
What's Special about Spatial?

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University of California
Santa Barbara

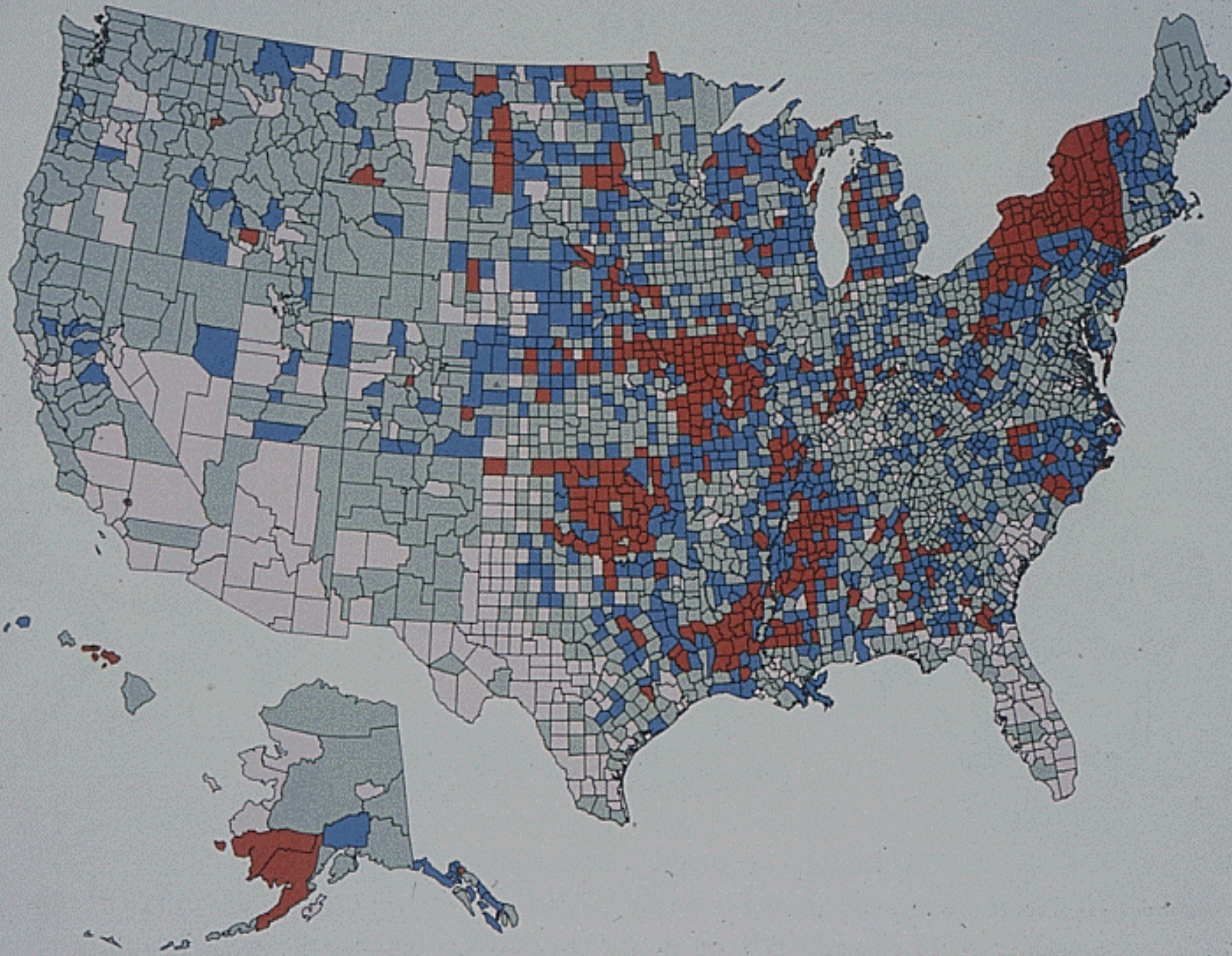
Outline

- GIS
- The Center for Spatially Integrated Social Science (CSISS)
- The W matrix

Definitions

- Spatial data
 - information about phenomena organized in a spatial frame
 - the geographic frame
- Spatial analysis
 - methods applied to spatial data that
 - add value
 - reveal patterns and anomalies
 - support decisions





The role of the GIS

- The infrastructure for handling data types
 - to spatial data as Excel is to tables, as S-Plus is to statistical data, as Word is to text
 - spatial data or geographic data?
 - the housekeeper
 - the editor
- The visualization tool

The GIS data types

- Discrete geographic features
 - points, lines, areas
 - the contents of maps
 - with associated attributes
 - countable
 - conceived as tables with associated feature geometry

Scottish Munros

- 1.. [Ben Hope](#)
- 2.. [Ben Kilbrack](#)
- 3.. [Ben More Assynt](#)
- 4.. [An Teallach](#)
- 5.. [Seana Bhraigh](#)
- 6.. [Ben Wyvis](#)
- 7.. [Sillich](#)
- 8.. [Sgorr Ruadh](#)
- 9.. [Moruig](#)
- 10.. [Sgurr na Ruaidhe](#)
- 11.. [Bia Bheinn](#)
- 12.. [Sgurr na Lapalch](#)
- 13.. [Ben Attow](#)
- 14.. [The Saddle](#)
- 15.. [Creag a' Mhaim](#)
- 16.. [Ladhar Bheinn](#)







- 17.. [Coireachan](#)
- 18.. [Ben Nevis](#)
- 19.. [Ben More](#)
- 20.. [Den Starav](#)
- 21.. [Braeriach](#)
- 22.. [Ben Avon](#)
- 23.. [Meall Chualch](#)
- 24.. [Mt Keon](#)
- 25.. [Deinn Dearg](#)
- 26.. [Glas Maol](#)
- 27.. [Driesh](#)
- 28.. [Schiehallion](#)
- 29.. [Ben Chonzie](#)
- 30.. [Den Lawers](#)
- 30.. [Ben Challum](#)
- 32.. [Ben Lomond](#)

Fields















- Geography as a collection of continuous variables
 - measured on nominal, ordinal, interval, ratio scales
 - vector fields of direction and magnitude
 - exactly one value per point
 - $z=f(\mathbf{x})$
 - population density, land ownership, zoning




Editor

Editor ▾ ▶  Task: Reshape Feature ▾ Target: uscnty ▾   


Untitled - ArcMap - ArcInfo

File Edit View Insert Selection Tools Window Help


























           12,173,794 ▾   









  28% ▾ 

Layers

-  uscnty

Display Source

Drawing                         


Arid 10        

119°25'10.10"W 34°41'9.73"N

Tools

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Editor

Editor ▾ ▶  Task: Target:  

