Technical Memorandum 83941

GEOGRAPHIC INFORMATION SYSTEMS AT THE GODDARD SPACE FLIGHT CENTER

Michael Goldberg

MAY 1982

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

TM 83941

GEOGRAPHIC INFORMATION SYSTEMS

AT THE

GODDARD SPACE FLIGHT CENTER

Michael Goldberg

Information Management Branch

May 1982

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

PRECEDING PAGE BLANK NOT FILMED

ABSTRACT

This document describes the basic functions of a Geographic Information System (GIS) and the different ways that a GIS may be implemented. It surveys the GIS software packages that are currently in operation at the Goddard Space Flight Center and discusses the types of applications for which they are best suited. Future plans for in-house GIS research and development are outlined.

CONTENTS

ILLUSTRATIONS

ACRONYMS

ASAP	Advanced Scientific Array Processor
DBMS	Data Base Management System
DEC	Digital Equipment Corporation
ERDAS	Earth Resources Data Analysis System
ERRSAC	Eastern Regional Remote Sensing Applications Center
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GRID/PIOS	GRID/Polygon Information Overlay System
GSFC	Goddard Space Flight Center
HP	Hewlett Packard
IBM	International Business Machines
IDIMS	Interactive Digital Image Manipulation System
M.A.P.	Map Analysis Package
MAUDE	Mobile Analysis and User Demonstration Experiment
NASA	National Aeronautics and Space Administration
SACC	Science and Applications Computing Center

ACKNOWLEDGEMENTS

The author acknowledges Mr. William J. Campbell, Dr. Philip J. Cressy, Ms. Mary G. Reph, and Dr. Paul H. Smith for their technical advice and editorial comments. The author also thanks Mr. Malcolm J. Tarlton for his graphics and Miss Pamela C. Bowling for yet another typing tour de force.

1. INTRODUCTION

The purpose of this report is to introduce the reader to Geographic Information System (GIS) technology and to survey the GIS software that is available to users at the Goddard Space Flight Center (GSFC).

A Geographic Information System is a set of procedures and computer programs that supports the acquisition, storage, manipulation, and display of spatially referenced data. A GIS is not a type of Data Base Management System (DBMS). In a DBMS, the data base consists of groups of records which can be thought of as being "cross-referenced" with one another. In a GIS, the data base consists of files which are independent and are catalogued only by the file management system of the computer where they reside. In fact, since GIS's evolved from techniques which geographers, cartographers, demographers, and natural resource managers invented for the automated handling of two-dimensional "map" data, they are more closely akin to image processing systems than they are to DBMS's.

Applications of Geographic Information Systems range from transmission line siting and wildlife habitat monitoring to suburban growth management and ski resort design. At the Goddard Space Flight Center, GIS applications typically involve the use of remotely-sensed satellite data in combination with data from other sources. Current or planned projects include a nuclear power plant siting study using Landsat and Thematic Mapper Simulator data, a program to employ Thematic Mapper data in hydrological modeling, and a research effort to examine the efficiency of computerized land-use classification techniques using data from the Multispectral Linear Array.

This report takes the point of view that a Geographic Information System is a tool which can be applied to a variety of spatial data processing problems. It will describe the basic functions of a GIS and the different ways that a GIS may be implemented. Then it will survey the GIS software packages that are currently in operation at Goddard and discuss the types of applications for which they are best suited. Finally, it will outline future plans for in-house GIS research and development.

2. THE BASIC FUNCTIONS OF A GEOGRAPHIC INFORMATION SYSTEM

A Geographic Information System has four basic functions: acquisition, storage, manipulation, and display.

2.1 DATA ACQUISITION

Nagy and Wagle[1] identify three sources of data for Geographic Information Systems: tabular data, such as are found in crop reports and census surveys; pictorial information, such as photographs and maps; and digital remotely-sensed data. Tabular data will not be discussed in this report, since they are essentially already in computer readable "alphanumeric" form.

Pictorial data are most commonly entered into a GIS by means of a digitizer. A digitizer consists of a "tablet" and a "head." The tablet is a table in which a fine wire mesh is embedded. The head is typically a glass-mounted crosshairs. A photograph or map is affixed to the tablet and the head is manually moved about over its surface, tracing points, curves, or area boundaries. When a button on the crosshair assembly is pushed, the head's position is electromagnetically sensed by the wire mesh and transmitted to a computer storage medium, such as tape or disk. To the computer, the digitizer's output is a list of coordinates.

