# Computer Mapping

## A State of the Art Report

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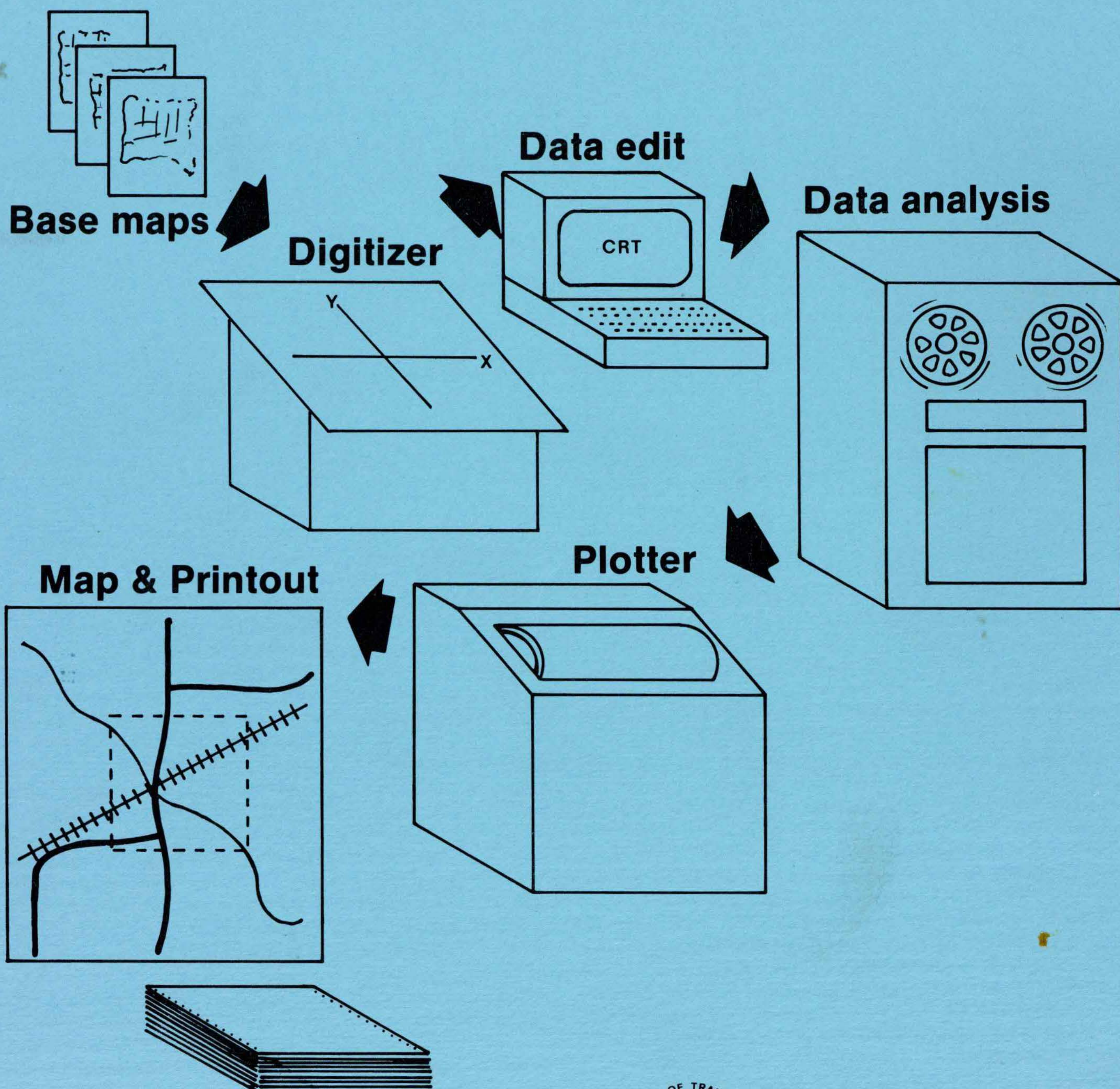


prepared by
Transportation Research Office
Planning & Research Division
Iowa Department of Transportation

# Computer Mapping
# A State of the Art Report

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# Abstract

Computer mapping is a new and developing technology prompted by the need for accurate maps and integrated data and the increased availability of computer systems. Trends are being established by many organizations, most of which are governmental agencies. Numerous projects are being started and many are in production mode. To this end, the Iowa Department of Transportation is beginning to investigate the possibility of a computer-aided mapping and records system.

The purpose of this report is to provide an introduction to computer mapping by defining terms and concepts, by examining current projects of various federal, state, and municipal agencies and by studying current vendor offerings. Some initial guidelines are suggested.

# Graduate Research Assistant Program

The Iowa Department of Transportation in cooperation with Iowa State University, Ames, Iowa sponsors a Graduate Research Assistant program. This program is administered through the Office of Transportation Research. Graduate students such as John Matrow are provided an assistantship through the Iowa Department of Transportation to conduct research activity on topics that are mutually beneficial to the Iowa Department of Transportation and the graduate student. John Matrow has previously prepared reports on computer graphics and choropleth mapping.

# Introduction

Computer mapping is a new and developing technology prompted by the need for accurate maps and integrated data and the increased availability of computer systems. Trends are being established by many organizations, most of which are governmental agencies. Numerous projects are being started and many are in production mode. To this end, the Iowa Department of Transportation is beginning to investigate the possibility of a computer aided mapping and records system.

The purpose of this report is to provide an introduction to computer mapping by defining terms and concepts, by examining current projects of various federal, state, and municipal agencies and by studying current vendor offerings. Some initial guidelines are suggested.

The scope of computer mapping investigated here extends primarily to production systems for planimetric maps. Systems for topographic and thematic mapping are also included where relevant.

Numbers in parentheses in the text refer to a citation in the bibliography. Terms are defined in Part I, Part III, and the Glossary and an index is provided at the end.

After reading this report, a person should have a clearer understanding of the elements in a computer mapping system. Initial requirements can then be started by those interested in a program of computer-aided mapping and records system.

# Part I - Questions and Answers

## 1. What is Computer Mapping?

Computer mapping is a very general term referring to the use of a digital computer in the compilation and production of maps. Broadly speaking, it includes the means to analyze and interpret information with a geographical or spatial structure.

Computer generated maps take advantage of a computer's unique capability to manipulate large volumes of data and proiduce graphic displays quickly and accurately.

Other terms which are used when referring to computer mapping are:

(1) Computer Cartography
(2) Computer-Assisted Mapping
(3) Computer-Assisted Cartography
(4) Automated Mapping
(5) Automated Cartography
(6) Computer-Aided Mapping
(7) Computer-Aided Cartography
(8) Digital Cartography
(9) Numerical Cartography

Since cartography is the science of preparing all types of maps and charts, one can see the general equivalence of terms.

## 2. Why Computer Mapping?

According to Teicholz and Dorfman (10), computer mapping is becoming increasingly in demand because of computer economics, the amount of available data, new and sophisticated mapping techniques, graphic hardware development, and the forthcoming conversion to the metric system (causing obsolescense in existing manual maps). The reasons why one might consider computer mapping include the speeding up of the map-making process, the acceleration of making map revisions, the potential cost reductions, the ability to create data bases, the reduction of manual drafting work, the reduction in worker requirements, and even the potential improvement of the aesthetic qualities of maps themselves.

The BJUMP system users in Burnaby, British Columbia (see Part IV) experienced a speed-up factor of 4.8 to 8 in computer mapping over manual mapping. They also concluded that the comparison was meaningless when one also realizes that a new data base and a management information system are of much added value.

William Radlinuski, Associate Director of the United States Geological Survey (USGS), has these reasons for automation:

1. Speed up the map-making process.
2. Improve the economics of mapping.
3. Generate digital data for direct dissemination and rapid manipulation to produce maps at different scales and with selected contents.
4. Facilitate map revision.
5. Reduce the incidence of errors.

Warren Schmidt, also of the USGS, has these reasons:

1. Economy
2. Speed
3. Original data in machine form
4. Volume
5. Accuracy
6. Graphic precision
7. Computation
8. Data Manipulability

In addition to all these reasons, this author supports the following reasons:

1. Information availability in graphic, listing, and data file forms for uses ranging from decision-making to information exchange.
2. Decreasing cost of computer hardware.

The biggest disadvantage of computer mapping is the high initial cost of equipment and training. Effective use, however, would spread the cost out over a period of time and savings as outlined above would also discount the cost.

## 3. How Does a Computer Mapping System Work?

The initial stage of this process is to convert the information on a source document such as a map or aerial photograph into digital data to be processed by a computer. The most common method of doing this is with a digitizer.

All of the converted or digitized information from a map or document is collectively called a file. The processing of a file is manipulating its various elements into a usable form. The file is also referred to as a data base.

After sufficient processing, the contents of a file can be displayed for the viewer. Generally, this is accomplished through utilization of an ink pen or series of ink pens instructed by the computer to draw points and lines on a piece of paper. This drawing device is called a plotter. Lines can also be drawn on a television-like screen using a device referred to as a graphics display.

The following diagram illustrates the basic computer mapping system process. The rectangles are computer processes, the circles represent data storage, and the arrows show flow of data.

## 4. What Is a Digitizer?

A digitizer is a device with an electronically sensitive table. In using the digitizer an operator uses a curser with cross-hairs to pinpoint locations on a map document. After positioning cross-hairs on the point location, the operator presses a button and the electronically sensitive table automatically computes the X-Y coordinates of the point. X usually represents the distance in inches from the left edge of the table and Y represents the distance in inches from the bottom of the table. This unique pair of numbers is coordinated to represent a point on a map. Coordinates defining two points can be connected to form a line. With this building block procedure, the operator can represent a series of drawings of points and lines. Most digitizers also have an interactive keyboard console whereby the operator can enter commands or messages to identify points or lines.

The coordinates and connecting links obtained from the digitizer are transferred to a magnetic tape. This tape is placed on another computer for processing the file. In a minicomputer configuration, the coordinates are sent directly to the computer to be processed and/or stored on a tape or disk.

Small digitizers are often called tablets and are often used for commands instead of using a keyboard. Costs may range from $1,000 to $50,000. The large digitizer systems have minicomputers for editing the data before putting it on tape. Digitizers now available have a resolution of accuracy that varies from 0.01" to 0.001".

## 5. What Are the Configurations of Computer Systems?

In a main-frame set-up, we are attempting to use a large computer which is often being used for data processing programs at the same time. Through a time sharing procedure the computer's powerful computation capabilities are more fully utilized. Time sharing results in having to compete for the computer's resources and there are limits to sharing which must be carefully considered. Programs requiring a maximum amount of memory or other resources must be executed on large computers. Examples of large memory programs are automatic contouring and large data base manipulation. The large computer is the traditional set-up and most people are familiar with it.

The main alternative to direct use of the large computer is the interactive graphics system that utiizes a mini-computer. The minicomputer can be utilized at all times in the mapping process. The mini-computer is usually the size of a desk and can have the input and output devices connected directly to it. Because of rapid technological advancements a minicomputer can have the capabilities and capacity of large computers of fifteen years ago and also be much faster at a fraction of the previous costs.

These two types of set-ups are also called off-line and on-line systems respectively.

**Figure 1. Basic Computer Mapping Process**

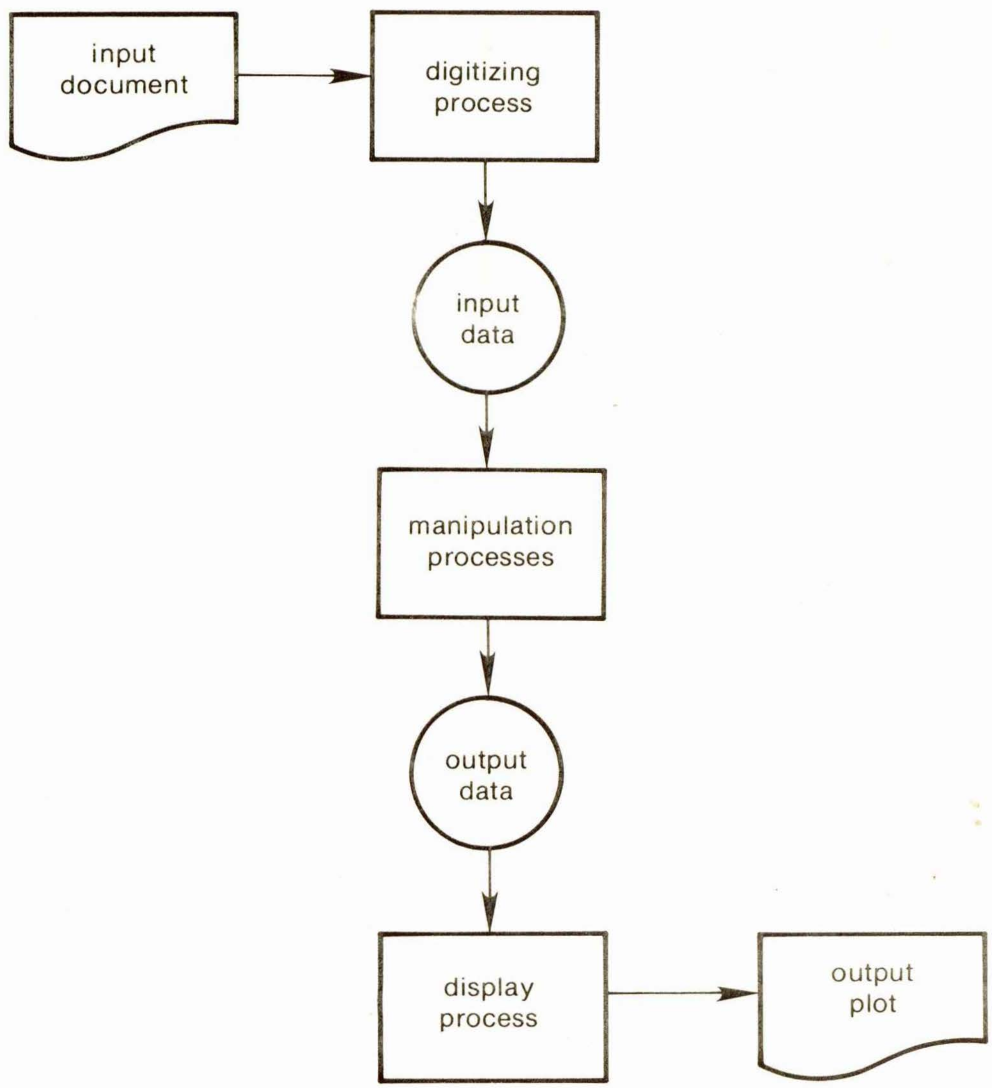


Figure 2. Large Computers - (Off-Line)

