

Topic 2

Desktop Mapping

2.1 The Evolution of GIS

Many aspects of business are inherently spatial endeavors. Certainly in real estate the focus is “location, location, location” and increasingly other aspects, such as marketing and sales, are being viewed within spatial contexts. While business applications of geo-spatial technology is relatively new the roots of the technology covers over half a century. In the 1950s weather reports began analyzing temperature, winds and barometric pressure in very primitive GIS environments. In addition to descriptive maps that report existing and past conditions, computer modeling provides predictions of coming weather patterns.

The introduction of computers in mapping not only automates existing procedures but enables an entire new quantitative approach to analysis of spatial relations. However, these data are particularly complex as they require two descriptors, namely the precise location of things (*where*) and a clear description of its condition and characteristics (*what*). For hundreds of years the link between the two descriptors was the traditional paper map utilizing manual analysis tools, such as pens, rub-on shading, rulers, planimeters, dot grids, and acetate sheets.

More recently, analysis of mapped data has become an important part of business operations. This new perspective marks a turning point in the use of maps-- from one emphasizing *physical descriptions of geographic space*, to one of *interpreting mapped data*, and finally, to *applying spatial relationships* in decision-making. This movement from "description to prescription" has set the stage for entirely new concepts in business planning and management.

Since the 1960's, the decision-making process has become increasingly quantitative, and mathematical models have become commonplace. Prior to the computerized map, most spatial analyses were severely limited by their manual processing procedures. The computer has provided the means for both efficient handling of voluminous data and effective spatial analysis capabilities. From this perspective, all geographic information systems are rooted in the digital nature of the computerized map.

The early 1970's saw **computer mapping** automate map drafting. The points, lines and areas defining geographic features on a map are represented as an organized set of X,Y coordinates. These data drive pen plotters that can rapidly redraw the connections at a variety of colors, scales, and projections. The map image, itself, is the focus of this processing.

The pioneering work during this period established many of the underlying concepts and procedures of modern GIS technology. An obvious advantage with computer mapping is the ability to change a portion of a map and quickly redraft the entire area. Updates to maps which could take weeks, such as a new sales territory, can be done in a few hours. The less obvious advantage is the radical change in the format of mapped data— from analog inked lines on paper, to digital values stored on disk.

During the early 1980's, the change in data format and computer environment was exploited. ***Spatial database management systems*** were developed that linked computer mapping capabilities with traditional database management capabilities. In these systems, identification numbers are assigned to each geographic feature, such as a timber harvest unit or wildlife management parcel. For example, a user is able to point to any location on a map and instantly retrieve information about that location. Alternatively, a user can specify a set of conditions, such as a specific forest and soil combination, and direct the result of the geographic search to be displayed as a map (see figure 2-1).

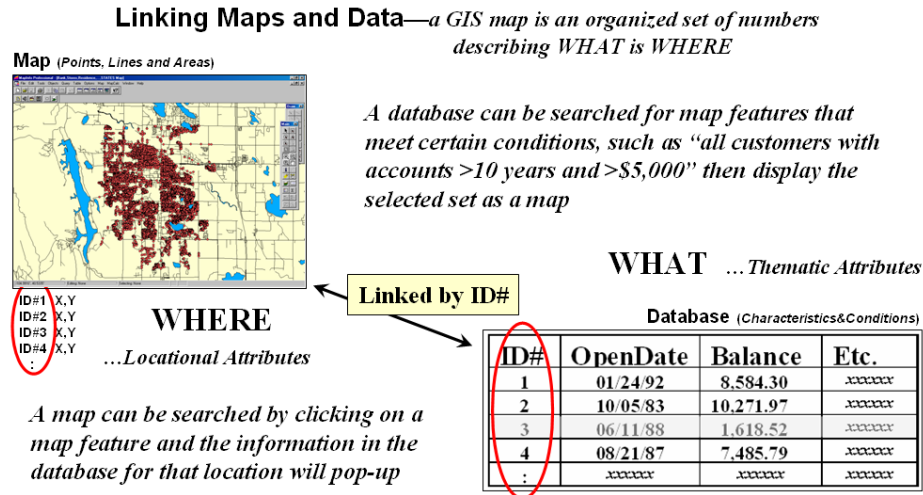


Figure 2-1. Spatial database management links a table describing the location of map features (customers) to a database containing descriptive attributes describing each feature (records).