Another common way for pictorial data to be entered into a GIS is through "manual encoding." A picture is subdivided into equal sized squares and a human interpreter assigns each square a number based upon its contents. Later, an operator types the numbers on keypunch cards or at a terminal and they are ingested into a computer. There they are stored as a two-dimensional array.

Sometimes, pictorial information is entered into a GIS automatically by using an "optical scanner." One type of optical scanner scans an area line by line (a "raster scanner") and another simulates manual digitizing (a "curve follower"). To a computer, a raster scanner's output is a two-dimensional array of numbers, while a curve follower's output resembles that of a digitizer.

Satellite remote-sensing is a second major source of data for Geographic Information Systems. Satellites employ sensors such as multispectral scanners and return-beam vidicons to scan the Earth's surface. The analog radiance measurements from these sensors are converted to digital form either by the satellite or by ground receiving stations. Geometric and radiometric corrections are then performed (on the ground) and the resultant data are stored on magnetic tape in the form of a "scene" made up of "scan lines." Often, digital remotely-sensed data undergo further processing, involving pattern recognition or "classification" techniques, before they are input into GIS's.

Data acquisition is typically the most time-consuming, error-prone, and costly element of geographic information processing. From a human point of view, manual digitization is a tedious process requiring great patience and precision. From an institutional point of view, it is difficult to keep account of the large volumes of multi-source information which GIS applications often require. Finally, from a computer point of view, those spatial processing algorithms which ingest data sets, convert them into a common format, and register them to a uniform base map may be highly complex and are often hardware-dependent.

2.2 DATA STORAGE

The two major approaches for storing georeferenced data correspond to the two major sources of those data. Polygon structure reflects the format of the data produced by digitizers. Grid structure matches the format of remotely-sensed digital data.

In polygon structure, there are three entities: points, lines, and regions. Points, which might represent isolated features on a map such as fire stations or historic sites, are stored as single coordinates. Lines, which represent features such as roads and rivers, are stored as a chain of coordinates. Regions, like counties or lakes, are stored in a chain of coordinates which encloses an area. Each of these three entities is usually preceded in computer storage by a "header" record which identifies it as a point, line, or region and which contains an associated thematic value. Polygon structure uses computer storage efficiently and inherently contains information about the topological relationships between regions, but it is generally difficult to write computer programs for editing and manipulating data stored in this format.

In grid structure, an area is simply stored as a two-dimensional array of numbers. Each number corresponds to a cell of uniform size. It is easy to write manipulative software for almost any application using this structure, but for spatially sparse data sets grid structure uses computer storage inefficiently (Reference 1). Also, grid structure is not as accurate as polygon structure for delineating region boundaries.

Sometimes, two or more grid-formatted pictures which have been spatially registered are placed in the same physical file in computer storage. These "multivariable files" or "multiband images" are often structured in "interleaved" format. In this format, cells which relate to the same geographic location, but which are from different sources, are stored adjacent to one another on tape or disk. Satellite data from multispectral scanners are transmitted in interleaved format to ground receiving stations and therefore are often stored in this format. Variants of interleaved format include "band-interleaved-by-pixel" and "band-interleaved-by-line."

2.3 DATA MANIPULATION

Manipulative operations on spatial data may be classified into four groups: reclassification functions, overlay functions, distance functions, and neighborhood functions. In this discussion, which is based upon Tomlin and Berry[2], outputs of the four types of functions are termed "maps." These maps are assumed to be stored in grid structure. A "category" is defined as a thematic value associated with a set of points, lines, and/or regions in a plane.

Reclassification functions create a new map by reassigning the categories of an existing map. Figure 1a. shows an example of a reclassification function. The DRYLAND map was created by combining the "forest" and "field" categories from the COVERTYPE map. Note that the reclassification was based upon <u>value</u>. That is, every cell on the COVERTYPE map which had the value for "forest" or "field" was assigned a new value corresponding to "land." Other types of reclassification functions reassign categories based on the <u>position</u> of cells within a map or based upon the <u>size</u> or <u>shape</u> of aggregations of cells.

