



# What is Where?

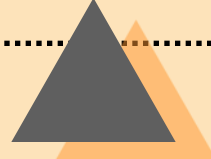
Getting Started With Geographic  
Information Systems

Chapter 5





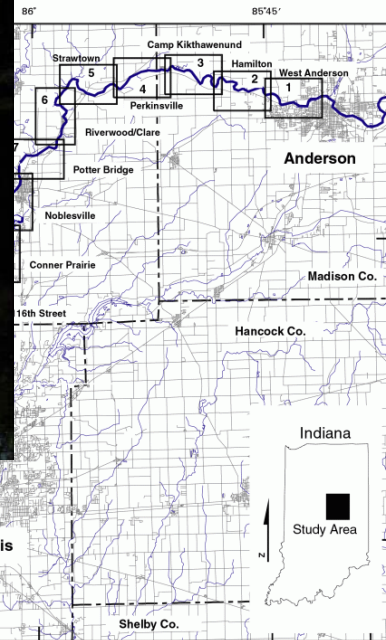
# You can use a GIS to answer the question: **What is where?**

- ◆ **WHAT:** Characteristics of attributes or features
  - ◆ **WHERE:** In geographic space
- 

# What and Where

## RIVERS, LAKES, AND CANALS

Intermittent stream	
Intermittent river	
Disappearing stream	
Perennial stream	
Perennial river	
Small falls; small rapids	
Large falls; large rapids	
Masonry dam	
Dam with lock	
Dam carrying road	
Perennial lake; Intermittent lake or pond	
Dry lake	
Narrow wash	
Wide wash	
Canal, flume, or aqueduct with lock	
Elevated aqueduct, flume, or conduit	
Aqueduct tunnel	
Well or spring; spring or seep	
<b>SUBMERGED AREAS AND BOGS</b>	
Marsh or swamp	
Submerged marsh or swamp	
Wooded marsh or swamp	
Submerged wooded marsh or swamp	
Rice field	
Land subject to inundation	



Base from U.S. Geological Survey digital data 1:100,000, 1983  
Universal Transverse Mercator projection, Zone 16, NAD 83

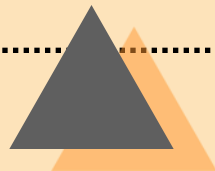
0 5 10 MILES  
0 5 10 KILOMETERS

Index of Bank-Condition Maps

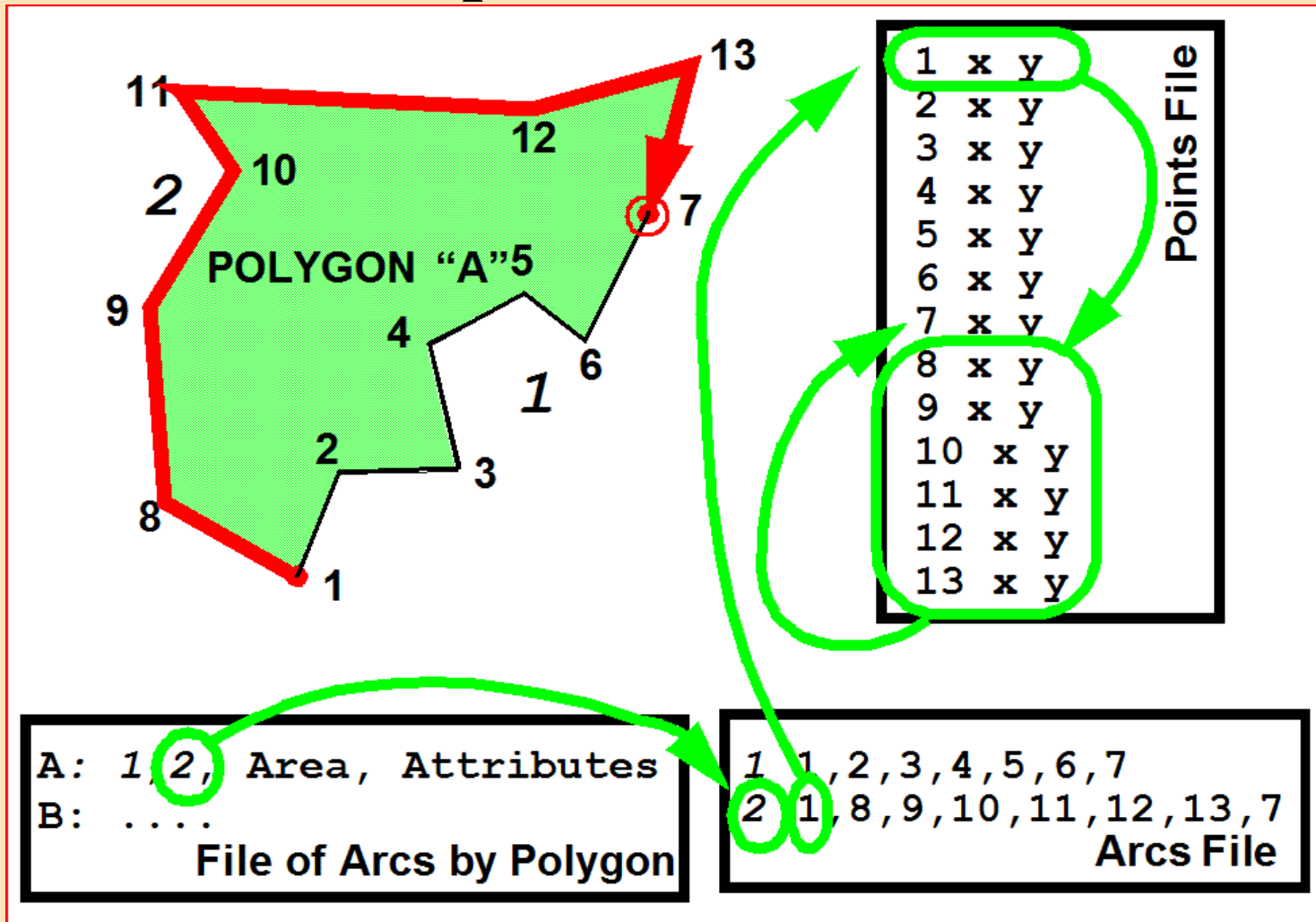


# *Review: Flat File Database*

	Depth	Flow	Condition
Stream	Value	Value	Value
Dam	Value	Value	Value
Canal	Value	Value	Value



# Arc/node map data structure with files





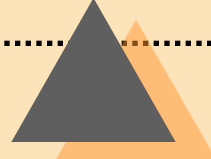
# A GIS links attribute and spatial data



## ◆ Attribute Data

- ◆ Flat File
- ◆ Relations

## ◆ Map Data

- ◆ Point File
  - ◆ Line File
  - ◆ Area File
  - ◆ Topology
  - ◆ Theme
- 



# What is a Data Model?

A logical construct for the storage and retrieval of information.

GIS map data structures are **map** data models.

**Attribute** data models are needed for the DBMS.

The origin of DBMS data models is in computer science.



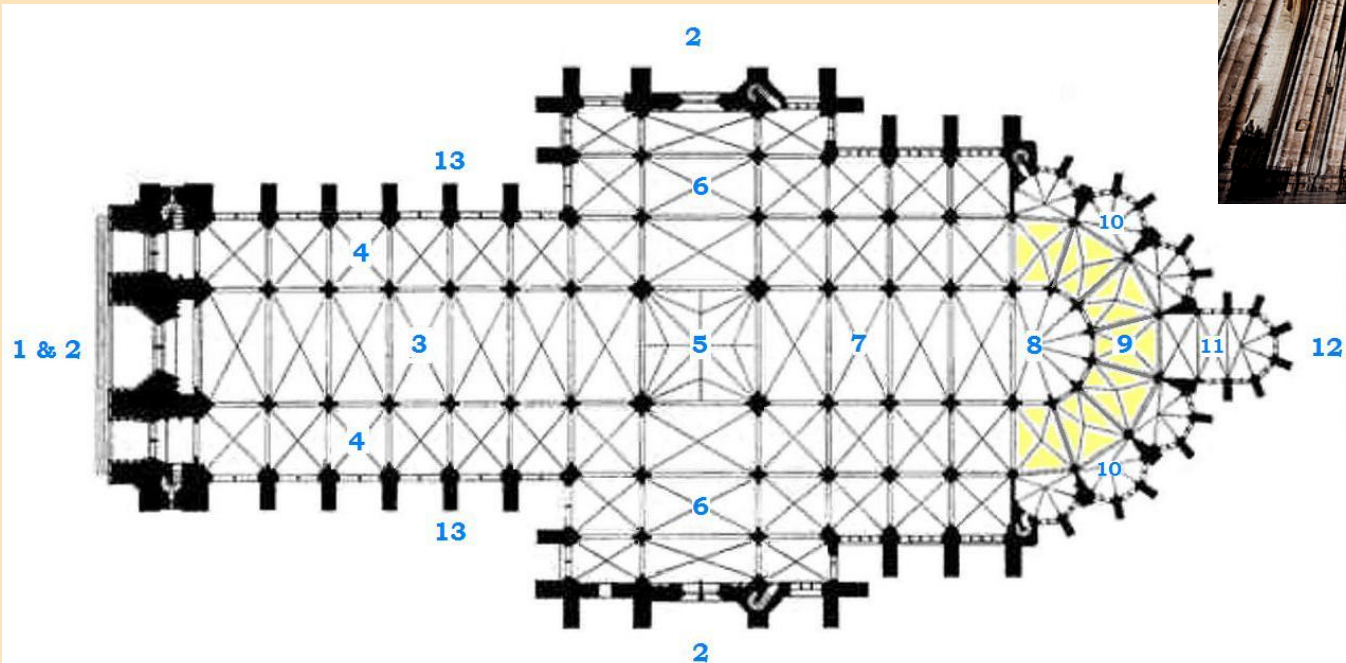
# Maps and Memory



*Joshua Foer (2011)  
“Moonwalking With  
Einstein:  
The Art and Science of  
Remembering  
Everything,”*



# Data Models and Memory

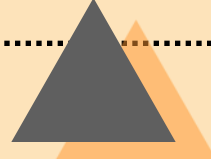


Amiens Cathedral, France

- |            |                     |                  |
|------------|---------------------|------------------|
| 1 West end | 6 Transept          | 11 Lady's chapel |
| 2 Facade   | 7 Choir             | 12 East end      |
| 3 Nave     | 8 Apse              | 13 Buttress      |
| 4 Aisle    | 9 Ambulatory        |                  |
| 5 Crossing | 10 Radiating chapel |                  |



# A DBMS contains:

- ◆ Data definition language
  - ◆ Data dictionary
  - ◆ Data-entry module
  - ◆ Data update module
  - ◆ Report generator
  - ◆ Query language
- 