Increasing demands for mapped data focused attention on data availability, accuracy and standards, as well as data structure issues. Hardware vendors continued to improve digitizing equipment, with manual digitizing tablets giving way to automated scanners at many GIS facilities. A new industry for map encoding and database design emerged, as well as a marketplace for the sales of digital map products. Regional, national and international organizations began addressing the necessary standards for digital maps to insure compatibility among systems. This era saw GIS database development move from project costing to equity investment justification in the development of corporate databases.

2.2 Map Analysis

In the 1990s a comprehensive theory supporting *map analysis* began to emerge. The dominant feature of this theory is that spatial information is represented numerically, rather than in analog fashion as inked lines on a map. These digital maps are frequently conceptualized as a set of "floating maps" with a common registration, allowing the computer to "look" down and across the stack of digital maps. The spatial relationships of the data can be summarized (database queries) or mathematically manipulated (analytical processing). Because of the analog nature of traditional map sheets, manual analytic techniques are limited in their quantitative processing. Digital representation, on the other hand, makes a wealth of quantitative processing possible.

Geophysicists have used spatial statistics for many years to characterizing the geographic distribution, or pattern, of mapped data. The statistics describe the spatial variation in the data, rather than assuming a typical response is everywhere. For example, field measurements of snow depth can be made at several plots within a watershed. Traditionally, these data are analyzed for a single value (the average depth) to characterize the watershed. Spatial statistics, on the other hand, uses both the location and the measurements at the plots to generate a map of relative snow depth throughout the entire watershed.

Spatial context, as well as analysis, provides insight into the geographic patterns and relationships. For example, forest managers can characterize timber supply by considering the relative skidding and log-hauling accessibility of harvesting parcels. Similarly a commercial real estate broker can characterize a parcel by its travel-time accessibility to customers and suppliers.

This "map-ematical" approach to mapping has evolved by extending conventional concepts that use sequential processing of spatial operators to perform complex map analyses. It is similar to traditional algebra in which primitive operations (e.g., add, subtract, exponentiate) are logically sequenced on variables to form equations.

However in map algebra, entire maps composed of thousands or millions of numbers represent the variables of the spatial equation.

Computer mapping, spatial database management and map analysis form the major eras in GIS evolution. Its current frontier is focused on refining these capabilities and adopting them to evolving computer environments and allied disciplines. Internet mapping, for example, provides access and processing of mapped data from remote locations. Multimedia mapping makes audio, video and images hot-linked to map features just a mouse-click away. Global positioning system (GPS) receivers are becoming ubiquitous. GIS-enabled palm and tablet PCs, as well as cell phones, enable users to interact with spatial information as daily routines. Remote sensing imagery is routinely used as a less abstract backdrop for complex GIS data.

While the current frontier is making GIS technology a fabric of society the three cornerstones identify its underlying theory and basic principles. Most introductory GIS courses emphasize computer mapping and spatial database management with minimal exposure to map analysis. This book flips the conventional approach and allocates just this chapter to CM and SDBM as a springboard to map analysis discussions in the remaining chapters.

2.3 Map Display and Query

From the broadest perspective, computer mapping and its paper-map legacy have a lot in common. Both are composites of individual map layers. For example, the familiar USGS Topographic hikers use is actually a composite of seven “printer separates”—red ink for roads, blue for water, green for vegetation, etc. A composite print of the map is formed by printing the color layers in sequence.

A composite computer map is organized in a similar manner. It is formed by displaying a series of map layers in an appropriate order. Figure 2-2 illustrates the construction of a composite map display. The individual Water Bodies layer is displayed on top of the stack with “opaque” blue assigned to its features. Locations without water features are treated as “transparent” and the features on underlying map layers are allowed to show through.

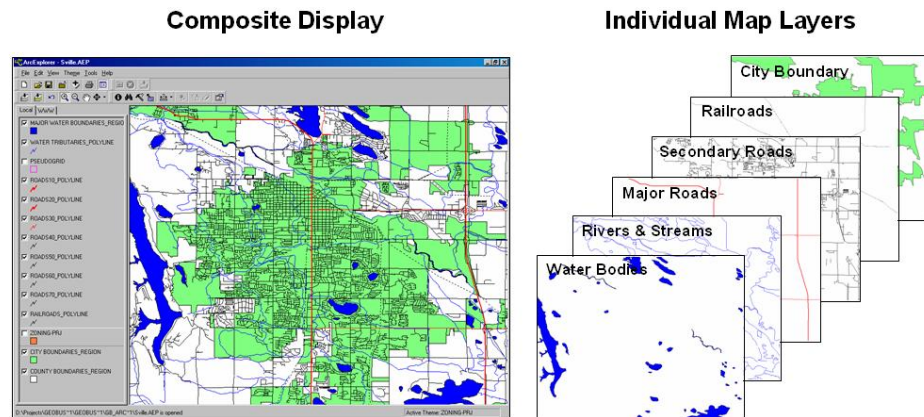


Figure 2-2. A composite map is formed by ordering the display of a series of individual map layers.