Untitled ArcMap ArcInfo

File Edit View Insert Selection Tools Window Help

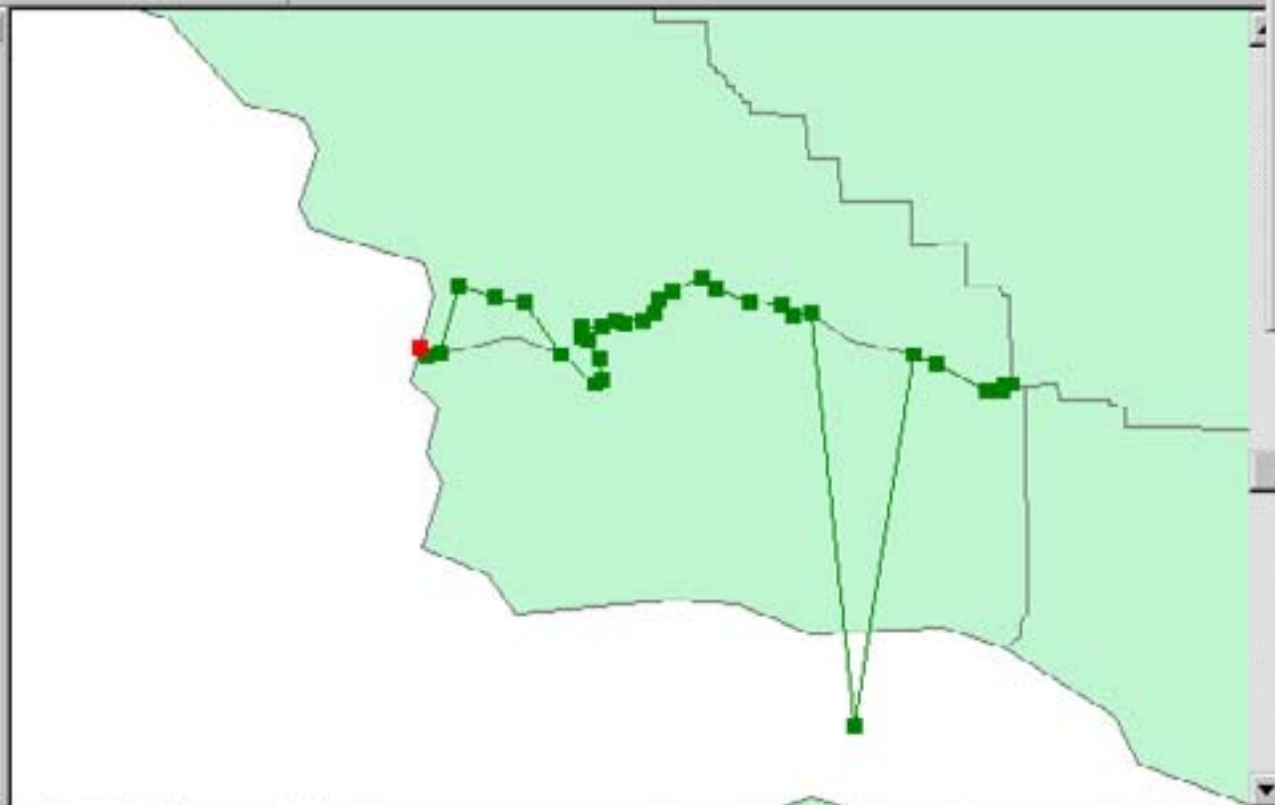
          1:1,901,122   

 100% 







Layers


- usgeog polygon

Display Source

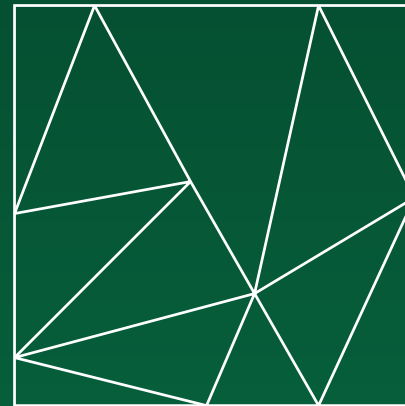
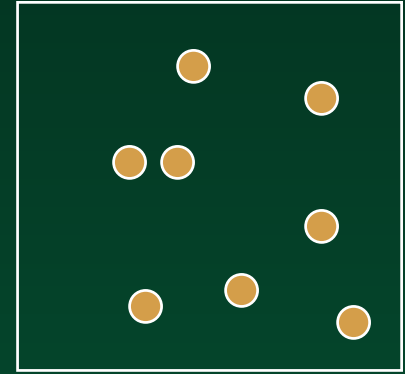
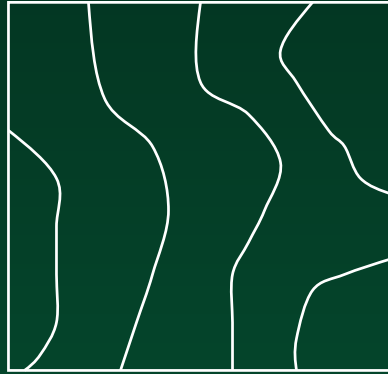
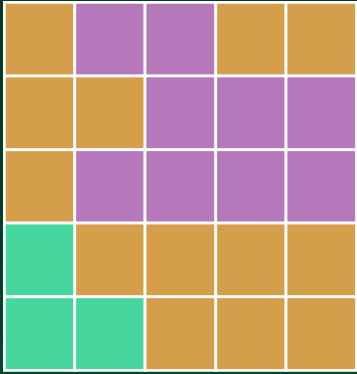


Tools

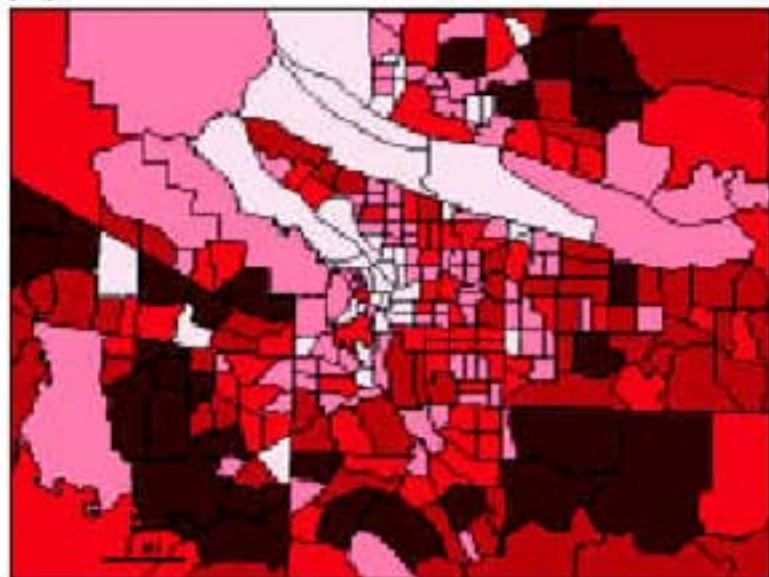
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Drawing     Arial 10 B I U   

121°17'17.34"W 34°12'12.74"N

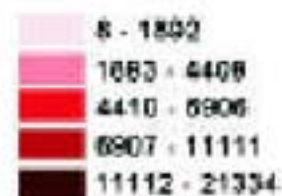
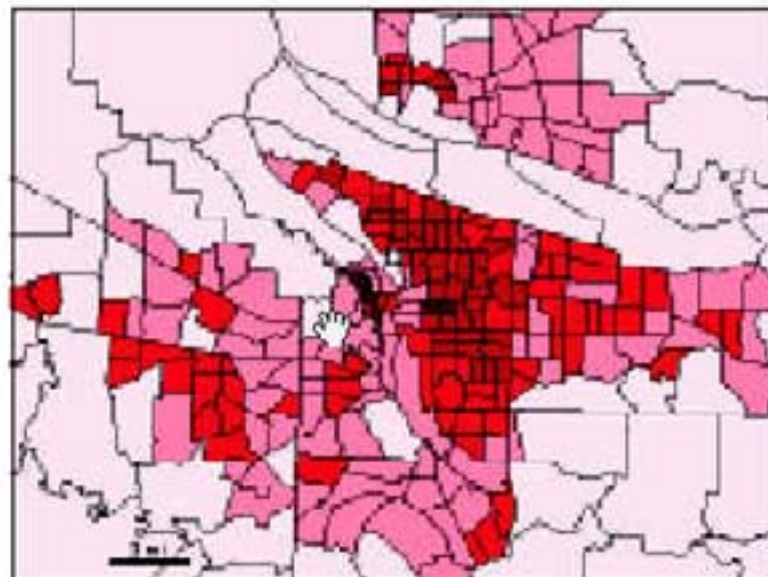


If you want to know approximately how many people each census tract has, map total population.



Census tracts by total population.

If you want to know where most of the people are concentrated, map population density.



Census tracts by people per square mile.

Taxonomies of spatial analysis

- Thousands of methods
 - every one a command, menu item, icon, ...
- Based on data type
 - point pattern analysis
 - area (polygon) analysis
 - analysis of interactions
 - Bailey and Gatrell, Haining, Unwin

A six-way conceptual classification

- Query and reasoning
- Measurement
- Transformation
- Descriptive summary
- Optimization
- Hypothesis testing

Queries and reasoning

- Real-time answers to geographic questions
 - Where is...?
 - What is this?
 - How do I get from here to here?
- Based on alternative views of a database



Location: E:\ArcFM Water\Samples\Data\ArcFMLand.mdb\Planimetric\RoadCL

File Edit View Go Tools Help

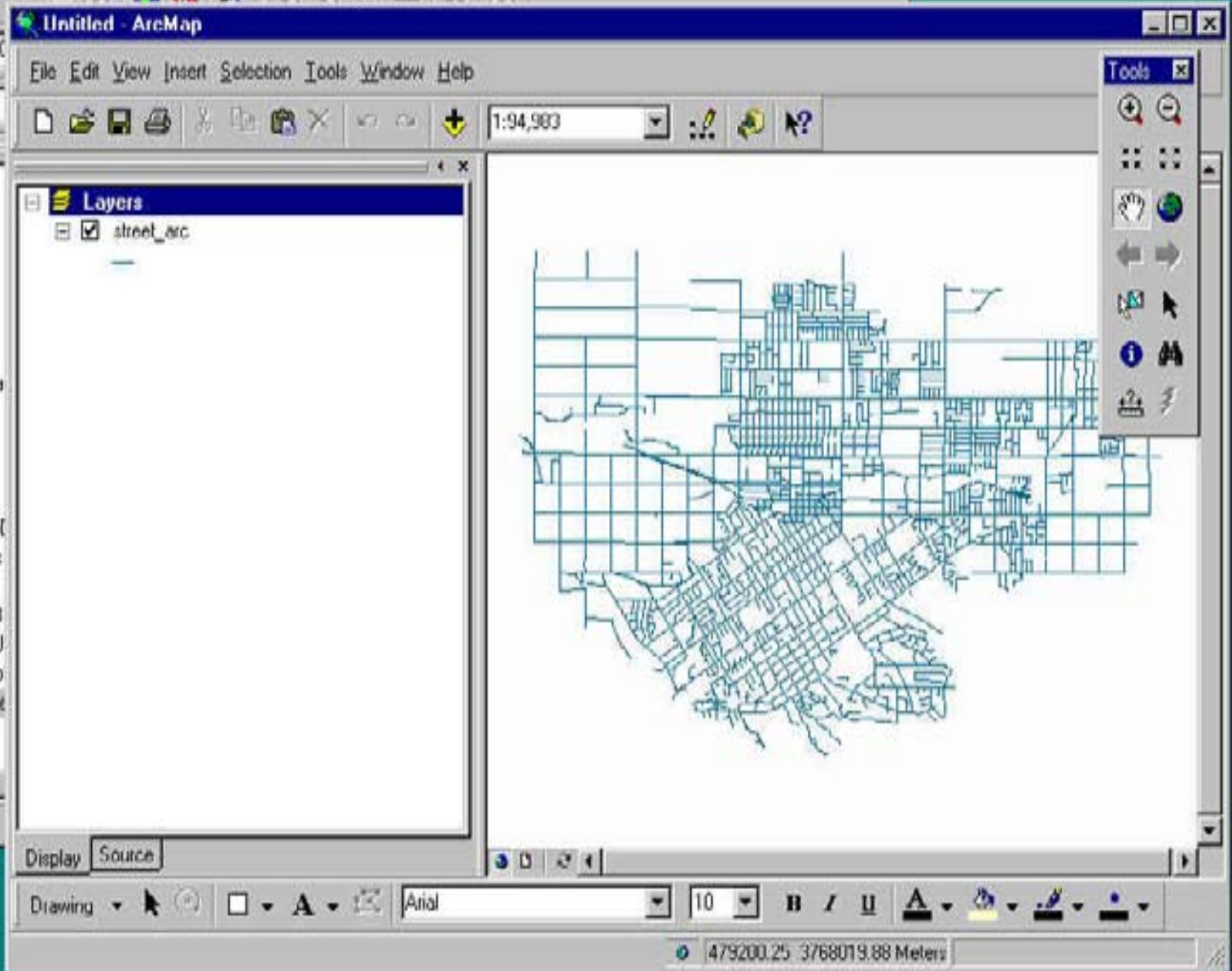
Stylesheet: ESRI

- E:\
 - 176b_labs
 - Acrobat3
 - Acrobat4
 - adl
 - ADOBEAPP
 - ArcFM Water
 - Data Model
 - Samples
 - Data
 - Images
 - ArcFMLand
 - Parcel
 - Planimetric
 - CityLimits
 - Hydro
 - RailRoadCL
 - RoadCL
 - RoadEOP
 - ArcFMSewer
 - ArcFMWater
 - Buildings

Contents Preview Metadata

The map preview displays a network of roads in green. The roads are concentrated in a central area and branch out towards the edges of the map. The background is white.