# The data dictionary

**IMPS 4.1 Data Dictionary - [Popstan.ddw (Record: POP-REC)]**

File Edit View Options Tools Window Help

Add Insert Delete Record Items Record: POP-REC

Item Label	Name	Data	Item	Start	Len	Occ	Dec	Sign
Line Number	P00-LINE-NUMBER	Numeric	Item	20	2	1	0	No
Relationship	P02-RELATIONSHIP	Numeric	Item	22	1	1	0	No
Sex	P03-SEX	Numeric	Item	23	1	1	0	No
Date of Birth	P04-DOB	Numeric	Item	24	8	1	0	No
Day of Birth	P04D-DAY	Numeric	SubItem	24	2	1	0	No
Month of Birth	P04M-MONTH	Numeric	SubItem	26	2	1	0	No
Year of Birth	P04Y-YEAR	Numeric	SubItem	28	4	1	0	No
<b>Age</b>	<b>P05-AGE</b>	<b>Numeric</b>	<b>Item</b>	<b>32</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>No</b>
Marital Status	P06-MARITAL-ST	Numeric	Item	34	1	1	0	No
Mother Living	P07-MOTHER-ALIVE	Numeric	Item	35	1	1	0	No
Place of Birth	P08-BIRTHPLACE	Numeric	Item	36	2	1	0	No
Residence in 1995	P09-1995-RESID	Numeric	Item	38	2	1	0	No
Attending School	P10-ATTEND-SCH	Numeric	Item	40	1	1	0	No
Highest Grade Completed	P11-HIGH-GRADE	Numeric	Item	41	2	1	0	No
Literacy	P12-RD-WR	Numeric	Item	43	1	1	0	No
Economically Active	P13-ECON-ACTIVE	Numeric	Item	44	1	1	0	No
Occupation	P14-OCCUPATION	Numeric	Item	45	2	1	0	No
Occupation by Major Branch	P14A-OCC-BRANCH	Numeric	SubItem	45	1	1	0	No
Industry	P15-INDUSTRY	Numeric	Item	47	2	1	0	No
Industry by Major Branch	P15A-IND-BRANCH	Numeric	SubItem	47	1	1	0	No
Work Status	P16-WORK-STATUS	Numeric	Item	49	1	1	0	No
Number of Children Ever Born	P17-CHILD-BORN	Numeric	Item	50	2	1	0	No
Number of Children Still Living	P18-CHILD-LIVING	Numeric	Item	52	2	1	0	No

Value Set	Value Label	From	To
Age		00	98
	Not Reported	99	
Age in 5 year groups	0 to 4 years	00	04
	5 to 9 years	05	09
	10 to 14 years	10	14
	15 to 19 years	15	19
	20 to 24 years	20	24
	25 to 29 years	25	29
	30 to 34 years	30	34

For Help, press F1

Start MS-DO... IMPS 4... Vickget... Getting ... 02:08 PM



# GIS and Data Retrieval

Ability of the DBMS or GIS to get back on demand data that were previously stored

Geographic search is the secret to GIS data retrieval.

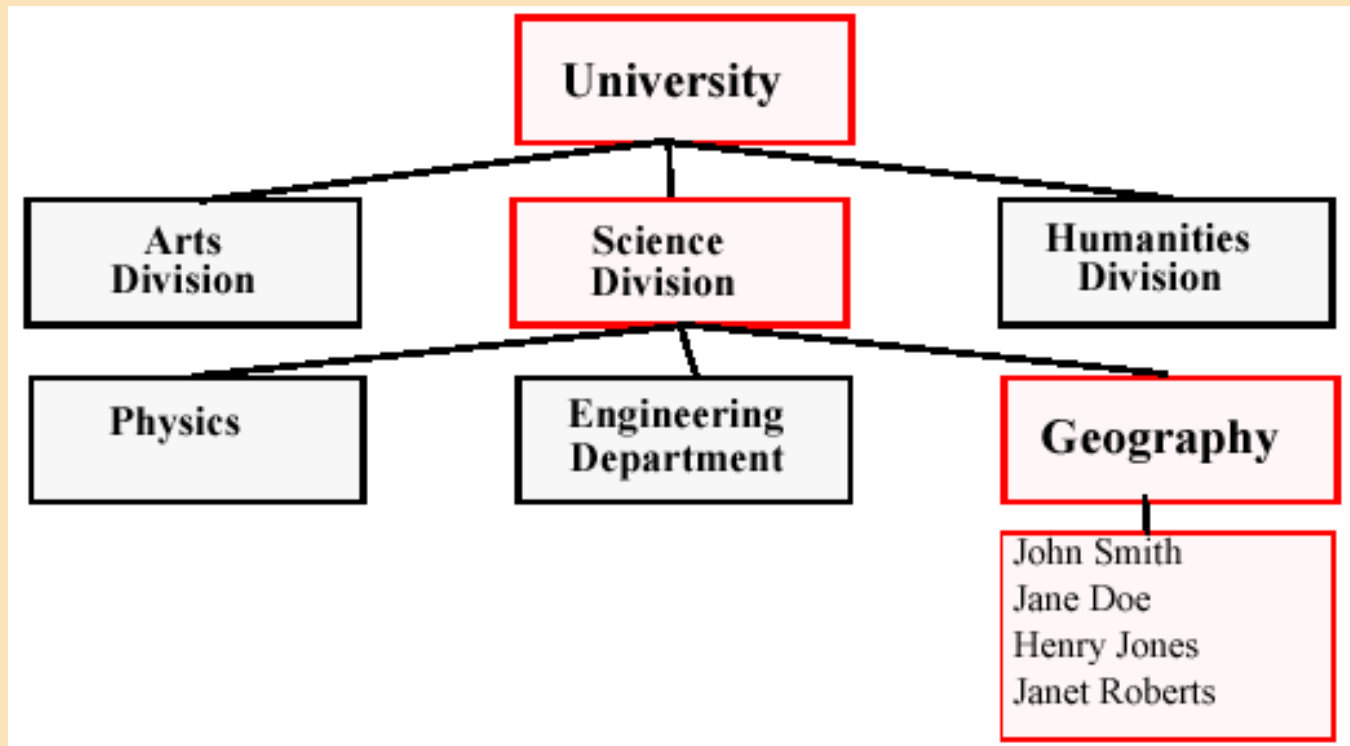
Many forms of data organization are incapable of geographic search

GI systems have embedded DBMSs, or link to a commercial DBMS

Examples: Access, Dbase, ORACLE, Excel, Paradox



Historically, databases were structured hierarchically in files...



# Inverted spatial hierarchies





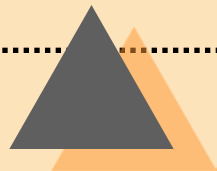
# Most current GIS data management is in relational databases

Based on multiple flat files for records

Dissimilar attribute structures

Connected by a common key attribute.

Key is a **UNIQUE** identifier at the  
“atomic” level for every record.



# Relational Data Bases

## Patient Record

Key	Check-in	Check Out	Room No.
42	2/1/98	2/4/96	N763
78	2/3/98	2/4/96	N712

FILE

## Purchase Record

Item	Date	Price	Customer	Key
Skate Board	2/1/98	49.95	John Smith	42
Baseball Bat	2/1/98	17.99	James Brown	78

FILE

## Accident Report

Date	Injury	Name	Key	Location
2/1/98	Broken Leg	John Smith	42	75 Elm Street
2/2/98	Concussion	Sylvia Jones	654	12 State Street
2/2/98	Cut on Ear	Robert Doe	123	2323 Broad Street

FILE



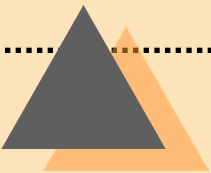


# Retrieval Operations

Searches by attribute: find and browse.

Data reorganization: select, renumber, and sort.

Compute allows the creation of new attributes based on calculated values.





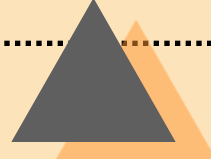
# Spatial Retrieval Operations

Attribute queries are not very useful for geographic search.

In a map database the records are features or themes

The spatial equivalent of a find is locate, the GIS highlights the result.

Spatial equivalents of the DBMS queries result in locating sets of features or building new GIS layers.



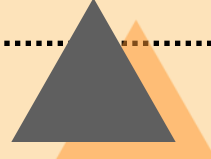


# The Retrieval User Interface

GIS query is usually by command line, batch, menu or macro.

Most GIS packages use the GUI of the computer's operating system to support both a menu-type query interface and a macro or programming language.

SQL is a standard interface to relational databases and is supported by many GISs.