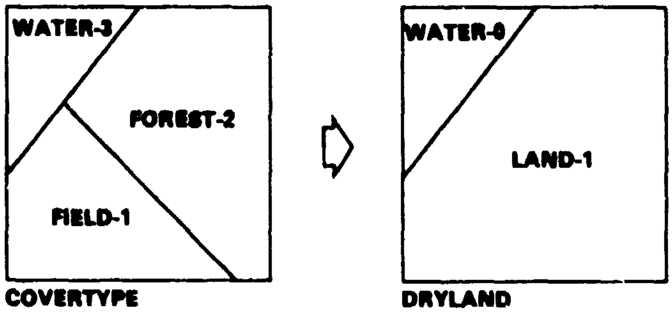


Figure 1a. A Reclassification Function

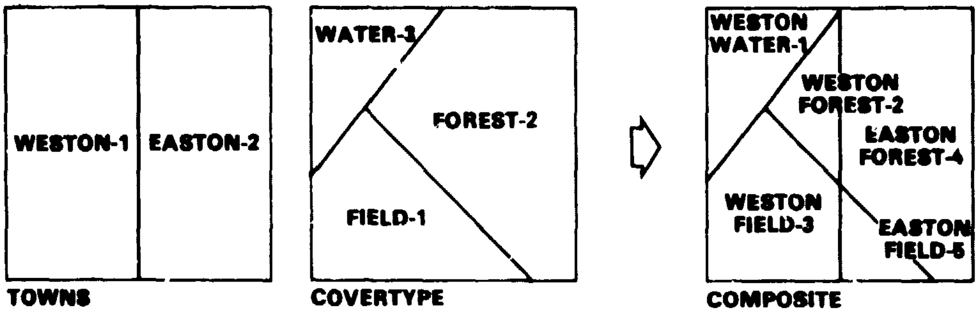


Figure 1b. An Overlay Function

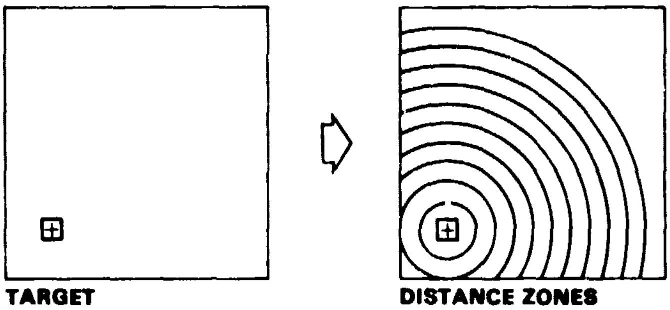


Figure 1c. A Distance Function

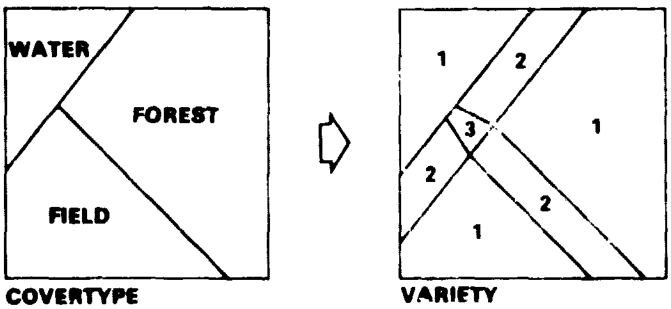


Figure 1d. A Neighborhood Function

Figure 1. Examples of GIS Manipulation Functions
(Courtesy of School of Forestry and Environmental Studies, Yale University)

Overlay functions define a new map based on the inter-relationship of two or more existing maps. In the example of Figure 1b., the COMPOSITE map was created by considering the joint occurrences of towns and land cover types. Note that the value of a given cell of the COMPOSITE map is a function of the values which occur for the cells at the same location on the TOWNS and COVERTYPE maps.

Distance functions define a new map as a function of the distance between points on an existing map. In Figure 1c., the value of each point on the DISTANCE ZONES map indicates the Euclidean ("as the crow flies") distance between that point and the target. Euclidean distances, however, are not suitable for certain applications. For example, the shortest driving distance between two cities depends upon the existence and configuration of roads. To handle problems of this sort, some distance functions have been developed which take account of generalized "barriers."