Preview: Geography





Untitled - ArcMap

File Edit View Insert Selection Tools Window Help

1:34.303

Layers

- street_arc

Tools

10 B / II A

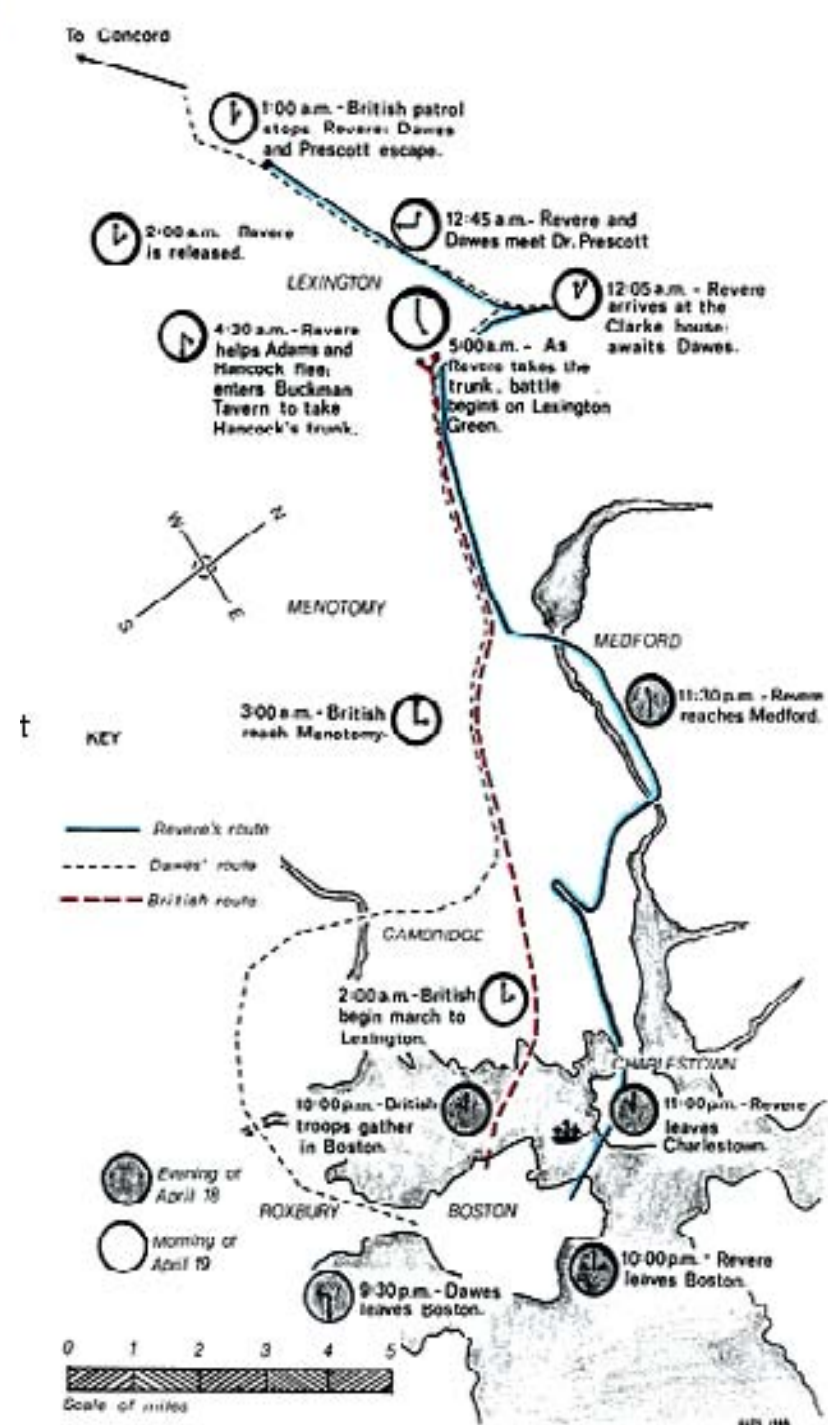
470471.45 3767617.79 Meters

Attributes of street_arc

FID_1	Shape	NAME	Shape_Length	Type
1	Polyline		136.500014433901	4
2	Polyline		267.503534104294	4
3	Polyline		403.25717951764	4
4	Polyline		806.22123346338	4
5	Polyline		403.006998608611	3
6	Polyline		799.93784833492	4
7	Polyline		800.741202203492	5
8	Polyline		53.400023458049	5
9	Polyline		398.754707416395	5
10	Polyline		123.104556726918	5
11	Polyline		95.6501002505001	5
12	Polyline		40.0053830742638	5
13	Polyline		135.607670712223	5
14	Polyline		90.6600280511209	5
15	Polyline		30.5051020119046	5
16	Polyline		91.3370072599947	5
17	Polyline		158.455728217768	5
18	Polyline		108.500000101048	5
19	Polyline		266.572276546260	5
20	Polyline		269.274931124029	5
21	Polyline		88.7588024628139	5
22	Polyline		134.601737966072	5
23	Polyline		62.0000200000000	5

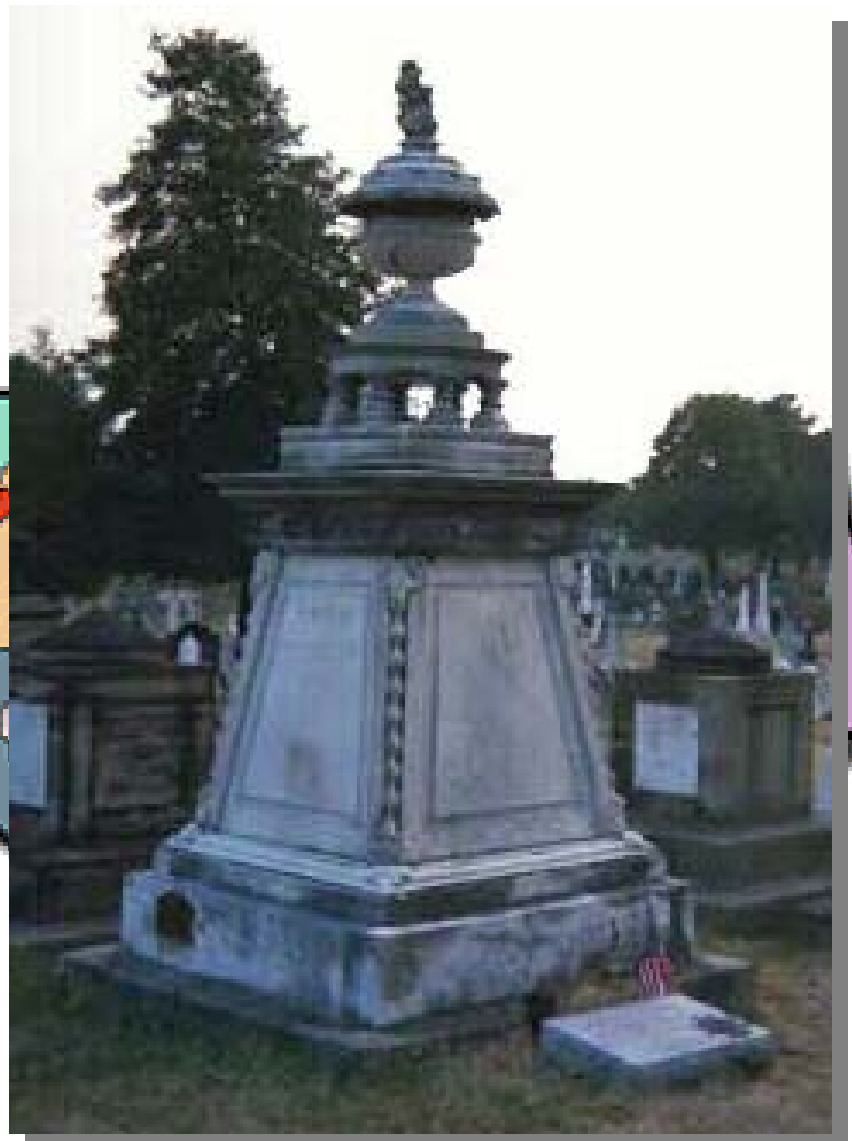
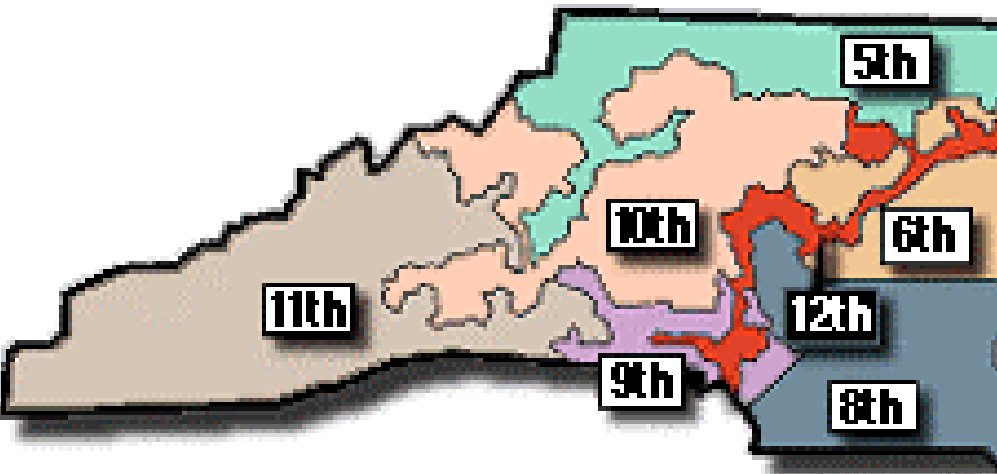
Record: 13 2102 out of *2000 Selected.

