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

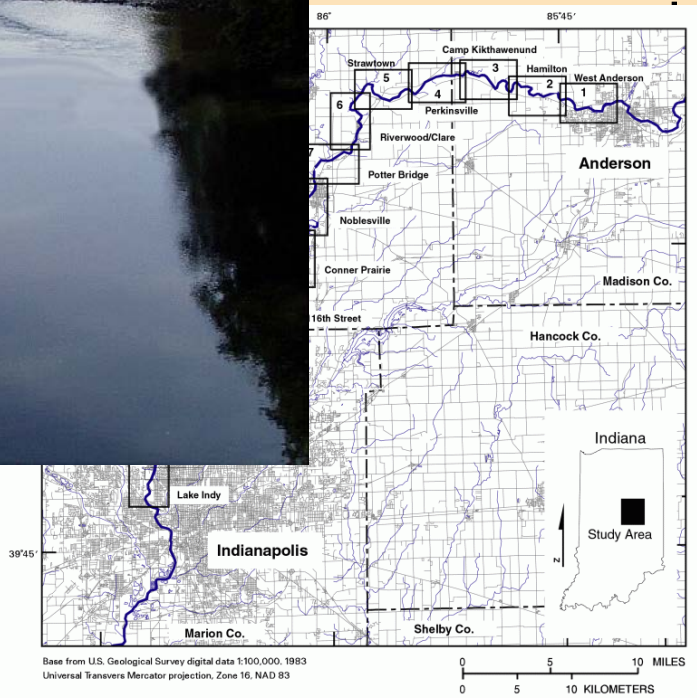
What and Where

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

SUBMERGED AREAS AND BOGS

- Marsh or swamp
- Submerged marsh or swamp
- Wooded marsh or swamp
- Submerged wooded marsh or swamp
- Rice field
- Land subject to inundation

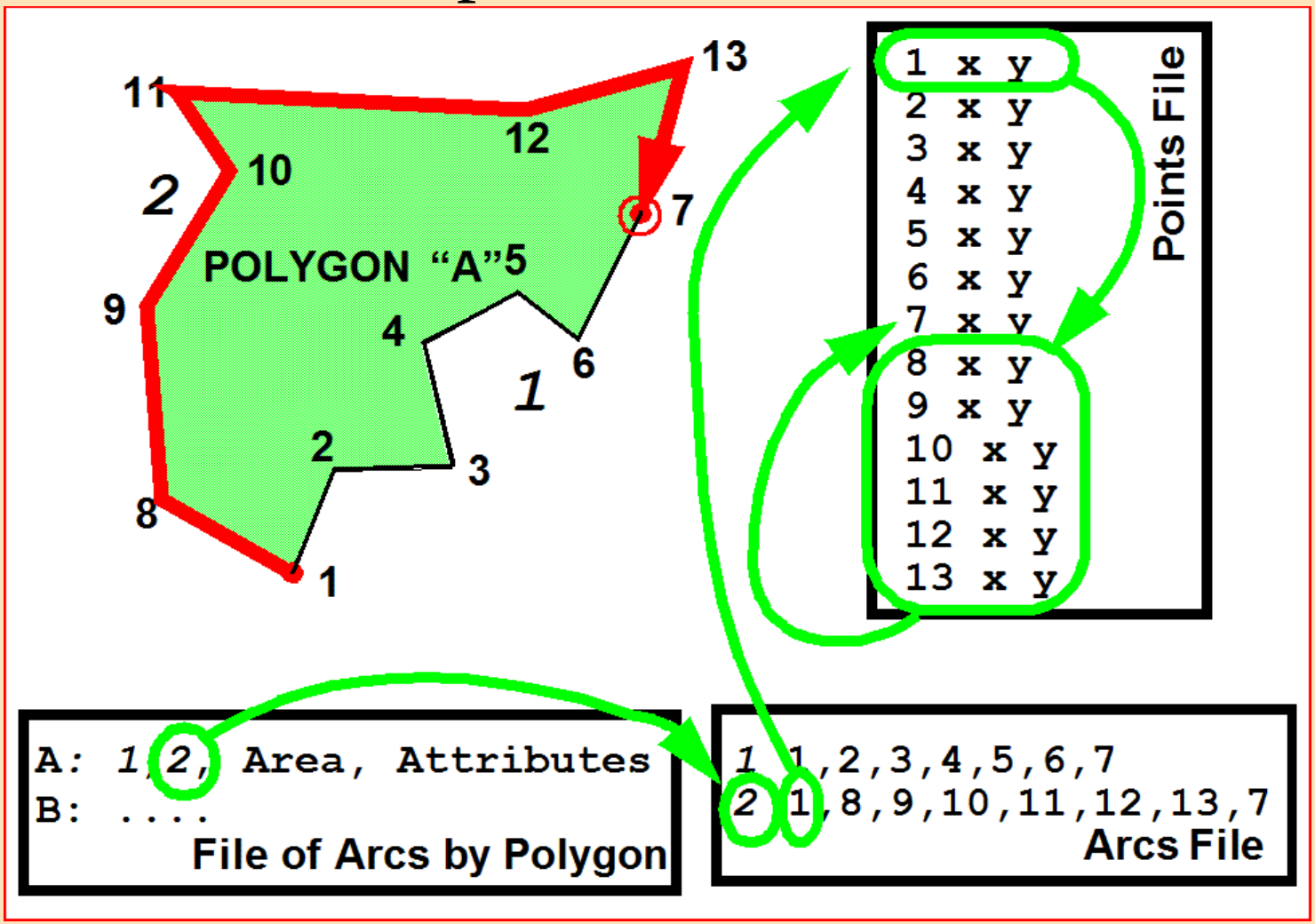


Index of Bank-Condition Maps

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?

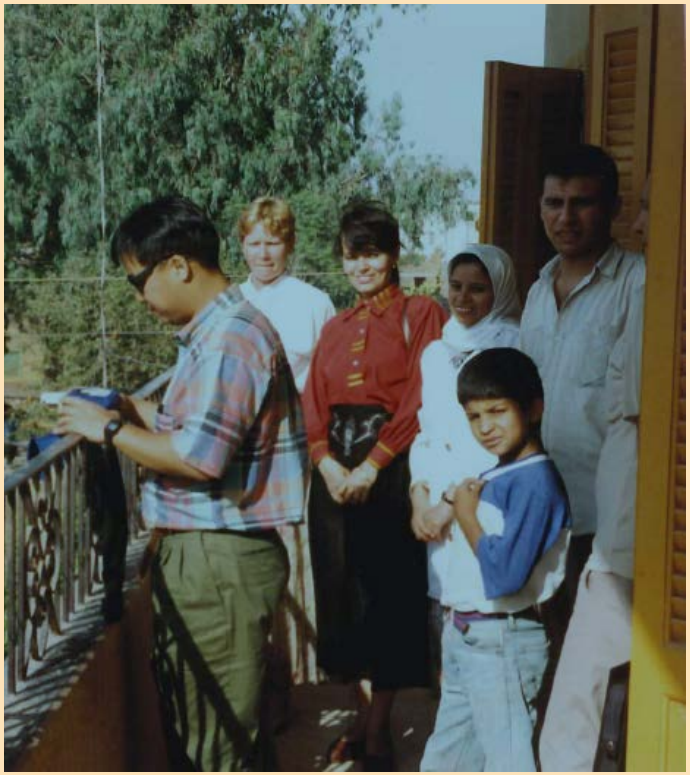
A logical construct for the storage and retrieval of information.

GIS map data structures are map data models.

Attribute data models are needed for the DBMS.

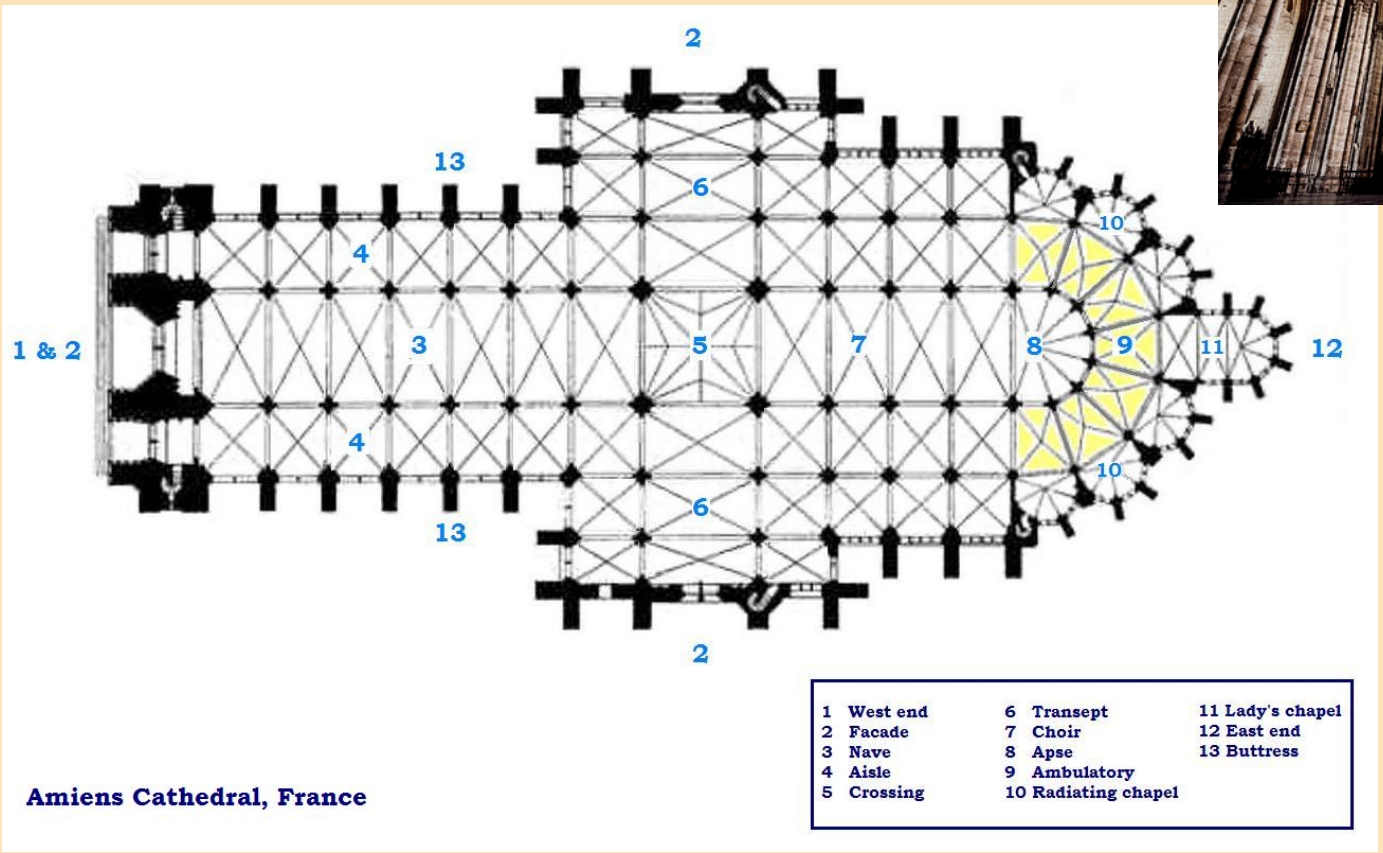
The origin of DBMS data models is in computer science.