Neighborhood functions create a new map based on the aggregated characteristic of neighboring points within an existing map. For example, the VARIETY map in Figure 1d. shows the number of different kinds of cover types which occur within a specified distance of each point on the COVERTYPE map. Other common neighborhood functions compute the category which occurs most often within a neighborhood or the number of occurrences of a given category within a neighborhood.

Reclassification, overlay, distance, and neighborhood functions are usually combined to perform "cartographic modeling" on sets of related maps. Cartographic modeling is the basis of most applications of geographic information systems.

2.4 DATA DISPLAY

In most applications of Geographic Information Systems, the final product consists of one or more maps. These maps can be displayed in a variety of ways. Natural resource decision-makers may want to view them during an interactive computer session so that environmental trade-offs can be studied. Cartographers, on the other hand, may be more interested in examining precision, standard scale, hardcopy products.

Display devices differ from one another in resolution, operating mode, operating speed, cost, transportability, and other factors. In general, they can be classified according to how the data that they display are stored.

Line plotters and vector-display devices are used for displaying information stored in polygon format. Line plotters draw pictures composed of numerous straight-line segments. The lines are drawn by ink pens on paper or synthetic material. Large, high-quality plots can be produced, but it can take hours to make a single map. Vector display cathode-ray tubes also draw pictures composed of straight-line segments, and, therefore, they are often used interactively. Coupled with hardcopy units, they can quickly produce relatively small maps of relatively low resolution (Reference 1).

Video displays, color film recorders, matrix plotters, and line printers are used for displaying information stored in grid format. Video displays produce a television-like picture, often with 512 x 512 addressable points. These devices are typically used interactively to produce color images. Hardcopy color products can be produced photographically by using a color film recorder. Matrix plotters produce black and white maps using techniques similar to those employed by electrostatic copiers and, therefore, have approximately the same resolution. An advantage of matrix plotters is their relatively low cost. Line printers, such as are found at most computer facilities, can also display gridded data. They are often used as the prime output device for transportable GIS software packages.

3. IMPLEMENTATION OF GEOGRAPHIC INFORMATION SYSTEMS

This section describes different ways of implementing Geographic Information Systems that satisfy the needs of users. For each of the basic GIS functions (acquisition, storage, manipulation, and display) it identifies some of the more important factors to be considered by the designer of a new GIS or an organization wishing to purchase an existing GIS.

3.1 ACQUISITION FUNCTION IMPLEMENTATION

As stated in section 2.1, data acquisition is probably the most time-consuming, error-prone, and costly element of geographic data processing. Therefore, the input data requirements of users should be examined especially carefully. The sources of the input data determine the basic hardware and software that are needed for acquisition. Pictorial information requires the use of a digitizer or optical scanner and the associated special-purpose computer programs, while remotely-sensed data must often be preprocessed by pattern recognition and geometric registration software. The volume of input data and the speed at which they must be ingested often determine the degree to which acquisition is automated. For example, a hydrologist doing research on a single watershed might be satisfied with manual digitization using batch mode editing, while a cartographic shop providing operational support to a nationwide soil survey might need automated raster scanners.

A common way of implementing GIS data acquisition is for manual digitization (occasionally with interactive editing) to be performed using a digitizer tablet attached to a special purpose minicomputer or microcomputer. Digitized pictures in polygon format are then transmitted to a larger computer where they are converted into grid format for ease of manipulation. An important design choice in systems with this configuration is whether or not they permit automated "polygon overlay." Polygon overlay is a software function which creates a new map in polygon format by determining the areas of intersection of overlapping polygons from two separately digitized maps. It is very useful for merging multisource data.

3.2 STORAGE FUNCTION IMPLEMENTATION

Geocoded data, like other data types, are most often stored on magnetic tape or random-access disk. Microcomputer systems usually store data on floppy disks. The volume of data to be stored, the speed at which the data must be accessed, and the storage cost per unit of data determine the particular configuration. Because of the enormous volume, remotely-sensed data are usually stored in a tape archive. Some systems have automated tape archives which allow a user to identify a file by its name only; the user doesn't have to remember the serial number of the tape reel on which the data are stored.

Data storage in Geographic Information Systems does not in general resemble data storage in Data Base Management Systems. Maps in grid format are not cross-referenced with one another as they would be in a DBMS. Instead, they exist as separate, unrelated files. Polygon-formatted files can be thought of as containing hierarchical data, such as which "island" polygons are contained within other polygons, but rarely if ever has a method been implemented that allows users to perform retrievals or updates based upon this information. However, in some GIS's the names of the maps and some other ancillary information about the data bank are stored in a file which the user may list. Most users would probably desire this capability.