Directions	Distance
1: Start out going East on HENLEY ST towards WARREN ST.	0.1 miles (0.1 km)
2: Turn RIGHT onto WARREN ST.	0.0 miles (0.1 km)
3: Turn RIGHT onto CHELSEA ST.	0.0 miles (0.1 km)
4: CHELSEA ST becomes CHELSEA ST/CITY SQ.	0.1 miles (0.1 km)
5: Turn RIGHT onto CITY SQ/NEW RUTHERFORD AVE/SR-99 N.	0.0 miles (0.1 km)
6: Stay straight to go onto NEW RUTHERFORD AVE/SR-99 N.	0.2 miles (0.3 km)
7: Turn SLIGHT LEFT onto SR-99 N.	0.4 miles (0.6 km)
8: Turn SLIGHT LEFT onto SR-99 N/RUTHERFORD AVE.	0.1 miles (0.1 km)
9: Turn SLIGHT LEFT onto SR-99 N.	0.3 miles (0.4 km)
10: Turn SLIGHT LEFT onto SULLIVAN SQUARE OPAS.	0.4 miles (0.7 km)
11: Turn SLIGHT LEFT onto MYSTIC AVE.	0.7 miles (1.1 km)
12: MYSTIC AVE becomes MYSTIC AVE/SR-38 N.	1.2 miles (2.0 km)
13: Turn LEFT onto HARVARD ST.	0.6 miles (1.0 km)
14: HARVARD ST becomes WARNER ST.	0.2 miles (0.3 km)
15: Turn RIGHT onto POWDER HOUSE SQ.	0.1 miles (0.1 km)
16: Turn RIGHT onto BROADWAY.	1.0 miles (1.6 km)
17: Turn LEFT onto ALEWIFE BROOK PKWY/SR-16.	0.4 miles (0.7 km)
18: ALEWIFE BROOK PKWY/SR-16 becomes ALEWIFE BROOK PKWY/SR-16/US-3.	0.4 miles (0.7 km)
19: Take CONCORD TURNPIKE/SR-2 W.	4.7 miles (7.6 km)
20: Take the WALTHAM ST. exit, exit number 54B, towards LEXINGTON.	0.2 miles (0.3 km)
21: Merge onto WALTHAM ST.	1.9 miles (3.0 km)
22: Turn RIGHT onto MASSACHUSETTS AVE/MASS AVE/SR-225.	0.0 miles (0.0 km)
Total Distance:	12.9 miles (20.8 km)
Estimated Time:	24 minutes



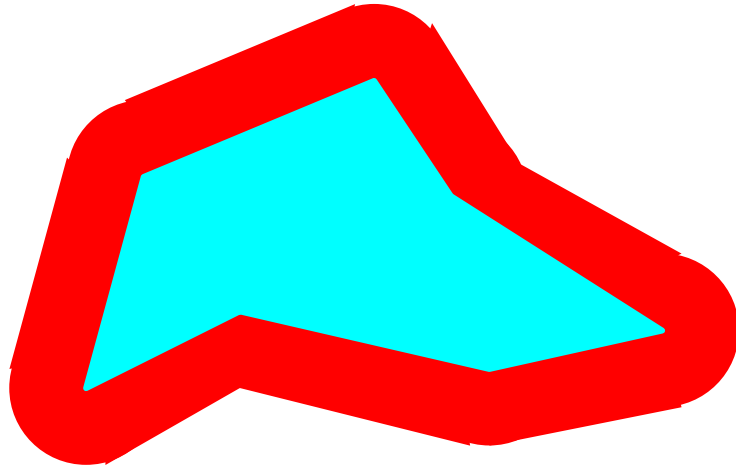
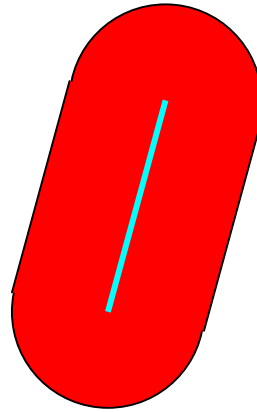
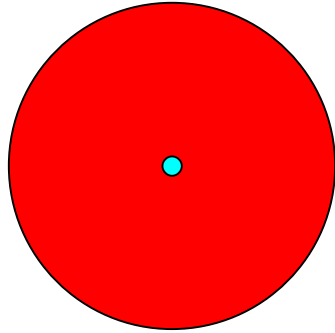
Measurements

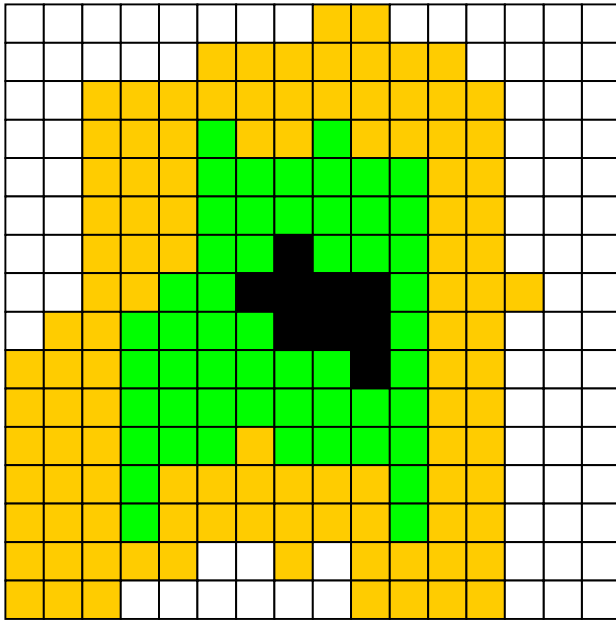
- Area
- Distance
- Length
- Perimeter
- Slope, aspect
- Shape







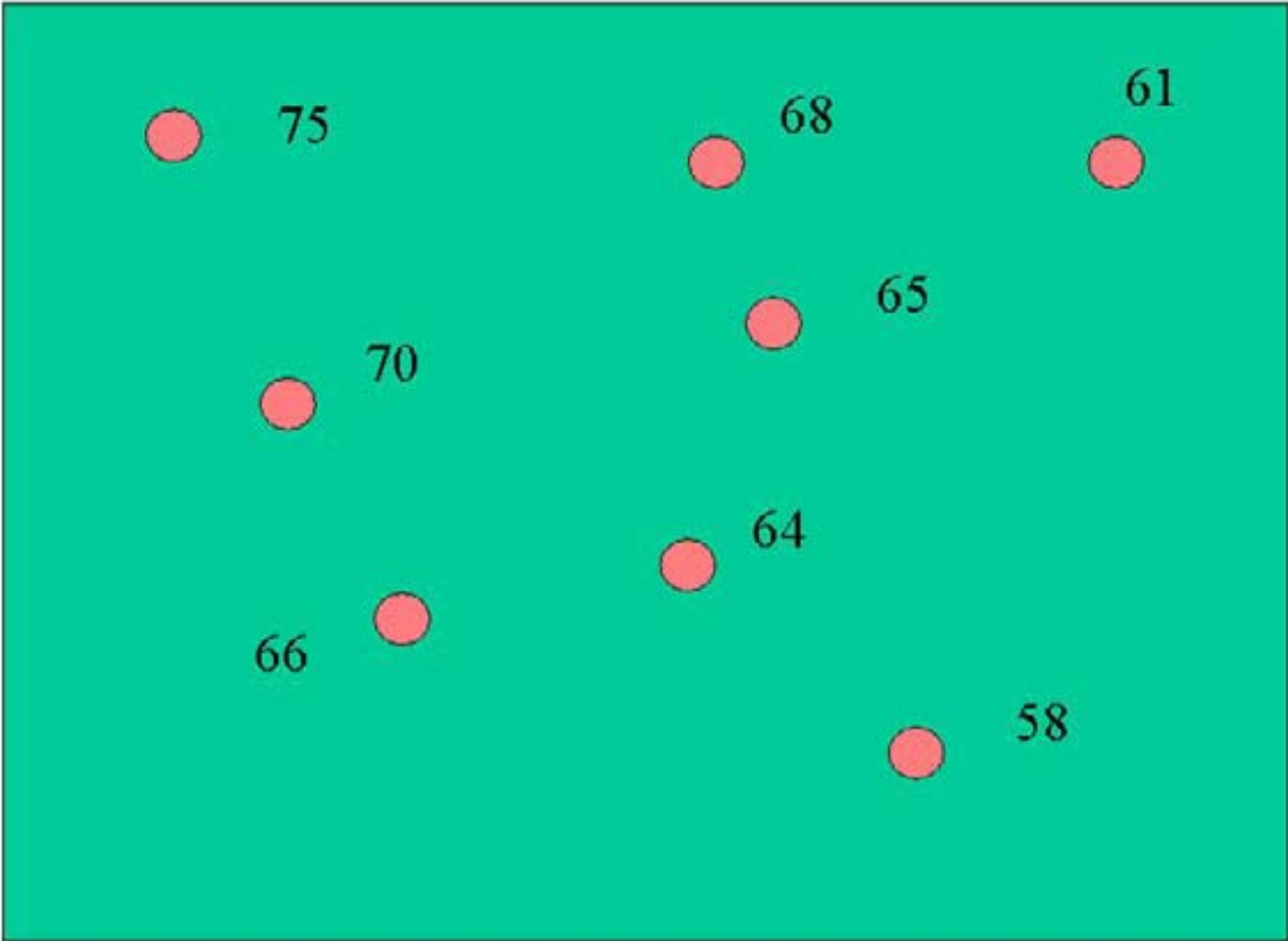
Transformations

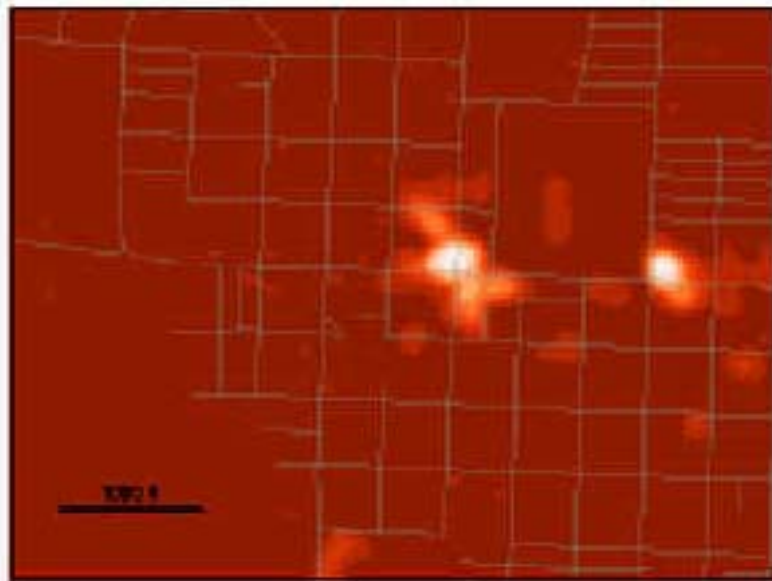
- Buffering
- Points in polygons
- Polygon overlay
- Spatial interpolation
- Density estimation