Unlike a paper map, entire layers in a digital map can be turned on or off and specific features on a layer can be re-colored. In addition, users can add entirely new layers of information, zoom in/out, pan up/down/across, and interact with the tabular information defining a map layer. For example, clicking on a feature (e.g., a lake) on an active layer pops-up a listing of its stored information, such as its name, size, recreational use, etc. Similarly, the tabular data linked to the map can be queried for an item(s) of interest that will be highlighted on the map.

The exercises at the end of this chapter provide hands-on experience with basic map display. The short set of tasks is designed to illustrate the conceptual approach and basic structure used in computer mapping and spatial database management. While much more experience is needed to fully understand important underlying theory and practice,

such as map projections and data encoding, the exercises provide a good frame of reference for understanding similarities and differences to procedures used in map analysis.

2.4 Data Characteristics

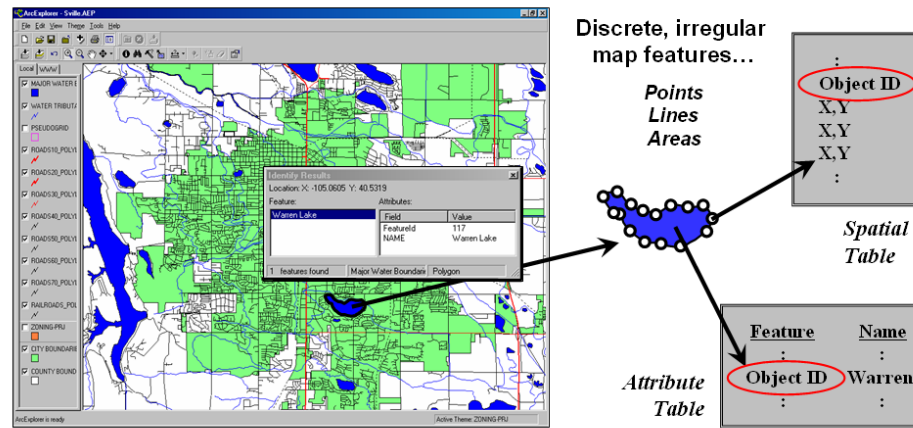


Figure 2-3. Vector data characterizes map features as collections of points, lines and polygons.

Critical to this understanding is the recognition of the different types of mapped data and their inherent advantages and limitations. **Vector data** is the most fundamental data type and represents objects in geographic space as collections of points, lines and polygons. For example, figure 2-3 shows the general data organization for a lake on the Water Bodies map layer. The boundary of the lake is defined by a sequence of point coordinates stored in a *spatial table*. The identification number for the set of points serves as a universal index that joins it to an attribute table containing text and numerical data associated with the feature.

The fundamental spatial unit in a vector system is the point. As shown in figure 2-4, a set of points can be used to identify relatively small map features such as customer residences. Each *point feature* is spatially defined by a pair of X,Y coordinates, such as longitude/latitude, that positions the point in geographic space.

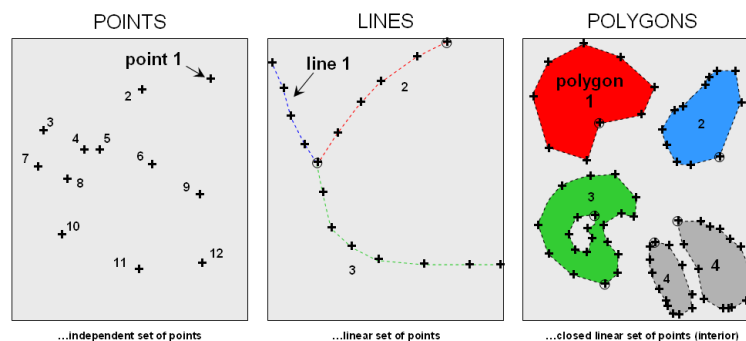


Figure 2-4. Maps containing point, line and polygon features are defined by organized sets of points.