Maps and Memory



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

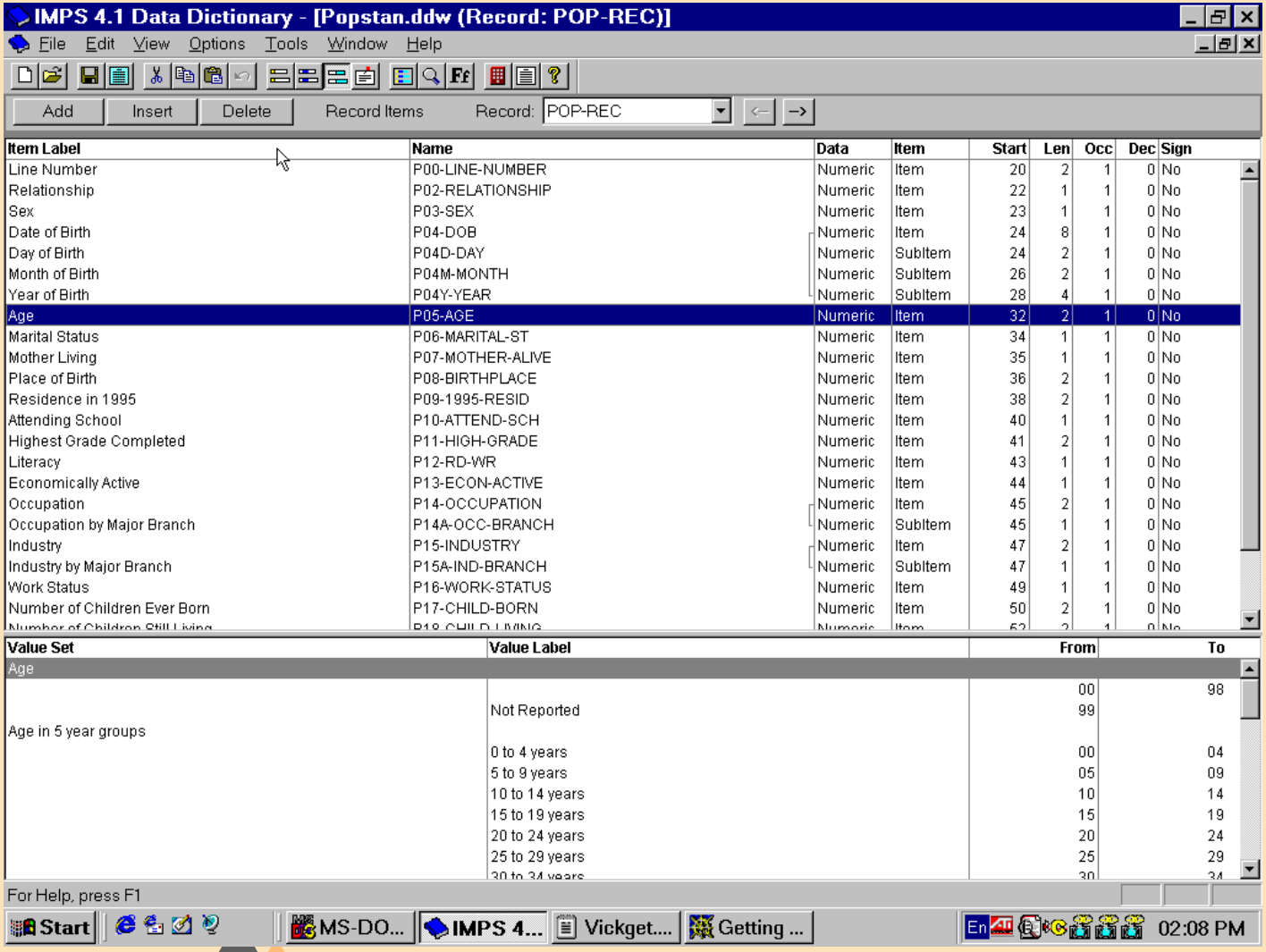
Data Models and Memory



A DBMS contains:

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

The data dictionary



GIS and Data Retrieval

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

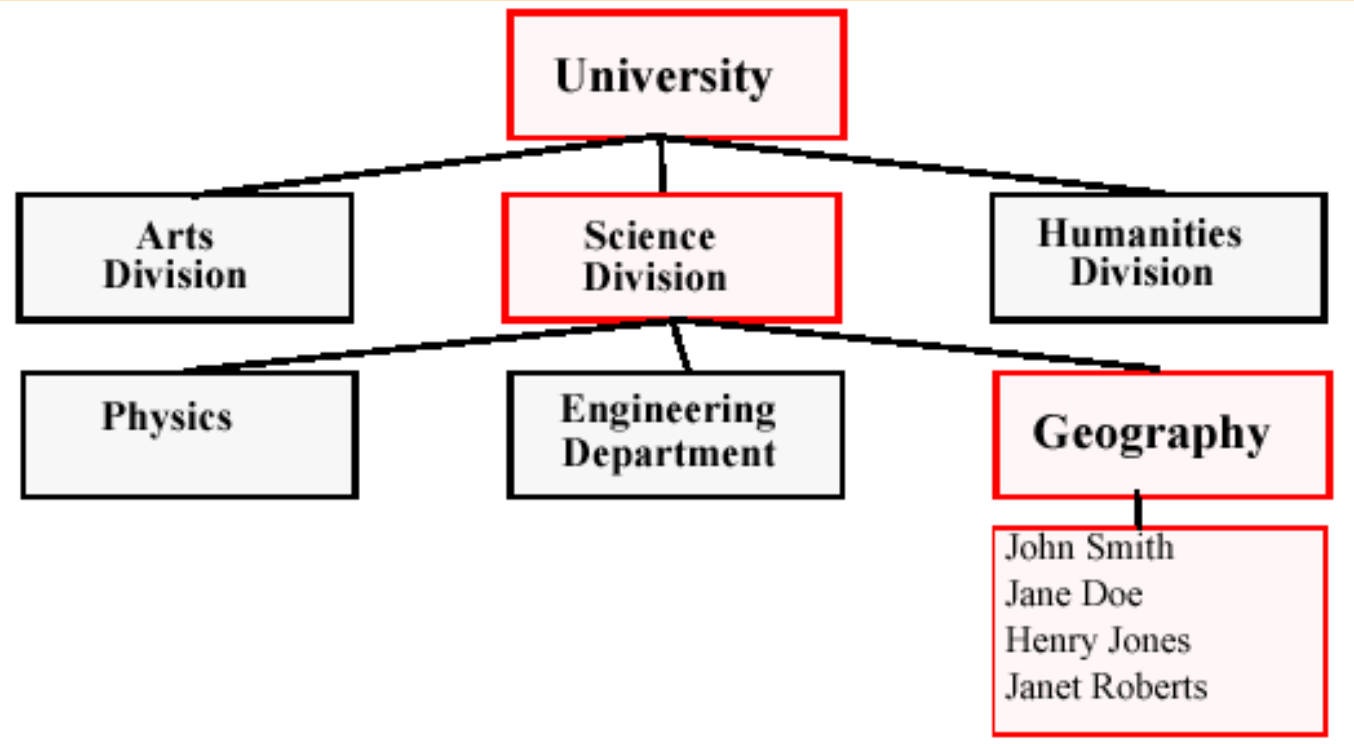
Geographic search is the secret to GIS data retrieval.

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

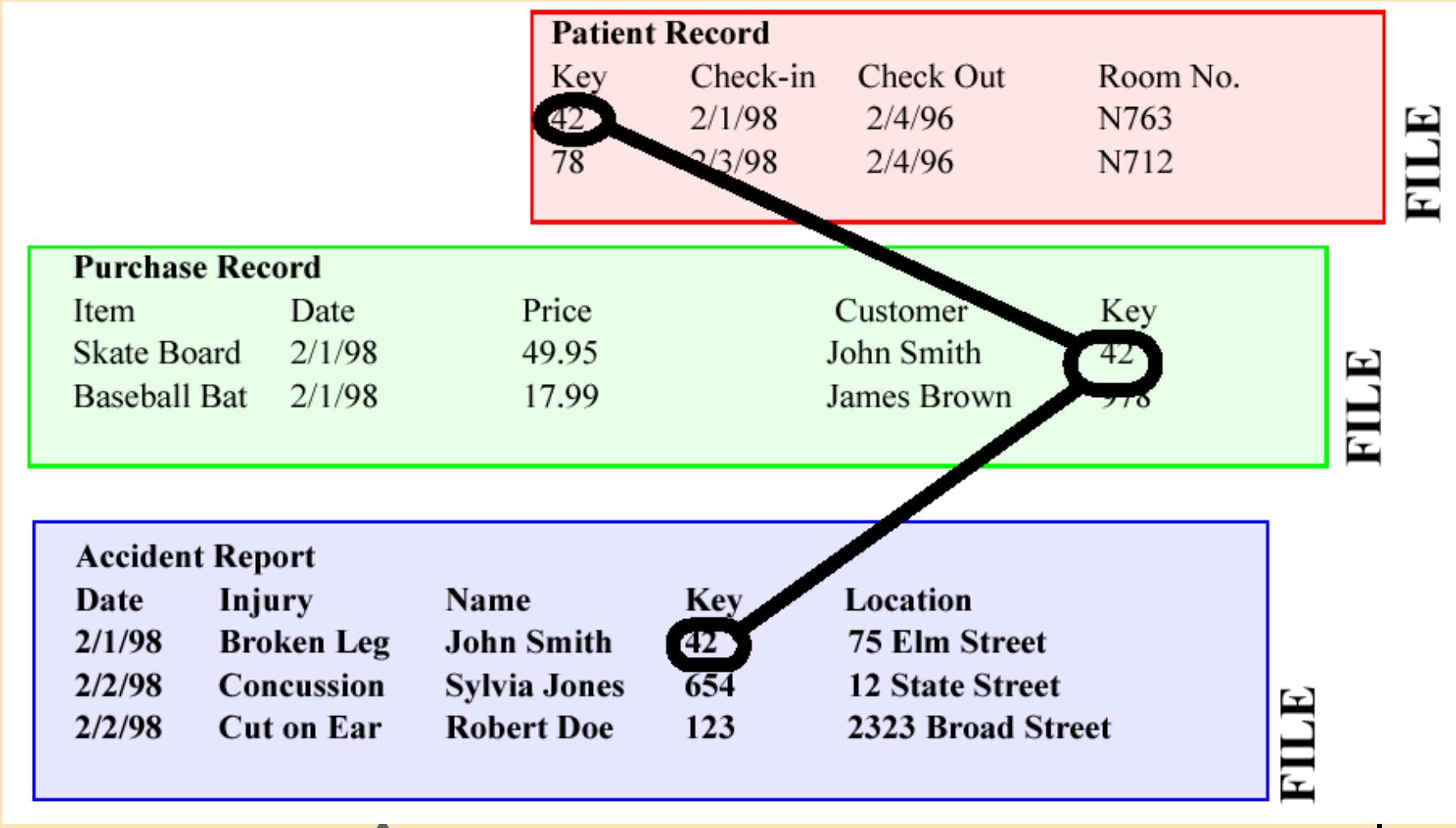
Based on multiple flat files for records

Dissimilar attribute structures

Connected by a common key attribute.

Key is a UNIQUE identifier at the "atomic" level for every record.

Relational Data Bases



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.