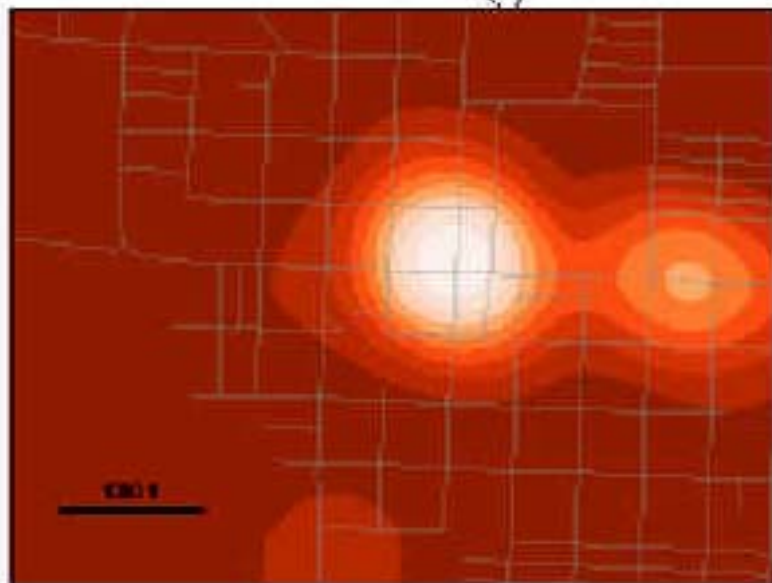


-  City limits
-  Areas reachable in 5 minutes
-  Areas reachable in 10 minutes
-  Other areas

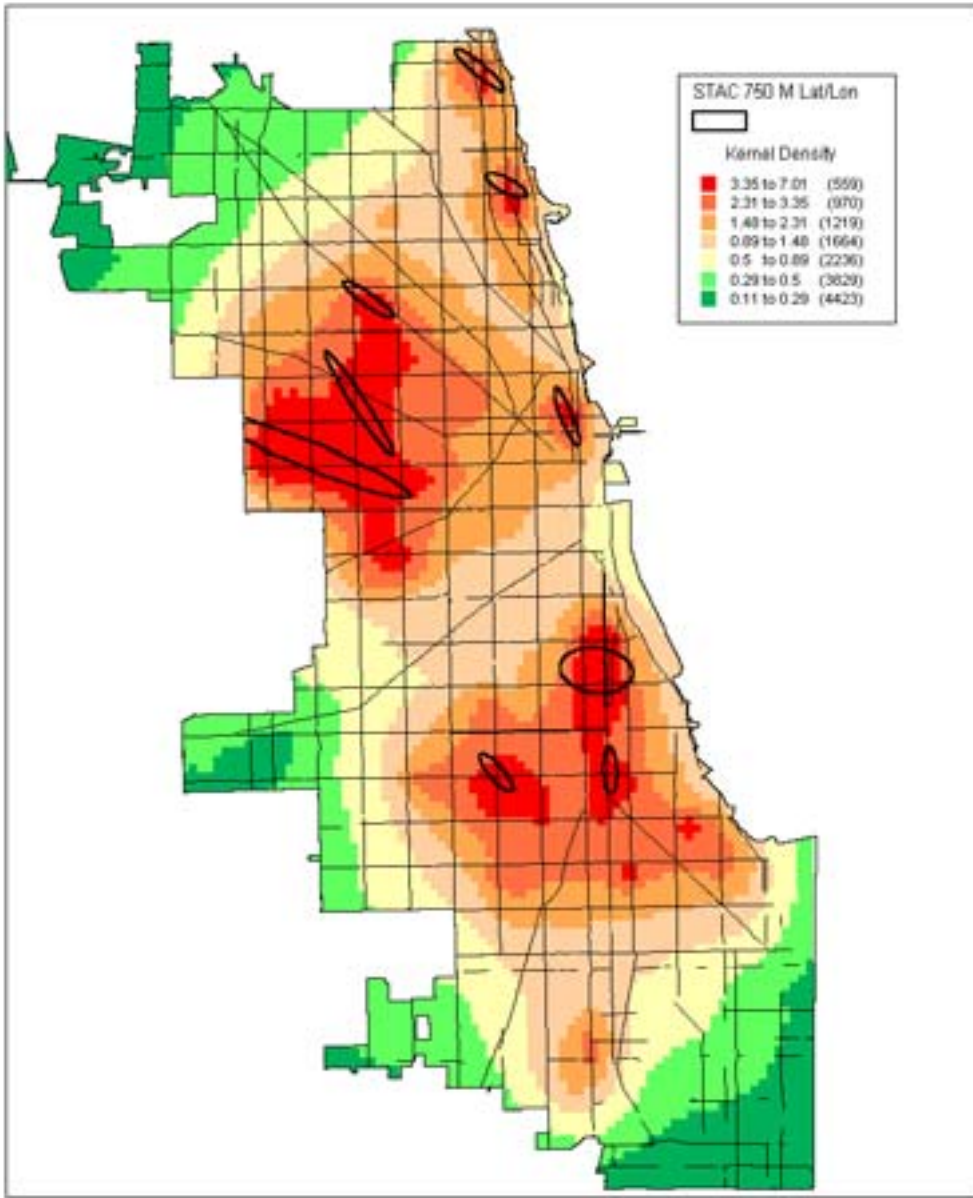




Search radius = 200 feet



Search radius = 1000 feet



Courtesy of Dick Block

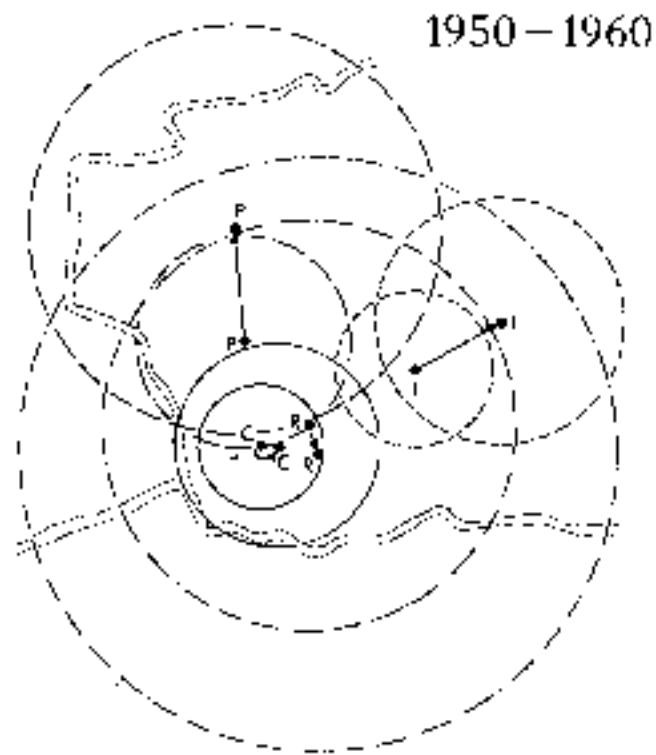
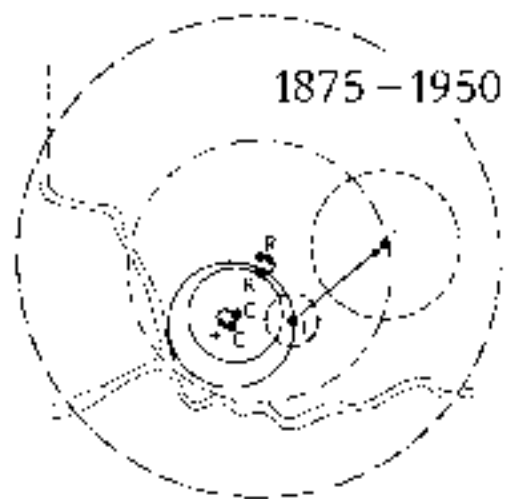
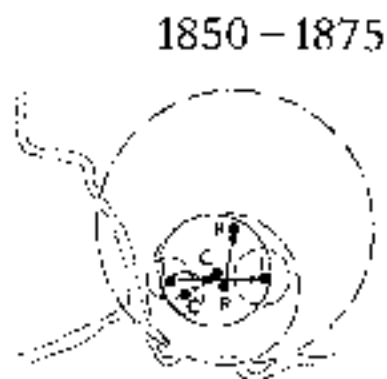
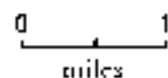
Descriptive summary

- Centers
- Measures of spatial dispersion
- Spatial dependence
- Fragmentation
- Fractional dimension

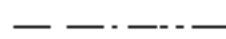
MASS MOVEMENTS OF LAND USE SURFACES

LONDON, ONTARIO

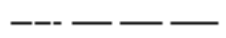
1850 - 1960



Land Use Surfaces



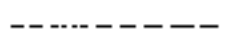
Residential (R)



Public -
Institutional (P)



Commercial (C)



Industrial (I)



Mean locations
of land use surfaces



Direction of
mass movements



Peak value
intersection; 1960

Industrial land includes railroad and warehouse properties.

Public and institutional lands included with residential land for 1850 - 1875 and 1875 - 1950.

Optimization

- Design to achieve specific objectives
- Location of central point-like facilities to serve dispersed demand
- Location of linear facilities
- Design of boundaries for elections



List View

WorkCtr Location Visit M067124

Name	Address	Units	Hrs/Mth	Type
1130 VERMONT	1130 VERMONT S	1	0.9 7	HY
625 NEW HAMPSHIRE	625 NEW HAMPSHIRE	1	0.9 2	HY
3611 WILSHIRE	3611 WILSHIRE BLV	1	0.8 6	HY
114 OXFORD	114 OXFORD S	1	0.8 3	HY
3099 OLYMPIC CAL KOREA B	3099 OLYMPIC BLVE	1	0.9 5	HY
542 MARIPOSA GORDON CHI	542 MARIPOSA S	1	0.8 5	HY
140 MARIPOSA AVE	140 MARIPOSA AVE	1	0.9 9	HY
209 MARIPOSA S	209 MARIPOSA S	1	0.8 5	HY
2930 FRANCIS	2930 FRANCIS	1	0.9 4	HY
248 OCCIDENTAL	248 OCCIDENTAL	1	0.9 3	HY
601 WESTMORELAND	601 WESTMORELAND	1	0.7 4	HY
303 COMMONWEALTH	303 COMMONWEAL	1	0.9 9	HY
2830 FRANCIS	2830 FRANCIS	1	0.9 7	HY
187 OXFORD OXFORD VILLA	187 OXFORD	1	0.9 8	HY
601 ARDMORE PUBLIC COUN	601 ARDMORE AVE	1	0.7 5	HY
3535 SIXTH ST.	3535 W SIXTH	1	0.7 5	HY
1052 MARIPOSA AVE	1052 S MARIPOSA	1	1.0 0	HY
128 MARIPOSA AV S	128 MARIPOSA AV S	1	0.8 4	HY
449 KINGSLEY BLDG	449 KINGSLEY DRIV	2	1.9 2	HY
445 HOBART	445 HOBART	2	1.8 6	HY
350 CATALINA BLDG	350 CATALINA STRE	1	0.9 6	HY
3500 EIGHTH STREET BLDG	3500 EIGHTH STRE	1	0.9 5	HY
3170 WILSHIRE BLDG	3170 WILSHIRE BLV	2	0.0 0	HY