3.3 MANIPULATION FUNCTION IMPLEMENTATION

Since cartographic modeling is the basis of most applications of Geographic Information Systems, and these applications vary greatly, there are more design choices for implementing data manipulation capabilities than there are for any of the other three GIS components.

The designer must first decide what manipulative functions to implement. A hydrologist studying changes in river courses might want a variety of overlay functions, but no neighborhood functions, while an engineer trying to locate a suitable site for a power plant might be primarily interested in neighborhood and distance functions. It is probably good practice to have at least one of each type of function on any research-oriented GIS, because the mere existence of a new spatial processing capability often inspires a fresh approach to the subject matter.

The second major design factor is the model of computer on which the manipulative functions are to reside. This often depends upon the size of the maps to be processed and the number of people having access to the GIS functions at a given time. For example, multiple users cannot presently process full Landsat scenes in a reasonable amount of time on a microcomputer.

Another major implementation factor is the communication between the user and the computer programs. In a batch environment, the user prepares the control information needed for running a function and then submits it to the computer. The job is placed in a queue for processing at a later time. In an interactive environment, the user's control information is immediately used by the computer to execute the function (often on a timesharing basis) while the user waits. The term "user-friendly" describes interactive systems in which the user does not have to supply computer-dependent information, such as format statements and device names. A person usually communicates with a user-friendly system by responding to computer prompts or through the use of an English-like command language.

A number of other design considerations are important to certain users. Those who use remote sensing as a data source may want access to image processing functions. Those who wish to implement a GIS on two or more different computers may be interested in a system with transportable software. (Note than even the most transportable software usually requires different communications protocols for interfacing with different hardware devices.) Others will want a GIS that has been implemented (and tested!) on the particular model of computer to which they already have access. Finally, experienced purchasers of software systems of all kinds usually insist on software that is maintained by the vendor.

3.4 DISPLAY FUNCTION IMPLEMENTATION

Devices for displaying spatial data were described in section 2.4. Interactive devices, such as vector display cathode-ray tubes and video displays, are generally used in interactive mode in conjunction with manipulative functions to allow the user to see immediately the result of his or her actions. Hardcopy devices, such as line plotters and line printers, can be used in either batch or interactive systems, but they don't supply the rapid feedback that some interactive applications need. Several interactive systems produce a line printer type of plot at the user terminal.

4. GEOGRAPHIC INFORMATION SYSTEMS AT GODDARD

Four Geographic Information Systems are currently available to users at the Goddard Space Flight Center. This section will describe the characteristics of each and discuss the applications for which they may be best suited. Figures 2 through 5 summarize the four systems. Figures 6 through 10 are sample output products from the four systems.

4.1 GRID/PIOS

"GRID/PIOS" stands for "GRID/Polygon Information Overlay System." This GIS is a product of the Environmental Systems Research Institute (ESRI) of Redlands, California. As its name implies, GRID/PIOS can perform polygon overlay as well as standard manipulative functions on grid-formatted maps. Goddard has two versions of GRID/PIOS, one on the IBM computers at the Science and Applications Computing Center (SACC), Code 603, and one on the Hewlett-Packard 3000 (HP-3000) at the Eastern Regional Remote Sensing Applications Center (ERRSAC), Code 902.1. Data are usually input to the system using a digitizer attached to a Digital Equipment Corporation (DEC) PDP-11/03 microcomputer. Digitized files in polygon format are transmitted to either the IBM computers or the HP-3000 where they are edited in batch mode. Once a map has been digitized with no errors (based on manual comparisons between the source map and line plots of the digitized file), a polygon-to-grid conversion program is run. The user may also encode grid-formatted files manually. Data in grid format are stored either as single maps ("single variable files") or multiple maps in band-interleaved-by-pixel format ("multivariable files"). GRID/PIOS emphasizes neighborhood functions for topographic analysis (such as slope and aspect determination), but also provides at least one of the other three kinds of manipulative function. These functions are executed in batch mode. A user-interface program, called GRID COMMAND, is available for creating control files interactively, but using it requires such an intimate knowledge of ESRI's documentation that it cannot be termed "user-friendly." Grid-formatted data can be displayed on a line printer, a matrix plotter, or a color film recorder. Polygon-formatted data can be displayed on a line plotter or on a matrix plotter (if the data are converted by a special plotting package).

