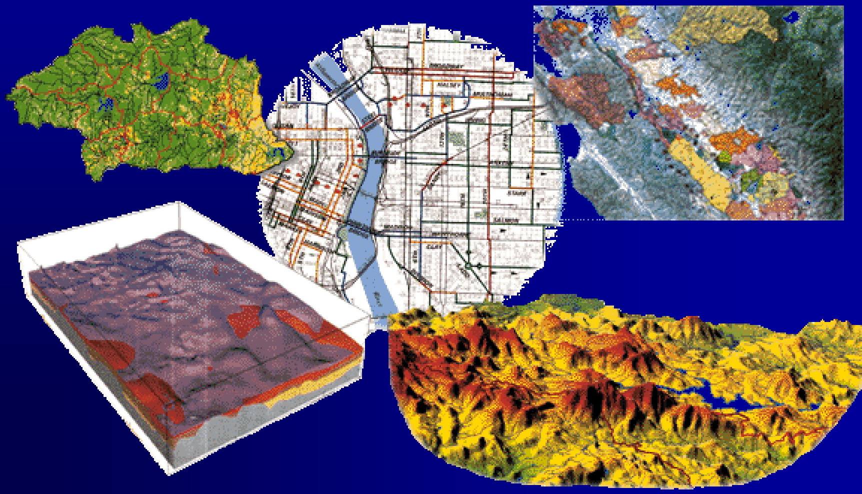
Location Allocation Modelling

Route Tracing



Visualization

For many types of geographic operation the end result is best visualized as a map or graph.



GIS provides new and exciting tools to extend the art and science of cartography.

Map displays can be integrated with reports, three-dimensional views, photographic images, and other output such as multimedia.

We Use GIS…

- Perform Geographic Queries & Analysis
- Improve Organizational Integration
  - Data Management
  - Sharing Data
- Making Maps
- Improved Efficiency

…for Better Decisions

Areas Where GIS Helps Utilities

- Map maintenance Switching
- Distribution Analysis
- Work Order Processing
- Leak Detection (Gas/water)
- Load Forecasting
- Ad Hoc Mapping
- Interface to external corporate databases
- Vehicle Tracing & Market Analysis
- Environmental Monitoring
- Lease Management.
- Right-of-Way Management.

Where GIS can help Municipal Infrastructures

- Land Use Planning
- Track Cadastral Information
- Community Development
- Aid in Crime Prevention
- Visualize Urban Structure
- Manage Local Resources
- Redistricting
- School Bus routing
- Garbage Collection Routing

Where GIS can help Transportation

- Transportation Infrastructure Management
- Fleet and Logistics Management
- Transit Management
- Point to Point Routing
  - Shortest Path
  - Closest Facility
  - Service Areas

Where GIS can help the Environmental Industry

- Site Remediation
- Waste Management
- Environmental Impact Assessment
- Natural Resource Management
- Policy Assessment
- Groundwater Modelling
- Environmental Compliance Permit Tracking
- Vegetation Mapping