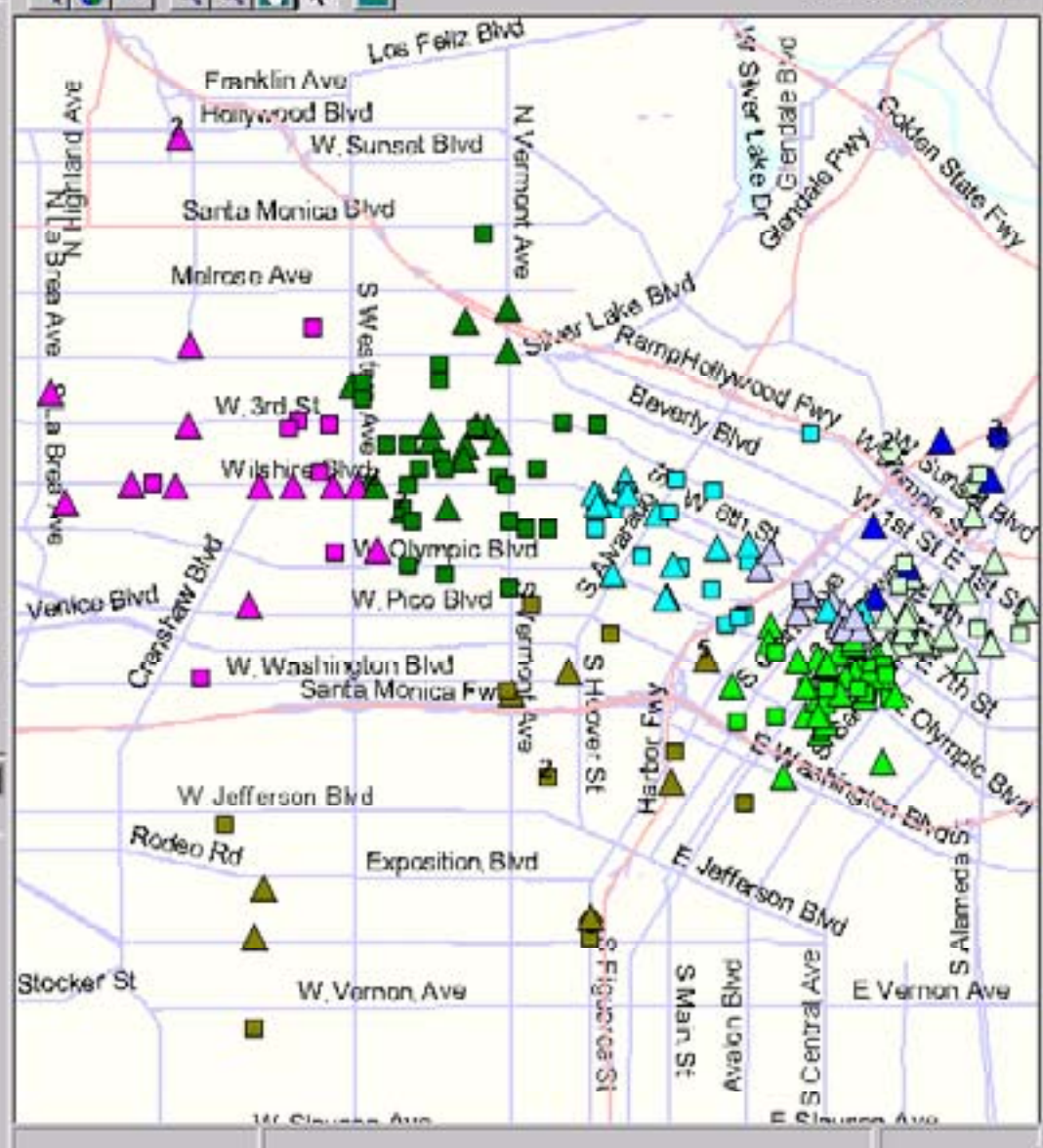
Chart

Chart All Dollars Units Hours CI



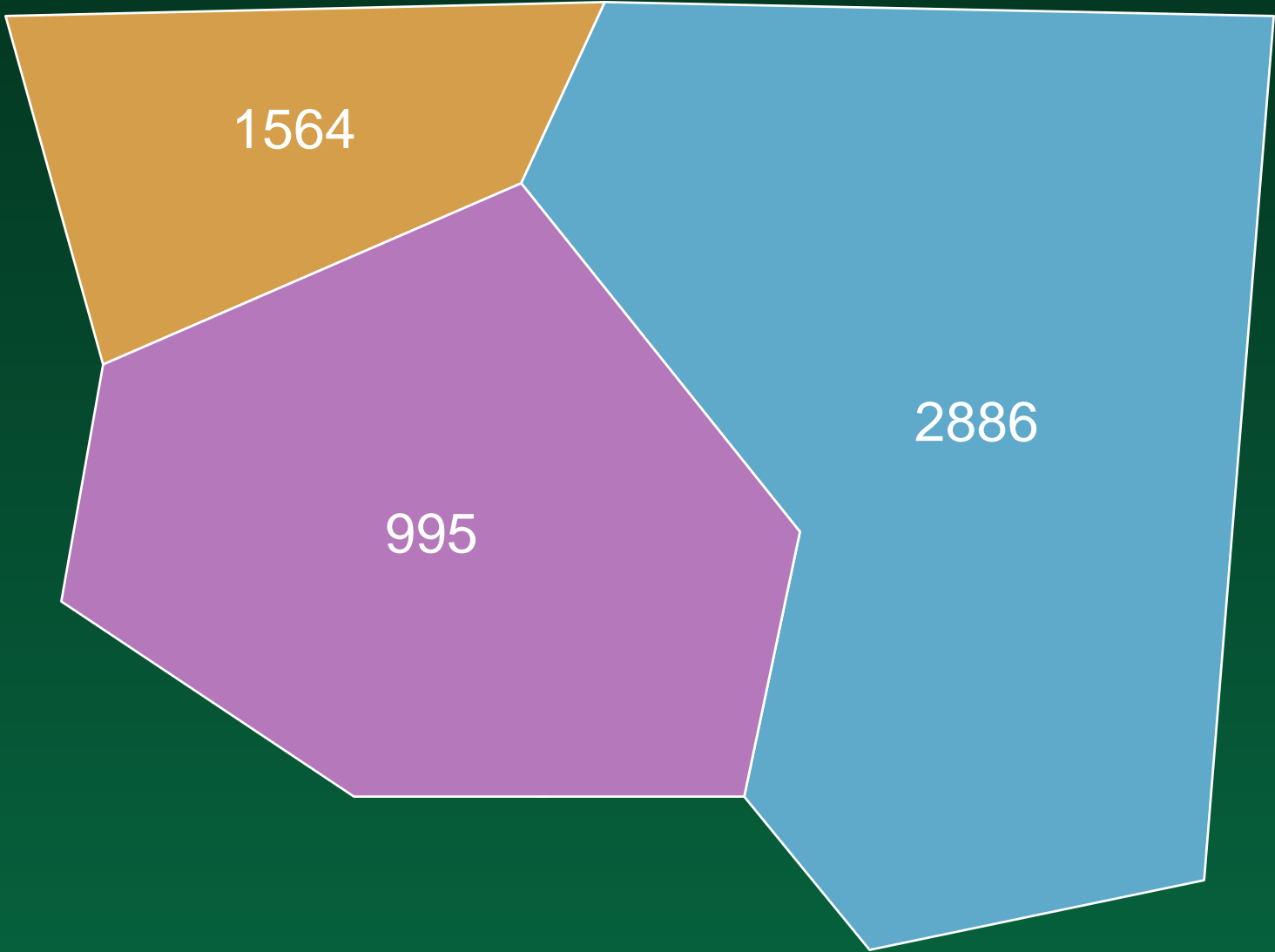
Map

Show selected only



Hypothesis testing

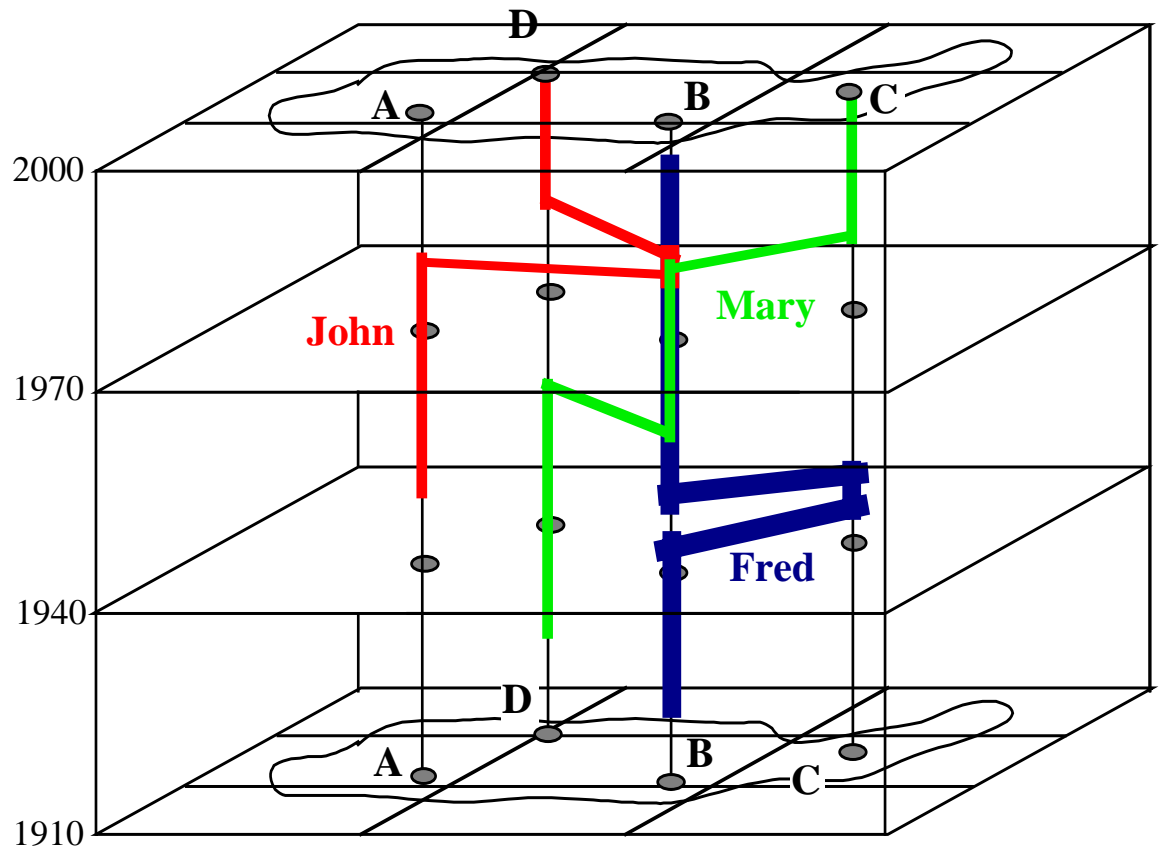
- Geographic objects as a sample from a population
 - what is the population?
- The independence assumption
 - the First Law of Geography
 - failure to find spatial dependence is always a Type II error
 - hell is a place with no spatial dependence