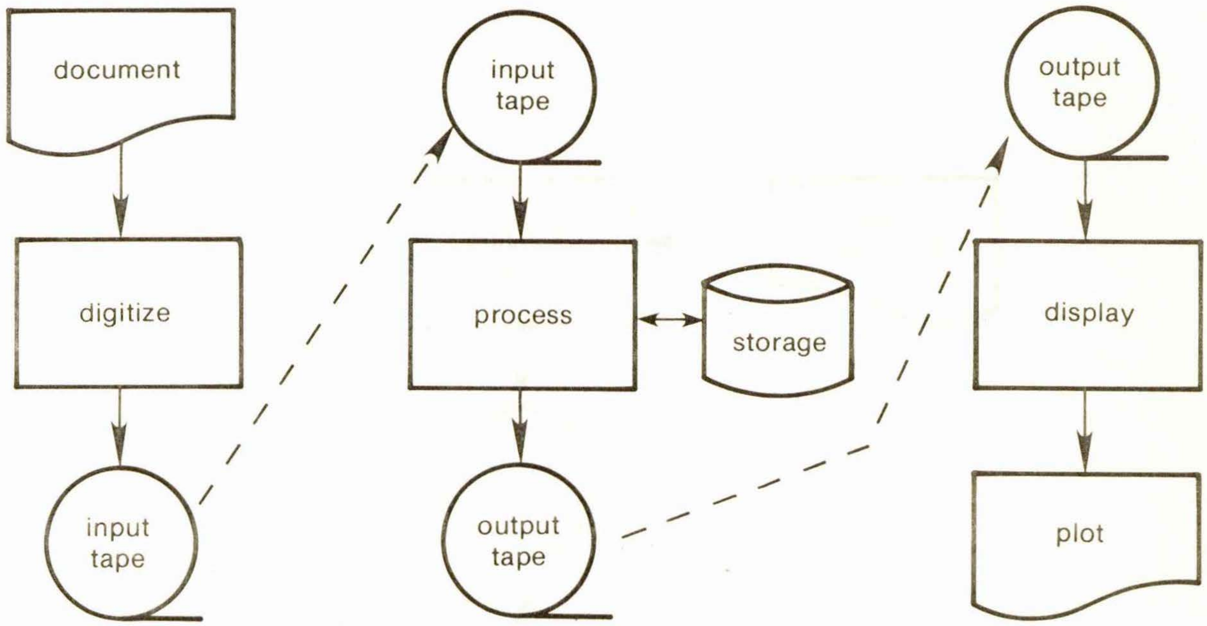
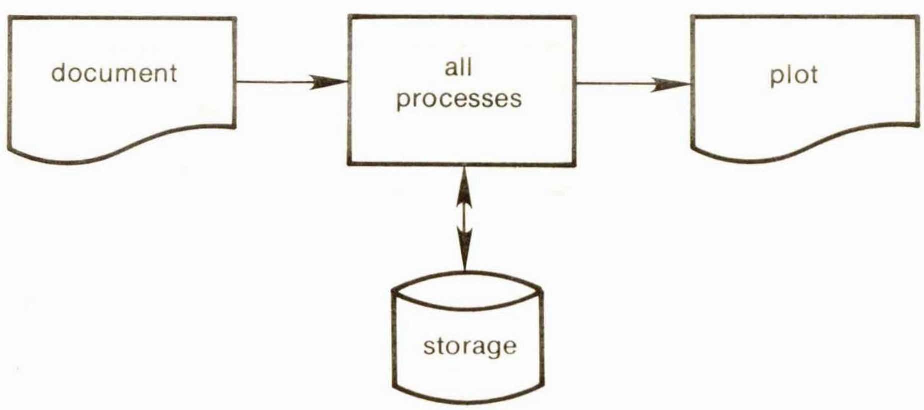



Figure 3. Mini-Computers - (On-Line)



The following advantages and disadvantages of each computer system are as follows:

**Large Computers:**

**Advantages:**
- large capacity
- superior speed
- vendor support
- commonly known (programming support)
- centralizes data processing

**Disadvantages:**
- competition for time
- competition for space
- dependence on operators (physical handling)
- large programming effort
- priorities among competition
- batch mode (no interaction)

**Mini-computers:**

**Advantages:**
- immediate availability
- interactive capabilities
- easily moved (small size)
- can create tape files for other computers
- low cost
- smaller programming effort (if any)
- dedicated
- can be directly connected to a large computer
- can be ready-to-run (pre-programmed)

**Disadvantages:**
- may require different programming (obscure machine architectures)
- lacks large capacity

## 6. What Does Interactive Mean?

This means an interaction between human operator and computer. Questions are asked or commands are given requiring a response. An example is a machine request for input and the operator typing in data. The operator requests a process and the computer does it. This communication occurs on a typewriter-like device or an alphanumeric cathode-ray tube (CRT) terminal. In contrast, there is the batch program environment where the user assembles data and control cards in a deck, submits the card deck for processing and waits several hours or more to obtain the output. A single error in the card deck can waste the entire run with additional time lost.

This delay and downtime can be eliminated when an interactive environment is used in constructing objects like programs, data files, or maps. The computer can "help" the operator by notifying him/her that they may have made errors or omitted some data. In a graphics situation, the computer may "draw" what is being digitized on a graphics CRT screen. The operator can immediately recognize errors and correct them. This method guarantees quality of input data better than any other method.

A typical interactive graphics system costs $170,000 and contains a mini-computer having 64K of memory, 10-megabyte moving-head disc, direct view storage tube graphic display, 11" by 11" tablet, 3' by 4' digitizer, and a medium speed (10 ips) drum plotter. (10)

## 7. How Does a Plotter Work?

A mechanical arm with an ink pen is positioned above a piece of paper. Plotter commands are a series of X-Y coordinates directing the pen movement. Each command instructs the arm to move with the pen either down or up, thus drawing a line to a point or just skipping to a point.

For high precision plotting a flatbed plotter is used to obtain the required accuracy. On a flatbed plotter the paper is flat and remains in a static position.

Often the paper is very long and rolls across a drum replacing the movement of the mechanical arm in one direction. It utilizes a combination of paper movement and arm movement to draw lines. This is called a drum plotter. It is less expensive than a flatbed plotter and occupies less space. It can be very accurate for a majority of applications.

Both of these devices can have several pens mounted on the arm and are capable of producing multi-color drawings. They are often referred to as incremental pen plotters. Plotters and their controlling devices are generally termed automated drafting systems.

There are several specialty plotters that are designed to do a specific job or produce a special product. Some of these are the scribe plotter which etches an open line on an opaque surface, the photo plotter which directs a beam of light on a large negative for graphic work, and the microfilm plotter which directs a beam of light on a small negative for microfilm filling of graphic data.

## 8. How Does a Graphics Display Work?

The simplest and most common graphics display is the Direct View Storage Tube (DVST). One can think of it as a plotter on a television-like screen because it "draws" lines to be displayed. If any changes are required, the entire picture must be erased and redrawn. The cost for DVST graphics display ranges from $5,000 to $12,000.

Another type of graphics display is the refresh vector display (RVD). The graphics are displayed in such a manner that immediate changes can be made without redrawing the entire display. There is no erasing and redrawing for deletion, addition or moving of points and lines. This capability is highly desirable due to its time saving features in making changes. It requires a very small computer of its own in order to immediately calculate changes and present the display. However, it is also more expensive. The cost of a RVD ranges from $10,000 to $20,000.

Other types of display are the plasma panel, the raster cathode ray tube and the scanned storage tube. Work is being done to improve resolution, add color and lower the prices of these graphics display devices.

## 9. What Types of Maps Can Be Produced?

The maps can be:

(1) Contour (Isarithm, Isopleth) - lines connecting points of equal value
(2) Choropleth - shaded zones showing densities
(3) Conformal - conforming in shape (little distortion)
(4) City street
(5) City plat - boundaries and subdivsions
(6) County
(7) State
(8) Country
(9) Road (transportation)
(10) Soils
(11) Geology
(12) Topographic - showing all important features including relief through contour lines
(13) Planimetric - showing all important features except relief
(14) Thematic (statistic) - includes contour, choropleth and types of data display
(15) Demographic - population density and distribution
(16) Land use
(17) Property Plats

## 10. Are Maps the Only Objective?

While maps are the primary output, another most common by-product is a data base which can be analyzed, manipulated, exchanged, accessed, and displayed in many forms. Almost all systems seek to achieve these abilities to some degree. These files are called (digital) cartographic data bases.

Since the majority of digitized map data is points and lines, what makes this data more effective is the ability to attach attributes or information to these lines and point. A line segment can be identified with only two pairs of coordinates. However, to this line segment, we could attach additional data such as street name, address range, census tract, city name, street type, identification numbers, zip code, county name, zoning codes, etc. In describing a highway segment we could also add pavement type, width, traffic volume, accident records, etc. It is also possible to attach coordinates to existing files of bridges, culverts, wells, railroad grade crossings, etc. The list of items is almost endless. An integrated base of this nature is generally termed a geographic base file. The programs that create and use a geographic base file are sometimes termed a geographic information system, geographic data system, or a geo-based information system. Other terms associated with cartographic data bases are: geoprocessing, geocoding, geographic data bank.

Another way to view this concept of geographic data is to consider the interaction and merging of data for the fields of Geography, Cartography and Computer Graphics (8). In any one of the fields by themselves, only a limited amount of data can be manipulated and displayed for the user. In Computer Graphics and Cartography, systems are developed to reproduce maps but the resultant data has no analytical power. In Geography and Cartography, the only product is a visual display of the geographic data. In Computer Graphics and

Geography, modeling and analytical techniques are applied to geographic data, but the statistical data produced is generally in the form of tables, graphs, charts, etc. and not a map.

In combining all three fields, a very powerful tool for manipulation of data emerges. It incorporates the cartographic display, the computer graphics techniques and the geographical analysis to produce a document or series of documents that visually display data.

## 11. How is Computer Mapping Growing?

According to Teicholz (12), sales in 1975 were $7 million and are estimated to be $20 million in 1978 for cartographic applications of "turnkey" (ready-to-run) interactive graphics mini-computer systems. Sales of these systems and all related data applications is expected to reach $240 million in 1978. Frost and Sullivan (6) estimate that by 1986 total sales in this area will increase to approximately $480 million.

In another report, Teicholz and Dorfman (11) feel that the most prevalent trend is toward interactive mini-computer based systems. One major vendor recently introduced a "turnkey" drafting system that costs $40,000.

There is considerable interest in various state and federal agencies toward computerization of the 1:24,000 scale quadrangle maps of the U.S. Geological Survey. Because of the magnitude of the task, some of the agencies digitize only what is needed for their own work. If coordinated and compatible, this could develop into a massive exchange program of data between various agencies. At the present time, however, no effort has been made to coordinate these data needs.

As will be seen in Part IV of this report, many municipal agencies are getting more deeply involved in computer graphics and mapping because of the numerous benefits associated with the integration of various management information systems. The Computer Assisted Mapping and Records Activities Systems (CAMRAS) project (see Memphis, Tennessee) is serving to develop guidelines and standards for others interested in creating a mapping and information system.

## 12. How is the Technology Progressing?

Some of the problem areas include input data reduction, raster-to-vector conversion, improved and lower cost output devices, clean and up-to-date cartographic data bases, better application and display software, and better management information systems.

Research is in progress in the fields of topologically oriented chain file data structures, digital terrain data bases, raster and vector data structures, computer mapping software, and specialized and general purpose applications software.

## 13. What Are Some Systems Design Issues for Land-Use Planning Information Systems?

Duecker and Drake (3) identified the following eight issues:

1. User needs - Use a method for assessing information needs.
2. Functional detail - carefully consider attributes and amount of detail.
3. Areal detail - capturing more detail requires more processing but results in greater analysis and display potential
4. Temporal detail - frequency of data collection
5. Data utility - cost is associated with the timeliness of data utility
6. System response - characteristics of hardware/software
7. Modeling methodology - methodology in which jurisdictional areas are used to forecast land-use requirements
8. Jurisdictional coordination - Appropriateness and the usefulness of the data by different jurisdictional groups

## 14. What Are Possible Approaches to Instituting Computer Mapping?

One method requires the sponsoring organization to purchase the hardware and do its own programming. This can be a very difficult task for those with little or no experience in computer graphics and cartography. Another way is to purchase the hardware and the software for an existing computer system. Compatability among all the components is a crucial component.

This author feels that the best way is to purchase a system that is "up and running" elsewhere. One of the major difficulties in purchasing an existing system is that individual data desires may not be available and the existing system may have to be drastically altered to meet those needs. The overriding consideration of any system is the establishment of the data requirements necessary to meet the needs of all agencies participating in such a program.

# Part II - Computer Mapping And Iowa

## 1. What Data Bases Currently Exist in Iowa?

The Advanced Mapping System of the Soil Conservation Service (see Section IV.A.2) has done the following counties using USGS quadrangle maps: Adair, Fayette, Black Hawk, Jasper, Lee, Sac, and Benton.

The following urban areas identified as Standard Metropolitan Statistical Areas have been encoded in GBF/DIME files for the Census Bureau (Section IV. A-3): Des Moines, Omaha/-Council Bluffs, Sioux City, Waterloo, Cedar Rapids, Dubuque, and Davenport/Rock Island/Moline/Bettendorf.

The City of Des Moines also has files on property, etc., as part of the Integrated Municipal Information System (see that section).

The U.S. Geological Survey has no files in Iowa and they don't anticipate many in the near future.

The Federal Highway Administration of the U.S. Department of Transportation has a file containing geodetic coordinates of all the county boundaries of Iowa.

The Iowa Geological Survey has files on well and water systems which have coordinates and can thus be plotted.

The National Aeronautics and Space Administration (NASA) launched satellites called LANDSAT, LANDSAT-2 and LANDSAT-C. They produce imagery data on tapes primarily in a gridded data base.

A firm called List Processing Company has a file called Geographic Data File which contains geodetic coordinates for every zip code zone main post office. X-Y coordinates are included for calculating distances.

## 2. What is the Status of Computer Mapping in Iowa?

Most of the activity has been in thematic mapping for geographic data analysis. The University of Iowa, including the Department of Geography and the Institute of Urban and Regional Research, has the following programs and systems:

1. Planning Land Use System (PLUS) - An analysis package which produces tables.
2. POWRMAP - Produces an outline map of Iowa and various sizes of circles representing data associated with Iowa cities.
3. SIGNMAP - Produces an outline map of Iowa and various symbols denoting data associated with Iowa cities.
4. CMAP - Produces choropleth maps on the line printer.
5. SYMAP - Produces choropleth, proximal, contour, trend surface, and residual maps on the line printer.
6. SYMVU - Draws three-dimensional maps on the pen plotter where, normally, peaks represent high values and the valleys represent low values.
7. MAPS - Similar to SIGNMAP, but uses the line printer.
8. COPLOT - Function unknown.
9. CALFORM - Produces choropleth maps on the pen plotter.
10. CONTR - Produces contour maps on the pen plotter.
11. SETUP/OPAQUE/VISIBL - Subroutines similar to SYMVU.
12. HIDE/HIDES - Subroutines similar to SYMVU.
13. SOLUP - Simulation of land-use patterns.

Coordinate data files are set up for some of these programs through the Digitizer/Graphics System. The Graphics Laboratory portion has an IMLAC PDS-4 mini-computer, an IMLAC graphics display, a SAC digitizer, an IMLAC hard copy unit and a keyboard. This system serves as a worker unit to an HP-2000 mini-computer through a program interface called PROTOCOL. The primary applications package is called DIGIT. Options in DIGIT include creating, editing, analyzing, storing, and displaying (plotting) files. Data may also be sent to an IBM 360/65 computer for processing and displaying.

Iowa State University, including the Land Use Analysis Lab (LUAL), the Association for Iowa Data Exchange and Service (AIDES), and the Computation Center has the following programs and subroutines:

1. CONTUR - Produces contour maps on the pen plotter.
2. THREED - Produces three-dimensional maps on the pen plotter.
3. GRIDS - Produces choropleth maps on the line printer.
4. SCANGEN - Produces choropleth maps on the line printer.
5. Multi-Scale Data Analysis and Mapping Program (MSDAMP) - Data is stored and analyzed using the gridded data base approach and shaded grid maps are produced on the line printer.

The Iowa Department of Transportation has the following programs:

1. CARTA - Produces contour maps on the pen plotter.
2. GPCP - Produces contour maps on the pen plotter.
3. CALFORM - Produces choropleth maps on the pen plotter.
4. SP99 - Produces choropleth and density maps on the pen plotter.
5. COPLOT - Plot Iowa county outlines on the pen plotter.

The Iowa Department of Social Services has two programs:

1. S470S102 - Produces choropleth county or district maps on the line printer.
2. S470S103 - Same as S470S102 but produces very large maps.

The Iowa Geological Survey is developing a graphics system composed of a Tektronix graphic display and a digitizer connected to the CYBER computer of the University of Iowa.

The City of Des Moines produces subdivision maps as part of the Integrated Municipal Information System as discussed in Part IV.

## 3. Why Should a State Look at Computer Mapping?

Since federal agencies cannot handle the enormous amount of data needed to cover the country and cities,and counties cannot handle the task economically and guarantee a compatible data base, the state can serve as a logical agency to assimilate such data for a computer mapping program. In addition, the state can distribute such data to federal, county, local and other state agencies as the need arises.