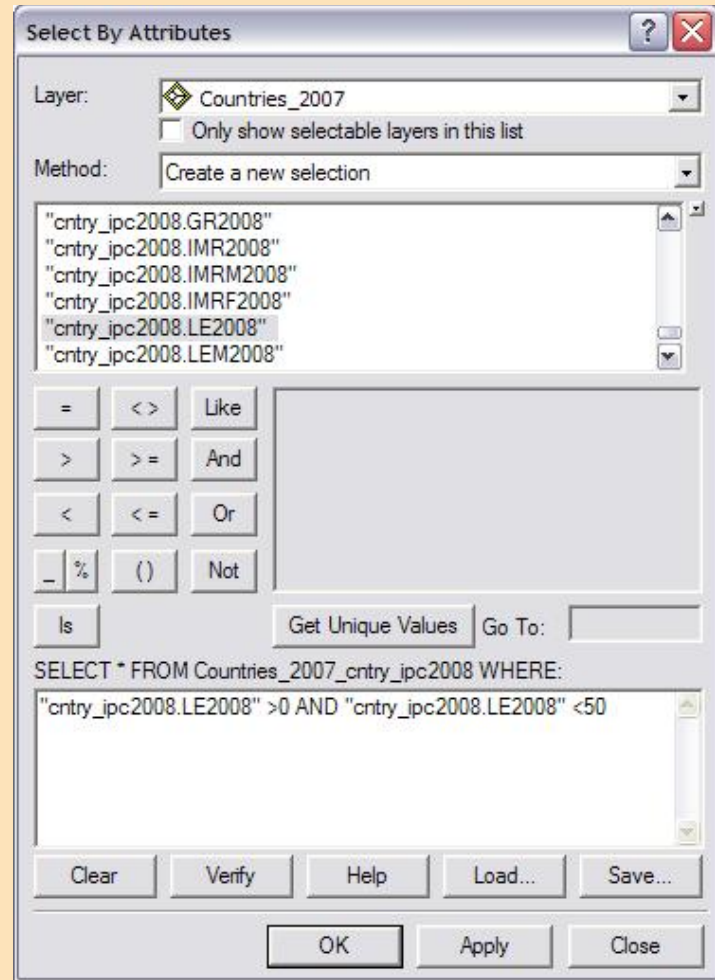
# DBMS queries via the query language

**sort**

**renumber**

**subset**

**search**

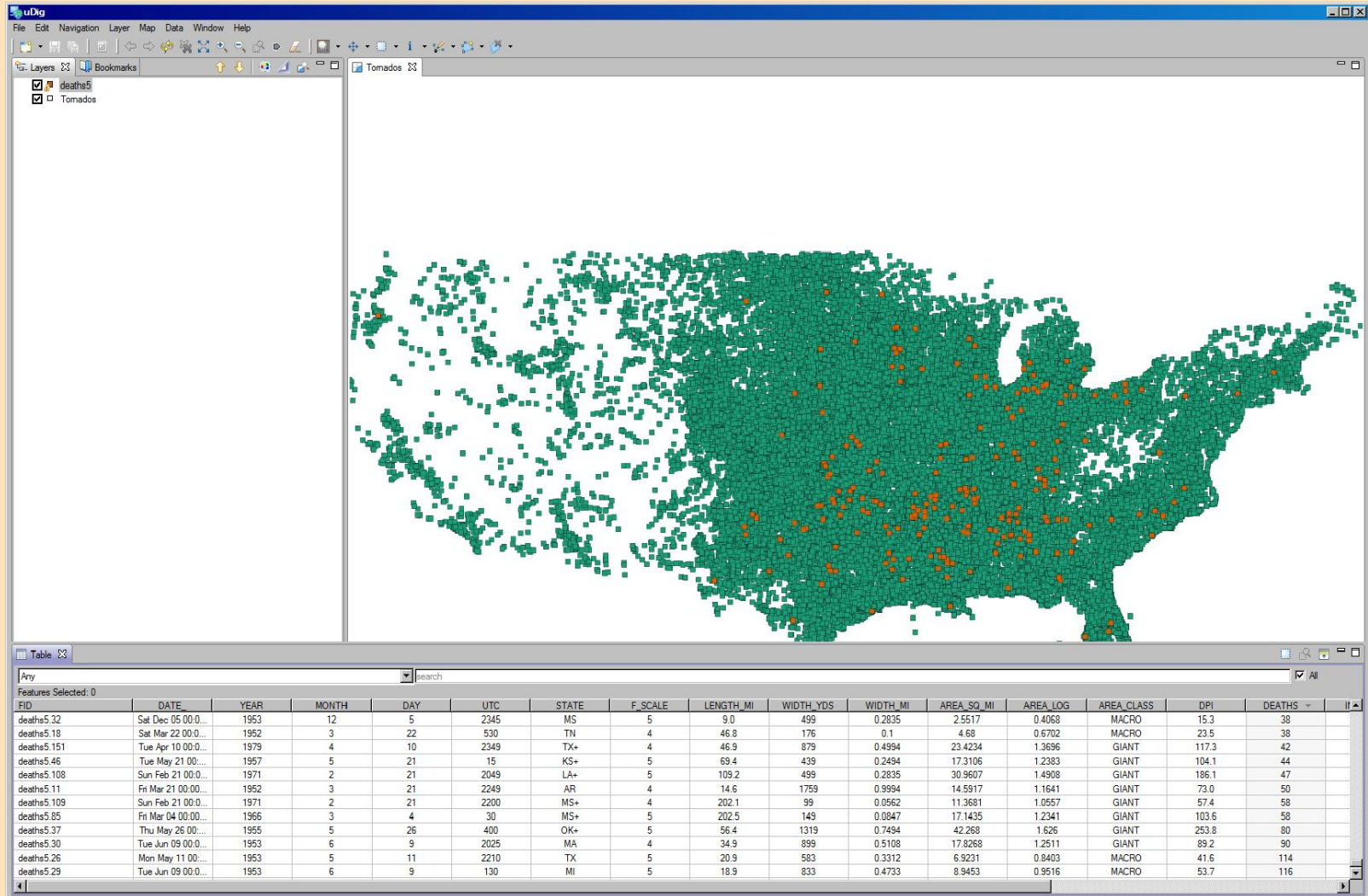


# Query: Search for City Name="Santa Barbara"

The screenshot shows the ArcView GIS 3.2 interface. The main map displays the United States with red points representing cities. The 'Attributes of Cities.shp' window is open, showing a query for 'City\_name = "Santa Barbara"'. Below the map, a table displays the attributes for the selected city, Santa Barbara.

Shape	City_fips	City_name	State_fips	State_name	State_city	Type	Capita	Elevation	Pop1990	Household	Males	Females	White	Black	Amer. es	Asian_p	Other	Hisp
Point	69070	Santa Barbara	06	California	0669070	city	N	42	85571	34348	41912	43659	66529	1320	756	1997	14367	
Point	17000	Duluth	27	Minnesota	2717000	city	N	620	85493	34563	40302	45191	81980	747	1837	768	161	
Point	68252	San Mateo	06	California	0668252	city	N	28	85486	35480	41467	44019	67170	3060	330	11377	3549	
Point	74300	Warwick	44	Rhode Island	4474300	city	N	64	85427	33437	40562	44865	83695	673	183	213	163	
Point	51622	Naperville	17	Illinois	1751622	city	N	700	85351	29101	42012	43339	78988	1795	78	4133	347	
Point	95745	Quincy	25	Massachusetts	2595745	city	N	20	84985	35678	39482	45503	77915	929	177	5577	388	
Point	25175	Gainesville	12	Florida	1225175	city	N	185	84770	31924	41727	43043	62186	18177	153	3343	911	
Point	86000	Westland	26	Michigan	2686000	city	N	636	84724	33110	40655	44069	80197	2829	467	831	400	
Point	64472	San Angelo	48	Texas	4864472	city	N	1848	84474	30661	40667	43807	66571	4057	319	961	12666	
Point	15000	Cheektowaga	36	New York	3615000	census designated place	N	-99	84387	33904	39794	44593	82915	914	121	351	86	
Point	66000	Racine	55	Wisconsin	5566000	city	N	626	84298	31767	39985	44313	64378	15551	273	458	3638	
Point	31000	Hammond	18	Indiana	1831000	city	N	591	84236	32146	40793	43443	71465	7743	203	348	4477	
Point	12000	Canton	39	Dio	3912000	city	N	-99	84161	33452	38843	45318	67890	15325	429	267	250	
Point	45384	McAllen	48	Texas	4845384	city	N	121	84021	24905	39968	44053	59603	288	165	576	23389	
Point	11530	Carson	06	California	0611530	city	N	40	83995	23808	41273	42722	29160	21953	496	20972	11414	
Point	18823	Decatur	17	Illinois	1718823	city	N	570	83885	34013	39257	44628	69164	13994	120	411	196	
Point	07850	Boulder	08	Colorado	0807850	city	N	5344	83312	34681	42065	41247	77090	1048	414	3208	1552	
Point	45860	Newton	25	Massachusetts	2545860	city	N	100	82585	29485	38062	44523	76323	1717	95	3700	390	
Point	13024	Carrollton	48	Texas	4813024	city	N	-99	82169	30452	40451	41708	68300	4014	348	5598	2909	
Point	00884	Alhambra	06	California	0600884	city	N	483	82106	28239	39104	43002	33543	1643	351	31313	15256	
Point	69000	Scranton	42	Pennsylvania	4269000	city	N	754	81805	32637	37496	44309	79498	1290	73	747	197	
Point	37490	Lynn	25	Massachusetts	2537490	city	N	30	81245	31954	38838	42407	67482	6545	227	3003	3988	
Point	06950	Billings	30	Montana	3006950	city	N	3124	81151	33181	38718	42433	76738	439	2569	479	926	
Point	41850	Lawton	40	Oklahoma	4041850	city	N	1109	80561	29566	39227	41324	57019	19575	2684	2621	2662	
Point	73335	Sioux City	19	Iowa	1973335	city	N	1117	80505	30488	38339	41966	74525	1848	1624	1195	1313	
Point	13330	Charleston	45	South Carolina	4513330	city	N	118	80414	30753	37951	42463	46023	33439	92	685	175	
Point	39225	Kenosha	55	Wisconsin	5539225	city	N	610	80352	29919	38697	41665	72139	5137	297	448	2331	
Point	42160	Kalamazoo	26	Michigan	2642160	city	N	-99	80277	29409	37849	42428	62039	15053	450	1505	1230	
Point	52500	Norman	40	Oklahoma	4052500	city	N	-99	80071	31907	39932	40079	70053	2861	3867	2572	718	
Point	50260	Nashua	33	New Hampshire	3350260	city	N	159	78652	31051	38078	40584	75300	1250	177	1536	856	
Point	14400	Coral Springs	12	Florida	1214400	city	N	-99	78443	27014	38771	40672	73949	2764	142	1684	904	
Point	63624	Reading	42	Pennsylvania	4263624	city	N	260	78380	31403	36776	41604	61640	7607	113	1114	7906	
Point	95990	Nowalk	09	Connecticut	0959990	city	N	-99	78331	30560	37794	40537	62106	12123	100	1290	2712	

# Sort: Locations by tornado deaths



# Query: Search using map

The screenshot displays the ArcGIS Desktop interface. The main map window shows a world map with numerous pink square points representing cities. A yellow rectangular selection box is positioned over the Gulf of Mexico region, highlighting a cluster of points. The left-hand pane contains a 'Projects' list with 'Chapter2' selected, and a 'Layers' list with 'cities' checked. The bottom pane shows a data table with 31 selected features. The table columns include FID, CITY\_NAME, GMI\_ADMIN, ADMIN\_NAME, FIPS\_CNTRY, CNTRY\_NAME, STATUS, POP\_RANK, POP\_CLASS, and PORT\_ID. The selected rows are highlighted in yellow.

FID	CITY_NAME	GMI_ADMIN	ADMIN_NAME	FIPS_CNTRY	CNTRY_NAME	STATUS	POP_RANK	POP_CLASS	PORT_ID
cities_52	Mobile	USA-ALB	Alabama	US	United States	Other	4	250,000 to 500,000	8770
cities_53	Sakakah	SAU-AJA	Al Jawf	SA	Saudi Arabia	Provincial capital	7	Less than 50,000	0
cities_54	Galveston	USA-TEX	Texas	US	United States	Other	6	50,000 to 100,000	9150
cities_55	Jumla	NPL-KRN	Karnali	NP	Nepal	Provincial capital	7	Less than 50,000	0
cities_56	Abu Zenima	EGY-JSI	Jarub Sina'	EG	Egypt	Other	7	Less than 50,000	48065
cities_57	Santa Cruz de Tenerife	ESP-CNR	Canarias	SP	Spain	Provincial capital	5	100,000 to 250,000	38160
cities_58	Tabuk	SAU-TAB	Tabuk	SA	Saudi Arabia	Provincial capital	6	50,000 to 100,000	0
cities_59	El Tur	EGY-JSI	Jarub Sina'	EG	Egypt	Provincial capital	7	Less than 50,000	0
cities_60	Las Palmas	ESP-CNR	Canarias	SP	Spain	Other	7	Less than 50,000	38170
cities_61	Ha'il	SAU-HAI	Ha'il	SA	Saudi Arabia	Provincial capital	7	Less than 50,000	0
cities_62	Buraydah	SAU-AGA	Al Qasim	SA	Saudi Arabia	Provincial capital	6	50,000 to 100,000	0
cities_63	Ad Damman	SAU-ASH	Ah Sharayah	SA	Saudi Arabia	Provincial capital	5	100,000 to 250,000	48335
cities_64	Aizawl	IND-MZR	Mzorani	IN	India	Provincial capital	6	50,000 to 100,000	0
cities_65	Fangcheng Gang	CHN-GNG	Guangxi	CH	China	Other	3	500,000 to 1,000,000	57745
cities_66	Thai Binh	VNM-TBI	Thai Binh	VM	Vietnam	Provincial capital	6	50,000 to 100,000	0

# Query: US Cities > 1000000 population

The screenshot shows the ArcView GIS 3.2 interface. The main map window displays a map of the United States with red dots representing cities. The 'Attributes of Cities.shp' window is open, showing a query for cities with a population greater than 1,000,000. The resulting data is shown in a table below.