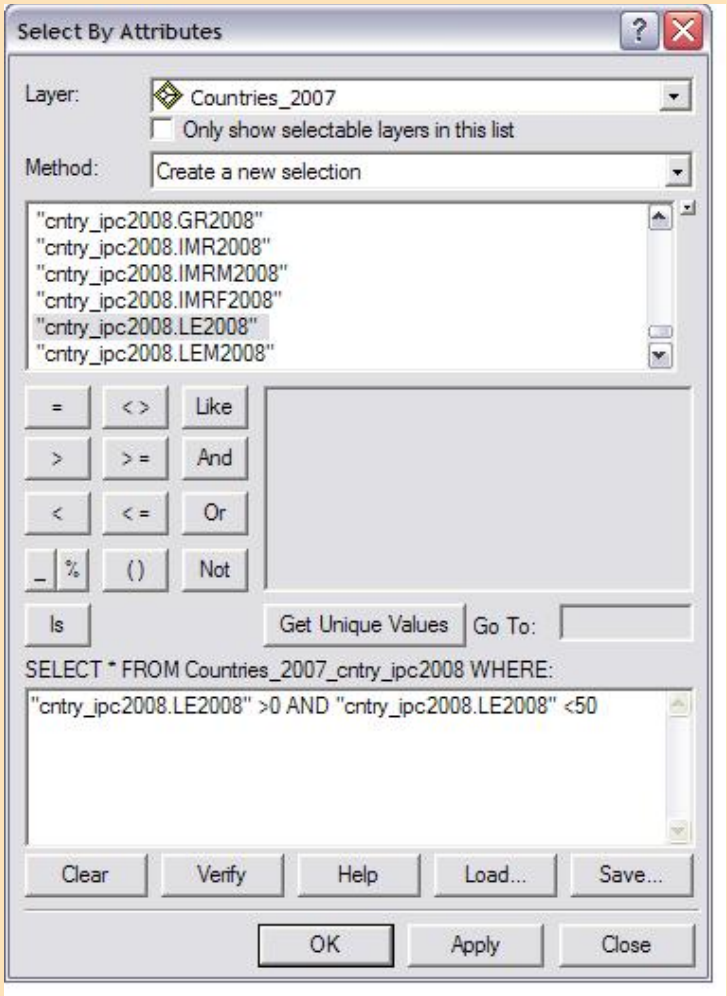
DBMS queries via the query language

sort

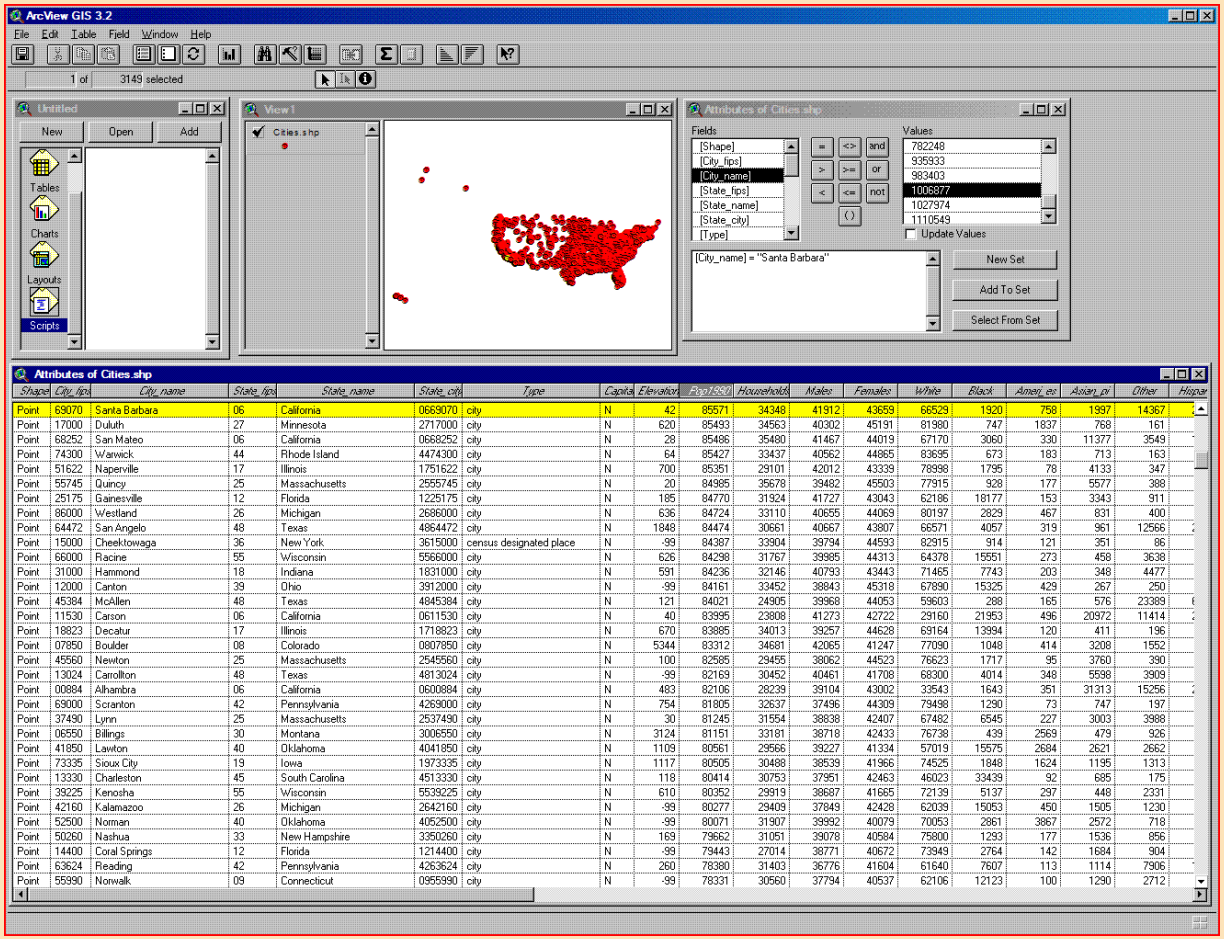
renumber

subset

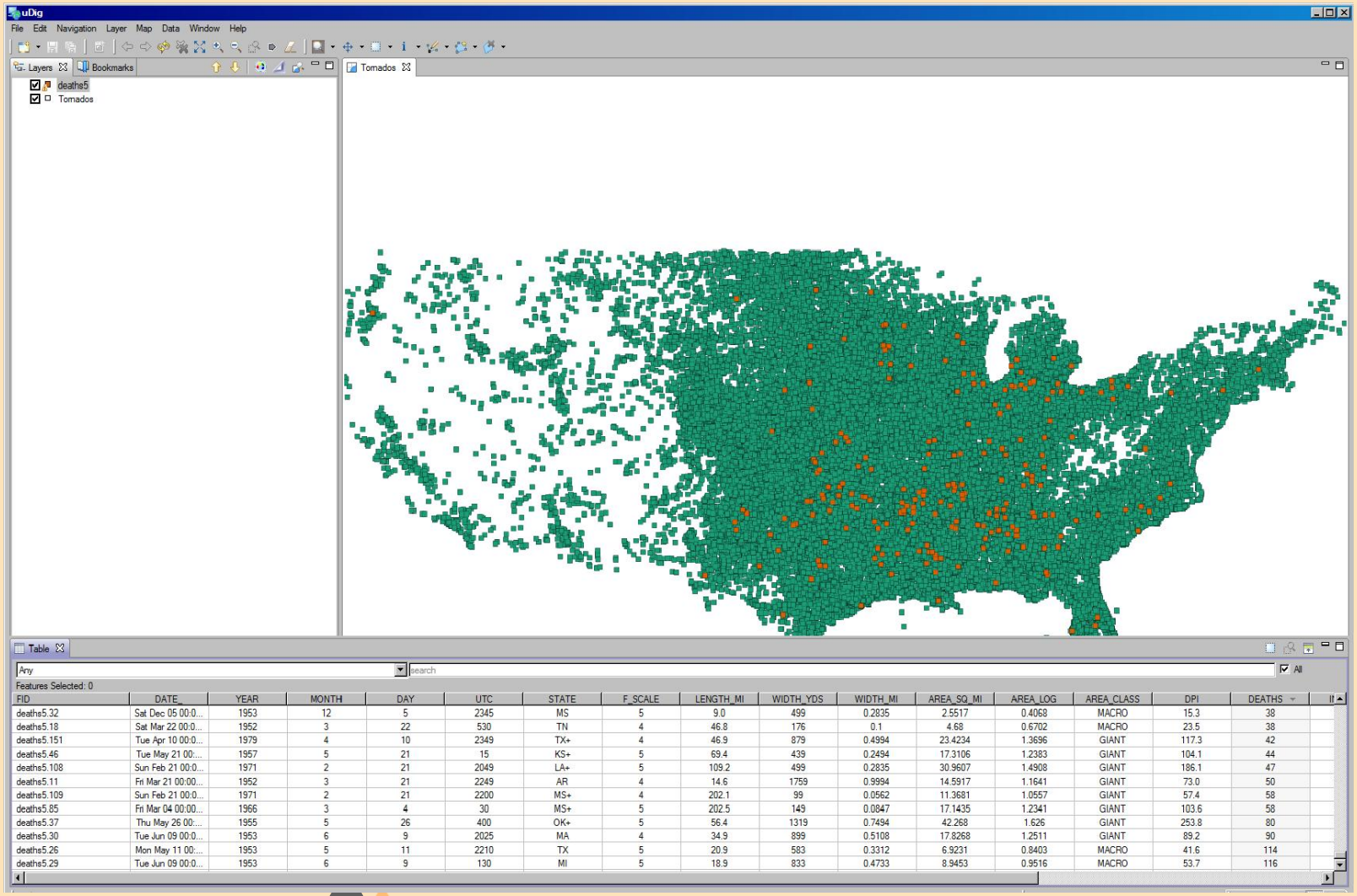
search



Query: Search for City Name=“Santa Barbara”