## 4. Who Will Benefit in Iowa From a Computer Mapping System?

The Iowa Department of Transportation, Office of Transportation Inventory, produces several series of maps used by governments, businesses, and the public. These include:

1. General Highway and Transportation (County)
   a. 1" = 1 mile (1:63,360)
   b. 1" = ½ mile (1:31,680)
   c. 1" = ¼ mile (1:15,840)
2. Township maps (1:126,720)
3. State Railroad Map (1:500,000)
4. 55 Urban Areas (from 1:18102 to 1:36205)
5. County outline map (1:500,000)
6. Tourist map (1:500,000, 1:360,000, 1:850,000)
7. 956 city maps (from 1:6,336 to 1:12,672)
8. Primary Road Condition State Map (1:500,000, 1:253,440)
9. Miscellaneous other maps at various scales.

Several are modified to produce other maps such as traffic maps, bridge maps, etc. They are also reduced for smaller maps.

As an example of potential labor savings, using the existing library of maps upwards to nine different maps would have to have cartographic corrections manually made if a new section of interstate highway were constructed. This update could be accomplished on only one map if a computer map system were adopted because of the single data base.

The Iowa Geological Survey produces maps in the study of geology, water resources, mineral resources, remote sensing, and land use.

The Office of Planning and Programming uses numerous thematic maps in their activities.

The Agricultural Experiment Station at Iowa State University is cooperating with the State Soil Conservation Service and the Federal Soil Conservation Service in the production of soil survey maps at a scale of 1:15,840 (4" = 1 mile). Aerial photos are composited by the federal government to provide a base photo map. These base photo maps are utilized in the field to determine soil types and other features such as roads, railroads, streams, buildings, boundaries, etc. and are added to the final map.

The Land Use Analysis Laboratory research portion of the Agricultural Experiment Station at Iowa State University has been developing land-use maps by computer using the line printer based on a gridded data base.

All other state, county and local agencies have utilized maps and related data files to some degree in carrying out their programs.

## 5. What Are Some Recommendations for Getting Into Computer Mapping?

Since the Iowa Department of Transportation maintains a complete library of transportation maps which form a base map for many other state, county and local agencies, the Iowa DOT should be one of the leading agencies initiating a computer mapping program. The base data for a transportation map should have the following items:

1. Streets and roads
2. Railroads
3. Rivers, streams and lakes
4. Buildings and cultural features
5. County, township, section and corporate boundaries

In addition to these basic features, other state, county and local agencies could add features for their particular application. A data base could be developed that would include an integrated file of various geographic data elements. In addition to the geographic data, a unified coordinate system would be developed.

Three major objectives of a computer mapping program should be:

1. Planimetric maps
2. thematic maps
3. useful data base

In order to achieve these in terms of production, the most likely input document at this time would be the USGS 7½ minute quadrangle maps (1:24,000). A proposal has been made to complete the quads for Iowa by 1983. More detailed documents such as large-scaled aerial photographs would drastically increase the amount of work involved.

The most economical choice of a computer system should be an interactive graphics system which has demonstrated its usefulness in an existing mapping program. Mapping capabilities to be considered should include being able to construct cartographic data bases and to attach attributes (data) to objects in the files. It should be able to develop coordinate referencing systems such as state plane, UTM, etc. Many character and line fonts should be available to the user. Various forms of retrieval processes such as by attribute, object, or location, in graphic and report format should be available. A high precision plotter is necessary for quality cartographic products.

Computer mapping is a process where system interfaces could be developed for two separate but related data base files. Such is the case for the Accident Location and Analysis System (ALAS) and the highway base records system. At the present time these two systems are not compatable but they could be integrated through the computer mapping process.

Elsewhere in the Iowa DOT, the Offices of Road Design and Right of Way are interested in the potential of data on utility locations and land ownership. The Office of Project Planning is interested in land-use and this is where a system which handles gridded data as well as vector data may be helpful.

Interfaces to other agencies is important because data can be exchanged, thus avoiding duplicated effort. For example, six or more Iowa counties have been done by the Federal Soil Conservation Service in Lincoln (see Part IV). Exchange of digitized data would save time and effort. Even if the flow is one-way, savings for another state agency becomes savings for the state.

Another factor to be considered is the ability to add on user stations to a system. Not only can more activity in mapping take place, but other applications such as transportation network analysis or engineering graphics can be realized.

Much has been said about vendor selection in terms of contractual agreements so I will just state that service after the sale is an extremely important factor.

# Part III. More Terminology

## 1. What is a Scanner?

The automatic vector scanner is used to digitize continuous-tone photographs and line drawings. Prices range upward from $20,000. The raw data has to be processed to recognize and create lines (also called vectors). Some firms offer software that exracts vector information from the scanned data, but these packages cost about $40,000. No one yet offers software to recognize text characters on a map.

## 2. What is a Line Follower?

The automatic line follower reduces a drawing to a series of lines as it digitizes. It traces over lines and records points needed to reconstruct them. An operator has to intervene when it comes to line intersections. A typical system costs more than $100,000.

## 3. What are Data Structures?

Since computers store only numbers and characters, we have to introduce meaning to data and show its relation to other data. This structuring produces the data structure, also called the data base or file structure.

Two major thrusts of development have been of the gridded data base and the vector data base. They represent rather different concepts of representations of space and each has its own special advantages.

A grid partitions a map with vertical and horizontal lines so that values may be assigned to the data in each cell. This data is easily stored and accessed in a two-dimensional array, i.e. data for the cell in row 2, column 6 is referenced by the pair (2,6). A typical use is when aerial photographs are interpreted as to the land use. Obviously, the smaller the cells, the higher the resolution. This is limited, though, by computer storage. An advantage of using grids is the availability of machines for automatic scanning and input as well as line printer output.

The building block for vector data bases is the point in space identified with X-Y coordinates. By connecting two points we have a line segment. By connecting line segments we obtain continuous lines and curves. These concepts form the bulk of the structure, but with a little more structure we can represent more relationships. If we connect the endpoints of several continuous line segments, we obtain a polygon (many-sided closed figure), which can be used to represent counties, city blocks, soil types, etc. If we interconnect lines to other lines at adjoining points, we obtain networks which can represent roads, streams, pipelines, etc. Sometimes interconnected line segments connecting one point of interest, such as an intersection, to another are called a chain and can have a different structure since they are often of less interest than the whole of the line. These are also called a chord, random line, snake, or segment.

To associate data with something like a line segment or point, we would group the information together in storage. For example, a well may be the group: (X-coordinate, Y-coordinate, well number). A city block segment may be the group: (X-coordinate for one end, Y-coordinate, X-coordinate for the other end, Y-coordinate, street name, range of house numbers). Likewise, values can be associated with polygons such as county populations.

The coordinates we speak of depend upon the coordinate system used. Plane systems produce X-Y coordinates. Units of measurement may be in real world feet or in actual map inches. Geodetic systems produce latitude-longitude coordinates in degrees. In general, it is possible to transform data from one system to another.

Data is often divided into groups with common characteristics. County, state and other highway data may be collected into a road network "layer". Streams and lakes may form a water layer. These layers are then composited to produce the final map.

## 4. What Happens to Data Files?

After initial construction of a file, the next action is always editing to correct mistakes and to finish assembling the data. Editing includes the addition, removal and modification of all types of features. Filtering is done to remove unnecessary or redundant data. Symbols and lettering to appear on the map are often added.

With a finished file, we may merge or combine it with other files to obtain a larger file. Adjacent features are joined and coordinates may be changed if they were originally independent.

Likewise we may window or extract a portion of file from a larger one. For example, we may want to look at one township in one county.

When data coordinates are stored with respect to a particular size map, such as one inch equals one mile, we may want to scale the data to produce larger or smaller maps. This is done by multiplying or dividing all coordinates by a constant.

To transform the coordinates is to add or subtract constant numbers with respect to the coordinates. This would move data, for example, from the upper left corner to the lower right corner of a map.

As mentioned earlier we can also change coordinate systems. This is based on formulas for projections of the earth's surface onto a plane surface and their corresponding inverse projection formulas.

Many files are divided into features or layers. This gives us the ability to select or extract certain features to be displayed or manipulated later. This is one of the strongest actions in terms of what we hope to gain from the structure. Not only can we select geographic features, but often we also get the attributes or information associated with those features. This data can always be processed by conventional data processing.

The final action is one of our primary purposes: display through plotters, or other output devices. This process often does scaling and transformations followed by the issuance of plot commands to the device.

## 5. What is Spatial Analysis?

Spatial analysis is primarily the visual analysis of the spatial distribution of information in a picture. Also called statistical geography, it attempts to determine such things as centroids of polygons, density per area, recognition of patterns or events and derivation of emerging trends.

Techniques used include choropleth, contour, density, proximal, and trend surface maps. Other methods include distortion according to valuers and three-dimensional views of polygons "raised" according to data.

Choropleth maps have zones defined and then shaded in accordance to some associated data. For example, darker shades mean higher values for some region.

Contour maps have lines connecting equal values in two dimensions. Very often, they are used to show elevation in topographic maps.

Density maps are similar to choropleth maps. The value of a region is divided by the area of the region to achieve a rate such as population per square mile.

Proximal means after values for some points are given, values for all other points are those of the nearest defined point.

Trend surfaces attempt to derive trends from the data distribution.

When statistical analysis is done on data with geographic associations such as breakdown by area, it is also called spatial analysis. This is true for network analysis, too.

## 6. What Are Projections?

Since the earth's surface is on a sphere and maps are flat and two-dimensional, locations on the earth have to be "projected" onto the map so features are not distorted. The mathematical methods used are called projections and the method used depends upon the desired map. For example, a map of the world needs a different method than a map of a county. Some of these methods are:

(1) Conic - where a cone on top of the earth is used to represent the data on the earth. A portion of the earth is "flattened" to become the planar map.
(2) Cylindrical - a cylinder around the earth is used.
(3) Equal Area - those projections which yield planar area proportional to actual area (excluding scale).
(4) Equidistant - those projections which yield linear length proportional to actual length (excluding scale).
(5) Lambert Conformal Conic - a type of conic projection.
(6) Albers Equal Area - a type of equal area projection.
(7) Polyconic - a type of conic projection with many cones.

## 7. What Are Some of the Plane Coordinate Systems?

The Universal Transverse Mercator (UTM) grid system takes the geodetic system of latitude-longitude and divides the earth into grids that are 6 degrees wide and 8 degrees tall. Each quadrilateral is divided into 100,000 meter zones. Within each zone, the meridian (north-south line) in the center is given a negative X value of 500,000 (meters). The equator is designated as having a y value of 0 for the northern hemisphere.

The U.S. Coast and Geodetic Survey (now the National Ocean Survey) worked out a system of plane coordinates for each of the states on either the Transverse Mercator or Lambert's conic projection. Larger states may have two or more overlapping zones. The units used are feet. The Iowa State Plane Coordinate System is the system for Iowa and it has a north zone and a south zone, both based on the Lambert projection.

A crude coordinate system is used by the U.S. Public Land Survey and is based on perfect six mile square blocks called townships. They are numbered in a north-south system and an east-west system based on a zero point. The township number (also called tier) is the north-south part and the range number is the east-west part. For example, Ames is in a square at 24E, 84N, which means it is the 24th square to the east and the 84th to the north of the zero point. Because of this imperfect representation of the surface, correction lines were surveyed every once in a while, resulting in non-six-mile square blocks on one side of the line. The thirty-six square miles within the township are called sections.

## 8. What is Photogrammetry?

Photogrammetry is defined as the art, science and technology of obtaining data on objects and the environment by recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy. It results in topographic map information and photo interpretation, which generates attribute data for thematic land-use maps.

Remote sensing is concerned with ultraviolet sensing, thermal infrared sensing, microwave sensing, and multispectral sensing as well as aerial photographs.

Road and highway designers use photogrammetry to extract elevations and other information from aerial photographs of the same area from different viewpoints. Through optics, the operator can "view" the ground in three dimensions and calculate the elevation of a point from known control points.

The Florida Department of Transportation is one organization which has connected a stereoplotter to their computer for direct transferral of data (see Section IV.B.2). The Iowa Department of Transportation and the Texas State Department of Highways and Public Transportation have stereoplotters which punch cards for later input to computer systems.

## 9. What is an Orthophotograph?

It is a composite of aerial photos which achieves an orthographic projection on a plane. With appropriate markings and legends added, a orthophotomap is produced. They may or may not include contours. Because imagery naturally depicts an area in a more true-to-life manner than the conventional line map, the orthophotomap provides an excellent portrayal of extensive areas of sand, marsh, or flat agricultural areas.

Orthophotoquads are a basic type of photoimage map prepared in U.S.G.S. quadrangle map format. They can be produced quickly because they are printed in shades of gray without image enhancement or cartographic symbolization. Orthophotoquads are valuable as map substitutes in unmapped areas and as complements to existing line maps.

## 10. What are Peripherals?

Peripherals are devices connected to a computer to provide communication (such as card readers, line printers, terminals, plotters, and digitizers) or auxiliary storage functions (such as disk drives, tape drives, and drums).

# Part IV - Current Systems In Use

## A. Federal Agencies

### 1. United States Geological Survey (USGS) (17)*

The USGS program to gather, process, and distribute basic cartographic data to map users is called the National Mapping Program (NMP). One of the major activities is the development of computer mapping in a program called the Digital Cartographic Application Program (DCAP).

The base categories of data are:

(1) Reference systems
(2) Hypsography (contours, slopes, elevations)
(3) Hydrography (water)
(4) Surface cover
(5) Non-vegetative features (soils)
(6) Boundaries
(7) Transportation systems (including pipelines, transmission lines, etc.)
(8) Cultural features
(9) Geodetic control and survey
(10) Geographic names
(11) Orthophotographic imagery

The major emphasis of DCAP will be providing data at an accuracy and level of detail equivalent to the 7½ minute quadrangle maps (1:24,000).

Two basic kinds of files are produced, processed and combined to form a final product. The first is called the digital line graph (DLG) which is planimetric data and the other is the digital elevation model (DEM) which consists of terrain elevations.

In DLG files, they initially have raw data from a digitizer which must be edited. They then construct the spatial relationships of the various line segments, such as identifying lakes, counties, etc.

Similarly, the DEM files are edited to remove obvious errors. The data is then interpolated and contoured to produce the final model.

Most development has gone into the DLG files. They use a Bendix (now Summagraphics) Datagrid and several Instronics (now Valcom) Gradicon digitizers. The digitized data is placed on tape and processed through the Unified Cartographic Line Graph Encoding System (UCLGES) on an IBM mainframe computer. This is where the major editing and all other related activities are accomplished.

In our region, the Rolla, Missouri office of the USGS operates a Gradicon digitizer. Data is sent to Reston, Virginia to be processed by UCLGES.

Another method of computer mapping being developed uses interactive mini-computers. Two Digital Data Editing Systems (DDES) produced by M&S Computing have been installed. These are designed for interactive editing of raw data.

USGS uses a CALCOMP 7000 plotter for data verification plotting and a Gerber Scientific 1232 for high precision plotting.

Pilot projects undertaken have been:

(1) Coal research project - National Coal Resource Data Bank
(2) Idaho Forestry Project - State of Idaho
(3) U.S. Forest Service Project
(4) Oregon & Montana - Bureau of Land Management, Forest Service, and Fish & Wildlife Service
(5) Boone County, Illinois - Census Bureau, Soil Conservation Service
(6) Montana - State of Montana

*The number indicates that most of the material in the section is derived from that reference number in the Bibliography for Part IV

When the USGS goes into production status, they estimate the cost of digitizing a 7½ minute quad to be $2,000. The file produced for a user would consist of line segments and points with attribute codes attached to both. Thus, the user would need software to reconstruct the networks, polygons, etc., as well as software for manipulating and displaying the reconstructed files.

Various map series of the USGS are available to the public for use. The popular 7½ minute quadrangle maps (1:24,000) are being digitized in other federal and state agencies (see Florida, Soil Conservtion Service, Michigan, Texas, Illinois). Other series being used are the 15 minute quads and the new 1:100,000 scale county maps. Under development is a proposed metric map series (1:25,000).

## 2. U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS) (11,16)

The Advanced Mapping System (AMS) is managed by the Cartographic Unit of the Soil Conservation Service of the U.S. Department of Agriculture. Primary emphasis is on soil survey maps, but many other features can also be digitized.