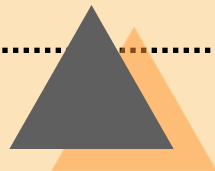
Shapeid	City pop	City name	State pop	State name	State city	Type	Capital	Elevation	Pop1990	Household	Males	Females	White	Black	Amer_es	Asian_pi	Other	Hispac
Point 51000	New York	36	New York	3651000	city		N	30	7322564	2819401	3437687	3884877	3827088	2102512	27531	512719	852714	17
Point 44000	Los Angeles	06	California	0644000	city		N	330	3485396	1217405	1750055	1735343	1841182	487674	16379	341807	796356	13
Point 14000	Chicago	17	Illinois	1714000	city		N	596	2783726	1025174	1334705	1449021	1263524	1067711	7064	104118	321309	5
Point 35000	Houston	48	Texas	4835000	city		N	-99	1630953	616877	809048	821505	859069	457990	4126	67113	242255	4
Point 60000	Philadelphia	42	Pennsylvania	4260000	city		N	45	1595577	603075	737763	847814	848586	631936	3454	43522	58079	4
Point 66000	San Diego	06	California	0666000	city		N	42	1110549	406096	566464	544085	745406	104261	6800	130945	123137	2
Point 22000	Detroit	26	Michigan	2622000	city		N	-99	1027374	374057	476814	951160	222316	777916	3655	8461	15626	2
Point 19000	Dallas	48	Texas	4819000	city		N	463	1006877	402060	495141	511736	556760	296394	4792	21952	126379	2
Point 55000	Phoenix	04	Arizona	0455000	city		Y	1090	983403	363921	487589	495814	803332	51053	18225	16303	94490	1
Point 65000	San Antonio	48	Texas	4865000	city		N	-99	935933	326761	450695	485238	678082	65884	3303	10703	179961	5
Point 68000	San Jose	06	California	0668000	city		N	87	782248	250218	397709	384539	491280	36790	5416	152815	95947	2
Point 04000	Baltimore	24	Maryland	2404000	city		N	32	736014	276484	343513	392501	287753	435768	2555	7942	1996	
Point 36010	Indianapolis	18	Indiana	1836010	city (remainder)		Y	717	731327	291946	347418	383909	954423	165570	1574	6852	2908	
Point 67000	San Francisco	06	California	0667000	city		N	63	723969	305584	362497	361462	387783	79039	3456	210876	42805	10
Point 35160	Jacksonville	12	Florida	1235160	city (remainder)		N	-99	635230	241384	310366	324864	456529	160283	1801	12182	4435	
Point 18000	Columbus	39	Ohio	3918000	city		Y	-99	632910	256996	309574	327336	471025	142748	1469	14993	2675	
Point 53000	Milwaukee	55	Wisconsin	5553000	city		N	634	628088	240540	296837	331251	398033	191255	5858	11817	21125	
Point 48000	Memphis	47	Tennessee	4748000	city		N	264	610337	229829	285010	325327	268600	334737	960	4805	1235	
Point 50000	Washington	11	District of Columbia	1150000	city		N	50	606900	249634	282970	323930	179667	399604	1466	11214	14949	
Point 07000	Boston	25	Massachusetts	2507000	city		Y	20	574283	228464	275972	298311	360875	146945	1884	30388	34191	
Point 63000	Seattle	53	Washington	5363000	city		N	-99	516259	236702	252042	264217	388858	51948	7326	60819	7308	
Point 24000	El Paso	48	Texas	4824000	city		N	-99	515342	160545	247163	268179	396122	17708	2239	5956	93317	3
Point 16000	Cleveland	39	Ohio	3916000	city		N	-99	505616	199787	237211	268405	250234	235405	1562	5115	13300	
Point 55000	New Orleans	22	Louisiana	2255000	city		N	-99	496938	188235	230883	266055	173954	307728	759	9678	5219	
Point 52006	Nashville-Davidson	44	Tennessee	4752006	city/county (remainder)		Y	440	488374	198585	231709	256665	360284	118627	1130	6852	1481	
Point 20000	Denver	08	Colorado	0820000	city		Y	5280	467610	210952	227517	240093	337198	60046	5381	11005	53980	10
Point 05000	Austin	48	Texas	4805000	city		Y	501	465622	192148	232473	233149	328542	57868	1796	14141	63315	10
Point 27000	Fort Worth	48	Texas	4827000	city		N	-99	447619	168274	220268	227351	285949	98532	1914	8910	52714	
Point 55000	Oklahoma City	40	Oklahoma	4055000	city		Y	1243	444719	178662	214466	230253	332539	71064	18794	10491	11831	
Point 59000	Portland	41	Oregon	4159000	city		N	-99	437319	187268	211914	225405	370135	33530	5399	23185	5070	
Point 38000	Kansas City	29	Missouri	2938000	city		N	800	435146	177607	206965	228181	290572	128768	2144	5239	8423	
Point 43000	Long Beach	06	California	0643000	city		N	29	429433	158975	216685	212748	250716	58761	2781	58266	58909	1
Point 77000	Tucson	04	Arizona	0477000	city		N	2386	405390	162685	197319	208071	305055	17366	6464	8901	67604	1



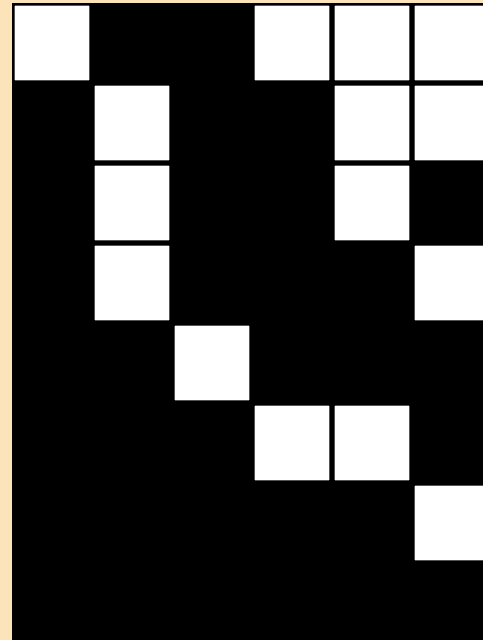
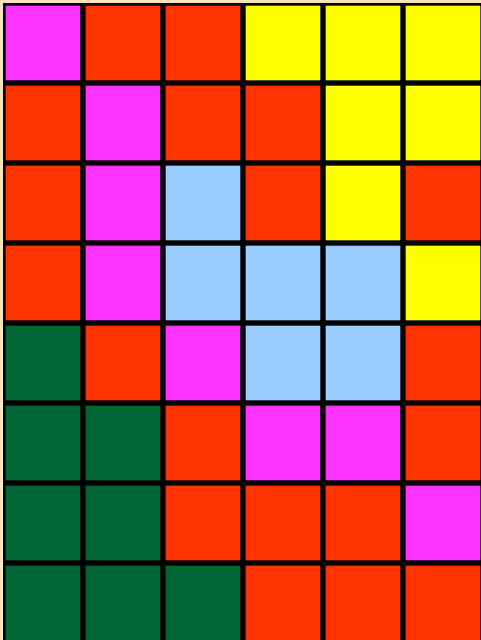
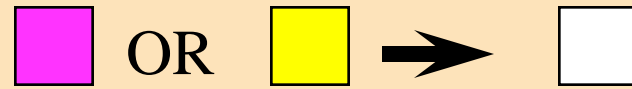


# Compute a new variable

- ◆  $\text{Density} = \text{Pop} / \text{Area}$
- ◆  $\text{Density} = \text{Count\_Points} / \text{Area}$
- ◆  $\text{Classed\_soils} = 1$  if ( $\text{soil\_fert} = 1$  and  $\text{soil\_drain} = 2$ )



# Recode

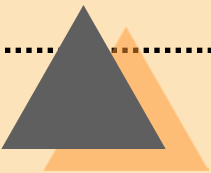




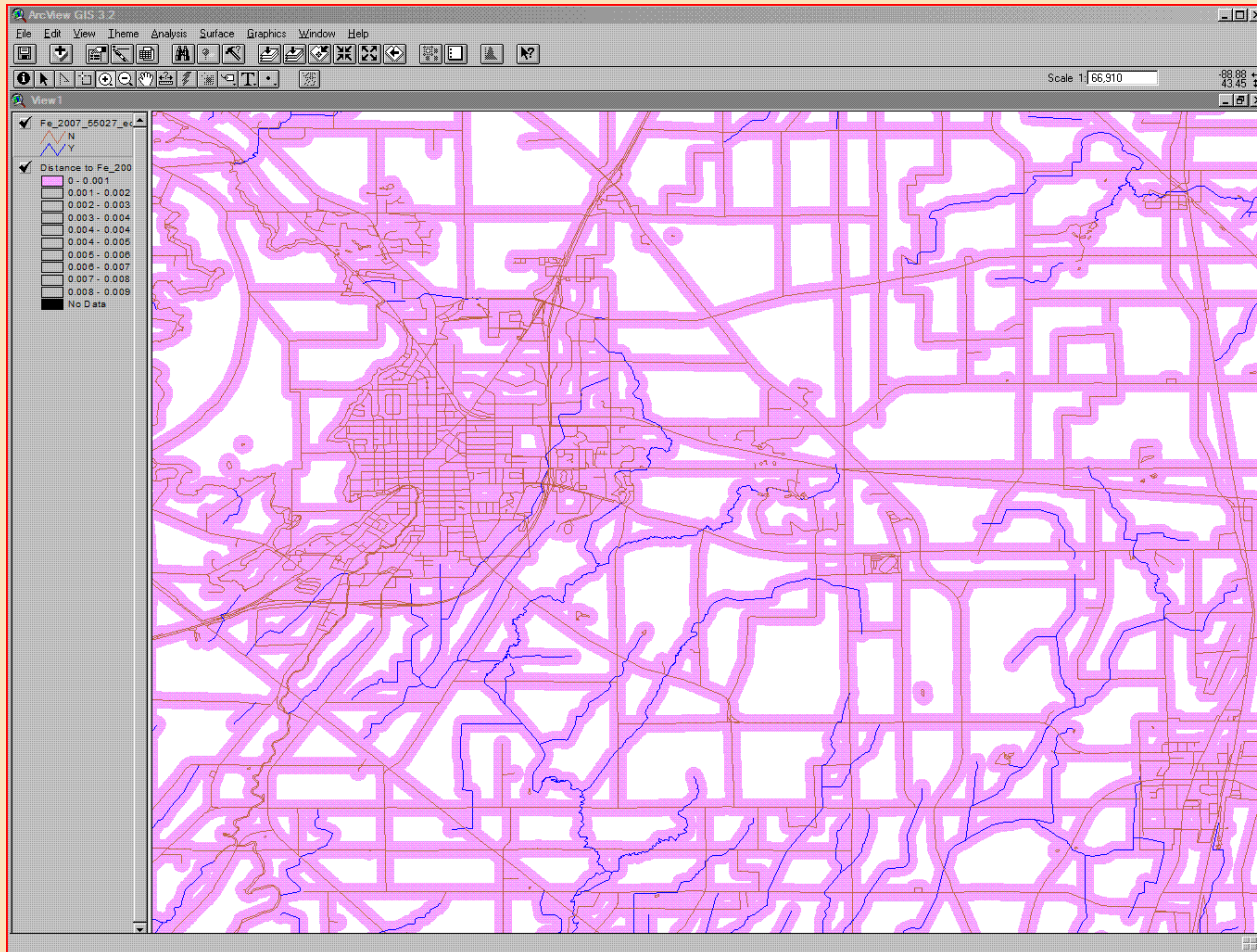
# Spatial Search

Buffering is a spatial retrieval around points, lines, or areas based on distance.