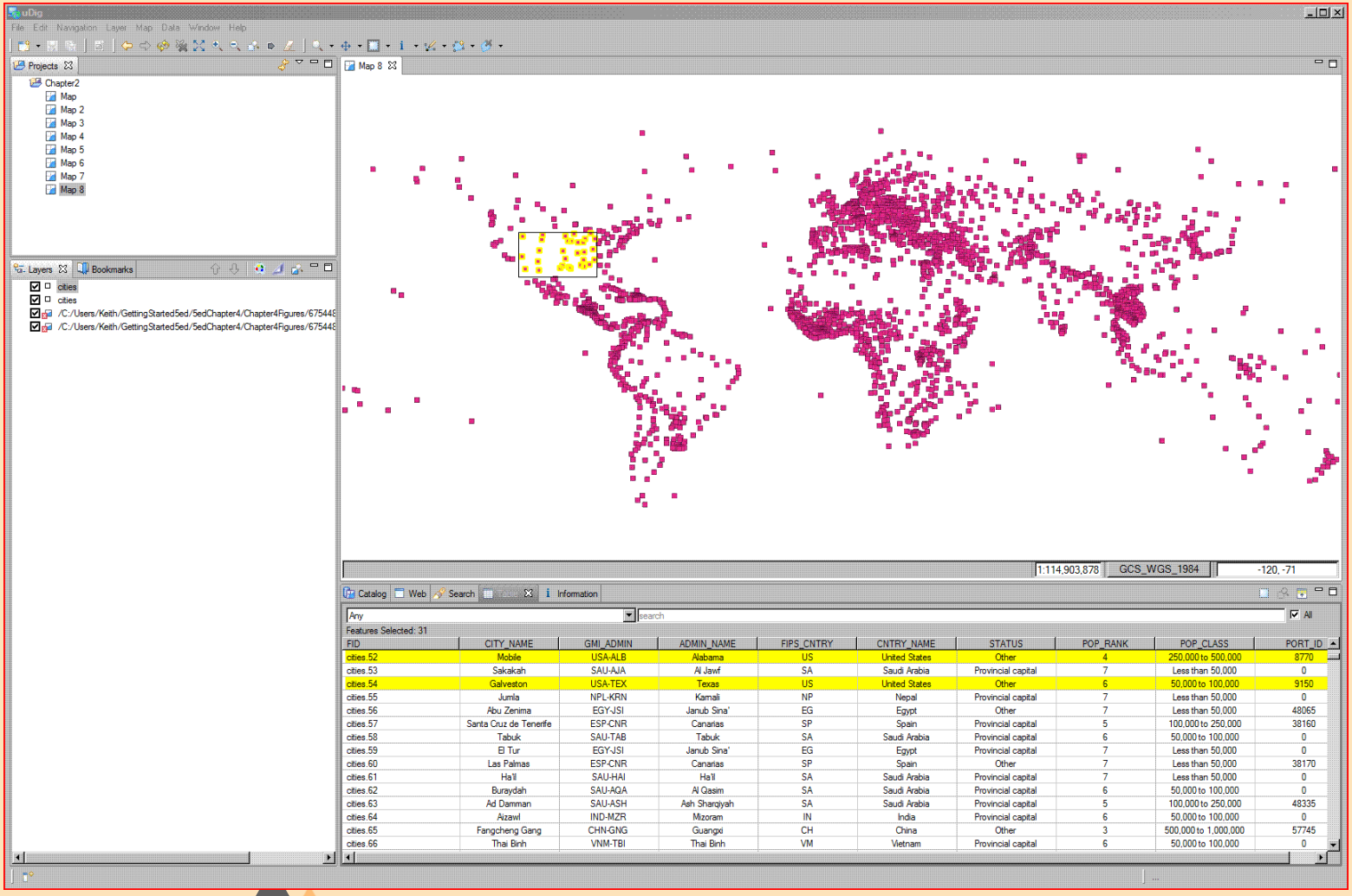


Sort: Locations by tornado deaths

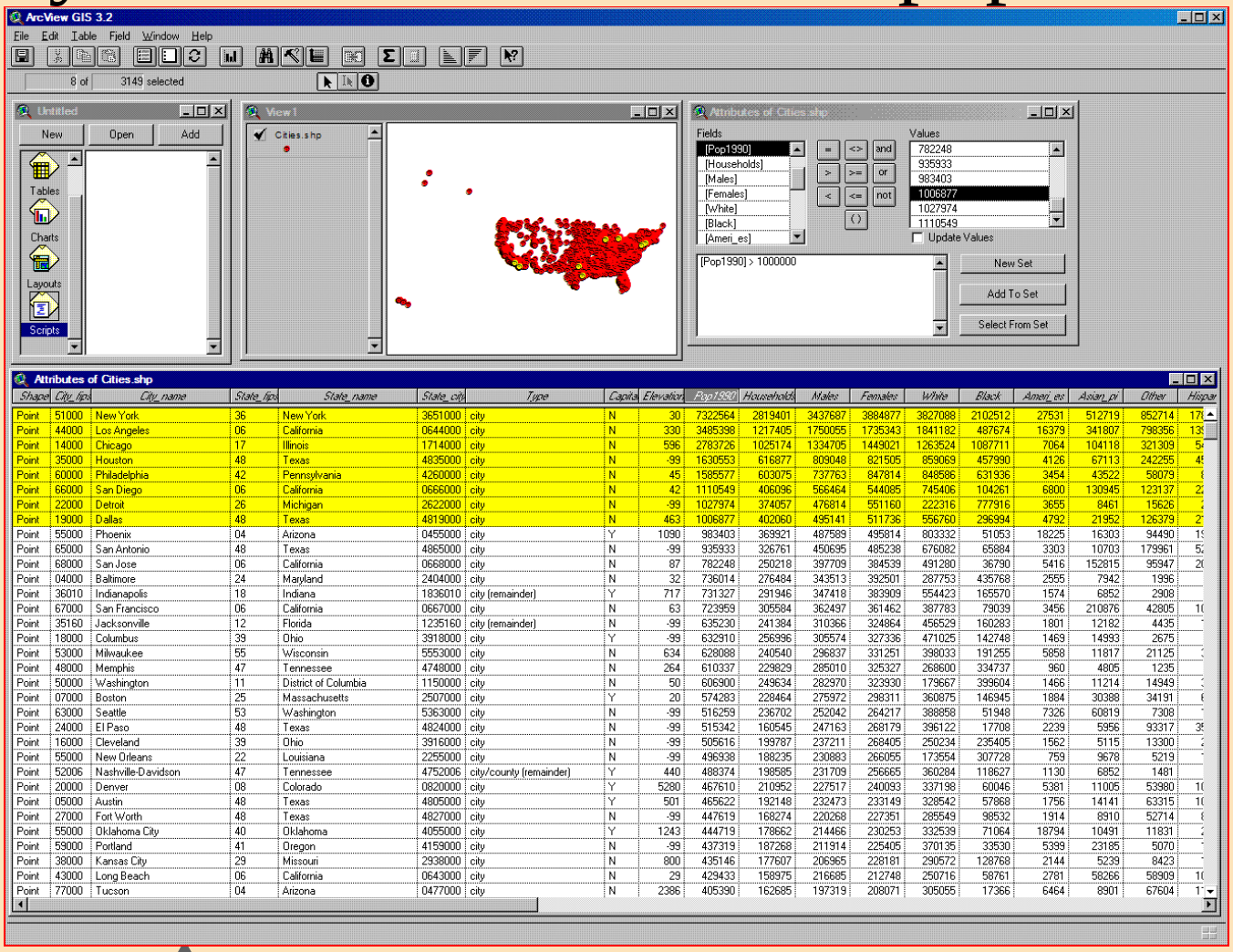


FID	DATE_	YEAR	MONTH	DAY	UTC	STATE	F_SCALE	LENGTH_MI	WIDTH_YDS	WIDTH_MI	AREA_SQ_MI	AREA_LOG	AREA_CLASS	DPI	DEATHS
deaths5.32	Sat Dec 05 00:0...	1953	12	5	2345	MS	5	9.0	499	0.2835	2.5517	0.4068	MACRO	15.3	38
deaths5.18	Sat Mar 22 00:0...	1952	3	22	530	TN	4	46.8	176	0.1	4.68	0.6702	MACRO	23.5	38
deaths5.151	Tue Apr 10 00:0...	1979	4	10	2349	TX+	4	46.9	879	0.4994	23.4234	1.3696	GIANT	117.3	42
deaths5.46	Tue May 21 00:...	1957	5	21	15	KS+	5	69.4	439	0.2494	17.3106	1.2383	GIANT	104.1	44
deaths5.108	Sun Feb 21 00:0...	1971	2	21	2049	LA+	5	109.2	499	0.2835	30.9607	1.4908	GIANT	186.1	47
deaths5.11	Fri Mar 21 00:00...	1952	3	21	2249	AR	4	14.6	1759	0.9994	14.5917	1.1641	GIANT	73.0	50
deaths5.109	Sun Feb 21 00:0...	1971	2	21	2200	MS+	4	202.1	99	0.0562	11.3681	1.0557	GIANT	57.4	58
deaths5.85	Fri Mar 04 00:00...	1966	3	4	30	MS+	5	202.5	149	0.0847	17.1435	1.2341	GIANT	103.6	58
deaths5.37	Thu May 26 00:...	1955	5	26	400	OK+	5	56.4	1319	0.7494	42.268	1.626	GIANT	253.8	80
deaths5.30	Tue Jun 09 00:0...	1953	6	9	2025	MA	4	34.9	899	0.5108	17.8268	1.2511	GIANT	89.2	90
deaths5.26	Mon May 11 00:...	1953	5	11	2210	TX	5	20.9	583	0.3312	6.9231	0.8403	MACRO	41.6	114
deaths5.29	Tue Jun 09 00:0...	1953	6	9	130	MI	5	18.9	833	0.4733	8.9453	0.9516	MACRO	53.7	116

Query: Search using map



Query: US Cities > 1000000 population

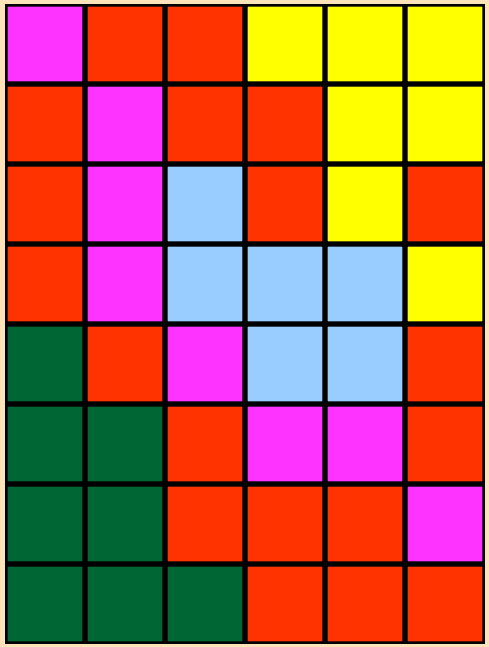


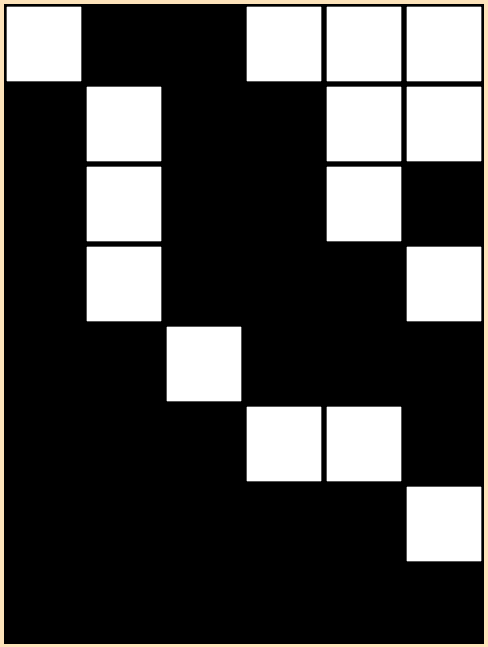
Shape	City_fips	City_name	State_fips	State_name	State_city	Type	Capital	Elevation	Pop1990	Households	Males	Females	White	Black	Ameri_es	Asian_pi	Other	Hispar
Point	51000	New York	36	New York	3651000	city	N	30	7322564	2819401	3437687	3884877	3827088	2102512	27531	512719	852714	17(
Point	44000	Los Angeles	06	California	0644000	city	N	330	3485398	1217405	1750055	1735343	1841182	487674	16379	341807	798356	13
Point	14000	Chicago	17	Illinois	1714000	city	N	596	2783726	1025174	1334705	1449021	1263524	1087711	7064	104118	321309	5
Point	35000	Houston	48	Texas	4835000	city	N	-99	1630553	616877	809048	821505	859069	457990	4126	67113	242255	4
Point	60000	Philadelphia	42	Pennsylvania	4260000	city	N	45	1585577	603075	737763	847814	848586	631936	3454	43522	58079	6
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	1027974	374057	476814	551160	222316	777916	3655	8461	15626	2
Point	19000	Dallas	48	Texas	4819000	city	N	463	1006877	402060	495141	511736	556760	296994	4792	21952	126379	2
Point	55000	Phoenix	04	Arizona	0455000	city	Y	1090	983403	369921	487589	495814	803332	51053	18225	16303	94490	1
Point	65000	San Antonio	48	Texas	4865000	city	N	-99	935933	326761	450695	485238	676082	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	554423	165570	1574	6852	2908	
Point	67000	San Francisco	06	California	0667000	city	N	63	723959	305584	362497	361462	387783	79039	3456	210876	42805	1
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	305574	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	6
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	173554	307728	759	9678	5219	
Point	52006	Nashville-Davidson	47	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	1
Point	05000	Austin	48	Texas	4805000	city	Y	501	465622	192148	232473	233149	328542	57868	1756	14141	63315	1
Point	27000	Fort Worth	48	Texas	4827000	city	N	-99	447619	168274	220268	227351	285549	98532	1914	8910	52714	6
Point	55000	Oklahoma City	40	Oklahoma	4055000	city	Y	1243	444719	178662	214466	230253	332539	71064	18794	10491	11831	2
Point	59000	Portland	41	Oregon	4159000	city	N	-99	437319	187268	211914	225405	370135	33530	5399	23185	5070	1
Point	38000	Kansas City	29	Missouri	2938000	city	N	800	435146	177607	206965	228181	290572	128768	2144	5239	8423	1
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

- Density = Pop / Area
- Density = Count_Points / Area
- Classed_soils = 1 if (soil_fert = 1 and soil_drain= 2)