As originally planned, there are four mini-computer sub-systems involved. The Scanning subsystem automatically converts all lines and points on a document into raw data. The Identification subsystem enables one to identify lines and enter symbols to the file. The Edit subsystem does the error correction, data base manipulation and final preparation for drafting (plotting). The Automatic drafting subsystem does the photoplotting. Little analysis is done since the line segment data structure can be used by other programs.

A different version is in operation in Lincoln, Nebraska which this author has observed. Utilizing an interactive graphics system by Computervision, they use a digitizer to enter each feature of a file. USGS quads from various states are used for most features and original artwork is used to digitize the soil features. Simultaneous editing of other files can be performed with a graphics terminal. Finished files are sent to Hyattsville, Maryland to the automatic drafting subsystem mentioned above to produce county soil association maps.

The present cost of a Computervision system is approximately $150,000 and the cost of the Gerber Scientific photoplotter is also approximately $150,000. The reason that the two installations are different is because the Hyattsville, Maryland system is designed to process and produce small maps of approximately two by three miles in size while the Lincoln, Nebraska system is for compiling county soil maps which average 24 by 24 miles in size. The maps are also different in content. Examples of county maps are in Part VI (page 35).

The agency has spent $1.4 million on seven mini-computer subsystems excluding the drafting. This is the only federal agency with the mini-computer based approach.

## 3. U.S. Department of Commerce - Bureau of the Census (3)

This agency is well known for their development of GBF/DIME which stands for Geographic Base File/Dual Indendent Map Encoding. They define a Geographic Base File as simply a street map in a form which can be used by computer. DIME is a method of representing map features numerically for processing by computer.

A GBF contains local address information-street names, intersections and zip codes, as well as the identification of geographic and political areas in which the local address falls (such as census blocks and tracts, townships, cities and counties). Other geographic identifiers can be added by users to include local statistical areas such as police precincts, school districts, transportation zones, and health reporting zones. The GBF/DIME System refers to a package of computer programs for establishing, maintaining, and using GBF/DIME files.

The basis of the technology is the line segment representation of a city street in terms of one block. Coordinates are established for both nodes (end points) making up the segment. The street name is added as well as the range of house numbers for each side of the street. Many more attributes can be added.

This is one system whose main focus is on information availability. Thus, many requests can be made to extract information, such as average income versus education by census tract in selected areas.

These files are created and maintained for the Standard Metropolitan Statistical Areas (SMSA's) of the nation. Those areas in Iowa with GBF/DIME files are: Des Moines, Waterloo, Cedar Rapids, Dubuque, Omaha/Council Bluffs, Sioux City and Davenport/Rock Island/Moline/Bettendorf.

With the appropriate software, any user can use these line segments to create data bases of networks (roads, etc.) and polygons (blocks, tracts, etc.). The Bureau is also very actively involved in the display of information, especially micrographics. Most maps are of the choropleth (shaded zone) type.

The base document for the files is the Metropolitan Map Series (MMS). This was the first set of maps uniform in format, scale, and content for the SMSA's. The base for these maps were planimetric maps of the USGS. Currently, the Bureau is getting ready for the 1980 Census which will result in about 300,000 maps.

## 4. Central Intelligence Agency (CIA)

The CIA began planning for cartographic automation in 1965 and initiated a pilot system two years later. Since the CIA is a producer of small scale thematic maps, it needed the capability to quickly vary all map parameters. The resulting system, called AUTOMAP, used a Bendix digitizer, IBM 2250 graphic CRT for correction, and IBM 360 computers for manipulation of input data into a cartographic data bank of the world. The same map frame is used to generate a plot on CRT devices and a wide variety of vector or raster plotting devices. The main reason for AUTOMAP was data manipulability with speed and computation following closely behind.

The Cartographic Automatic Mapping (CAM) program is the output portion of AUTOMAP mentioned above. It generates commands for five plotters that plot a variety of functions on any one of six azimuthal, four conic, five cylindrical or three other map projections.

Data banks developed by the CIA are the World Data Bank I (input scale 1:12,000,000 with 100,000 points) and World Data Bank II (input scale 1:3,000,000 with 6,000,000 points). These data banks are primarily country and water boundaries.

## 5. Defense Mapping Agency (DMA)/U.S. Army (16)

The DMA is responsible for fulfilling worldwide military requirements for air, land and marine charts and maps. The DMA Topographic Center (DMATC) provides the land part of these.

The U.S. Army Engineer Topographic Laboratories (USAETL) performs research for the DMA. They are a U.S. Army Corps of Engineer lab whose mission is to conduct research in the mapping sciences, and they view the DMA as a customer who makes known to them their requirements in this area.

The first production system of the DMATC was the Semi-Automated Cartographic System (SACARTS). The input is handled by the Control, Ganticule, and Grid (CONGRD) software and the Symbols, Names and Placement System (SNAPS). The core software is the Graphic Improvement Software Transportation System (GISTS) which handles:

(1) Coordinate system conversion
(2) Digital Topographic Information Base (DTIB)
(3) Vertification plotting
(4) Updating
(5) Continuity
(6) Symbol Enhancement
(7) Application of final symbolization and smoothing

Equipment includes two Calmagraphic Digital Systems, seven Bendix (now Summagraphic) DataGrid digitizers, CALCOMP and Xynetics flatbed plotters and other graphic equipment. The main emphasis of the entire system is the production of topographic (mainly relief) maps for military requirements.

Another current activity of the two agencies is an experimental digital interactive facility utilizing advanced computer hardware. The Digital Image Analysis Laboratory (DIAL) uses a CDC 6400 as host computer, a Goodyear STARAN associative array processor, and an image softcopy/hardcopy/digitizing subsystem (PDP-11/50). Applications beside automated cartography include digital image processing, stereo-photogrammetry and storage and retrieval.

The process for map compilation is:

(1) tracing, resulting in an overlay per feature
(2) digitize each overlay
(3) data processing
(4) color separation
(5) print five-color map

In a raster processing time study, the following map functions were investigated:

(1) registration mark detection
(2) character recognition
(3) vectorization
(4) skew correction
(5) line break detection
(6) line smoothing
(7) line symbol generation

The timing results showed 9.5 hours for an IBM 360/40 and 52 seconds for the STARAN.

Fixed point arithmetic and short word lengths characterize the chosen applications on this experimental facility.

## 6. National Ocean Survey (NOS)/National Oceanic and Atmospheric Administration (NOAA) (16)

NOS has responsibility for producing both nautical and aeronautical charts. Their three major objectives related to computer mapping are:

(1) Nautical Data System Project - operation of a complete automated nautical data system by 1980 from data acquisition through production and distribution.
(2) Aero Charting Automation Project -automated production of aeronautical charts with a complete data system by 1980.
(3) National Geodetic Survey - establishment of a digital data base for geodetic control and North American datum by 1979.

## 7. Department of Interior-Bureau of Land Management (BLM) (16)

The Bureau of Land Management (BLM) is developing a graphic-based geographic information system for resource management. Data will be generated on land-use categories, such as soil, water, forage, wood, minerals, wildlife and recreation. Selective retrieval of overlay map data can be achieved, sealed and then interrogated for resource information. Analysis capabilities include calculation of areas, lengths, counts, summations, and the display of the results in graphs and tables.

Orthophoto maps at a scale of 1:12,000 were used for a major part of the area to generate base maps. The primary data also comes from aerial photos, existing maps, photogrammetry and inventories. The system allows for storage, selective retrieval, comparison, sorting, transformation, and summation of both tabular and geographic data. Outputs include printer, plotter, graphic display and hard copy units.

All of this is done on an IBM 370 using the batch oriented MAP/MODEL system of the University of Oregon. It provides polygon edit capabilities, merging of attributes to map data, calculations, overlays, selective retrieval, summary and plotting. This author feels that this system may be the same one discussed in the section on Eugene, Oregon.

In Riverside, California, BLM is acquiring a geo-based information system from Camarc Design Systems of San Francisco (4). It will be used to inventory basic resource information such as vegetation, soils, geologic and mineral filed notes, archeological sites, wildlife, hydrology, slope, etc. They will utilize a Data General Eclipse C330 mini-computer along with a 36" Zeta drum plotter, a large table digitizer and a Tektronix graphics display.

## 8. U.S. Air Force (8)

At the Rome Air Development Center (RADC), a U.S. Air Force research and development organization, a computerized digital mapping system, the Advanced Cartographic System (ACS), is being developed to encompass the entire cartographic process. The envisioned system is made up of four major subsystems:

(1) photogrammetric
(2) graphic line compilation
(3) product preparation
(4) cartographic data bank

This system was developed at RADC's Experimental Cartographic Facility (ECF) which utilizes a Calma 303 digitizer, a PDP-9 minicomputer and a CALCOMP 563 plotter. An AS-11B analytical stereo-plotter is also used to produce X-Y-Z (i.e., elevation included) data for points.

The four primary feature types are:

(1) contours
(2) drains
(3) roads
(4) cultural

Main input is aerial photographs and USGS 7½ minute quadrangle maps.

# B. State Agencies

## 1. Texas (10)

The Texas Automated Mapping System of the Texas State Department of Highways and Public Transportation offers the engineer new dimensions in map compilations and measurements for transportation planning.

Photogrammetric data from aerial photographs is used to create files of all cultural and terrain features. Individual features can be selected as well as small areas within a large area. Updating is a primary concern as well as display of different scalers. Statistical analysis is done with respect to perimeters, areas, etc.

Many converted stereoplotters are hooked up to a mini-computer designated as the data acquisition system. The data is transferred to the Interactive Graphics System (IGS) mini-computer from M&S Computing to be corrected at an edit station and displayed and analyzed at an application station. The Texas Automated Plotting System (TAPS) is used for plotting on flatbed and drum plotters.

This system is being utilized along with their Road Design System (RDS) as a base for the development of their Interactive Graphics Aided Design System. Its objective is interactive highway design with graphics displays.

Primary maps produced by the mapping system are planimetric, topographic, land use, design and interchange conditions. The mapping system is also used to create geographic data bases for larger area maps such as county and city maps. USGS 7½ minute quadrangle maps compose the base which is updated using current 1" = 2,000' aerials.

## 2. Florida (13)

In September, 1977, the Florida Department of Transportation purchased an Interactive Graphics System for use in the State Topographic Office. The primary objective was use of interactive graphics techniques in mapping applications.

The state awarded the November, 1976 bid to M&S Computing of Huntsville, Alabama. The system was tested in May, installed in July, and accepted in September of 1977.

This Interactive Graphics Design System (IGDS) is used for these major applications:

(1) County mapping - existing general highway maps at 1 inch = 1 mile scale are digitized and updated through field inventories and aerial photographs. Twenty-one levels (layers) are used. An example is in Part VI.
(2) Land use and vegetation inventory -photographs are interpreted and appropriate data entered.
(3) Photogrammetric mapping from an on-line stereo plotter - a KERN PG-2 stereo plotter is interfaced to capture 2- and 3-dimensional data from aerial photographs. Planimetric and topographic maps are produced.
(4) Topographic mapping - field survey notes are used to interactively construct a map.
(5) Urban mapping - existing base maps were digitized in order to produce mileage files.

Future plans include investigation of more engineering applications. The system is also tied to the IBM mainframe through an interface.

## 3. Illinois (5)

ILLIMAP is a computer system used by the Illinois State Geological Survey for converting locations described legally to plottable X-Y coordinates and for drawing base maps. Section corner coordinates from USGS quadrangle maps make up a basic part of the system file along with coordinates for state and county boundaries.

An Autotrol digitizer was used with punched card output. Data was processed on an IBM 360/75 computer to create files. Plots were done on a CALCOMP plotter. The generated data file has also been used by other programs for generating contour and choropleth maps. Given a township, range, tier set of identifiers, the 100,000 point file produces base maps on the plotter.

## 4. Michigan

The Michigan Department of State Highways and Transportation presently has an interactive graphics system obtained from M&S Computing, Inc. of Alabama. This dedicated system consists of a PDP 11/70 mini-computer, a tape drive, three disk drives, a Versatec on-line electrostatic plotter and ten graphic user stations. Six of the user stations are design/digitizing stations consisting of Tektronix 4014 and 613 graphic displays, digitizing board and menu tablets. Another design-only station has everything but the digitizing board. The remaining three stations are attached to stereoplotters in the photogrammetry unit. They do not have digitizing boards, but do have microprocessor interfaces to the PDP for Z-coordinate transformations. An anticipated upgrade will include another PDP 11/70 with peripherals, six more stations and a CALCOMP 960 plotter. Currently, plotting is done off-line on a CALCOMP 1036 drum plotter and a Xynetics 2000 flatbed plotter. Present applications include:

(1) bridge design - preliminary to final plans
(2) road design - plan sheets, critical path diagrams
(3) photogrammetry - including planimetric maps and digitized terrain files (used as input to a Numerical Ground Image System)
(4) land-use mapping - including digitized land use data for input to the Environmental Information System
(5) right-of-way maps and plans
(6) county map digitizing - using 1" = 1 mile maps
(7) traffic and safety - layouts, diagrams, plans

Future plans in mapping include using USGS quadrangle maps instead of existing 1" = 1 mile maps for the county map application.

## 5. North Carolina

On October 15, 1977, the Land Resources Information Service (LRIS) a new state agency, took delivery of a Comarc Geo-Based Information System from Comarc Design Systems of San Francisco. Fifteen other state agencies are already relying on the system for projects ranging from the precise identification of state timber holdings to the prediction of archeological sites.

The configuration consists of a Data General Eclipse mini-computer, tape drive, disc drive, line printer, drum plotter, video display terminal, a Tektronix 4010 graphics display and a 44" x 60" digitizer. Comarc calls the system an Interactive Graphics System (IGS). All data is tied together by the North Carolina State Plane Coordinate System.

Some of the analytical capabilities include:

(1) Simultaneous handling of data in point, line, polygon, or grid format
(2) Perform extracts of data by label, polygon, window, minimum and/or maximum area
(3) Perform overlays and sieve analysis of any combination of point, line, polygon, or grid information
(4) Calculation of acreage, distance, proportion, percentage, volume under a surface
(5) Conversion of polygon data to grid cells and grid data to polygon
(6) Calculation of proximity to a point, line or polygon
(7) Perform extreme value search
(8) Perform updates and edits on data files
(9) Calculate slope, aspect and view exposure
(10) Calculate impoundment or flood levels based on topography
(11) Produce file reports and summaries
(12) Produce maps at any scale with title block, border, and options for shading and use of 4 colored pens
(13) Produce plots in perspective

Some examples of anticipated uses of an interactive graphics systems include:

(1) Soil association data
(2) Use land use data
(3) Historic properties
(4) Archeological modeling
(5) Resource inventory
(6) Economic Development
(7) Coordinated Permit letting
(8) Forestry
(9) Areas of environmental concern

The staff for the North Carolina mapping program is composed of seven persons including the project director, secretary support, two applications analysts, a systems analyst, an application programmer and a digitizer/operator.

## 6. Minnesota (9)

The Minnesota Land Management Information System (MLMIS) was developed to provide a location for the centralized storage and analysis of accurate and reliable natural resource information necessary for state and local government decision makers to make land management decisions. The core of the MLMIS is a computerized data bank of land resource information that has been collected by various state and federal agencies. It contains statewide data on land use, zoning, land ownership, bedrock geology, mineral potential, soils, forest cover, water orientation, and highway orientation. The system was developed by the Center for Urban and Regional Affairs at the University of Minnesota for the State Planning Agency (SPA).

Data is interpreted from aerial photographs and keypunched to form the gridded data base. Overprinting is done on a line printer to shade the cells for output.

## 7. New York (7)

The Traffic and Safety Division of the New York State Department of Transportation is developing a Centralized Local Accident Surveillance System (CLASS) to maintain and analyze records on almost 60,000 accidents a year on almost 100,000 miles of public roads in New York.

The major elements of CLASS are:

1. An accident site location map using interactive graphic techniques and a link/node coding scheme. A node is a point of interest along the highway (e.g. intersection, railroad crossing) and a link is the segment between two nodes;
2. A data base containing highway information and accident data oriented to the link/node system;
3. A software system which allows the data base information to be accessed, summarized, and analyzed, and permits communication to occur between the graphic and non-graphic files.