Overlay is a spatial retrieval operation that is equivalent to an attribute join.



# Buffer



# Types of overlay operations

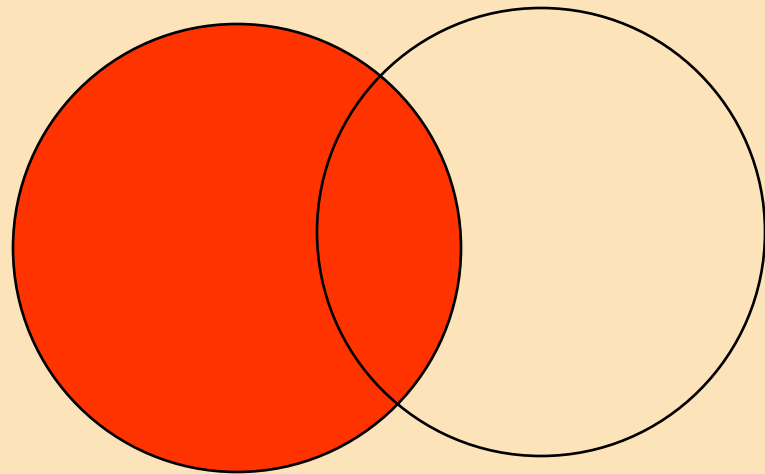
**And**

**Or**

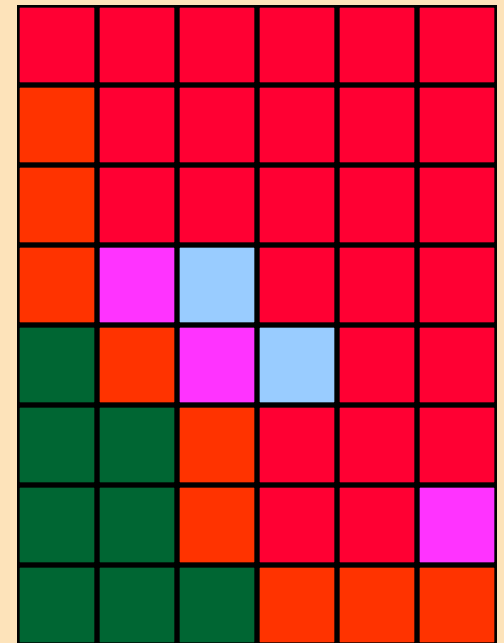
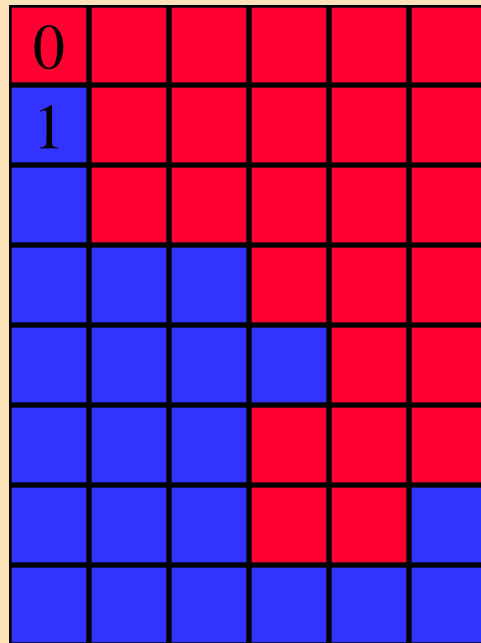
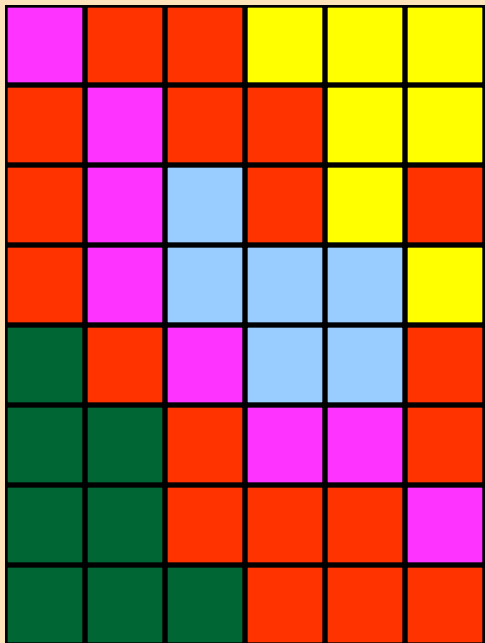
**Max**

**Min**

**Exhaustive set**

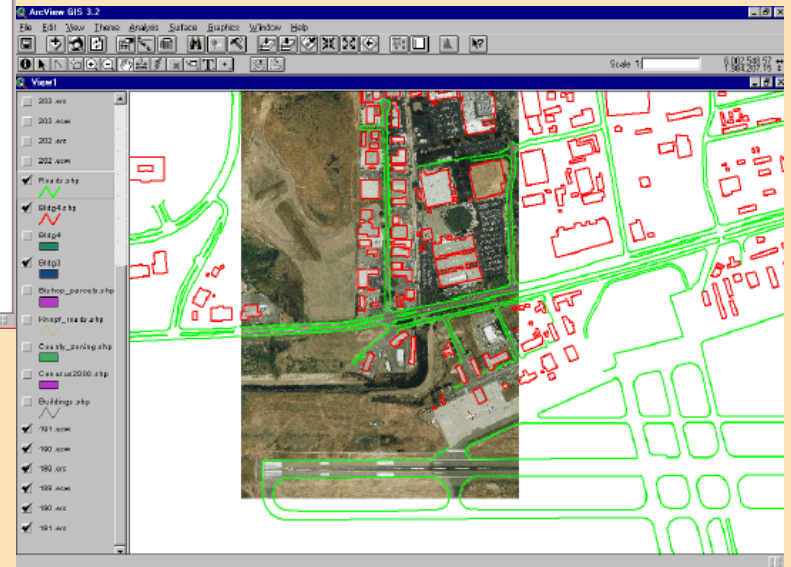
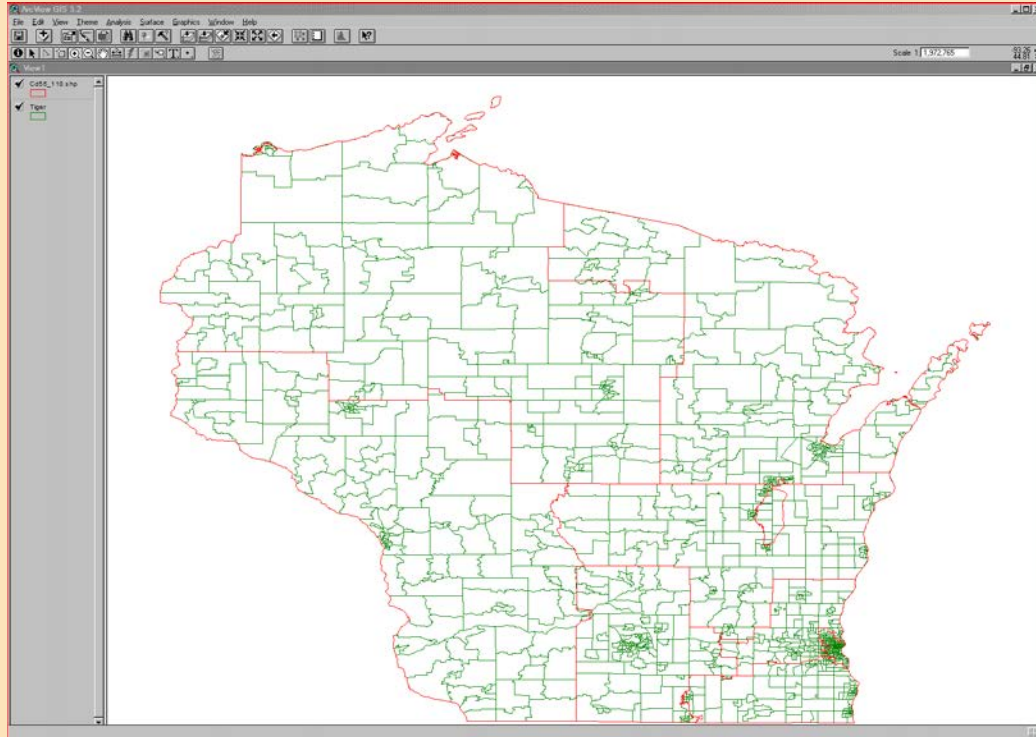