Recode



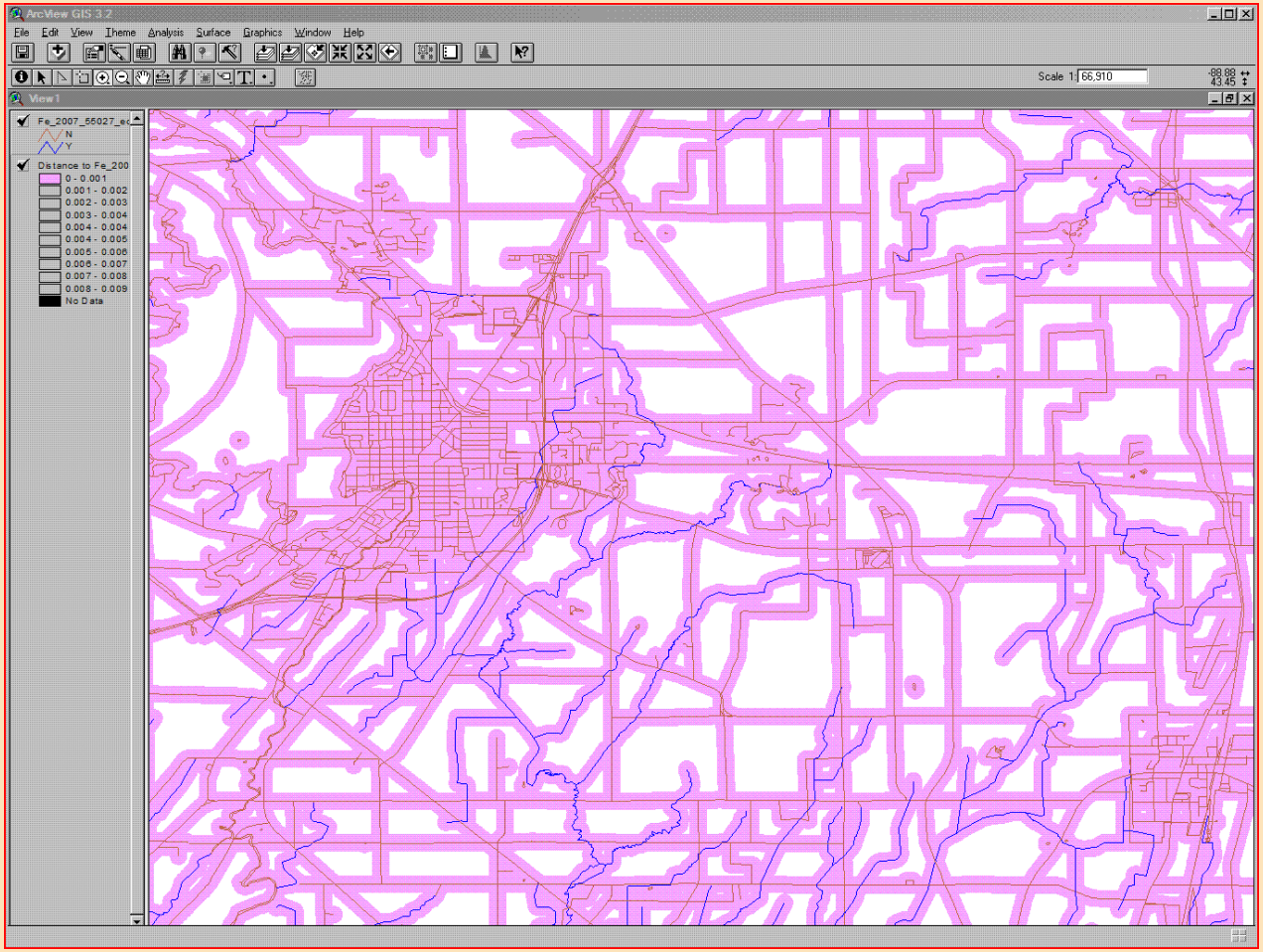


Spatial Search

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


ArcView GIS 3.2
File Edit View Theme Analysis Surface Graphics Window Help
Scale 1: 66,910
View1
Fe_2007_55027_e
N
Y
Distance to Fe_200
0 - 0.001
0.001 - 0.002
0.002 - 0.003
0.003 - 0.004
0.004 - 0.004
0.004 - 0.005
0.005 - 0.006
0.006 - 0.007
0.007 - 0.008
0.008 - 0.009
No Data

Types of overlay operations

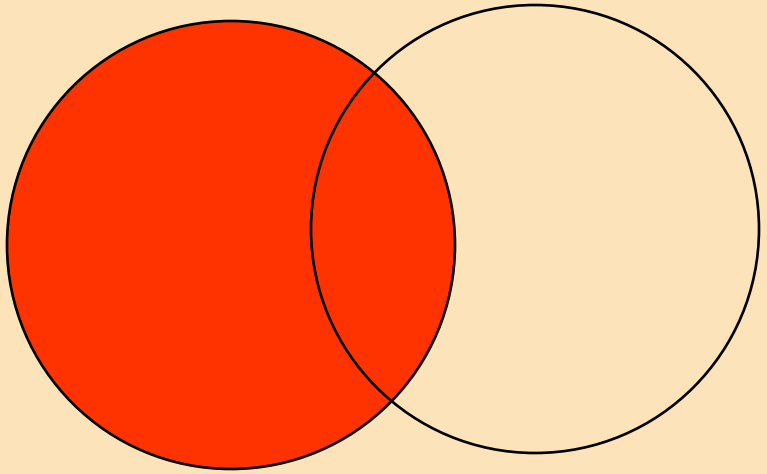
And

Or

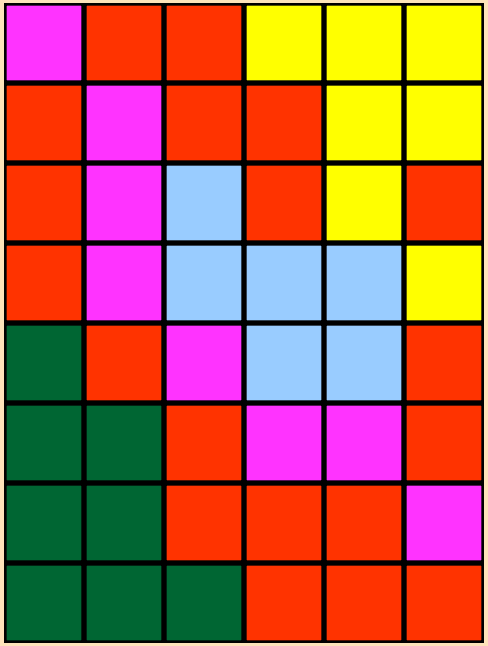
Max

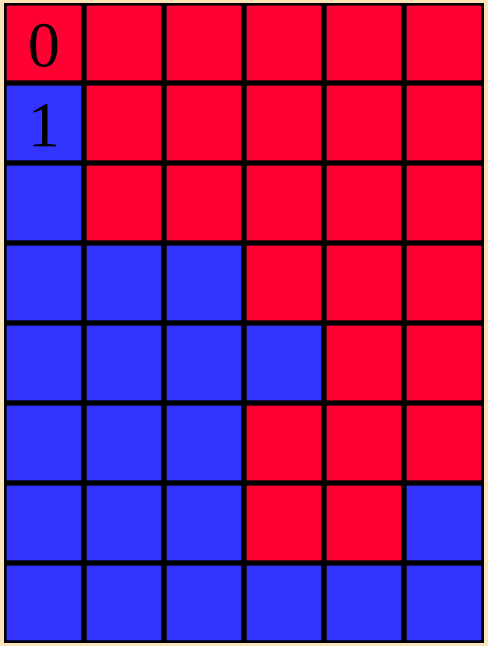
Min

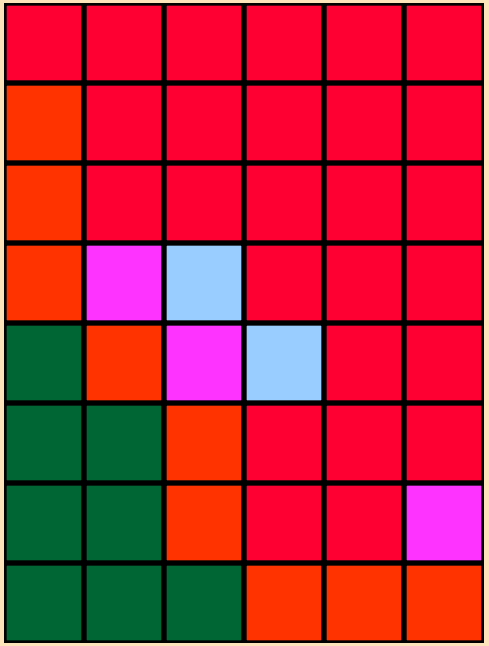
Exhaustive set



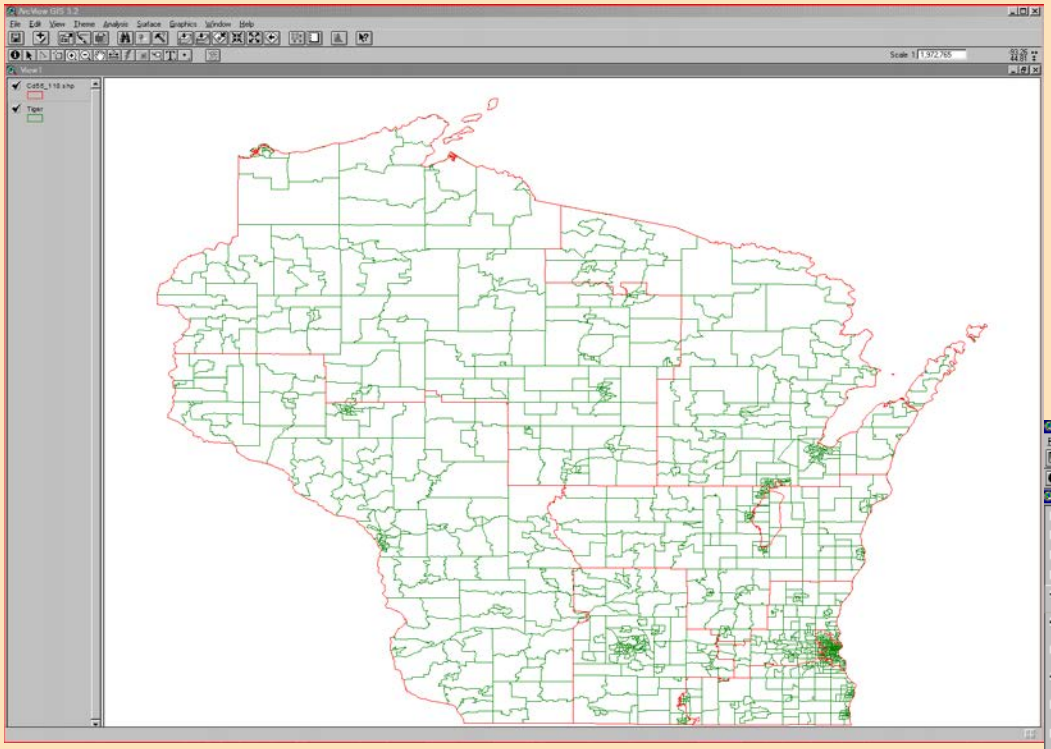
Overlay: Multiply (Masking)