1990

Information lost to the representation

- All sub-polygon spatial variation
- All within-decade temporal variation
- All identities
 - instead of $\langle xy, \text{person} \rangle$ we have
 $\langle R, \text{number} \rangle$
 $\langle xy, xy, xy, xy, \dots, R \rangle$



Challenges of GIS

- How to characterize what is missing?
 - error, accuracy, uncertainty
- How to choose the best representation?
 - confounding influences
- How to support many data models in a single software package

Weaknesses of GIS

- There are too many possible data models
 - special-purpose GIS
 - lack of interoperability
- Difficult to add data models retroactively

Objectives, Structure, and History of CSISS

Research infrastructure

- Facilities that serve generic needs
 - economies of scale
- The Hubble Telescope
 - high fixed costs distributed over many users
- Infrastructure funding at NSF
 - South Pole
 - advanced computation

Generalizing the concept

- Shared computational facilities
- Shared data archiving and access
- Software tools
 - shared licenses
 - shared development
- Education and training
 - investments in skills
 - high leverage

General principles:

1. Integration

- Linking data through common location
 - the layer cake
- Linking processes across disciplines
 - spatially explicit processes
 - e.g. economic and social processes interact at common locations

Environmental

Map Layer

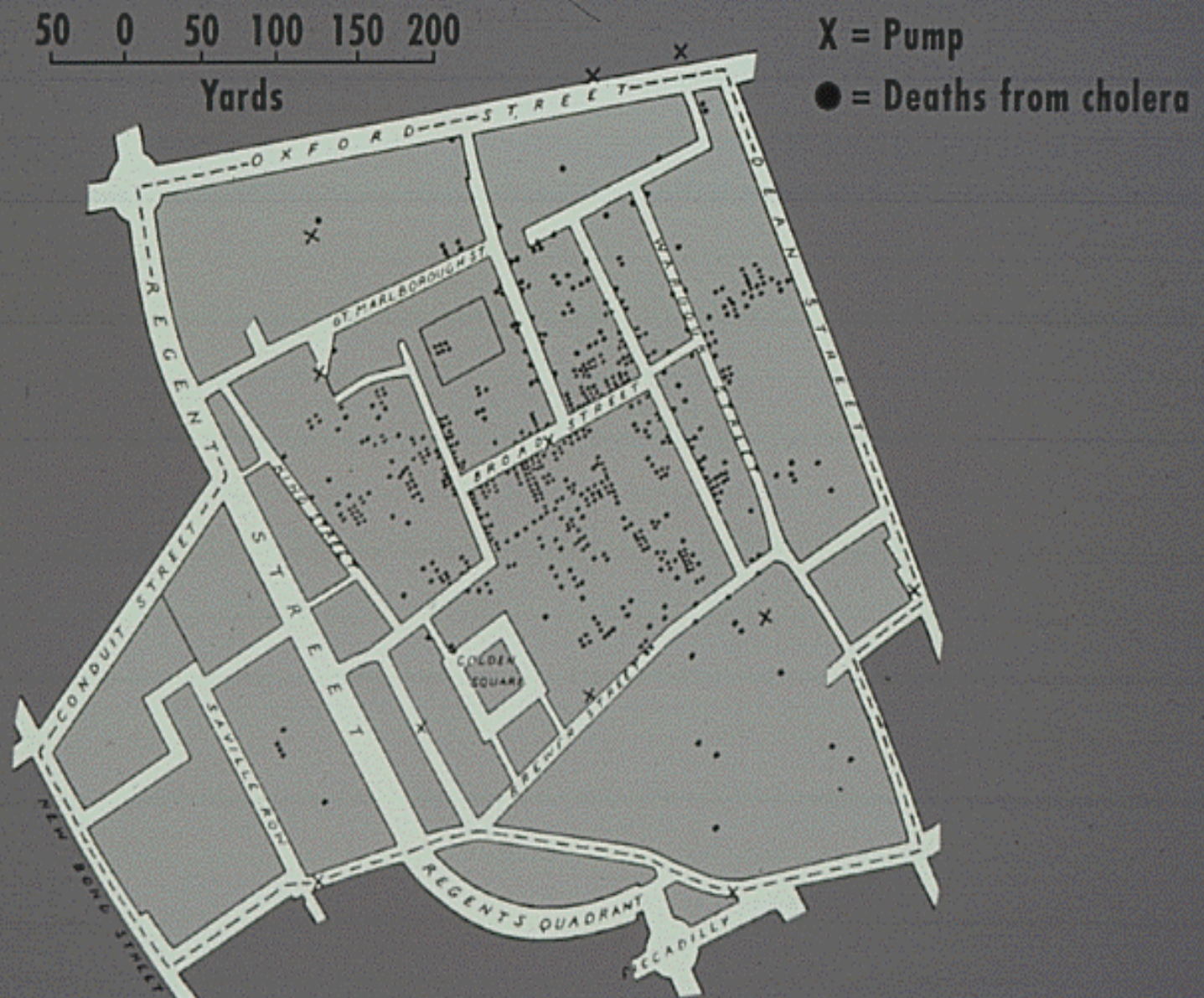
Format

Attribute Tables

Environmental	Map Layer	Format	Attribute Tables
Geology		Polygon	3-5
Hazard Areas		Polygon	6-10
Existing Land Use		Polygon	2-4
Noise Contours		Polygon	2-4
Floodplain		Polygon	3-5
Soils		Polygon	3-5
Vegetation		Polygon	1-3
Surficial Hydrology		Line/Polygon	12-15
EIR Study Areas		Point/Polygon	1-3
Planning Study Index Reference		Point	1-3

2. Spatial analysis

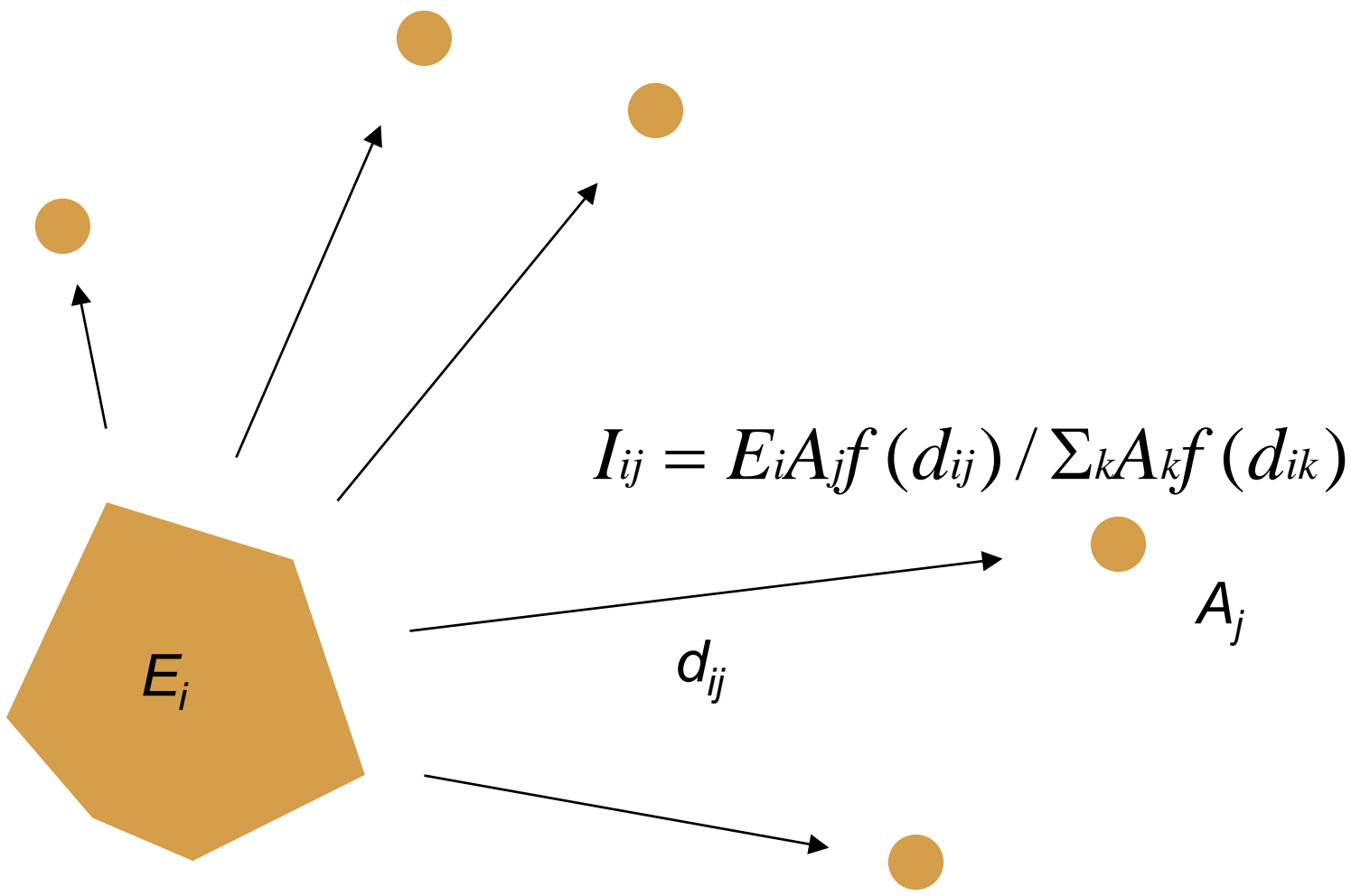
- Social data collected in cross-section
 - longitudinal data are difficult to construct
- Cross-sectional perspectives are rich in context
 - can never confirm process
 - though they can perhaps falsify
 - useful source of hypotheses, insights



**The Snow Map of Cholera Incidence in the Area of Broad Street, London, in 1854.
The contaminated water pump is located at the center of the map, just to the right of the D in BROAD STREET.**

3. Spatially explicit theory

- Theory that is not invariant under relocation
- Spatial concepts (location, distance, adjacency) appear explicitly
- Can spatial concepts ever *explain*, or are they always surrogates for something else?