GRID/PIOS is a widely used system which has been implemented on a number of different computers. It is suitable for a variety of applications, especially those where polygon overlay is desired. Because it has few user-friendly features, however, effective operation requires a person who has a working knowledge of computers and who has become familiar with ESRI's highly complex user documentation. It should also be noted that numerous software bugs have been detected by users. Taking these considerations into account, GRID/PIOS is probably best suited for research applications which do not require interactive analysis and in which the analyst has computer experience and time to read and understand the documentation.

4.2 M.A.P.

The Map Analysis Package (M.A.P.) was written at the Yale University School of Forestry and Environmental Studies. Goddard's version of M.A.P. resides on the IBM computers at SACC. M.A.P. processes grid-formatted data exclusively, and these data are usually encoded manually by the user. Manual encoding is not as much a drawback as it may seem, because the maps which this system normally stores consist of only about 50 x 50 cells. M.A.P. features an English-like command language and a very wide variety of manipulative functions. There are six reclassification functions, eleven overlay functions, three distance functions, and seven neighborhood functions. M.A.P. also provides file management and display functions, including a function which lists the names of the user's maps along with other ancillary information. All M.A.P. processes can function interactively. Maps are usually displayed as printer-plots at the user terminal.

M.A.P. was designed as a teaching tool. Because it functions interactively and has a command language which can be mastered quickly even by someone with no computer experience, M.A.P. is ideal for the training courses which are conducted at ERRSAC.

ORIGINAL PAGE IS
OF POOR QUALITY

4.3 ERDAS 400

ERDAS 400 was designed by Earth Resources Data Analysis Systems, Incorporated, of Atlanta, Georgia. ERDAS 400 is a microcomputer-based system with both geographic data processing and image processing capabilities. It is implemented on a Cromemco Z2, with a Z80 central processor. At GSFC, data (in grid format and often remotely-sensed) are input to ERDAS 400 over a phone line from another computer, such as ERRSAC's HP-3000, where the data were originally stored. The vendor also claims that this sytem can be interfaced with a digitizer, but GSFC's implementation of ERDAS 400 does not include a digitizer. Data are stored on a floppy disk, tape cassette or 16-megabyte hard disk. ERDAS 400 has a reclassification function, an overlay function, and a distance function, but no neighborhood function. (The source code for these functions was originally part of Harvard University's "Imgrid" GIS.) ERDAS 400 can also perform a wide range of image processing functions, including coordinate transformation, supervised and unsupervised classification, and image filtering. It is a single-user system. The user executes all functions interactively, selecting the desired control information from a menu displayed on a video terminal. Output data can be displayed on a color video display or a matrix printer.

ERDAS 400 can merge remotely-sensed data with data from other sources and provide user-friendly manipulation and display capabilities. It is the only GIS in existence today which combines these functions in a low cost microcomputer environment. As such, it was chosen for "MAUDE," the Mobile Analysis and User Demonstration Experiment, a modified van which ERRSAC personnel drive to state and local government offices to demonstrate applications of remote sensing and Geographic Information Systems. ERDAS 400 is a prototype of the kind of low cost GIS/Image Processing System that state and local governments (as well as businesses) may apply to their immediate and future needs.

4.4 IDIMS/GIS

IDIMS/GIS consists of five computer programs which provide the Interactive Digital Image Manipulation System (IDIMS) with a GIS capability.

IDIMS (a product of the Electromagnetic Systems Laboratories of Sunnyvale, California) is a comprehensive image processing system which runs on the HP-3000 minicomputer at ERRSAC. It features nearly 150 functions for ingesting, managing, manipulating, and displaying images of a wide variety of types and formats. It has an interactive digitizing system and special purpose functions for inputting remotely-sensed data. Data storage is managed by an automated tape archival system. IDIMS is a multiple-user system, and users communicate with it either through a command language or by choosing options from a menu. Certain time-consuming functions have been implemented on the Advanced Scientific Array Processor (ASAP), which is a vector processor linked to the HP-3000. The ASAP can increase program execution speed by a factor of five to ten. IDIMS displays images by using a vector display device (for digitizing), color video screen, matrix plotter, or color film recorder. Cameras are often used to produce hardcopy output.