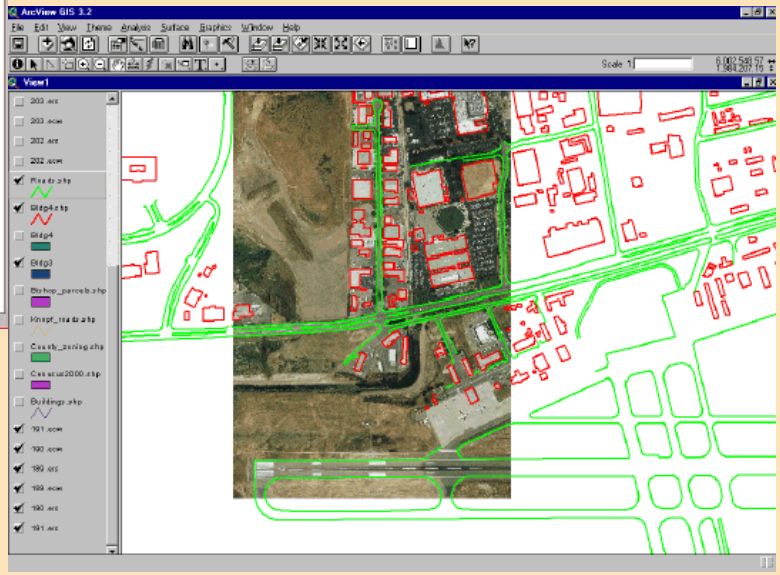




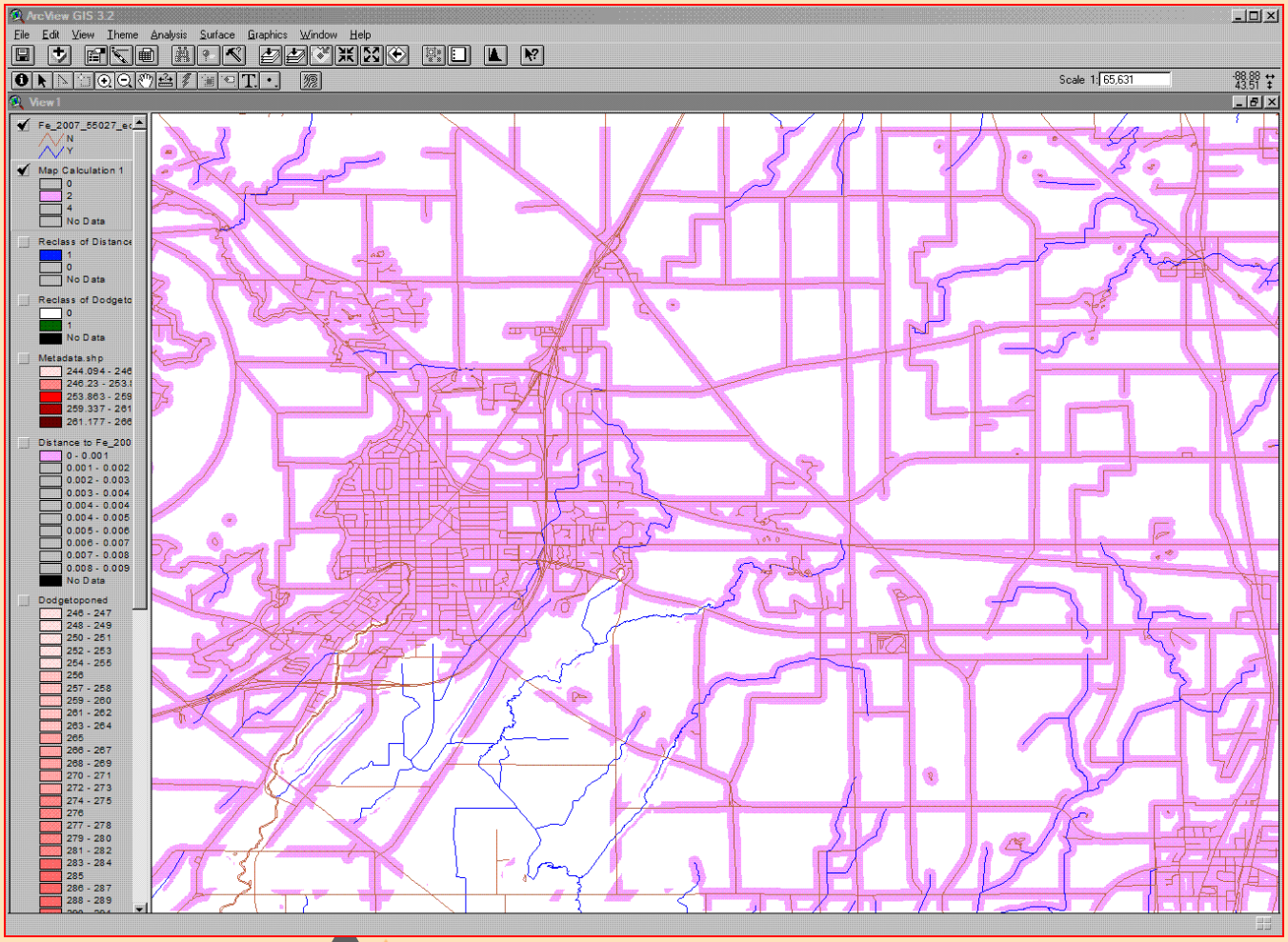
Data overlay



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

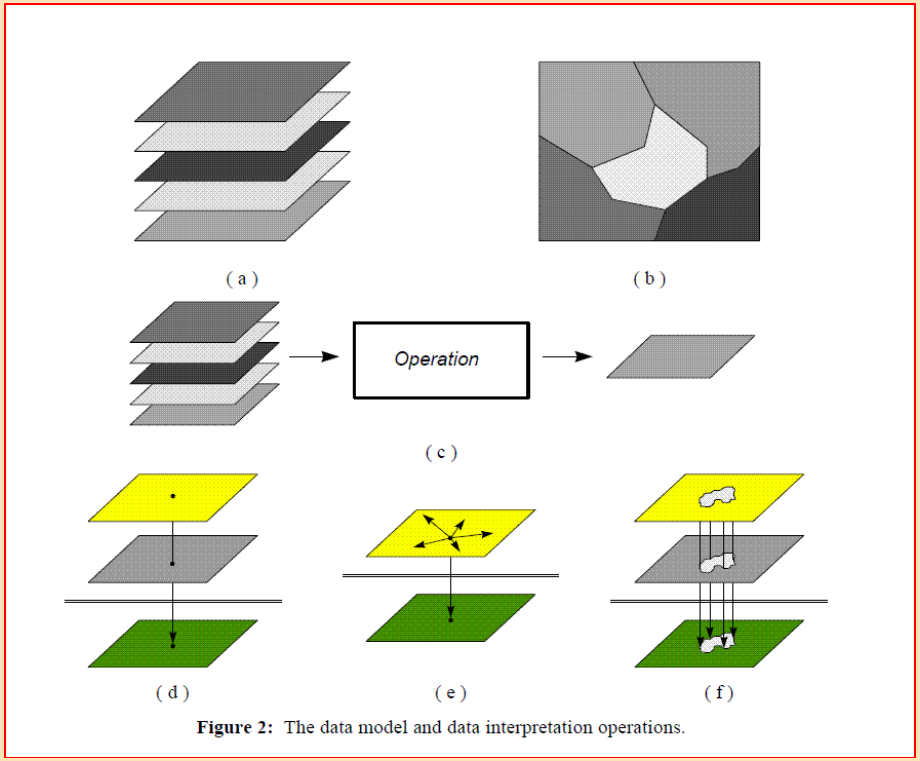
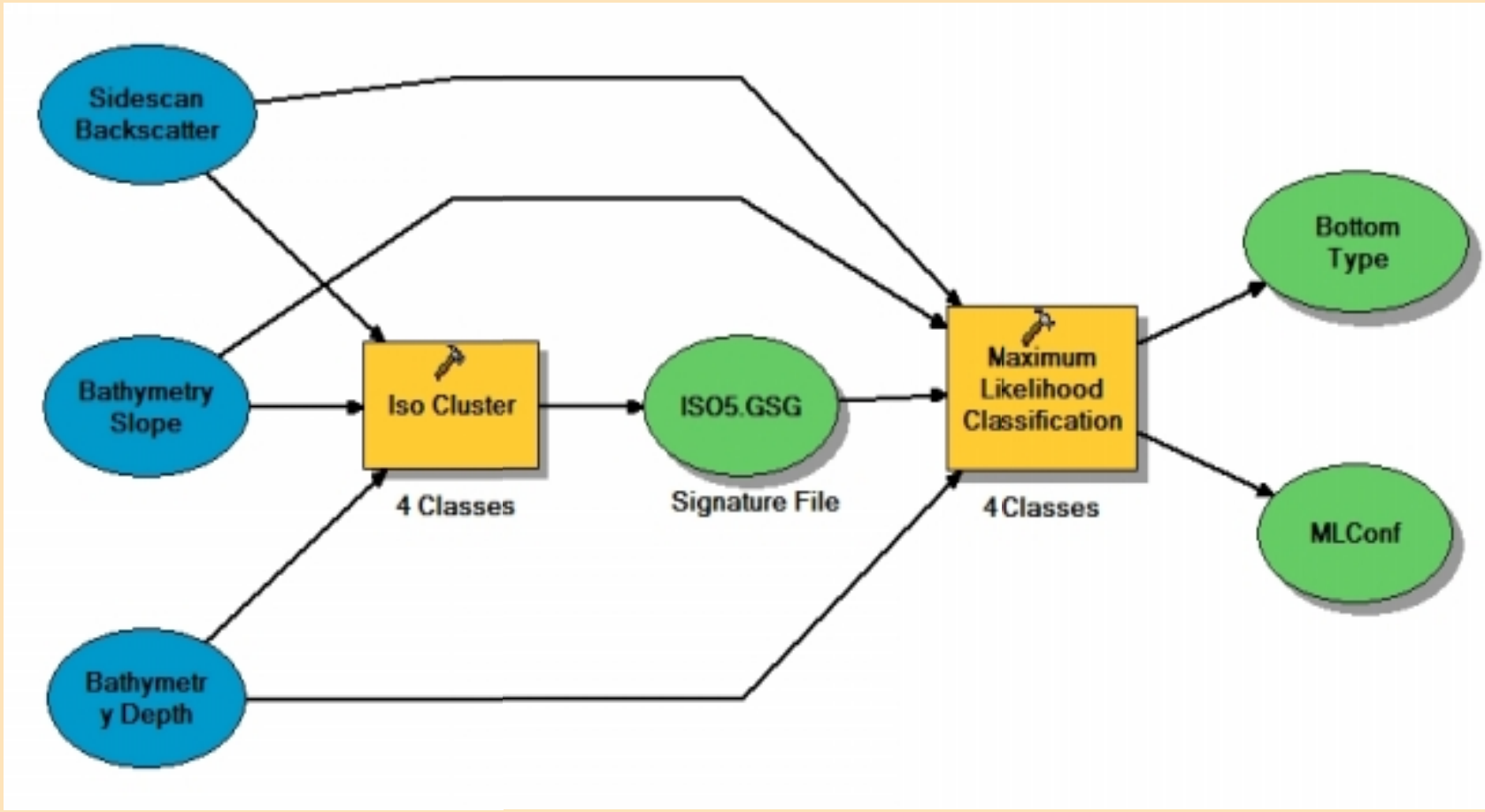


Figure 2: The data model and data interpretation operations.