# Overlay: Multiply (Masking)

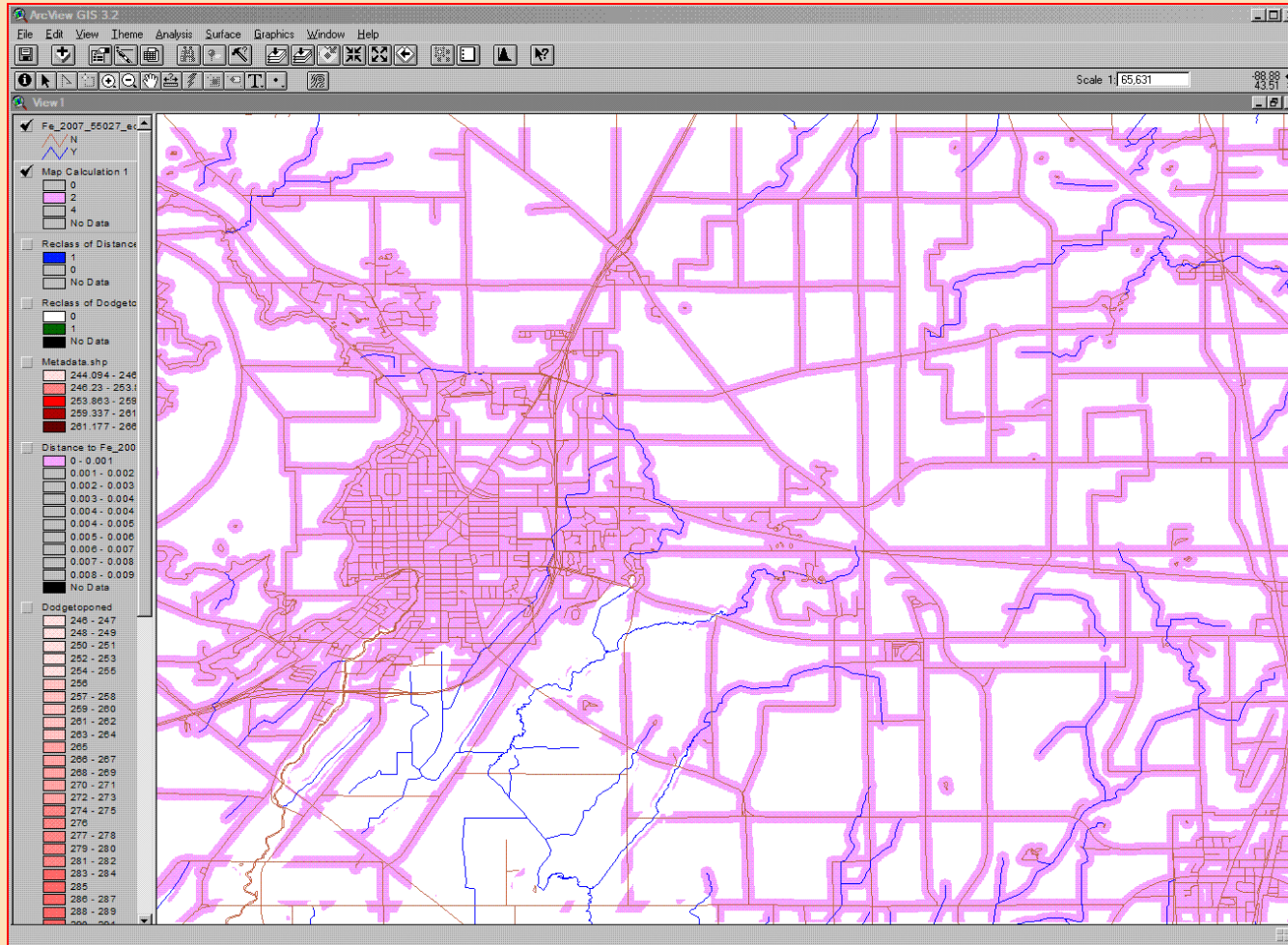


# Data overlay

With or without a new set of regions



# Overlay: (Near road or stream) and over elevation



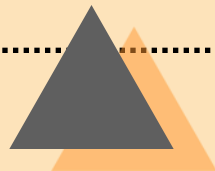




# Complex Retrieval: Map Algebra

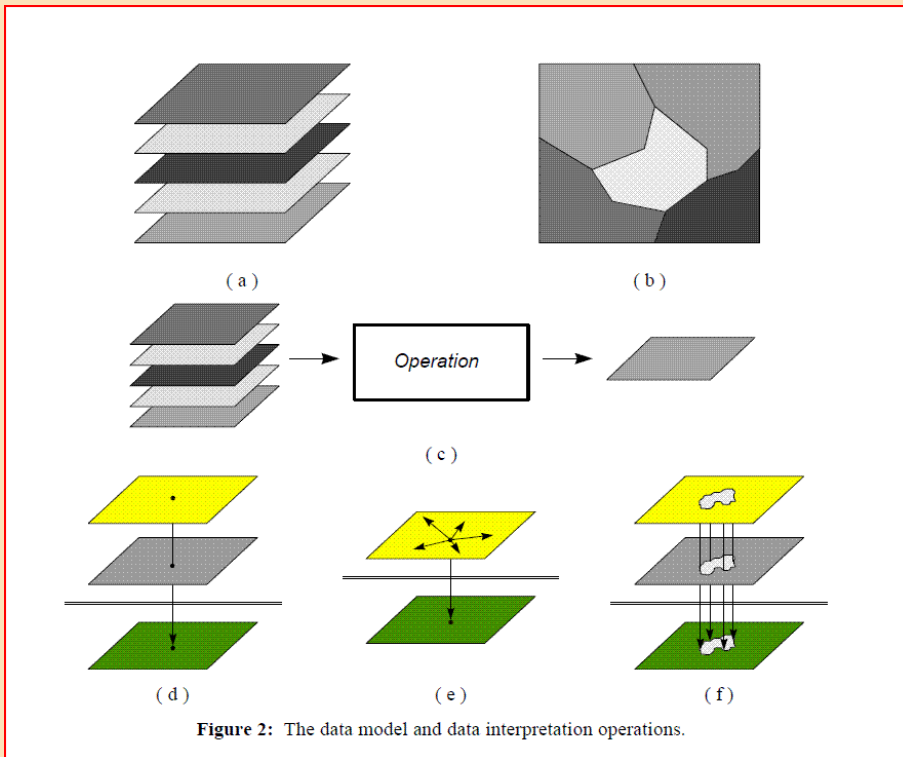
Combinations of spatial and attribute queries can build some complex and powerful GIS operations, such as weighting.

Weighted overlay analysis really just complex retrieval.

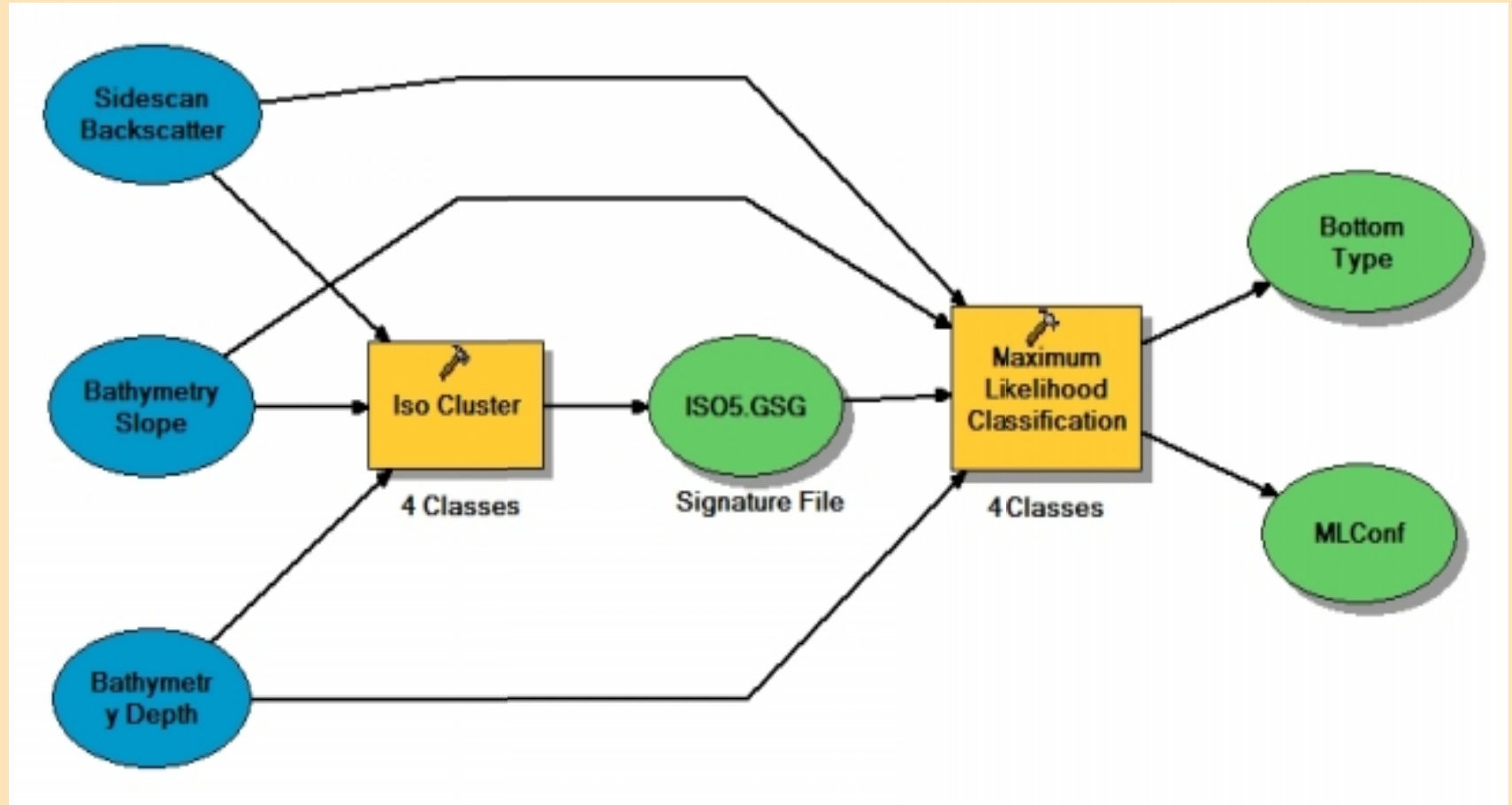


# Tomlin's Operations: Map algebra

Local (per pixel)  
Zonal (by patch)  
Focal (around entity)  
Global (whole map)



# ESRI's Model Builder

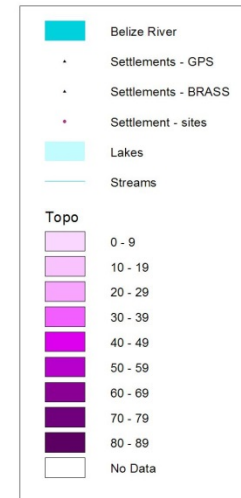
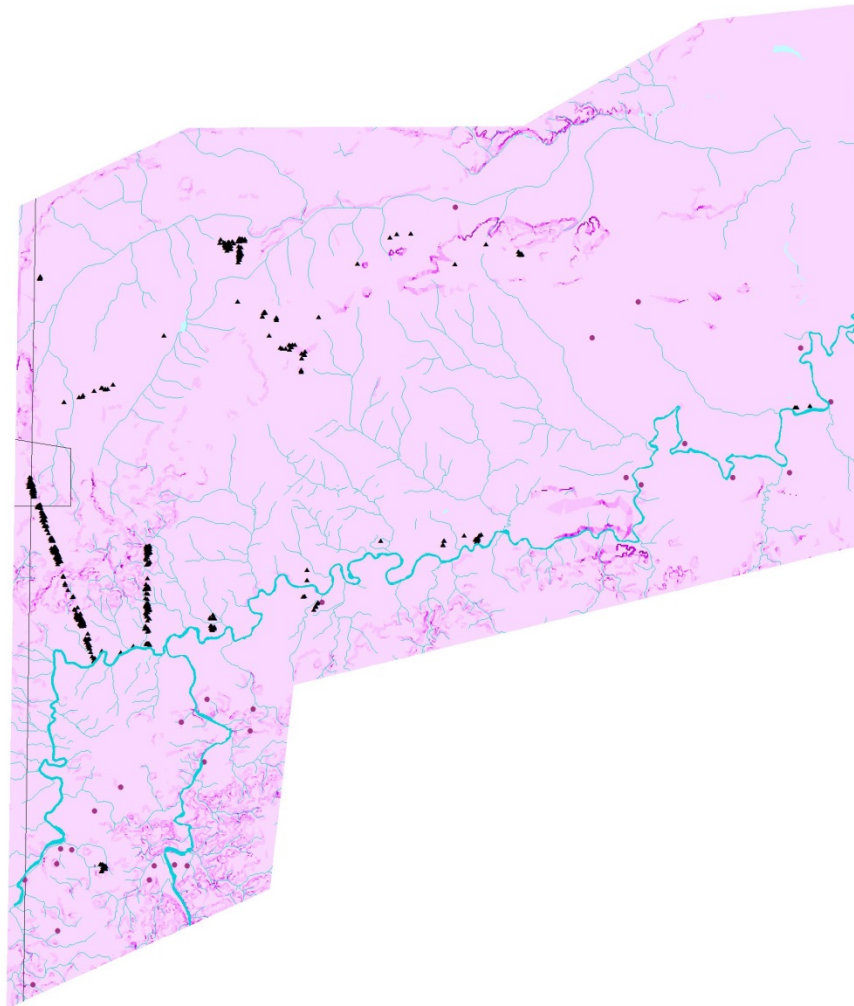