Line features, such as a road or stream, are organized as a linear sequenced set of points. Each line has a beginning and an end point (circled in the figure) with the intervening points implicitly identifying the series of line segments forming the line. In displaying a line the computer draws a series of short lines on the screen or plotter as it mathematically connects the coordinates. Complex linear networks track which lines are connected and the potential flows between them, such as one-way streets and no-left-turn intersections.

Polygon features, such as a city boundary, are formed by a line (linear sequence set of point) that closes on itself. In this instance, the computer draws the closed line then assigned a color to its interior. Complex polygons can contain islands of different conditions or fragmented occurrences, such as a different ownership contained within a parcel or an individual parcel split by a highway.

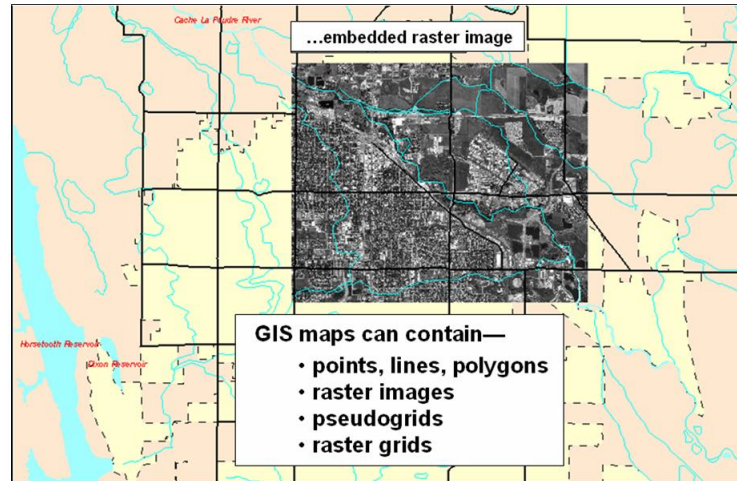


Figure 2-5. The four basic GIS data types represent geographic space in different ways.

It is important to note that the map features in a vector-based mapping system identify discrete, irregular spatial objects with sharp abrupt boundaries. Other data types—raster images, pseudo grids and raster grids—treat space in entirely different manner forming a spatially continuous data structure.

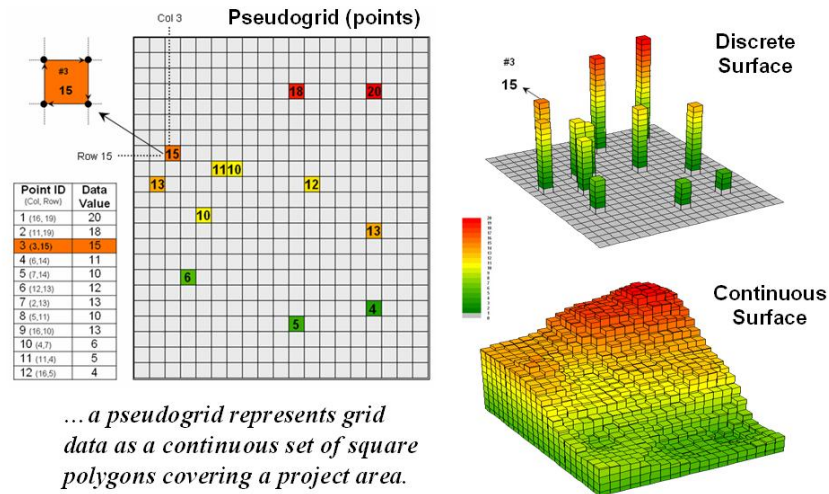


Figure 2-6. Pseudogrids treat geographic space as a continuous surface.

A **pseudo grid** is formed by a series of uniform, square polygons covering an analysis area (figure 2-6). In practice, each grid element is treated as a separate polygon—it's just that every polygon is the same shape/size and they all abut each other—with spatial and attribute tables defining the set of little polygons. For example, in the upper-right portion of the figure a set of discrete point measurements are stored as twelve individual “polygonal cells.” The interpolated surface from the point data (lower-right) is stored as 625 contiguous cells.