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

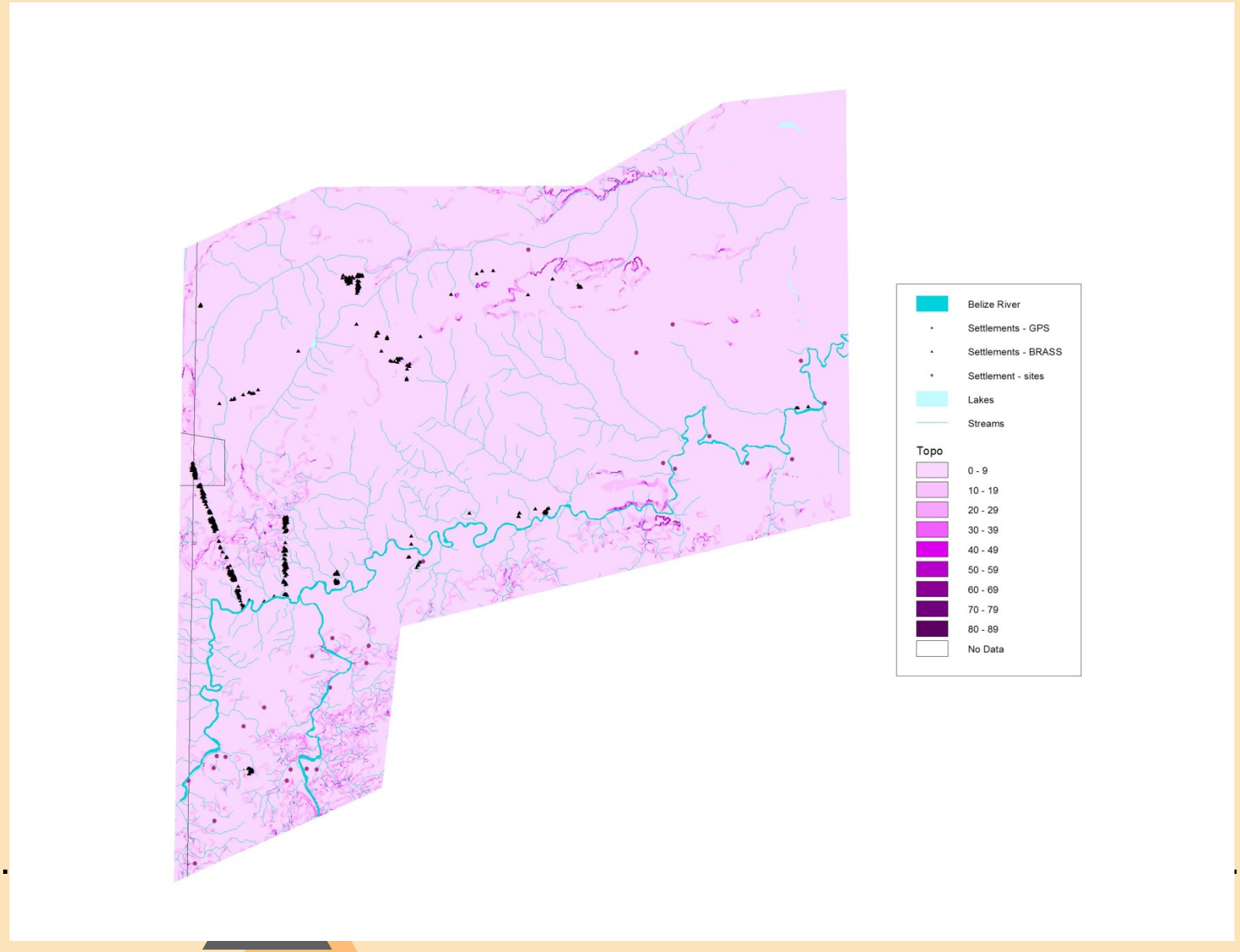
ESRI's Model Builder



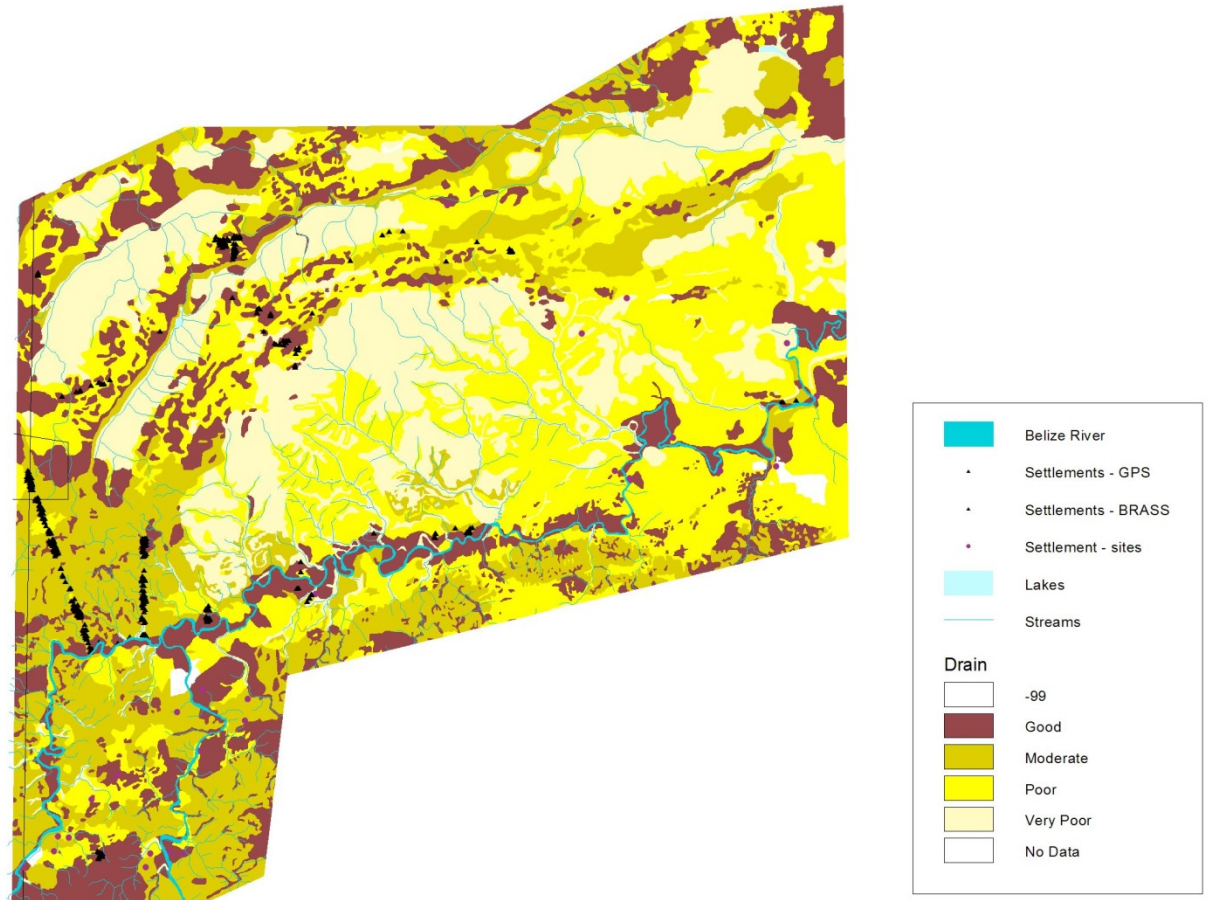
Weighted Overlay Analysis

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

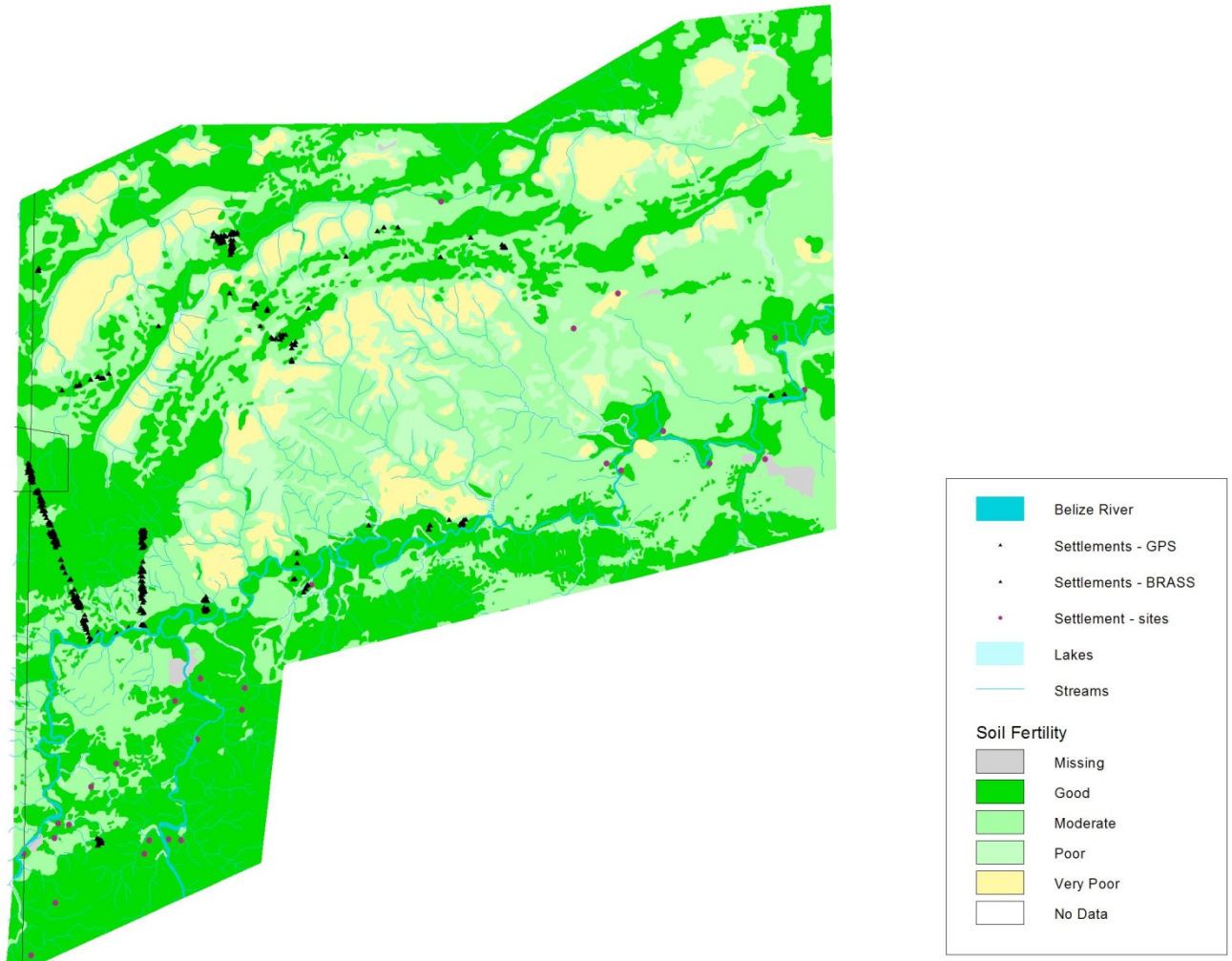
Topographic Slope (in percent)