The three primary types of information available from CLASS are:

1. Accident data and analysis;
2. Inventory of highway characteristics;
3. Cartographic products.

The system runs on the Interactive Graphics Design System (IGDS) developed by M&S Computing of Huntsville, Alabama. It has four stations, four disk drives, two tape drives, a line printer, and a Konsberg flatbed plotter.

The total cost of development will be about $2 million with the hardware/software/-maintenance contract representing $750,000. The remainder is for two years of operation. These costs are about the same as was estimated to prepare these products using standard cartographic procedures for the reference maps. The advantages of interactive graphics justified the selected approach.

A staff of seven prepare input documents. Five persons do the digitizing and map production. Three people run the computer, plotter, and perform typical data processing functions.

Since the input documents are 7½-minute USGS quadrangles, a new county base map series is being planned.

The advantages of CLASS are:

1. More effective safety analysis
2. More complete accident information
3. Earlier identification of emerging safety problems
4. Reduced duplication of effort
5. Increased professional productivity
6. More effective management of reconstruction and safety funds
7. Accurate road inventories and current maps

The CLASS project was totally funded under the Séction 402 Highway Safety Grant Program of the Federal Government.

The computer system was acquired in the summer of 1978 and the development/creation phase will last three years.

### 8. Other State Agencies

The New Hampshire Department of Public Works and Highways uses a CALMA Corp. digitizer and a CALCOMP 563 plotter for:

(1) acquiring coordinates for use in Census Bureau geographic base files
(2) acquiring digital data that may be plotted at various scales to serve as a base reference for the drafting at large scale highway maps.

The New York Office of Planning Coordination uses the Land Use and Natural Resource (LUNR) inventory. Land-use is obtained from aerial photographs and placed on a gridded data base.

The State of Maryland uses the Maryland Automated Geographic Information (MAGI) system which includes data on water quality, geology, transportation facilities, land ownership, soils, vegetation, and slope in a gridded data base.

## C. City or Regional Agencies

### 1. Eugene, Oregon (14,15)

The Geographic Data System, started in 1971, is conducted by the Regional Information System (RIS) for the Lane Council of Governments (LCOG), U.S. Bureau of Land Management, the cities of Eugene and Springfield and Lane County. More than 30 public agencies participate in RIS.

Lane County currently operates an IBM 370/158 computer with 236 terminals. Graphic hardware includs a CALCOMP drum plotter, two Tektronix graphics displays and graphics tablet, and a Calma digitizer.

Initially, 750 tax maps were digitized, edited, and compiled in two years into a complete parcel file containing land-use data for the Eugene-Springfield metropolitan area. A standardized file of boundaries (e.g. census tracts, precincts) was established in 1975.

The software package used is called the MAP/MODEL system of the University of Oregon. Digitizing, editing, combining, overlaying and plotting are all provided in a series of compatible batch programs. It is very flexible, but very hard to completely comprehend. There is also sizeable overhead cost in both file space and execution time. Portions are being abandoned in favor of on-line interactive programs.

The data base is composed of "parcels" for land, rivers, streets, etc. Each parcel record contains, along with the Oregon State Plane Coordinates, data on land-use, acreage, zoning, property value, etc.

Digitizing is now done on Tektronix 4081 interactive graphics terminals with tablets. Cost factors of the digitizing/editing system include the following:

(1) 12 worker months of programmer time -programmers already familiar with equipment and software.
(2) $100,000 for two work/display stations
(3) use of the IBM 370 (shared)
(4) two or three persons full time for digitizing and editing

Eugene's Planning Department has made the most use of the system both in graphics output and information retrieval. Future uses include the following:

(1) comprehensive land use planning
(2) transportation planning
(3) public utilities management
(4) social services delivery analysis and planning
(5) dispatching and routing of emergency vehicles
(6) environmental quality analysis

### 2. Burnaby, British Columbia (2,6)

The Burnaby Joint Utility Mapping Pilot Project (BJUMP) officially commenced on the acceptance of the computer-assisted mapping system on December 31, 1976. BJUMP's objective is to thoroughly examine the effectiveness of a computer-assisted mapping system in a joint-agency working environment, for the purpose of creating and maintaining utility mapping over a substantial portion of Burnaby. Another objective was metric maps and calculations.

A Synercom ST-700 mapping system was installed for use by the city and the local utilities. The PDP mini-computer based system uses aerial photos, existing maps, legal plans, and survey control for input. Custom maps produced include utilities, highways, forests, assessments, land use, engineering, planning, traffic, surveying, fire and police, real estate, etc. The system cost about $400,000, including two digitizers and four keyboard CRT terminals.

The project timetable shows initiation of operational production in February, 1979, and completion of inputting the base data in January, 1980. The major emphasis is on facility data management where information in regular computer files are tied together with coordinates. The concept is very similar to CAMRAS in Memphis, Tennessee (see Section IV-C-5.). The foundation of the base map files are the block lines.

In a savings comparison of computer drawing versus manual drawing of maps, they observed ratios of 4.8:1 to 8:1. However, when they included the benefits of facility data management, they felt the comparison became meaningless. They also concluded that using existing maps when possible was much better and faster than conducting a survey.

## 3. Santa Rosa, California (10)

The Santa Rosa Planning Information System was designed and developed for the city of Santa Rosa by Comarc Design Systems, Inc., a San Francisco firm. Parcels were encoded from maps provided by the City at a variety of scales. Approximately 60,000 parcels were digitized with the exact parcel boundary, the parcel centroid and the Assessors Parcel (AP) being stored.

Integrated to this base are environmental data, interpretive data, traffic data, planning data and assessors data. A unique aspect of this system is the fact that grid maps and files can be produced by converting parcel polygons to grids. Polygon files are used for accuracy while grid files are very efficient in terms of processing. A Tektronix graphic display unit in Santa Rosa is linked to Comarc's minicomputer which has a Talos digitizer. A hard copy unit and a plotter are used for hard output.

## 4. Nashville, Tennessee (16)

The Location and Mapping Program (LAMP) is an urban information system consisting of a variety of physical planning, management, and control systems. A variety of overlays can be generated and displayed on a graphics display (such as sewer systems, traffic accidents, and census data), and statistical analysis performed on any of the attributes associated with the GBF (geographic base file). Base maps were developed primarily from county property maps. Output is on a microfilm plotter. The following systems were inputs:

(1) inventory of highway environment
(2) development of land accounting system
(3) order distribution network
(4) sanitary sewer system
(5) storm sewer system
(6) public utility physical inventory

Land parcels were digitized using the state plane coordinate system. Two files are maintained: a parcel based file and a subdivision description file. There are a variety of interactive capabilities including editing, centroid, calculation, updating and deletion. Retrieval is done either by parcel name or by coordinates. The control systems implemented include:

(1) daily activity reporting system
(2) permit control system
(3) complaint control system
(4) work order control system
(5) resource allocation and scheduling
(6) precinct analysis
(7) sewer load analysis system
(8) water distribution analysis system
(9) transportation planning system
(10) land use planning system

Data from a digitizer is processed on an IBM 370/145 computer. Generalized applications supported by the base system include scheduling/dispatching, inventory, districting, map overlay, and topographic mapping. Dr. Joel Orr was director of the LAMP project from conceptualization through implementation. M&S Computing of Huntsville, Alabama also provided assistance in development of the system.

## 5. Memphis, Tennessee (1)

The Computer Assisted Mapping and Records Activities Systems (CAMRAS) is a project of the American Public Works Association (APWA). It was conceived as a joint-use planning, engineering, and management tool for the efficient and effective use of information needed by a large number of public agencies and companies operating within a common area.

The program proposes to develop, promulgate and implement suggested procedures and standards for jointly funded, and shared-use, computer-assisted, geo-based location record systems based on an implemented system. Memphis is serving as the site of the model test application. In addition to the city, active participants will include Shelby County, the State of Tennessee, and the private and public utilities servicing the area.

Total cost is projected to $1.7 million and it will be funded by APWA, the Memphis Consortium of users and other participating agencies. End products will include documentation with standards and procedures for conducting problem definition, feasibility, benefit/cost ratio, specifications, photogrammetry, interagency agreements and operator training manuals.

Input will be done through aerial photography and ground survey. After input, the data base will be accessible by subject as well as by area. The fundamental components of the data base will be the parcel boundary, address, street name, hydrography, parcel identifier, city limits/political boundaries, curb, sidewalk, and control (monuments).

Equipment is expected to be selected and delivered by May, 1979.

## 6. Des Moines, Iowa (16)

The Integrated Municipal Information System (IMIS) of the City of Des Moines attempts to correlate and aggregate municipal and urban environment data. Geocoding techniques are used to develop a data base made up of data from the following sources:

1) Plan and Zoning Commissions
2) Traffic and Transportation Bureau
3) Community Development Board
4) Public Works Department
5) Finance and Building Inspection Services
6) Urban Development Board
7) Assessor's Office
8) County Audits
9) County Treasurer

The project was funded in the 1960's by the Federal Department of Housing and Urban Development (HUD) to develop a large number of computerized municipal data files, which are just now beginning to be updated and used. The project has as a goal the integration of various subsystems and the ability to cross-reference data between various on-line files.

Another joint system, developed by the Battelle Institute, is GEOPLANS, which does the geographic data aggregation for the storage retrieval and linking of the various data source files. GEOPLANS uses a common geographic referencing index to relate data files in different agencies to each other. This system enables the individual agencies to maintain their data base, but by adding this pointer-file system, data can be aggregated across agency lines.

Although the main computer operations go through the Polk-Des Moines Computer Center, the mapping activities take place in the city offices as this author has observed. Aerial photographs and existing plat maps are digitized on a Bendix (now Summagraphics) DataGrid digitizer. The data is put on tape, processed and a plot tape is produced. The plotting takes place on a CALCOMP plotter in the city offices.

## 7. San Diego, California (16)

The Integrated Regional Environment Management (IREM) Project was developed by the County of San Diego Environment Development Agency. The project provides regional environmental services as well as administration and management services. Graphic in nature, it deals with impact studies primarily involving air pollution models.

## 8. Columbus, Ohio (16)

This project is called BENCHMARK, was developed by the Battelle Memorial Institute and Ohio State University, and is directed by the Academy for Contemporary Problems. It attempts to provide data concerning the problems in a metropolitan area and to assist decision makers in making more effective public policy. Information on basic social, economic, and ecological conditions is available to public policy researchers. Data on social profiles of institutions and neighborhoods within a region are also collected. The model will provide projections of future alternatives for the Columbus area and will provide graphic outputs of computer maps from the data base.

## 9. Fort Collins, Colorado (16)

The Regional Economic Study (RES) started in 1971 with the establishment of uniform files, data flow, and shared data between a variety of urban departments. The hardware consists of a DEC PDP-10 mini-computer, a Houston Instrument DP-drum plotter and a Tektronix graphic display.

The Larimer County, Fort Collins model is significant in that it tries to deal with the day-to-day planning decisions that must be made, rather than with the more accepted long-range comprehensive planning decisions.

Most services are non-graphic in nature and include:

1) utility billing
2) engineering data for utilities
3) general accounting
4) policy reporting
5) hydraulic analysis
6) traffic flow analysis

The increasing number of graphic capabilities include land, boundary line and property mapping, surface approximation, and general contouring software.

Most significant of the on-line data files is the collection of land-use and housing inventory data which is updated weekly. Initially, base maps were created from air photos for a 213 square mile area at scalers of 1" = 200' and 1" = 600'. The data is then matched and merged with existing files. Over 17,000 structures and parcels have been mapped to date at a cost of $25,000 (not including monthly administrative costs).

## 10. Kansas City, Kansas (16)

The Computer Mapping Project of Kansas City and Wyandotte County, Kansas, has resulted in the development of a comprehensive data base and a heavy use of computer mapping techniques.

The data base developed for this project consists of a GBF/DIME file (see Census Bureau) and a parcel file. Base maps were developed at a scale of 1:1200 which were made by stereo photogrammetric methods using the Kansas State Plane Coordinate System. All maps included planimetric features and two-feet contour intervals.

A number of choropleth mapping programs, dot mapping and street network mapping programs were developed for use with pen plotters. The entire system is called GRAFPAC II and is implemented on IBM, Honeywell, and CDC computers. Using a multi-pen plotter, a variety of line fonts and color maps have been developed.

The maps files have been merged to existing data files on such items as streets and street signs. Most of the applications result in choropleth maps using the 1970 Census of Population and Housing Data. Current mapping plans are to use the parcel file to generate parcel outlines, permit the entry of parcel data and the display of parcel related data.

## 11. Los Angeles, California (16)

The Multiple Input Land-Use System (MILUS) is a further development of the Land-Use Management Information System (LUMIS) of the Jet Propulsion Laboratory (JPL). LUMIS is based on low-altitude aerial photos and consists of two systems: Land-Use Planning and Management System (LUPAMS) based on data from the County Assessor's Office for each parcel, and GEO-BEDS based on a DIME file (see Census Bureau) format and incorporating census-type information.

The MILUS system utilizes satellite image (raster scan) data in conjunction with tabular and graphic data that are geographically crossreferenced. Application areas include metropolitan land-use categories, regional resource inventory, and general modeling and forecasting systems. An interface program takes the raster scan data and uses a reference polygon (map) to enable pointers to be generated to tabular data records. The reference polygon is usually a street outline, such as an individual city block.

Results of two test cases show that the system tends to be cheaper to operate than any manual photo interpretation, manual coordinate digitization, or polygon overlay system. A current project is the development of a program to automatically convert DIME files to reference polygons.

Although operational costs are still low, system costs are high. It currently uses an IBM 370/155 and expensive image processing equipment.

Another project underway is tax mapping for the County of Los Angeles. The County is using a Computervision System for data entry and tax parcel identification, measuring, and output of data files used directly in tax preparation.

## 12. Atlanta, Georgia (16)

An unusual cooperative project among several public utilities and government agencies was initiated in mid-1974 and called the Georgia Coordinate Mapping Project. The Atlanta Gas Light Co., the City of Atlanta, the Georgia Power Co., Southern Bell Telephone, and the Georgia Department of Transportation jointly contracted to obtain orthophotographs, stereophotographs, planimetric maps, planimetric key maps, and digitized data base tapes of the city of Atlanta area, including centroids of buildings and street intersections.

The Systems and Programming Office of the City received the tapes and is responsible for updating the maps for itself and the other members of the group. The other groups received sets of 100 foot scale planimetric key maps and 833-scale and 500-scale stereophotographs. All data is referenced by state plane coordinates.

A 21" graphics terminal is used to interactively update, manipulate and display the data. An automated drafting subsystem does the plotting. As of 1978, the Georgia Department of Transportation has not used the data tapes.

# Part V - Vendors

Material in this section is derived from manufacturers brochures, advertisements, and some personal communications. Therefore, it is not formal as in a questionnaire and should not be regarded as complete and all inclusive.

Since the primary trends are in interactive graphics systems with mini-computers, the following vendors and systems will be examined:

1) Gerber Scientific Instruments - Interactive Design and Drafting System (IDS)
2) California Computer Products, Inc. (CALCOMP) - Interactive Graphics System (IGS)
3) Bendix (now Summagraphics, Inc.) -System 100
4) Keuffel & Esser (K + E)/H. Dell Foster Co. - IGS/330
5) Calma - Calmagraphic Interactive (CGI)
6) Synercom Technology, Inc. - MAP-IN
7) Comarc Design Systems - Interactive Graphics System (IGS)
8) Applicon, Inc. - Applicon Graphic system
9) M&S Computing, Inc. - Interactive Graphics Design System (IGDS)
10) Computervision Corp. - Designer System

The following symbols are used in the tables:

1) M - million
2) K - thousand
3) DVST - Direct View Storage Tube
4) HP - Hewlett-Packard
5) DG - Data General
6) PDP - computer system family from Digital Equipment Corp. (DEC)
7) CC - CALCOMP
8) C - circuits
9) D - drafting
10) F - FORTRAN
11) -- Not Available or Unknown at time of Report Preparation.

Table I is for the hardware. Table II is on the software capabilities of each system. Table III is essentially a checklist of terms found in the brochures in connection with mapping uses. Some terms may be similar to or include other terms and like terms were not combined. Table IV is for other information such as costs, applications, operating systems, languages, and first delivery dates.