While pseudo grids store full numeric data in their attribute tables and are subject to the same vector analysis operations, the explicit organization of the data is both inefficient and too limited for advanced spatial analysis as

each polygonal cell is treated as an independent spatial object. A **raster grid**, on the other hand, organizes the data as a listing of map values like you read a book—left to right (columns), top to bottom (rows). This implicit configuration discussed in the next section (topic 3.0) identifies a grid cell's location by simply referencing its position in the list of all map values.

2.5 Future Directions

During the early development of GIS, the two alternative data structures for storing mapped data were hotly debated. The traditional data model (points, lines, polygons) closely mimics the manual drafting process by representing map features as a set of lines which, in turn, are explicitly stored as a series of X,Y coordinates. The alternative raster structure establishes an imaginary grid over a project area and then implicitly stores information for each cell in the grid. The early debate attempted to determine the universally best data structure. The relative advantages and disadvantages of both were viewed in a competitive manner that failed to recognize the overall strengths of a GIS approach encompassing both formats.

By the mid-1980's, the general consensus was that the nature of the data and the processing desired determines the appropriate data structure. The realization of the duality of mapped data structure has had significant impact on geographic information systems design and application.

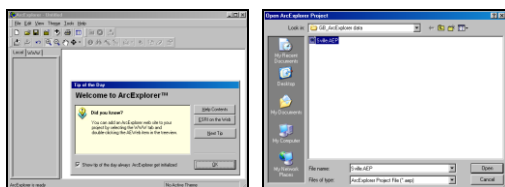
From one perspective, map features form sharp boundaries that are best represented as points, lines and polygons. Streets and property ownership are examples where lines are real and the data are certain. Other data, such as likelihood of sales and relative competitive advantage are interpretations involving spatial relationships among several maps. The placement of lines identifying these conditions is subject to judgment, statistical analysis of field data, and broad classification of continuous spatial distributions. From this perspective, the sharp boundary implied by a line is artificial and the data itself is based on interpretation.

2.6 Exercises

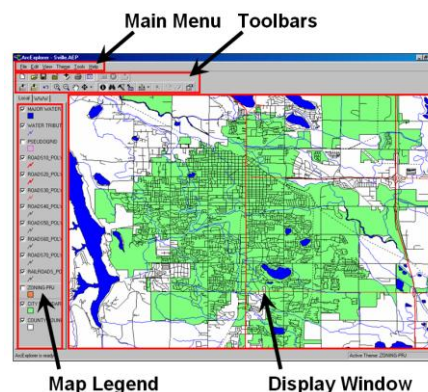
Access *ArcExplorer* using the Sville.aep database by selecting **Start→Programs→ESRI→ArcExplorer 2.0→ArcExplorer**. From ArcExplorer's main menu, select **File→Open** and specify ...\\Sville.AEP as the project to open. Press the **Open** button to plot the data.


In addition to these basic components special dialog boxes will pop-up depending on the operation selected. The pop-up windows are for specifying input or contain summary reports. This exercise focuses on the basic display of vector maps.


2.6.1 Interacting with Vector Maps



The ArcExplorer user interface consists of four components—*Main Menu* with drop-down lists, *Toolbars* with direct-access buttons, *Display Window* for 2D plotting of mapped data and a composite Map Legend containing symbology for all of the maps in a project.

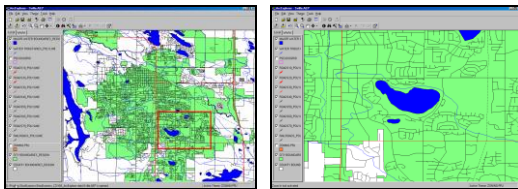


 Maximize the program window by clicking on the **Maximize** button in the upper-right corner.

 In the map legend portion of the window, click on and off the display **Check box** beside the various map layers. Note that some of the maps are formed by a set of line features while others are formed by a set of polygon features. Point, line and polygon features are stored as a series of connected X,Y points and identified by a unique ID-number.



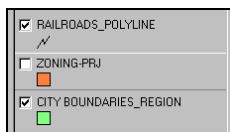
Click the button with the **Zoom In** button (+ magnifying glass). Click and hold the mouse button down just outside the upper left portion of the map and drag a rectangle that outlines a portion of the map. When you release the button, the map will “zoom” to the area you outlined.



Try the **Zoom Out** button (- magnifying glass) and the **Pan** button (hand) to zoom out and pan the map. Use the **Direction** button (arrows) to pan in fixed steps. Press the “down arrow” beside the *Direction* button to choose pan direction (north, south, east, and west).