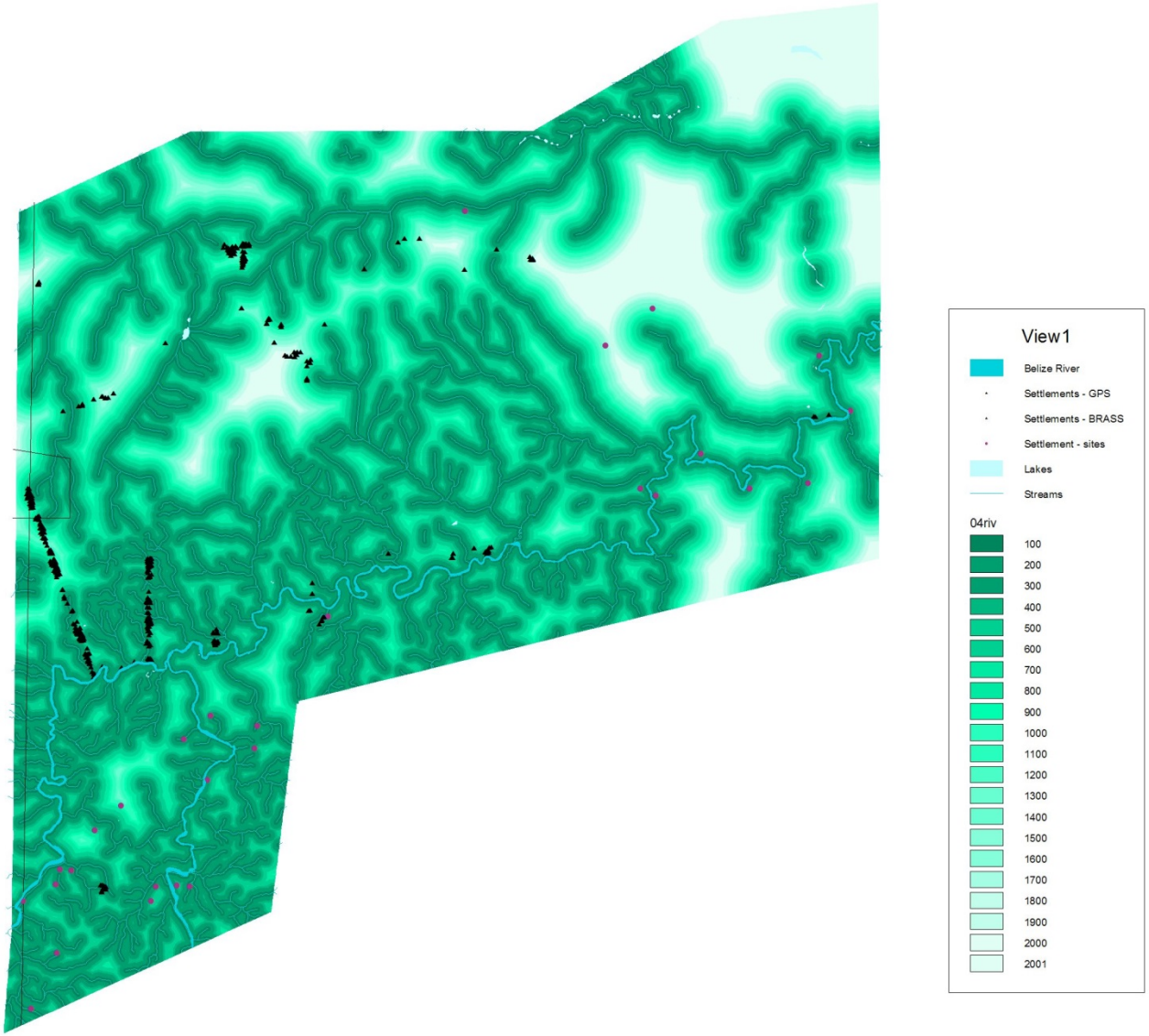
Soil drainage property



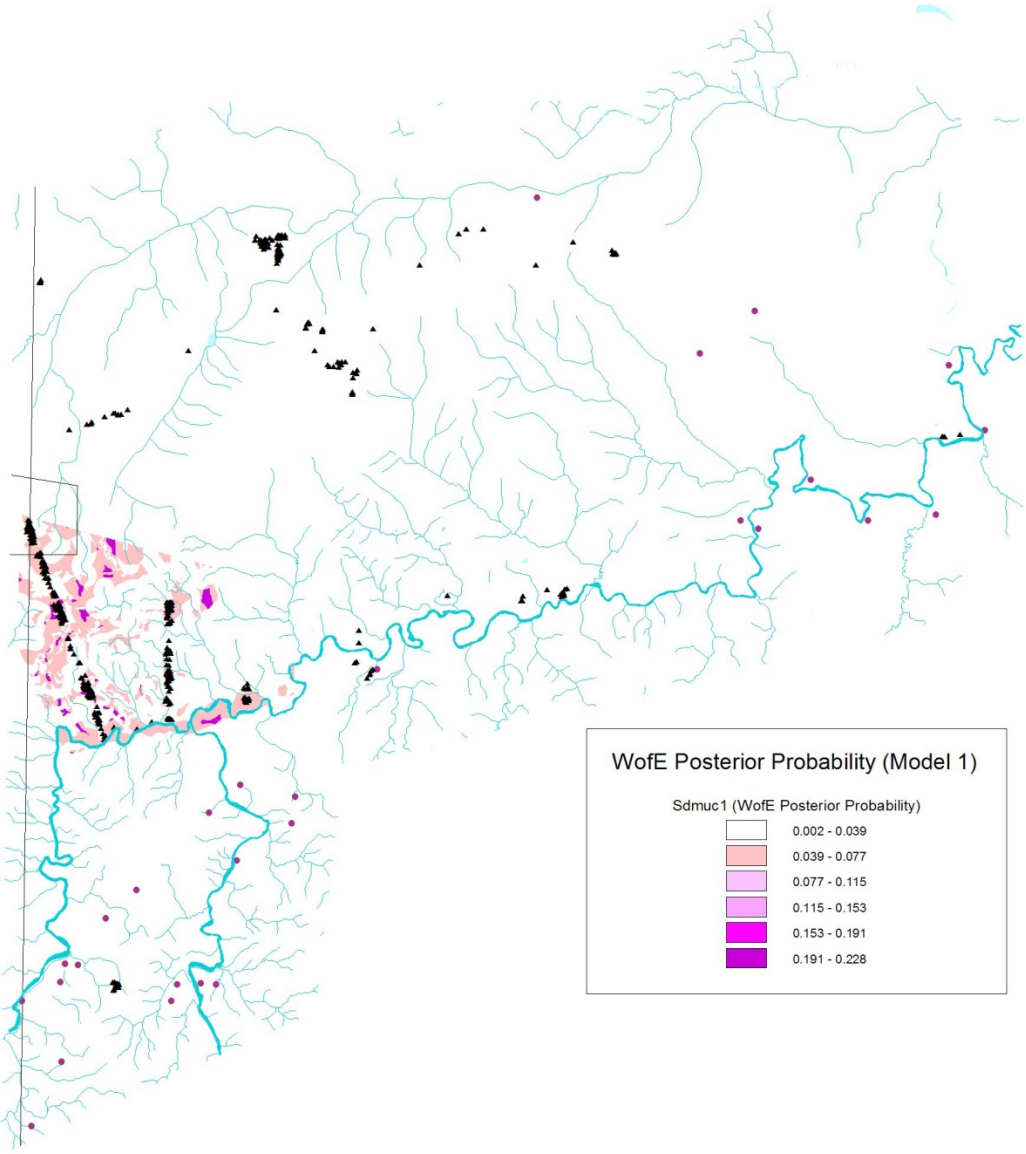
Soil fertility



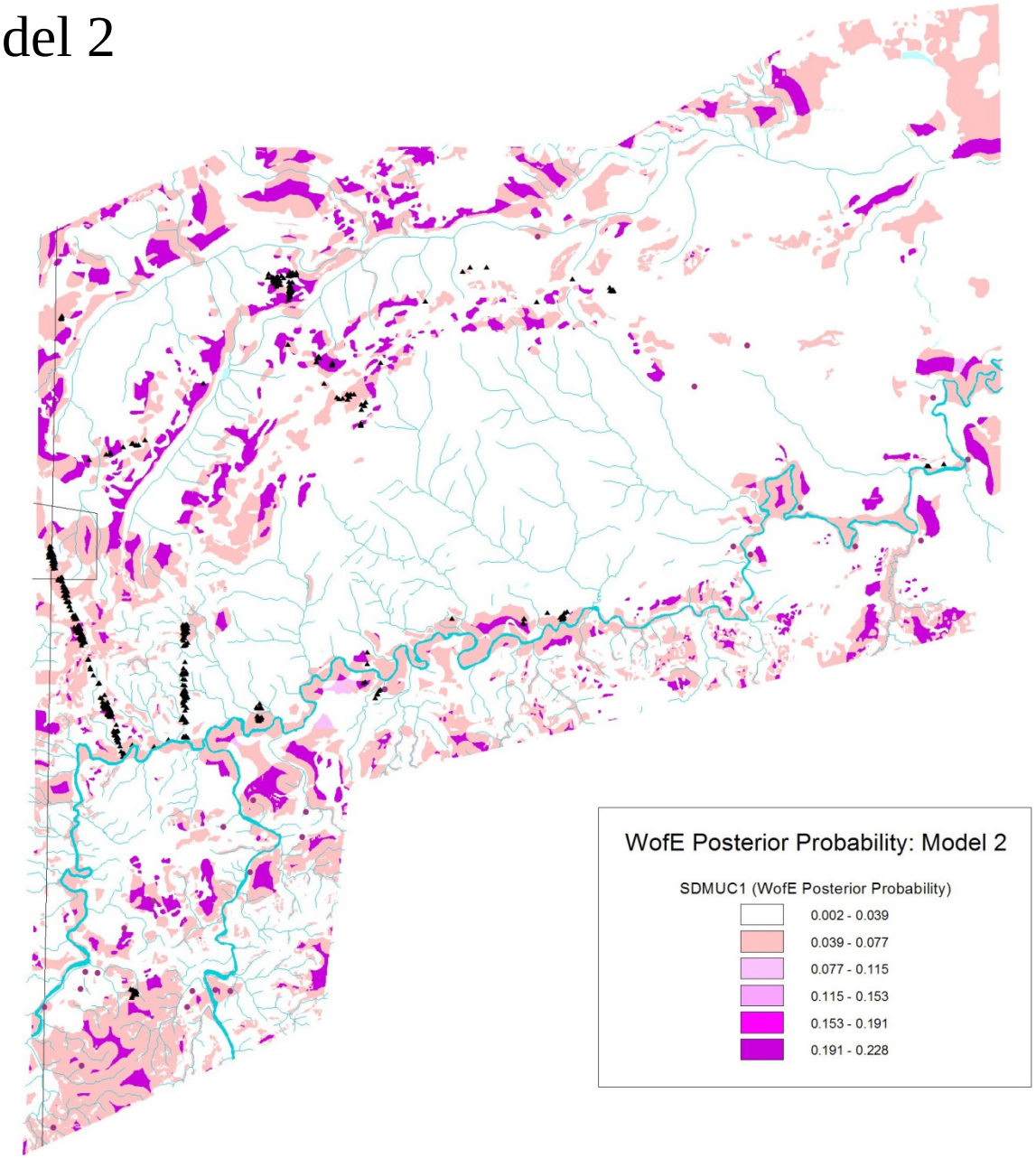
Distance to streams



WofE Model 1


WofE Posterior Probability (Model 1)
Sdmuc1 (WofE Posterior Probability)
0.002 - 0.039
0.039 - 0.077
0.077 - 0.115
0.115 - 0.153
0.153 - 0.191
0.191 - 0.228

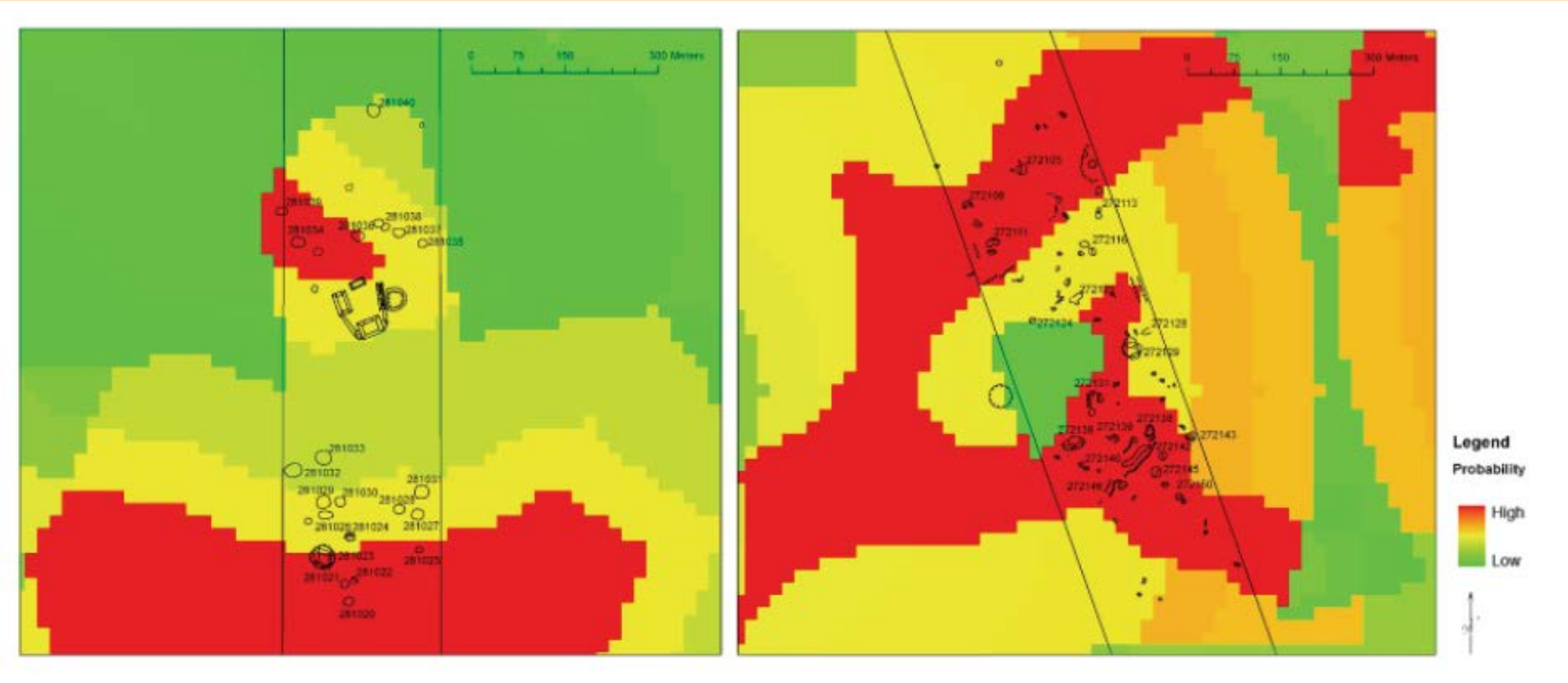
WofeE Model 2



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?