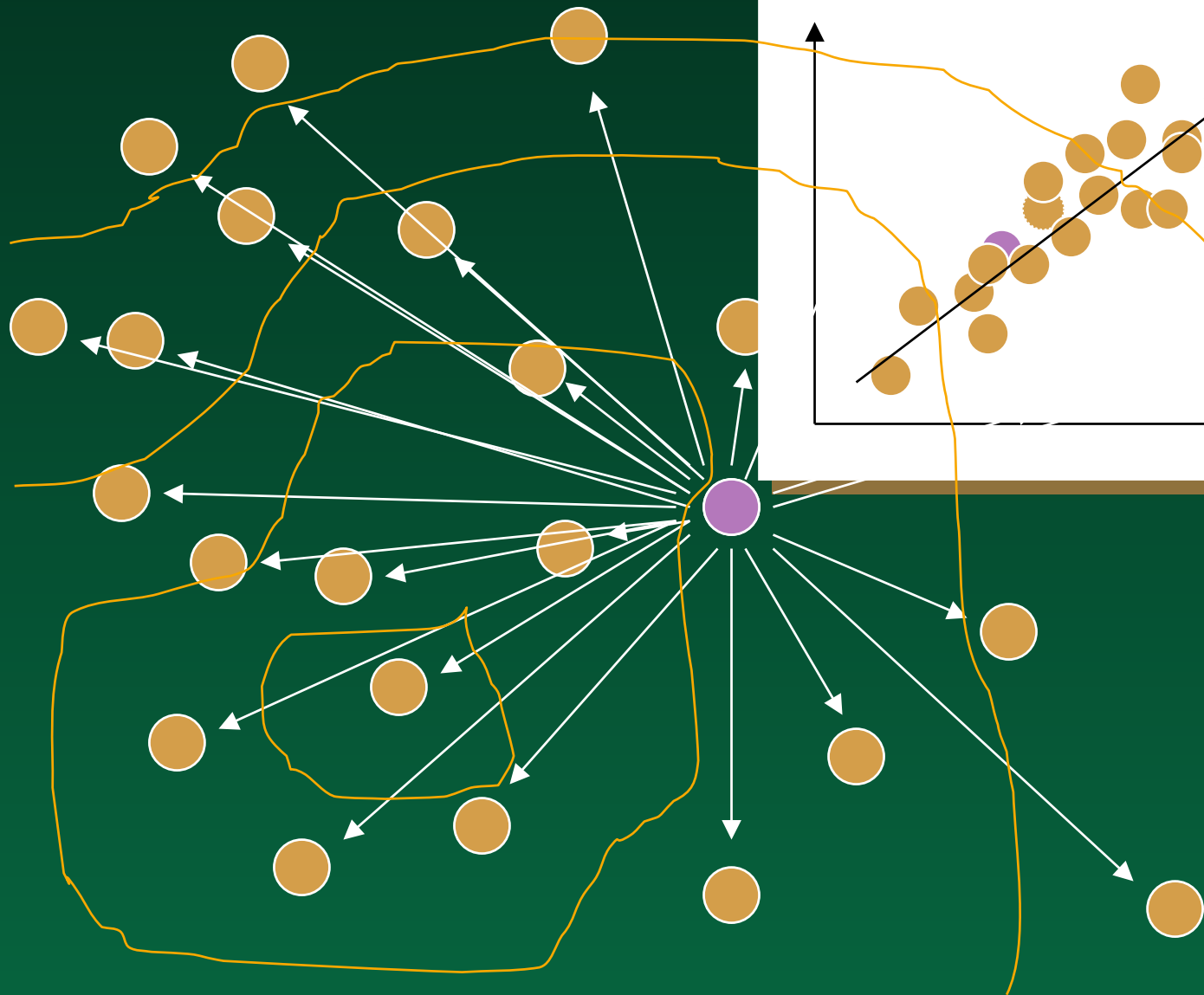
4. Place-based analysis

- Nomothetic - search for general principles
- Idiographic - description of unique properties of places
- An old debate in Geography

The Earth's surface

- Uncontrolled variance
- There is no average place
- Results depend explicitly on bounds
- Places as samples
- Consider the model:

$$y = a + bx$$



5. Knowledge and policy

- Policy requires the projection of general knowledge in spatial context
 - the implications of this process in this location
 - alternative futures visualized under local circumstances
- GIS combines the general (processes, models, algorithms) with the specific (database of local details)

6. Place-based search

- Location as an organizing dimension to information
 - much information can be georeferenced
 - much more than maps and images
- The Geolibrary
 - what have you got about *there*?
 - impossible physically, feasible digitally

Prototype geolibraries

- National Geospatial Data Clearinghouse
 - *www.fgdc.gov*
- Microsoft's Terraserver
 - *terraserver.microsoft.com*
- Alexandria Digital Library
 - *alexandria.ucsb.edu*

WICK PLACENAME SEARCH
 Search the entire world for...

 Find
 er "Rome" if you want Rome, Italy.
[See information](#)

GENERAL SEARCH
 Select collection to search
 DL Catalog
[See collections](#)

Set geographic region
 the map to the right to set the geographic
 ent of the search, or directly enter bounding
 rordinates below.

N

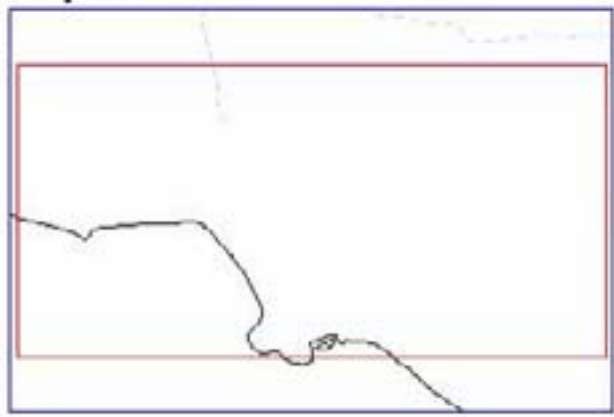
 W E

 S

Words to search for

 Any of the above words
 All of the above words
 Exact phrase

Map Browser



Click map to:

 Change location to:

Navigation controls including directional arrows, zoom in/out buttons, a shape selection tool, and a Reset button.

ADL Search Results

The query that produced these results can be found at [the bottom of this page](#).

- DRG o33117g6, Digital Raster Graphic of BLACK STAR CANYON, CA.**
Type: maps. **Format:** TIFF. **Date:** 1988. **ADL identifier:** adl_catalog:800279.
[HIGHLIGHT IN MAP](#) · [COMPLETE DESCRIPTION](#) · [BROWSE GRAPHIC](#) · [ACCESS/DOWNLOAD](#)
- DRG o33117g7, Digital Raster Graphic of ORANGE, CA.**
Type: maps. **Format:** TIFF. **Date:** 1981. **ADL identifier:** adl_catalog:800280.
[HIGHLIGHT IN MAP](#) · [COMPLETE DESCRIPTION](#) · [BROWSE GRAPHIC](#) · [ACCESS/DOWNLOAD](#)
- DRG o33117g8, Digital Raster Graphic of ANAHEIM, CA.**
Type: maps. **Format:** TIFF. **Date:** 1981. **ADL identifier:** adl_catalog:800281.
[HIGHLIGHT IN MAP](#) · [COMPLETE DESCRIPTION](#) · [BROWSE GRAPHIC](#) · [ACCESS/DOWNLOAD](#)

CSISS mission

- The CSISS mission recognizes the growing significance of space, spatiality, location, and place in social science research. It seeks to develop unrestricted access to tools and perspectives that will advance the spatial analytic capabilities of researchers throughout the social sciences.

Seven CSISS programs

- National Workshops
- Software Tools
- Virtual Community
- Best Practice Examples
- Place-Based Search
- Learning Resources
- Specialist Meetings

The W Matrix

Abstraction of geographic space

- Cartograms



- Invariance under rotation, displacement, reflection
- Reconstruction from a distance matrix
- Reconstruction from ranked distances
 - ordered metric data (Coombs)

Space as a matrix

- W where w_{ij} is some measure of interaction
 - adjacency
 - decreasing function of distance
 - invariant under rotation, displacement, reflection
 - readily obtained from GIS
 - reflects a discrete object conceptualization

The Modifiable Areal Unit Problem

- Openshaw and Taylor
 - 99 counties of Iowa
 - % Republican voters, % over 65
- 48 regions: $-.548$ to $+.886$
- 12 regions: $-.936$ to $+.996$
- Solutions:
 - manipulate to determine range
 - strengthen theoretical framework

Applications of the W matrix

- Spatial regression
 - add spatially lagged terms weighted by W
 - Anselin's SPACESTAT
- Moran and Geary indices of spatial dependence

$$c = \frac{(n-1) \sum_i \sum_j w_{ij} (x_i - x_j)^2}{2 \sum_i \sum_j w_{ij} \sum_i (x_i - a)^2}$$

Social versus spatial

- W estimated
- Well-defined discrete object conceptualization
- Direct measures of interaction
- W calculated
- Discrete objects as arbitrary regions, MAUP
- Surrogate measures of interaction

Cross-Product Statistics

- Let \mathbf{C} be a matrix of similarities between objects
- Consider the cross-product

$$\Gamma = \sum_i \sum_j c_{ij} w_{ij}$$

Properties of Γ

- Generalizes Moran and Geary
- Measures the correlation between social and spatial
- Simple randomization tests based on permutation
- Hubert, Golledge, and Costanzo, *Geographical Analysis* 13(3): 224-233, 1981

Social versus Spatial

- The ability to explain
 - empirical estimates versus measurements
- Additional arguments supporting spatial
 - context
 - integration
 - implementation
- A fruitful basis for collaboration