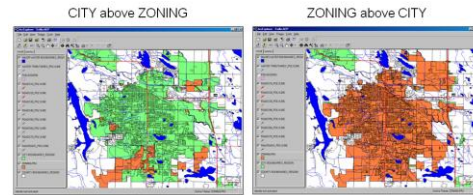
View the entire project area by clicking “**Zoom to Full Extent**” button at the extreme left side of the toolbar. Spend some time using the navigation tools to explore the map set.



Click on the **ZONING-PRJ** map name to make it active (legend area will become “raised”). Click on the **Zoom to Active Theme** button to center on the Smallville area.

Click the check box to the left of the “**ZONING-PRJ**” legend to make its display visible. Note that the zoning information (orange) obscures the city information (green). Click and drag the **ZONING-PRJ** layer below the **CITY BOUNDARIES** layer. Note that the city

boundary now obscures the zoning information. Return the zoning map “above” the city map.

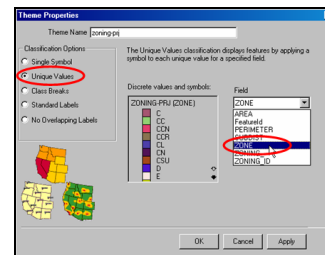


The position of a map in the map legend window is analogous to viewing a set of transparencies on a light table—maps on top obscure information beneath them.

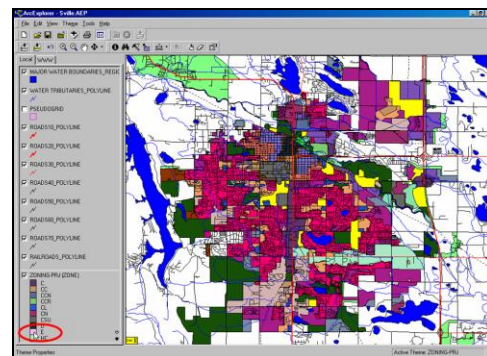
2.6.2 Vector-based Thematic Mapping



Activate **ZONING-PRJ** map (click on its map name; legend raises) then click on the **Theme Properties** button (or simply double-click on the **ZONING-PRJ** map name) to pop-up its *Theme Properties* dialog box.



Set *Classification Options* to **Individual** and select the *Field* as **ZONE** and press the **OK** button. The individual polygons comprising the Zoning map will be displayed with colors indicating the different zoning classes.



Click on the color box (pink) for zoning type “E” and its instances will be highlighted in bright yellow.



Click on the **Clear Selection** button (eraser) to clear the highlighted polygons. Click on the **Clear Thematic Classification** button (brush) to remove the classification.

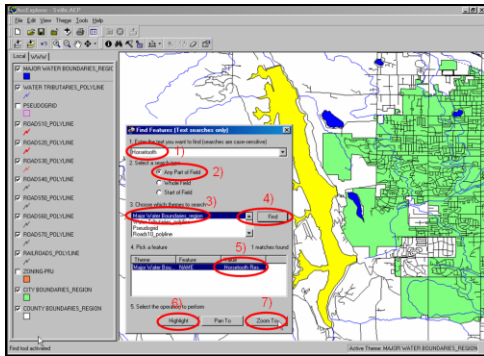


Activate the **Major Water** map layer (click on its map name; legend raises). Click on the **Identify** button (letter “i”) then click on a lake to pop-up information about the map object.



Click on the **Find Features** button (binoculars) to pop-up its dialog box. Complete the box by specifying...

- 1) Enter the word **Horsetooth**
- 2) Click “**Any part of a field**”
- 3) Select “**Major Waterbodies_region**”
- 4) Click the **Find** button to locate any map feature that is associated with the word *Horsetooth*
- 5) Select the feature **Horsetooth Res**
- 6) Click on the **Highlight** button to highlight the feature
- 7) Click the **Zoom To** button to center the feature in the display window.

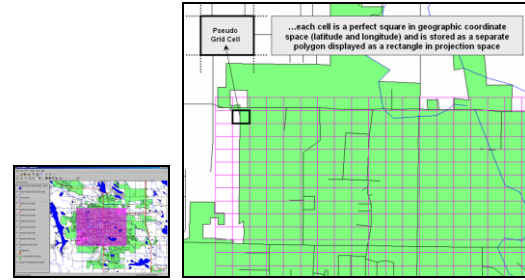


The result highlights and centers the display on the Horsetooth Reservoir. The *Query Builder* tool (hammer) is similar but enables full geo-query processing, such as evaluating data ranges demonstrated in the next section.