No vendor preferences are intended in these tables. A formal survey would certainly provide more information. Our intent is to give the reader an idea of what to expect when examining systems. The characteristics shown for each system reflect to a certain extent the availability of data on each system at the time this report was prepared. Before ruling out or deciding on any one system it would be advisable to obtain more information regarding the capacity and versatility of the system offered by each vender. This is particularly needed in today's rapid changes and advancements occurring in the computer technology field.

## Table I - Hardware

| | Gerber | CALCOMP | Bendix | H. Dell Foster | Calma | Synercom | Comarc | Applicon | M&S | Computervision |
|---|---|---|---|---|---|---|---|---|---|---|
| Digitizer | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Tablet | -- | Yes | -- | Yes | Yes | -- | -- | Yes | Yes | Yes |
| CRT/Keyboard | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Magnetic Tape | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Typewriter Terminal | Yes | -- | Yes | Yes | Yes | Yes | -- | Yes | Yes | Yes |
| Interface to Mainframe | -- | -- | -- | Yes | -- | -- | Yes | Yes | Yes | -- |
| CRT/Stylus | Yes | -- | -- | -- | -- | -- | -- | Yes | Yes | -- |
| Graphics Display | DVST | Yes | -- | DVST | DVST Refresh | DVST | DVST | DVST | DVST | DVST |
| Disk (maximum) | Yes | Yes | -- | Yes | 4 | 4 | 16 | Yes | 8 | 4 |
| Floating Point Hardware | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yes |
| Plotter/Digitizer | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yes |
| Pen Plotter | Own | CC | CC | Own | Yes | -- | CC, Zeta | Yes | CC | CC, Gerber |
| Electrostatic Plotter | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | Yes |
| Stereoplotter Input | -- | -- | -- | Yes | Yes | -- | -- | Yes | Yes | Yes |
| Card Reader | -- | Yes | -- | -- | -- | Yes | -- | -- | Yes | Yes |
| Graphic Hardcopy (dry silver) | Yes | -- | -- | Yes | -- | -- | -- | Yes | Yes | Yes |
| Line Printer | -- | Yes | -- | -- | -- | Yes | Yes | Yes | Yes | -- |
| Maximum Work Stations | 6 | 4 | 4 | 4 | 6 | 8 | -- | 20 | 12 | 8 |
| Processor | HP 2100A | Own | DG Nova | DG Nova | DG Eclipse | PDP 11 | DG Eclipse | PDP 11 | PDP 11 | Own |
| Interaction | Joy Stick | -- | -- | Tablet | Tablet | Tablet | Tablet | Tablet | Tablet | Tablet |

*note - definitions of symbols on page 6.

## Table II - Software

| | Gerber | CALCOMP | Bendix | H. Dell Foster | Calma | Synercom | Comarc | Applicon | M&S | Computervision |
|---|---|---|---|---|---|---|---|---|---|---|
| Line Fonts | -- | -- | 3 | Yes | -- | Yes | -- | Yes | 4 | 64 |
| Data Smoothing | -- | -- | -- | -- | -- | Yes | -- | -- | Yes | Yes |
| Filtering | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yes |
| Centerline Expansion & Joints | -- | -- | -- | -- | -- | Yes | -- | -- | Yes | Yes |
| Text Fonts | -- | -- | 2 | -- | -- | -- | - | -- | 255 | 9 |
| Fonted Crosshatch | -- | -- | Yes | Yes | -- | -- | -- | -- | -- | Yes |
| Layers (overlays) | -- | -- | 99 | 16 | 32 | -- | 13 | Yes | 63 | 192 |
| Polygon Data Structures | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | Yes |
| Attribute Printouts | -- | Yes | -- | -- | -- | Yes | Yes | Yes | Yes | Yes |
| Graphic Commands | Yes | Yes | Yes | Yes | Yes | Yes | -- | -- | Yes | Yes |
| Rectification | -- | -- | -- | -- | Yes | Yes | -- | -- | -- | Yes |
| Sectioning (windowing) | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | Yes |
| Paneling (joining) | -- | -- | -- | Yes | -- | -- | -- | -- | Yes | Yes |
| Line Closure | -- | -- | -- | -- | -- | -- | -- | -- | Yes | Yes |
| Bearing and Distance | -- | -- | -- | -- | -- | -- | -- | Yes | -- | Yes |
| Attributes | -- | Yes | -- | -- | Yes | Yes | Yes | -- | Yes | Yes |
| State Plane Coordinates | -- | -- | -- | -- | -- | Yes | Yes | -- | -- | Yes |
| Geodetic Coordinates | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | Yes |
| Area, Volume, Centroid Calculations | -- | -- | -- | -- | Yes | -- | Yes | Yes | Yes | Yes |
| Cut & Fill Calculations | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Township, Range Coordinates | -- | -- | -- | -- | -- | -- | Yes | -- | -- | -- |
| LANDSAT Data Input | -- | -- | -- | -- | -- | -- | Yes | -- | -- | -- |
| COGO Data | -- | -- | -- | -- | -- | Yes | -- | Yes | -- | -- |
| Projections | -- | -- | -- | -- | -- | -- | Yes | -- | -- | -- |
| Map Symbols | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yes |
| Grid & Vector Data Bases | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |

## Table III - Mapping Uses

| | Gerber | CALCOMP | Bendix | H. Dell Foster | Calma | Synercom | Comarc | Applicon | M&S | Computervision |
|---|---|---|---|---|---|---|---|---|---|---|
| Utilities | -- | Yes | Yes | -- | Yes | Yes | -- | Yes | Yes | Yes |
| Pipeline | -- | -- | -- | -- | -- | -- | -- | -- | Yes | Yes |
| Tax | -- | Yes | Yes | -- | Yes | -- | Yes | Yes | Yes | Yes |
| Land Use | -- | -- | -- | Yes | Yes | -- | Yes | Yes | Yes | Yes |
| Transportation/Roads | -- | -- | Yes | -- | -- | Yes | Yes | Yes | Yes | Yes |
| Natural Resource | -- | -- | -- | Yes | -- | -- | Yes | -- | Yes | Yes |
| Census Analysis | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yes |
| General Cartography | -- | -- | -- | -- | -- | -- | -- | -- | Yes | Yes |
| Soils | -- | -- | -- | Yes | -- | -- | Yes | -- | Yes | Yes |
| Topography | -- | -- | -- | -- | Yes | -- | Yes | Yes | Yes | -- |
| Geology | -- | -- | -- | -- | Yes | -- | Yes | -- | Yes | Yes |
| Slope | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Vegetation | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Hydrology | -- | -- | Yes | -- | Yes | Yes | Yes | -- | Yes | Yes |
| Forest | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Pollution | -- | -- | -- | -- | -- | -- | Yes | -- | -- | -- |
| Archeology | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Zoning | -- | -- | -- | -- | Yes | Yes | Yes | -- | Yes | -- |
| Parcel/Subdivision | -- | -- | -- | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Earthwork Analysis | -- | -- | -- | -- | -- | -- | Yes | -- | Yes | -- |
| Interpretive | -- | -- | -- | -- | -- | -- | Yes | -- | -- | -- |
| Boundaries (political) | -- | -- | Yes | -- | Yes | -- | Yes | -- | Yes | Yes |
| Planimetric | -- | -- | -- | -- | Yes | -- | -- | Yes | Yes | -- |
| Thematic/Statistical | -- | -- | -- | -- | Yes | Yes | -- | -- | Yes | -- |
| Urban Planning | -- | -- | -- | -- | -- | -- | -- | Yes | Yes | -- |

## Table IV - Other Information

| | Gerber | CALCOMP | Bendix | H. Dell Foster | Calma | Synercom | Comarc | Applicon | M&S | Computervision |
|---|---|---|---|---|---|---|---|---|---|---|
| First Delivery Date | 1973 | 1978 | 1972 | 1973 | 1971 | -- | -- | 1970 | 1972 | 1969 |
| Primary Application | C | D, Maps | C, Maps | Maps | C | Maps | Maps | C | C,D, Maps | C,D, Maps |
| Typical Cost | $120K | 71K | 91K-110K | 150K | 131K-170K | -- | 300K | 122K | 450K | 150K |
| Add a Station Cost | $40K-70K | -- | 35K | -- | 24K-34K | -- | -- | 18K-36K | 25K | 32K-40K |
| Operating System | HP | -- | -- | DG | Own/DG | PDP | DG | Own | PDP | Own |
| Sales in 1974 | 1M | -- | 2M | 4.5M | -- | -- | -- | 10M | .2M | 13M |
| Language | F | -- | F | F | -- | -- | F | -- | F | F |

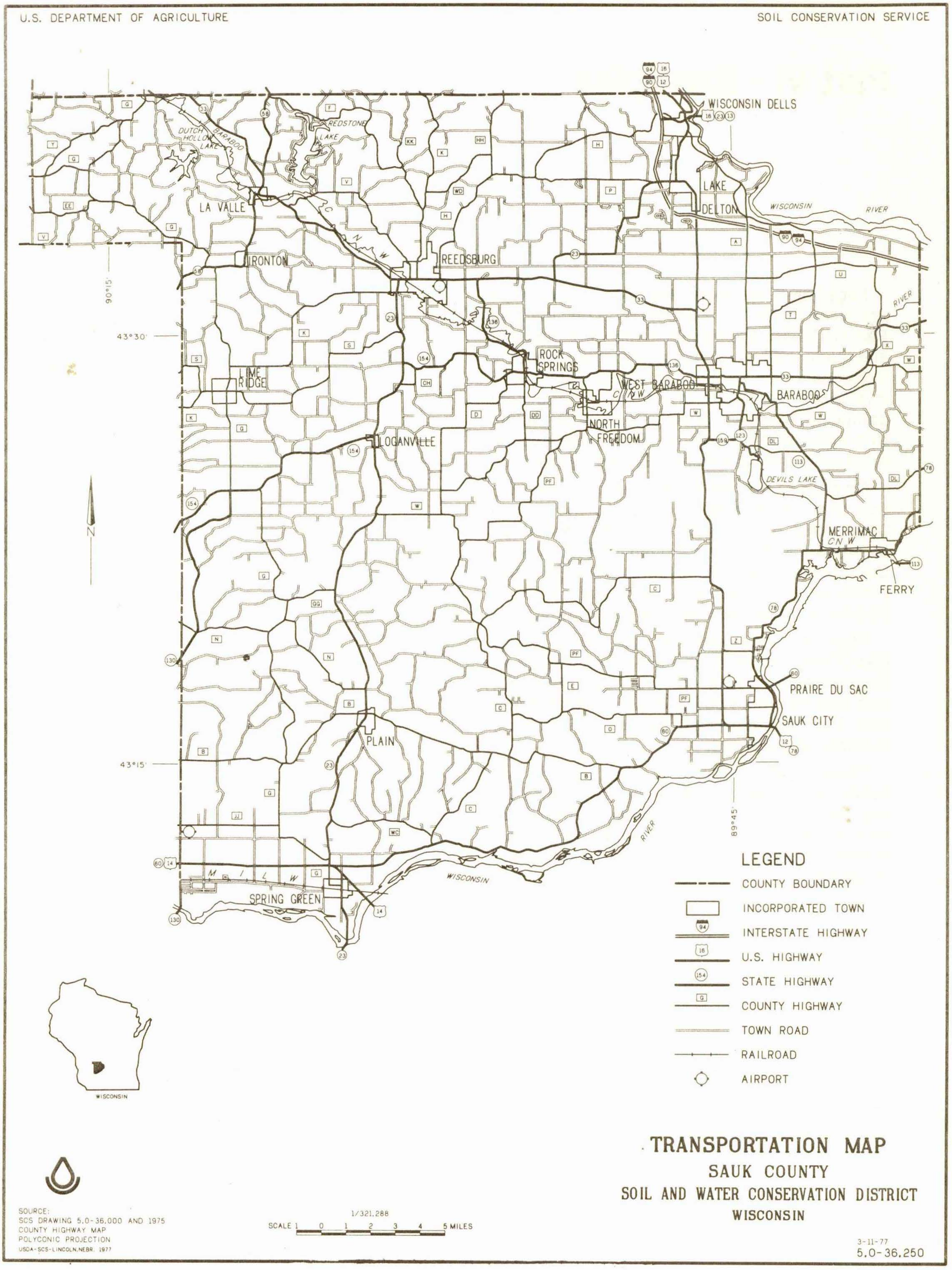
# Part VI - Examples

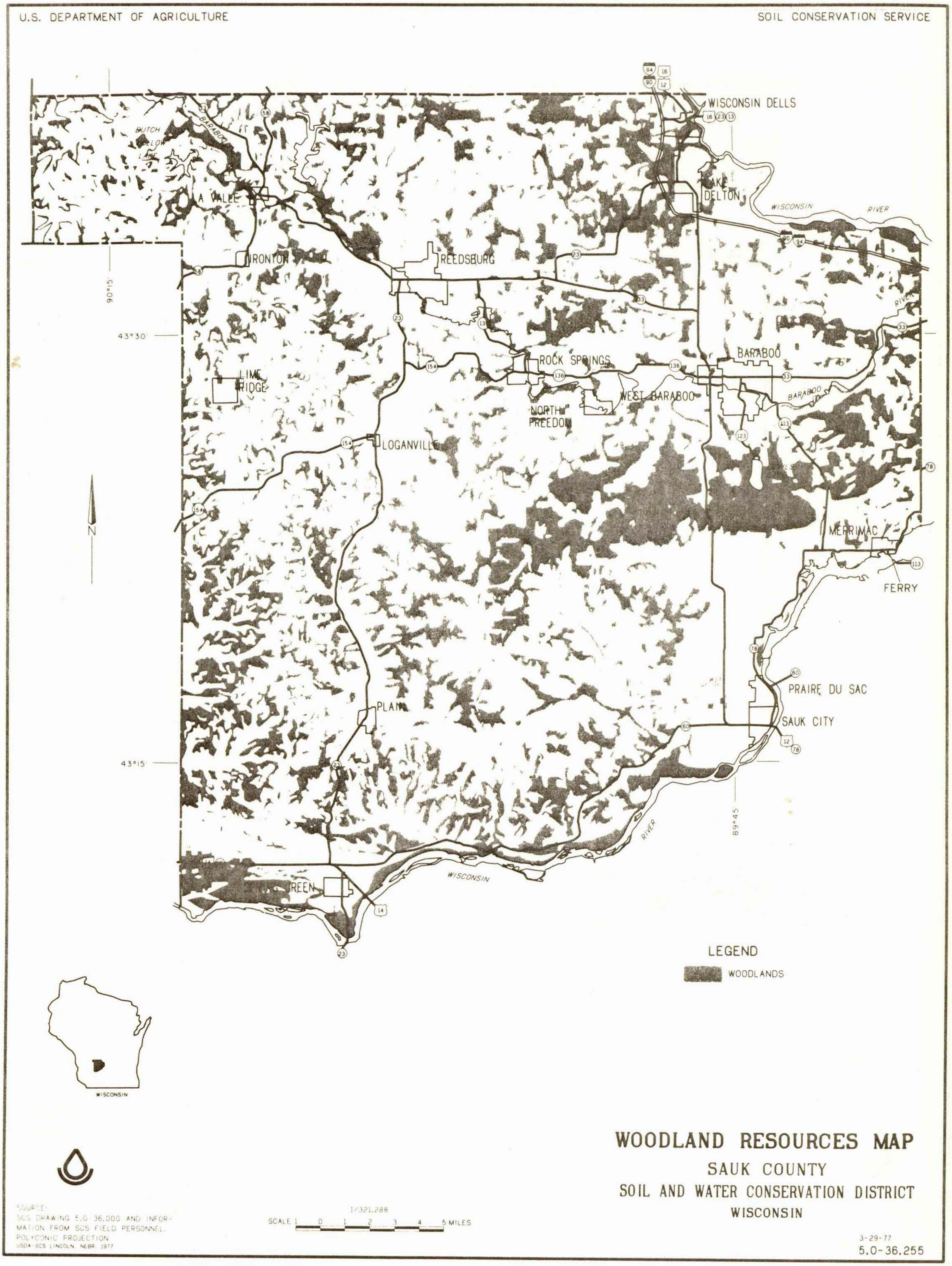
Pages 36-40 are examples of computer maps produced by the Soil Conservation Service (See Part IV). USGS quadrangle maps were digitized and combined in Lincoln, Nebraska using a Computervision System. This data was sent to Hyattsville, Maryland where the various data components were plotted using Gerber Scientific Instruments machine. From these separations color overlays were prepared for printing.