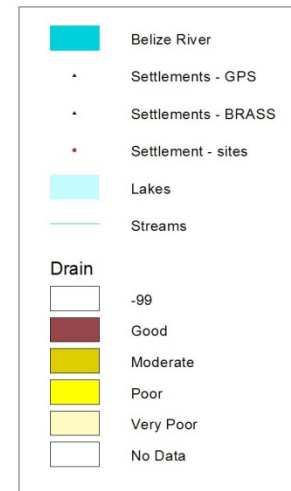
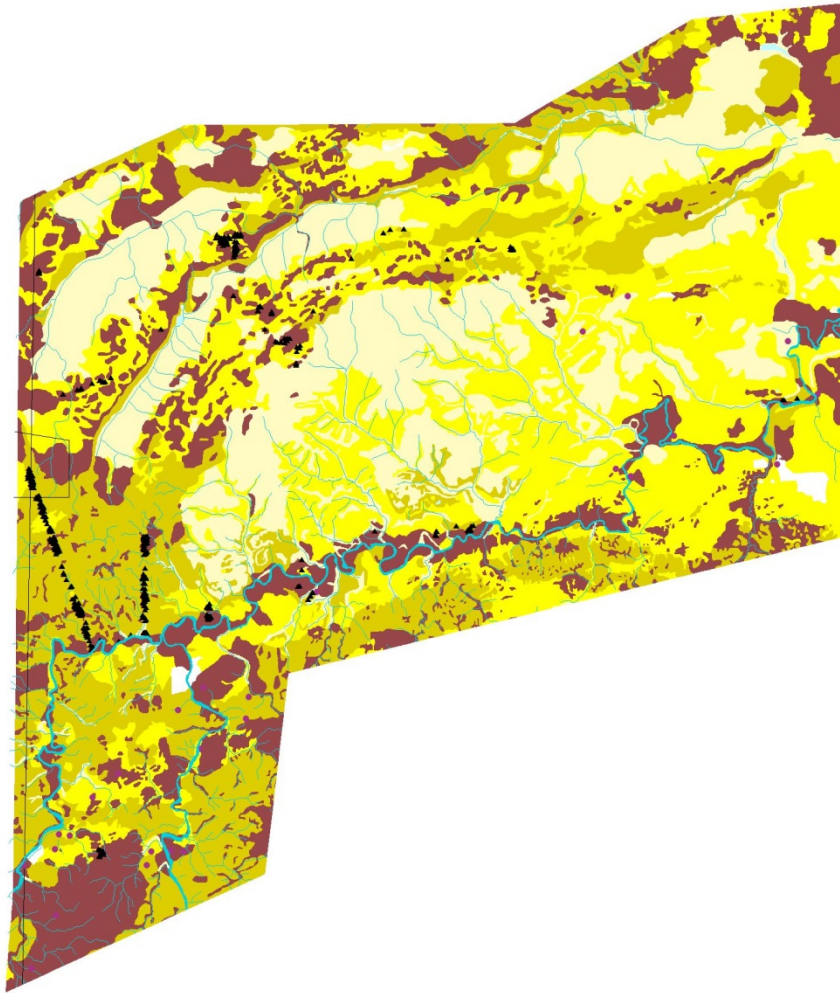
# Weighted Overlay Analysis

Ford, A., Clarke, K, Raines, G. (2009) Modeling Settlement Patterns of the Late Classic Maya Civilization with Bayesian Methods and Geographic Information Systems, *Annals of the Association of American Geographers*. Vol. 99, pp. 496-520

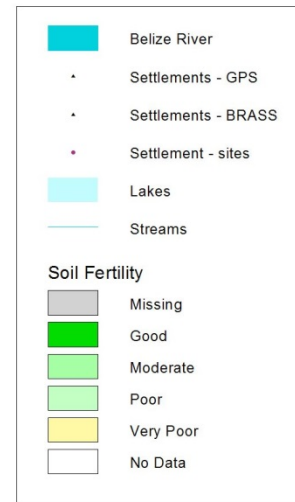
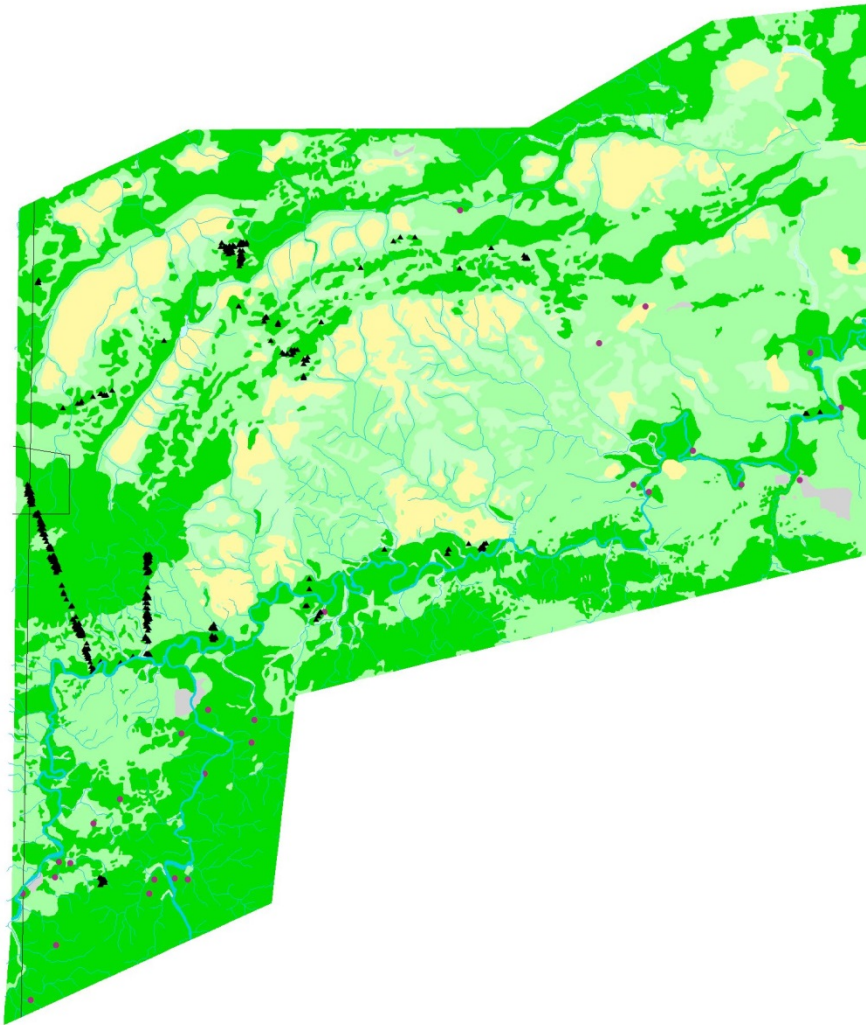
# Topographic Slope (in percent)