2.6.3 Using Pseudo-Grids

Clear any highlighted features (eraser button), activate the ZONING-PRJ map (raised legend), zoom to that map layer (floating maps button) and turn off its display (checkbox unchecked). Now activate and display the **PSEUDOGRID**

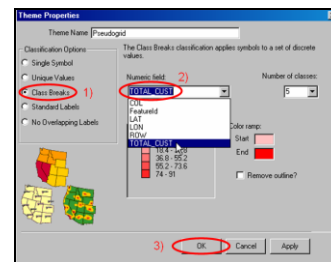
map then zoom in (+ magnifying glass) to a small portion of the top-left part of the grid.



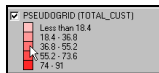
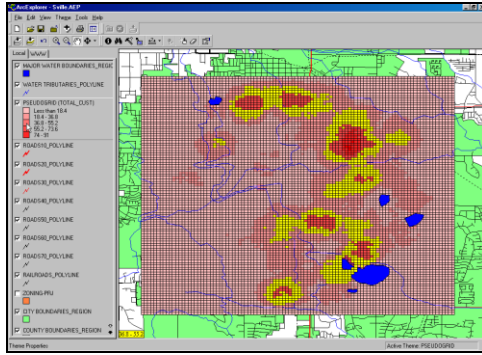
Each cell is a perfect square in geographic coordinate space (latitude and longitude) and is stored as a separate polygon displayed as a rectangle in the projection space shown here. In this pseudogrid there are 100 columns by 100 rows representing 10,000 sample locations that are analogous to research plots—it’s just that there is a sample plot everywhere throughout the study area.

Subsequent topics in this book develop the numerical (mathematical and statistical) implications of an “analysis grid” and the wealth of analytical operations it spawns, however the following exercise focus on merely the display of grid data within a desktop mapping system.

Use the zoom and pan tools to center the entire pseudogrid in the display window. Double-click on the **PSEUDOGRID** map name to pop-up its *Thematic Properties* window. Complete the box by...



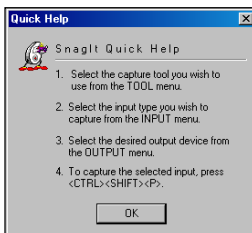
- 1) Selecting **Class Breaks** as the *Classification* type
- 2) Selecting **TOTAL_CUST** in the drop-down list under *Numeric Field* for the data to be classified
- 3) Press the **OK** button to display.



Each cell in the analysis grid is assigned a color based on the data value stored at that location. For example, clicking on the mid-range color box identifies all of the grid locations that have *TOTAL_Cust* values falling in the range 36.8 to 55.2 customers within a half-mile circle around any of the highlighted cells. The dark red locations identify “pockets” with nearly a hundred customers—areas with high concentration of nearby customers.

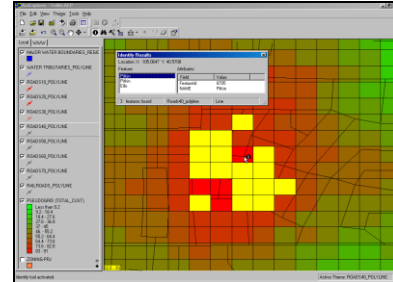
As a means of review and testing your retention of some of the desktop mapping procedures you have experienced...

- ✓ Repeat the pseudogrid thematic mapping procedure but this time specifying 10 classes and a color ramp beginning with light green and progressing to dark red.
- ✓ Reposition the pseudogrid map layer so the road layers appear above it.
- ✓ Zoom-in on the area with the highest concentration of customers.
- ✓ Identify the customer density data value (number of nearby customers) at the cell(s) with the highest concentration.
- ✓ Identify the street names at the intersection occurring in the grid cell with the highest concentration of customers.



Obtain a screen capture of the result by entering **Start→Programs→SnagIt→SnagIt** to activate the *SnagIt* program. Simultaneously press the keys Ctrl/Shift/P,

highlight the portion of the screen to capture and click the mouse. Click the **Finish** button save the image to use in report preparation. All of the graphics used in this book were captured using SnagIt.



You can exit the program by selecting **File → Exit** or by clicking on the “X” in the upper-right corner of the MapCalc program window. If you want to save your work, specify a new file name, such as *GB_Topic2.aep*.