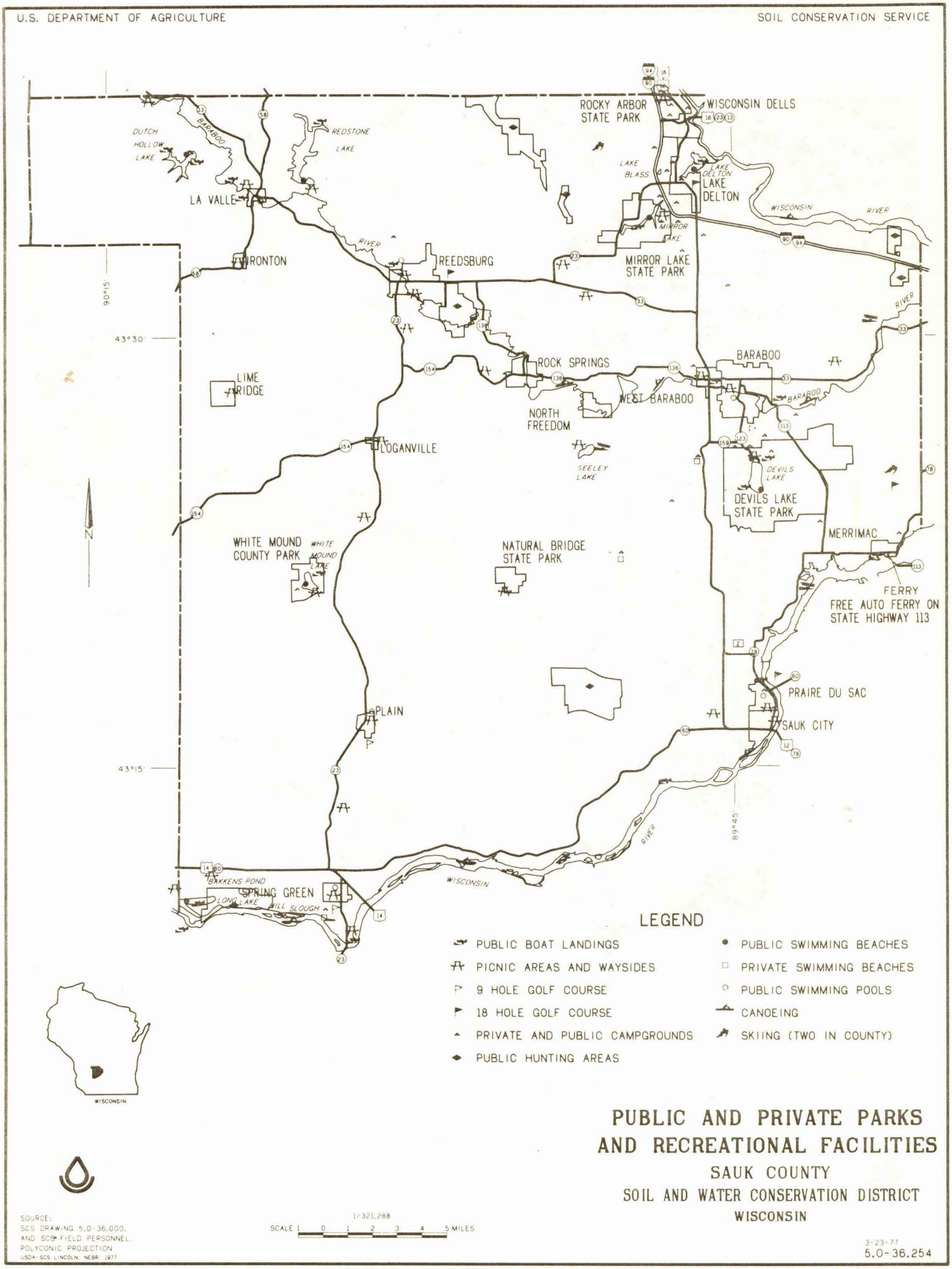
On page 41 is a reproduction of a sample portion of a county map produced by the Florida Department of Transportation (see Part IV) on an Interactive Graphics Design System by M&S Computing. It was done on a CALCOMP 960 plotter which can use a ballpoint, wet ink, or felt tip pen on paper, vellum, and mylar surfaces.

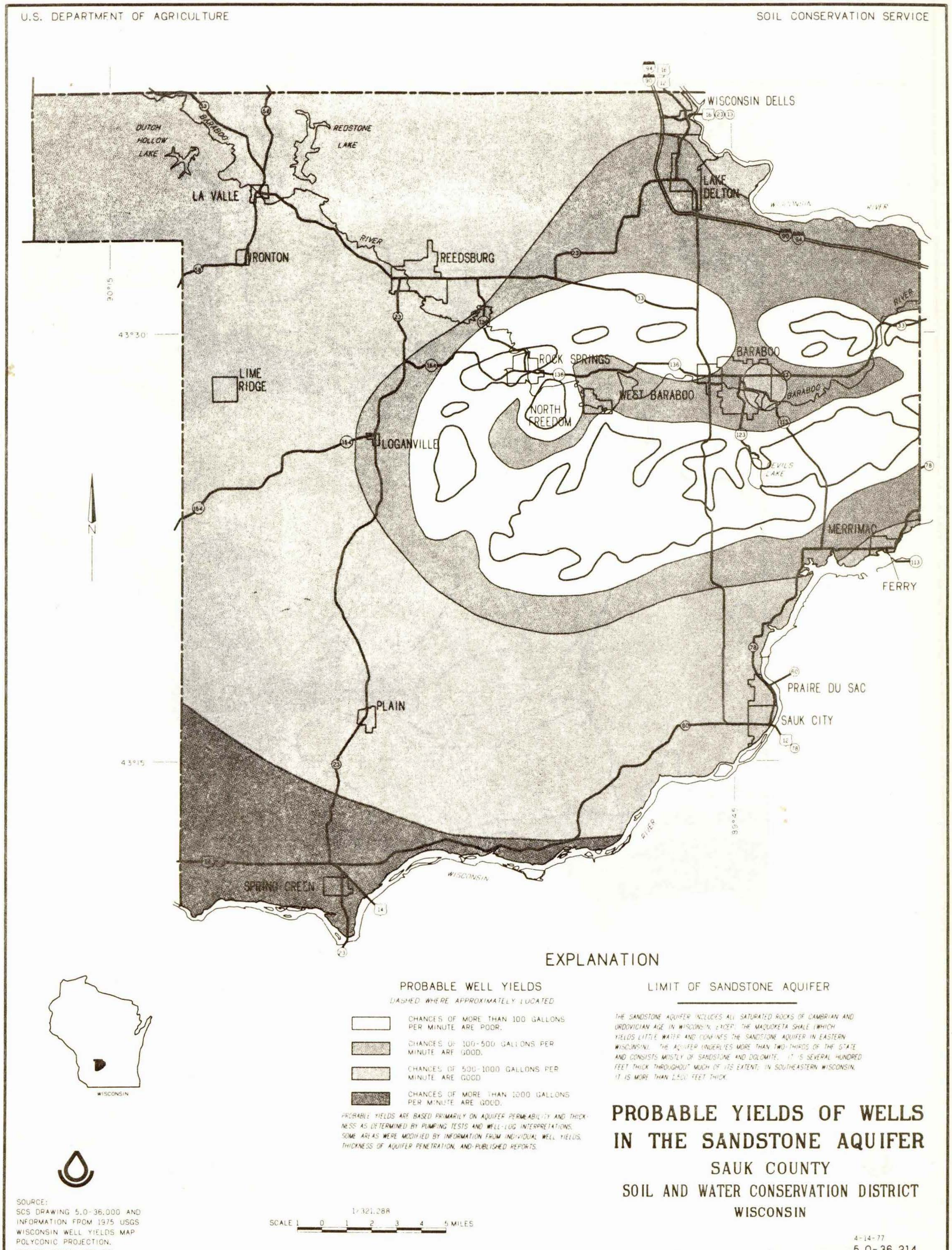
Page 42 illustrates a map done on a CALCOMP Plotter at the Iowa Department of Transportation using the program CALFORM and data from the Federal Highway Administration. The illustration has been reduced 80% for publication purposes.

These examples serve to illustrate the versatility and detail that can be accomplished using computer mapping techniques. These are only limited examples and in no way reflect the maximum capability that exists in computer mapping.


U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WISCONSIN DELLS
LAKE DELTON
WISCONSIN RIVER
DUTCH HOLLOW LAKE
BARABOO
REDSTONE LAKE
LA VALLE
IRONTON
REEDSBURG
C N W
ROCK SPRINGS
LIME RIDGE
WEST BARABOO
BARABOO
NORTH FREEDOM
LOGANVILLE
DEVILS LAKE
MERRIMAC
FERRY
PRAIRE DU SAC
SAUK CITY
PLAIN
SPRING GREEN
M I L W
WISCONSIN
RIVER
90°15'
43°30'
43°15'
89°45'
N
LEGEND
COUNTY BOUNDARY
INCORPORATED TOWN
INTERSTATE HIGHWAY
U.S. HIGHWAY
STATE HIGHWAY
COUNTY HIGHWAY
TOWN ROAD
RAILROAD
AIRPORT
WISCONSIN
TRANSPORTATION MAP
SAUK COUNTY
SOIL AND WATER CONSERVATION DISTRICT
WISCONSIN
SOURCE:
SCS DRAWING 5.0-36,000 AND 1975
COUNTY HIGHWAY MAP
POLYCONIC PROJECTION
USDA-SCS-LINCOLN,NEBR. 1977
1/321,288
SCALE 1 0 1 2 3 4 5 MILES
3-11-77
5.0-36,250

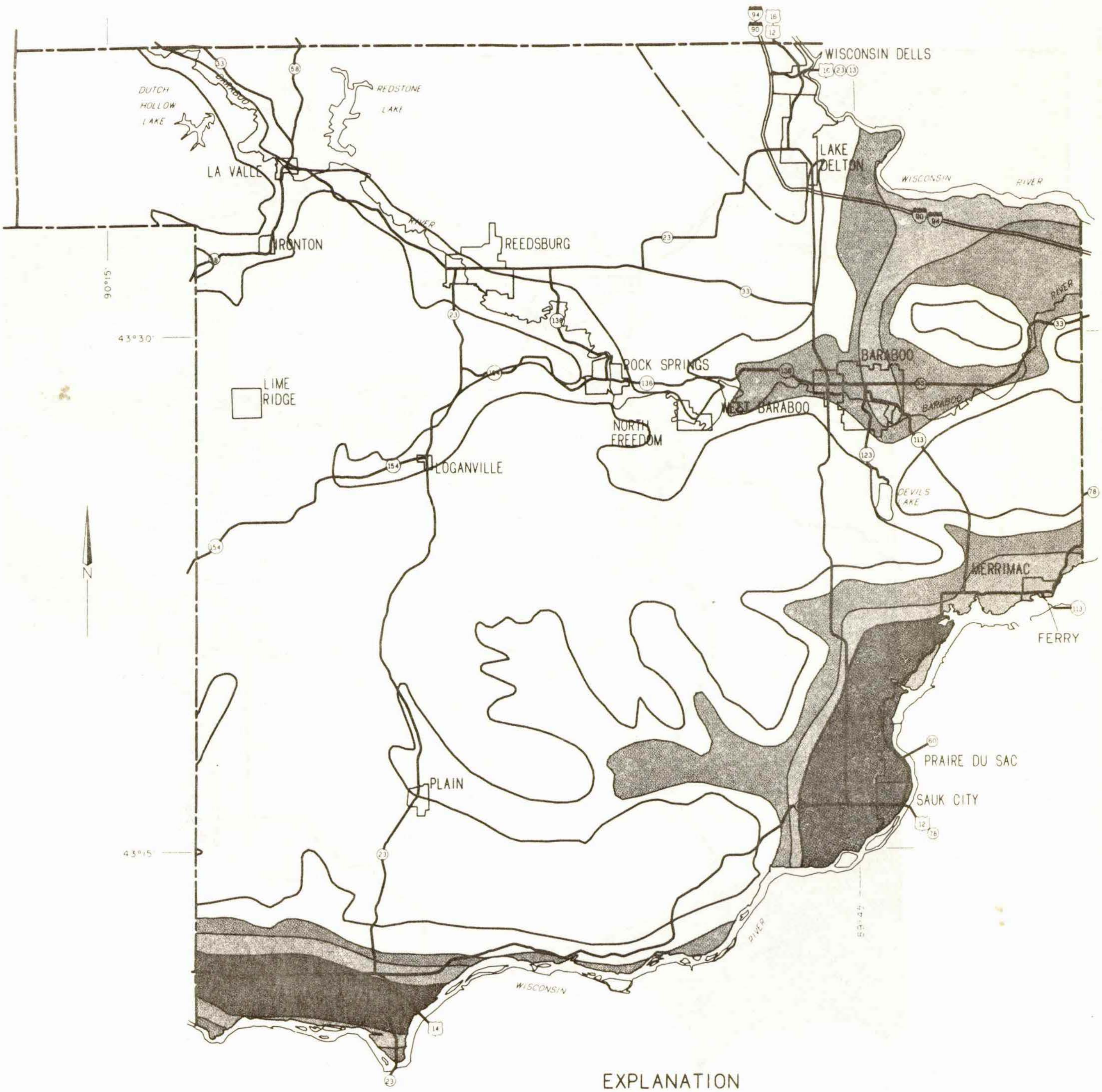

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WISCONSIN DELLS
LAKE DELTON
WISCONSIN RIVER
DUTCH HOLLOW LAKE
BARABOO
LA VALLE
IRONTON
REEDSBURG
ROCK SPRINGS
BARABOO
WEST BARABOO
NORTH FREEDOM
LIME RIDGE
LOGANVILLE
MERRIMAC
FERRY
PRAIRE DU SAC
SAUK CITY
PLAIN
SPRING GREEN
WISCONSIN
RIVER
90°15'
43°30'
43°15'
89°45'
N
LEGEND
WOODLANDS
WISCONSIN
WOODLAND RESOURCES MAP
SAUK COUNTY
SOIL AND WATER CONSERVATION DISTRICT
WISCONSIN
SOURCE:
SCS DRAWING 5.0-36,000 AND INFORMATION FROM SCS FIELD PERSONNEL.
POLYCONIC PROJECTION
USDA-SCS LINCOLN, NEBR. 1977
1/321,288
SCALE 1 0 1 2 3 4 5 MILES
3-29-77
5.0-36,255


U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROCKY ARBOR STATE PARK
WISCONSIN DELLS
DUTCH HOLLOW LAKE
BARABOO
REDSTONE LAKE
LA VALLE
LAKE BLASS
LAKE DELTON
LAKE DELTON
MIRROR LAKE
WISCONSIN
RIVER
RIVER
IRONTON
REEDSBURG
MIRROR LAKE STATE PARK
RIVER
90°15'
43°30'
ROCK SPRINGS
BARABOO
LIME RIDGE
WEST BARABOO
BARABOO
NORTH FREEDOM
LOGANVILLE
SEELEY LAKE
DEVILS LAKE
DEVILS LAKE STATE PARK
N
MERRIMAC
WHITE MOUND COUNTY PARK
WHITE MOUND LAKE
NATURAL BRIDGE STATE PARK
FERRY
FREE AUTO FERRY ON STATE HIGHWAY 113
PRAIRE DU SAC
PLAIN
SAUK CITY
43°15'
89°45'
RIVER
BAKKENS POND
SPRING GREEN
LONG LAKE
MILL SLOUGH
WISCONSIN
LEGEND
PUBLIC BOAT LANDINGS
PICNIC AREAS AND WAYSIDES
9 HOLE GOLF COURSE
18 HOLE GOLF COURSE
PRIVATE AND PUBLIC CAMPGROUNDS
PUBLIC HUNTING AREAS
PUBLIC SWIMMING BEACHES
PRIVATE SWIMMING BEACHES
PUBLIC SWIMMING POOLS
CANOEING
SKIING (TWO IN COUNTY)
WISCONSIN
PUBLIC AND PRIVATE PARKS AND RECREATIONAL FACILITIES
SAUK COUNTY
SOIL AND WATER CONSERVATION DISTRICT
WISCONSIN
SOURCE:
SCS DRAWING 5.0-36,000,
AND SCS FIELD PERSONNEL.
POLYCONIC PROJECTION
USDA-SCS LINCOLN, NEBR. 1977
1/321,288
SCALE 1 0 1 2 3 4 5 MILES
3-23-77
5.0-36,254