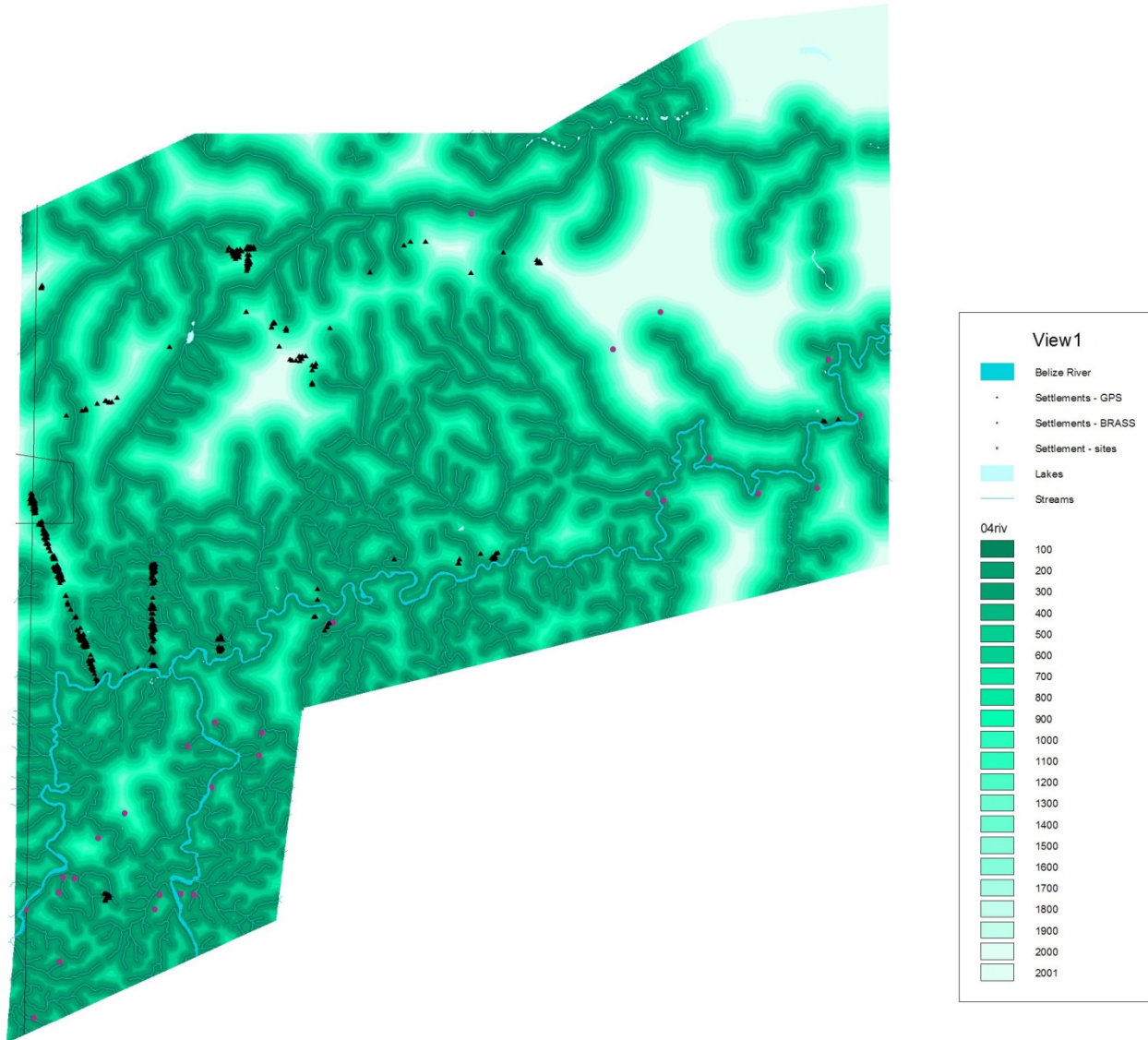
# Soil drainage property



# Soil fertility

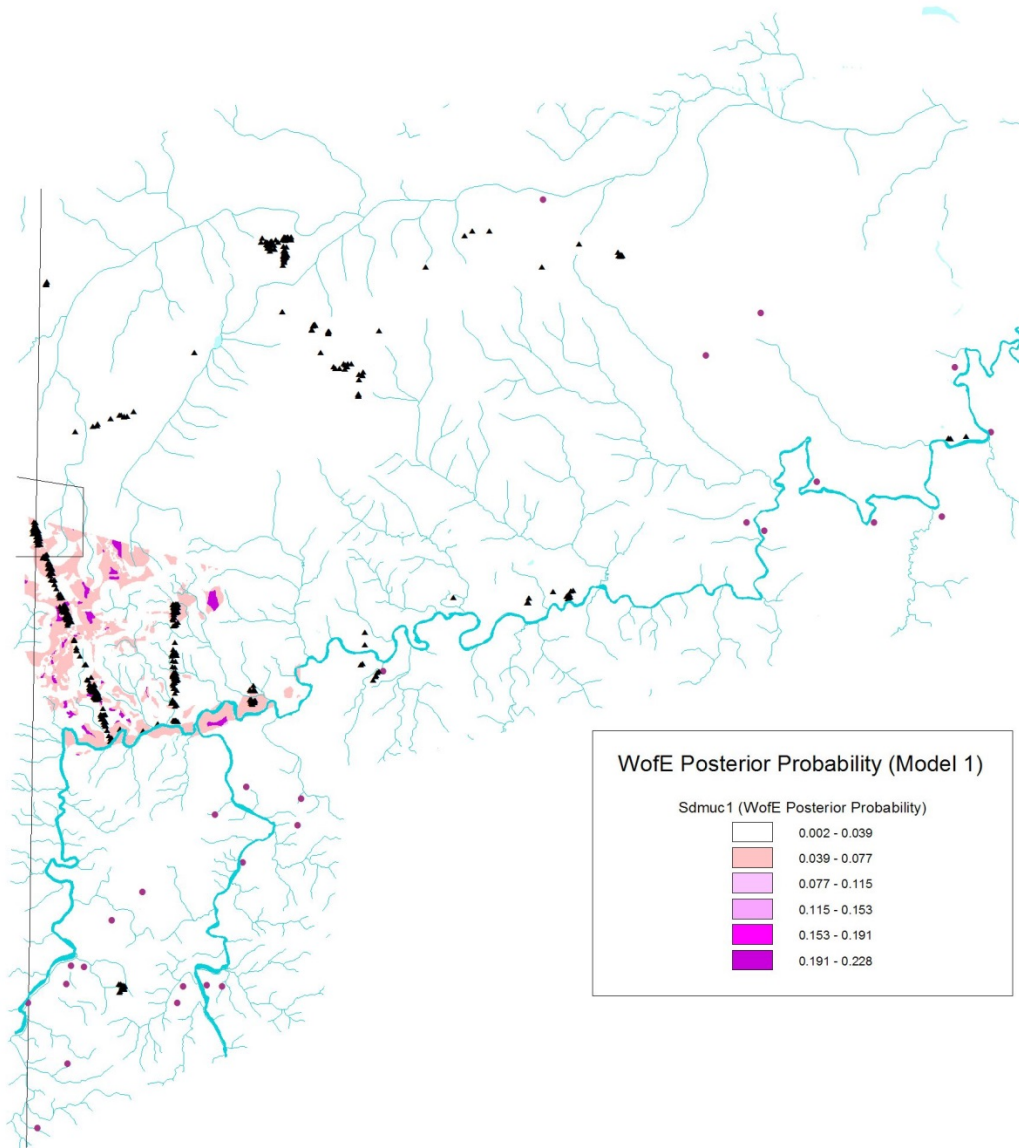


# Distance to streams

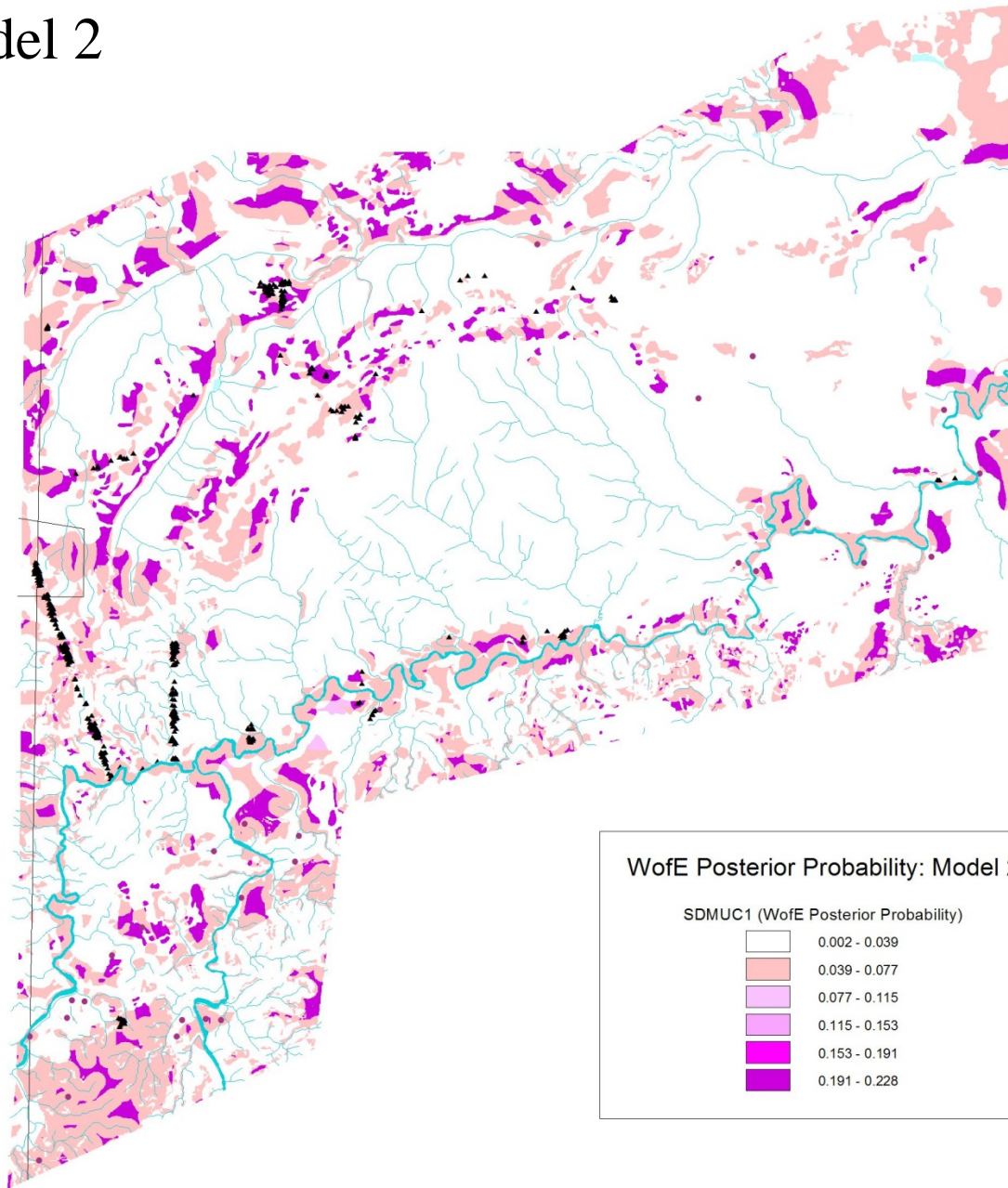




# WofE Model 1

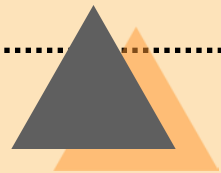


# WofeE Model 2

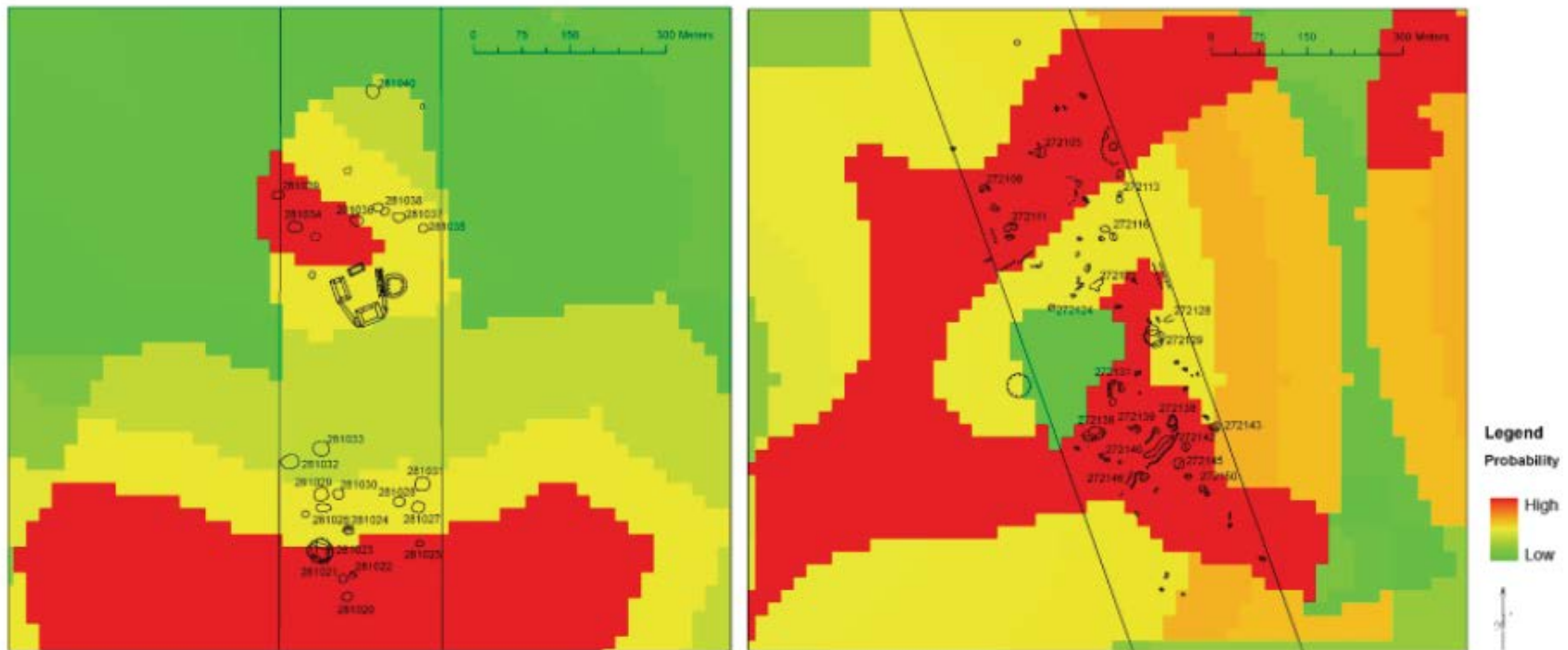




# Results

- ◆ Model explains 75% of settlement locations
  - ◆ Eliminated lakes, Strahler order, Belize river as contributory factors
  - ◆ Streams important up to 400m
  - ◆ Validation with GPS field data
  - ◆ Extending model to regional data
- 

# Actual sites



# Unsurveyed sites added by GPS and LiDAR mapping





Coming next...

Why is it there?