U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WISCONSIN DELLS
DUTCH HOLLOW LAKE
BARABOO
REDSTONE LAKE
LA VALLE
LAKE DELTON
WISCONSIN
RIVER
IRONTON
REEDSBURG
ROCK SPRINGS
BARABOO
WEST BARABOO
NORTH FREEDOM
LIME RIDGE
LOGANVILLE
DEVILS LAKE
MERRIMAC
FERRY
PRAIRE DU SAC
SAUK CITY
PLAIN
SPRING GREEN
WISCONSIN
43°30'
43°15'
90°15'
89°45'
N
EXPLANATION
PROBABLE WELL YIELDS
DASHED WHERE APPROXIMATELY LOCATED
CHANCES OF MORE THAN 100 GALLONS PER MINUTE ARE POOR.
CHANCES OF 100-500 GALLONS PER MINUTE ARE GOOD.
CHANCES OF 500-1000 GALLONS PER MINUTE ARE GOOD
CHANCES OF MORE THAN 1000 GALLONS PER MINUTE ARE GOOD.
PROBABLE YIELDS ARE BASED PRIMARILY ON AQUIFER PERMEABILITY AND THICKNESS AS DETERMINED BY PUMPING TESTS AND WELL-LOG INTERPRETATIONS. SOME AREAS WERE MODIFIED BY INFORMATION FROM INDIVIDUAL WELL YIELDS, THICKNESS OF AQUIFER PENETRATION, AND PUBLISHED REPORTS.
LIMIT OF SANDSTONE AQUIFER
THE SANDSTONE AQUIFER INCLUDES ALL SATURATED ROCKS OF CAMBRIAN AND ORDOVICIAN AGE IN WISCONSIN, EXCEPT THE MAQUOKETA SHALE (WHICH YIELDS LITTLE WATER AND CONFINES THE SANDSTONE AQUIFER IN EASTERN WISCONSIN). THE AQUIFER UNDERLIES MORE THAN TWO-THIRDS OF THE STATE AND CONSISTS MOSTLY OF SANDSTONE AND DOLOMITE. IT IS SEVERAL HUNDRED FEET THICK THROUGHOUT MUCH OF ITS EXTENT; IN SOUTHEASTERN WISCONSIN, IT IS MORE THAN 1,500 FEET THICK.
PROBABLE YIELDS OF WELLS IN THE SANDSTONE AQUIFER
SAUK COUNTY
SOIL AND WATER CONSERVATION DISTRICT
WISCONSIN
SOURCE: SCS DRAWING 5.0-36,000 AND INFORMATION FROM 1975 USGS WISCONSIN WELL YIELDS MAP
POLYCONIC PROJECTION.
USDA-SCS LINCOLN, NEBR. 1977
1:321,288
SCALE 1 0 1 2 3 4 5 MILES
4-14-77
5.0-36,214

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE




# EXPLANATION

## PROBABLE WELL YIELDS

*DASHED WHERE APPROXIMATELY LOCATED*

- CHANCES OF MORE THAN 100 GALLONS PER MINUTE ARE POOR.
- CHANCES OF 100-500 GALLONS PER MINUTE ARE GOOD.
- CHANCES OF 500-1000 GALLONS PER MINUTE ARE GOOD.
- CHANCES OF MORE THAN 1000 GALLONS PER MINUTE ARE GOOD.

*PROBABLE YIELDS ARE BASED PRIMARILY ON AQUIFER PERMEABILITY AND THICKNESS AS DETERMINED BY PUMPING TESTS AND WELL-LOG INTERPRETATIONS. SOME AREAS WERE MODIFIED BY INFORMATION FROM INDIVIDUAL WELL YIELDS, THICKNESS OF AQUIFER PENETRATION, AND PUBLISHED REPORTS.*

## LIMIT OF SAND-AND-GRAVEL AQUIFER

*DASHED WHERE APPROXIMATELY LOCATED*

*THE SAND-AND-GRAVEL AQUIFER INCLUDES ALL SATURATED PERMEABLE GLACIAL MATERIAL AND SOME RECENT ALLUVIUM OVERLYING WISCONSINS BEDROCK. IT UNDERLIES MORE THAN THREE-FOURTHS OF WISCONSIN AND IS ESSENTIALLY THE ONLY SOURCE OF GROUND WATER IN THE NORTH CENTRAL ONE THIRD OF THE STATE. THE AQUIFER OCCURS AT THE LAND SURFACE OR BURIED BENEATH LESS PERMEABLE MATERIALS. IT IS COMMONLY LESS THAN 100 FEET THICK BUT IS LOCALLY THICKER THAN 300 FEET. ABOUT ONE FOURTH OF WISCONSINS MUNICIPALITIES OBTAIN THEIR WATER SUPPLY FROM THIS AQUIFER.*


# PROBABLE YIELDS OF WELLS IN THE SAND-AND-GRAVEL AQUIFER

## SAUK COUNTY

### SOIL AND WATER CONSERVATION DISTRICT

### WISCONSIN

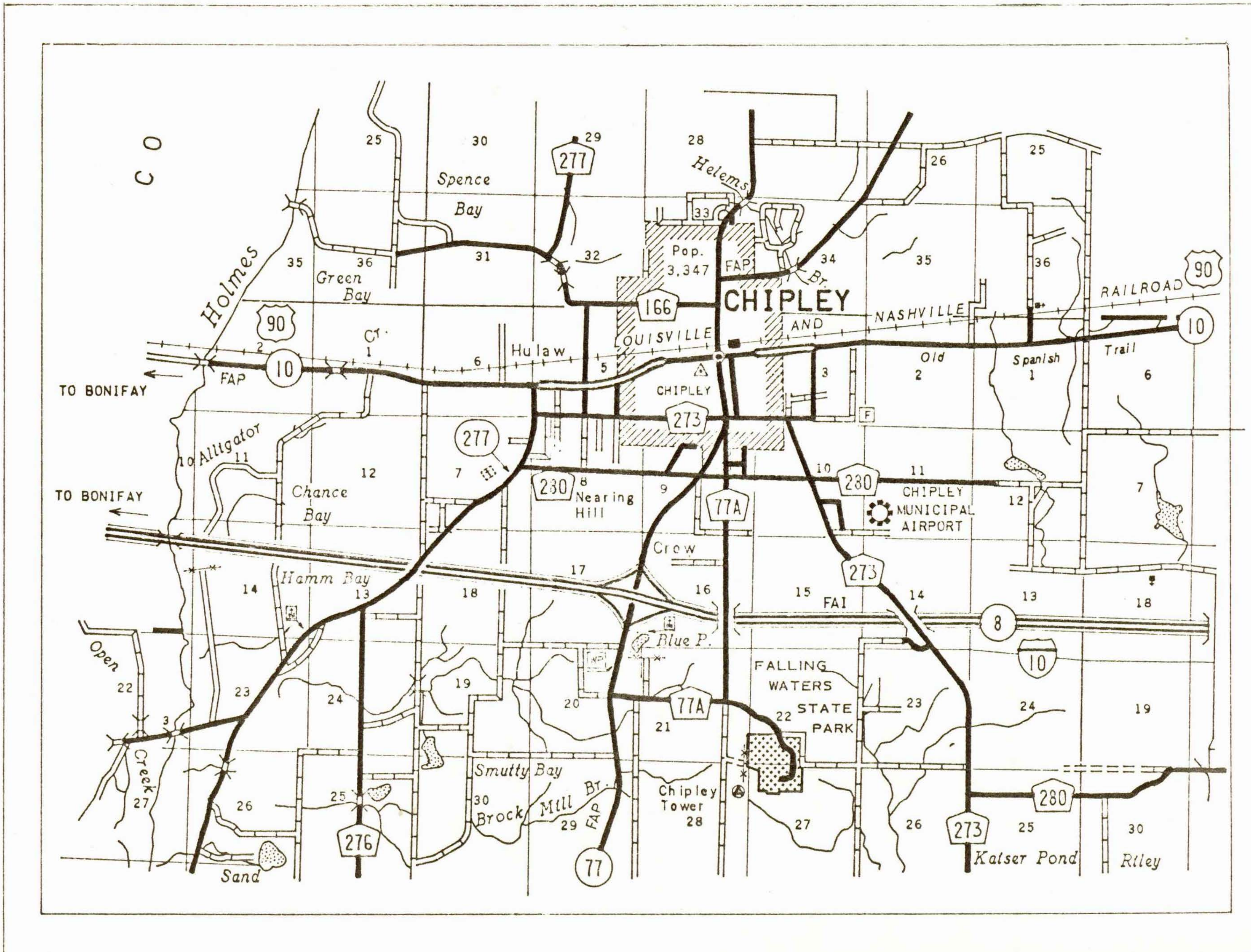
SOURCE:
SCS DRAWING 5.0-36,000 AND INFORMATION FROM 1975 USGS WISCONSIN WELL YIELDS MAP.
POLYCONIC PROJECTION.

USDA-SCS LINCOLN, NEBR. 1977

1/321,288

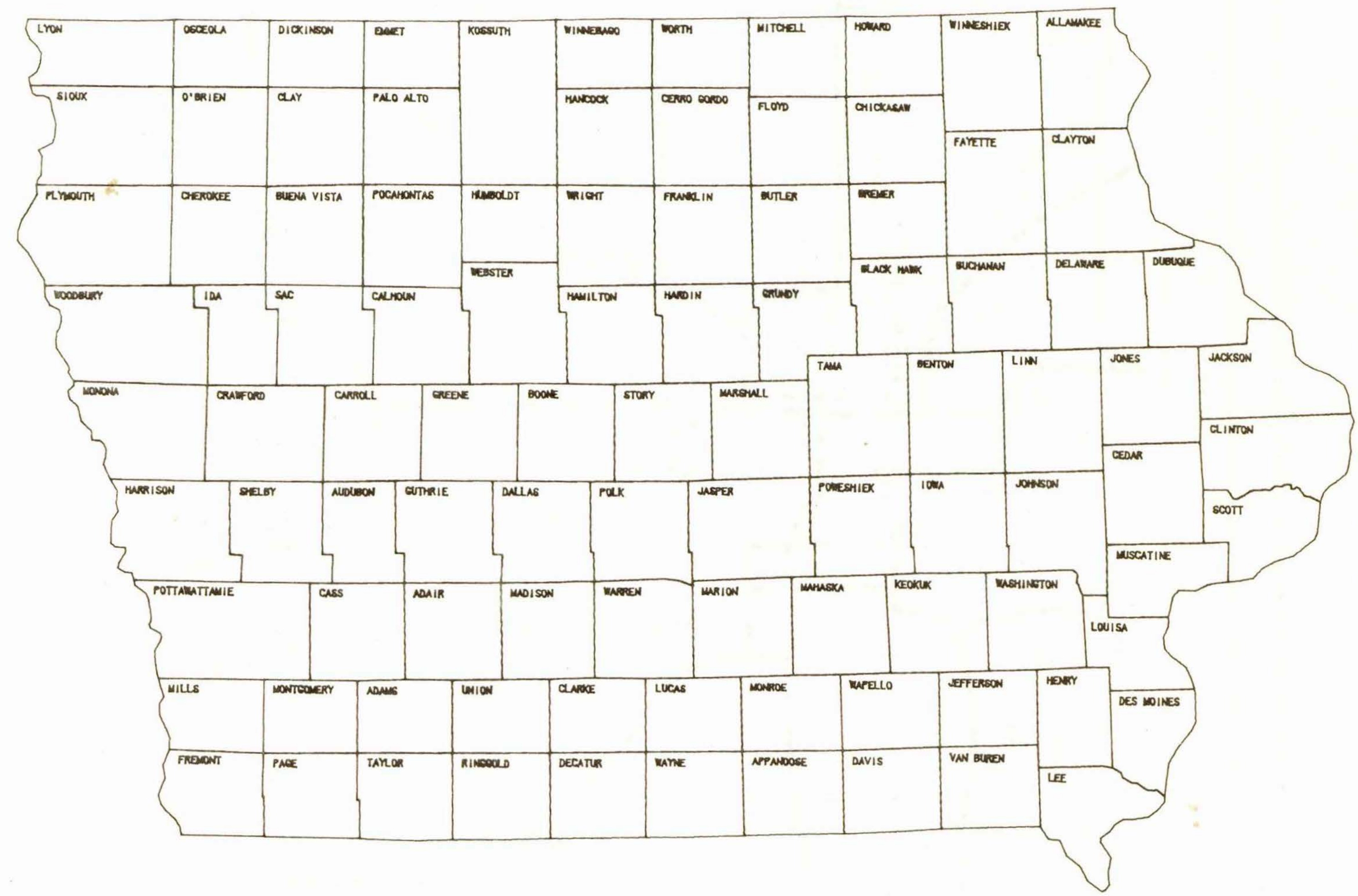
SCALE 1 0 1 2 3 4 5 MILES

4-14-77
5.0-36,215



CO
Holmes
TO BONIFAY
TO BONIFAY
Spence
Bay
Green
Bay
Hulaw
Helems
Pop.
3,347
CHIPLEY
LOUISVILLE
AND
NASHVILLE
RAILROAD
FAP
Br.
Cr.
Old
Spanish
Trail
CHIPLEY
Alligator
Chance
Bay
Nearing
Hill
Crow
CHIPLEY
MUNICIPAL
AIRPORT
Hamm Bay
FAI
Blue P.
Open
Creek
FALLING
WATERS
STATE
PARK
Smutty Bay
Brock Mill Br.
FAP
Chipley
Tower
Sand
Kaiser Pond
Riley
277
166
90
10
273
280
77A
8
10
276
77

# IOWA COUNTIES



# Glossary Of Terms Not Defined In Text

**accuracy** - the degree to which a measurement is known to approximate a given value.

**algorithm** - a step by step procedure which stops.

**centroid** - the mean position of a polygon determined by the X and Y means of the polygon points.

**choropleth mapping** - maps composed of shaded zones where zones with a common value or value range have the same shade or color.

**compatibility** - the ability of two objects to match at the point(s) where they join.

**electrostatic plotter** - a plotter which uses vector-to-raster conversion and rolls the paper out in one direction, putting very tiny dots on it to form lines and characters.

**geodetic coordinates** - exact coordinates on the earth based on its actual shape. Expressed in latitude-longitude.

**hard copy unit** - a device attached to graphic displays and CRT displays which chemically produces a (dry silver) picture of what is on the display.

**hardware** - all the devices and components of a computer.

**latitude** - a number in the geodetic coordinate pair denoting the angle in degrees between a point, the center of the earth and the nearest point on the equator. Example: the North Pole is 90 degrees north.

**longitude** - a number in the geodetic coordinate pair denoting an angle in degrees east or west in terms of an east-west circle running through a point which is divided into 360 degrees. Example: Ames is 94 degrees west.

**LUDA** - Land Use Data Analysis, a federal program of providing satellite data.

**micrographics** - graphics in reduced forms such as microfilm and microfiche.

**planimetric** - maps attempting to show geography without respect to elevation, therefore planar.

**raster scan** - a technique for generating or recording an image with an intensity controlled, line-by-line sweep across the entire display surface. Televisions use this method.

**rectification** - taking the "tilt" out of photograph when it wasn't taken perpendicular to a surface.

**repeatibility** - the ability to accurately repeat coordinates when a point is digitized twice or plotted twice.

**resolution** - a measure of the ability of a device to differentiate values. Example: a plotter may have a resolution of .001 inch.

**software** - all the programs (instructions) running on a computer.

**thematic** - maps showing structure of a distribution such as populations, average rainfall, graph production, etc. Maps used in spatial analysis.

**topographic** - maps attempting to show all geography including elevations by using contour lines.

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# Keyword Definition Index

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