IDIMS/GIS was developed by the author of this Technical Memorandum. It consists of a reclassification function, an overlay function, a distance function, and a neighborhood function. These functions are all written in standard IDIMS application function form, which means that they can be executed through the use of the command language or in menu mode. IDIMS/GIS also has a utility function for cartographic modeling, which allows the user to put together a combination of the four other functions into a single "macro" that can be executed as though it were a unique function. The cartographic modeling utility is a version of an existing IDIMS utility with minor cosmetic changes.

IDIMS/GIS can accommodate multiple users processing large (Landsat-sized) data sets. As such, it is at present the most popular GIS at GSFC for major projects such as the NASA/Corps of Engineers project in hydrological modeling and the NASA/Nuclear Regulatory Commission power plant siting study.

5. FUTURE PLANS

Research and development in the field of Geographic Information Systems need to be conducted in order to address a number of problem areas and to keep pace with the growing variety of new projects involving advanced sensor systems.

GIS research at the Goddard Space Flight Center will focus on the problems of merging multisource geocoded data, storing these data efficiently, and keeping track of the large volumes of data that many applications require. Merging geocoded data requires that data from different sources be registered to a common base map and converted into a common format and spatial resolution. Research in this area will center on investigating methodologies (such as ESRI's "integrated terrain unit mapping") which permit data merging to be performed consistently. Research into data storage will be more theoretical. The advantages and disadvantages of polygon and grid formats will be weighed, and other storage strategies (such as tree structures and linked allocation of arrays) will be studied. The problem of keeping track of large volumes of data will be addressed by investigating how GIS and data base technology may be used cooperatively.

GIS development at GSFC will concentrate on using the knowledge obtained from GIS research to enhance the capabilities of the existing software systems. This will include the addition of new manipulative functions and the creation of software interfaces between GIS's and systems such as the Pilot Climate Data Base Management System and the Landsat Assessment System.

GRID/PIOS = GRID/POLYGON INFORMATION OVERLAY SYSTEM

INPUT: BATCH DIGITIZING WITH POLYGON OVERLAY

STORAGE: GRID OR POLYGON

MANIPULATION: AT LEAST ONE OF EACH TYPE OF FUNCTION,
EMPHASIS ON TOPOGRAPHIC ANALYSIS, BATCH MODE,
COMPLEX DOCUMENTATION, MANY BUGS

DISPLAY: LINE PRINTER, MATRIX PLOTTER, COLOR FILM RECORDER,
LINE PLOTTER

Figure 2. GRID/PIOS Summarized

M.A.P. = MAP ANALYSIS PACKAGE

INPUT: HAND ENCODING OF SMALL MAPS

STORAGE: GRID ONLY, DATA BANK CONTENTS CAN BE LISTED

MANIPULATION: MANY FUNCTIONS, INTERACTIVE, ENGLISH-LIKE COMMAND LANGUAGE

DISPLAY: USER TERMINAL

Figure 3. M.A.P. Summarized

ERDAS 400 = EARTH RESOURCES DATA ANALYSIS SYTEM 400

INPUT: AT PRESENT, PHONE LINE FROM ANOTHER COMPUTER

STORAGE: AT PRESENT, GRID ONLY (ON FLOPPY DISK)

MANIPULATION: NO NEIGHBORHOOD FUNCTION, INTERACTIVE (MENU MODE), HAS IMAGE PROCESSING

DISPLAY: COLOR VIDEO, MATRIX PLOTTER

Figure 4. ERDAS 400 Summarized

IDIMS/GIS = INTERACTIVE DIGITAL IMAGE MANIPULATION SYSTEM/
GEOGRAPHIC INFORMATION SYSTEM

INPUT: INTERACTIVE DIGITIZER, SPECIAL INGEST SOFTWARE

STORAGE: GRID OR POLYGON, CAN LIST USER'S CATALOG, HAS AUTOMATED TAPE ARCHIVE

MANIPULATION: EXTENSIVE IMAGE PROCESSING, INTERACTIVE (MENU MODE OR USER LANGUAGE)

DISPLAY: COLOR VIDEO, MATRIX PLOTTER, PHOTO PRODUCTS

Figure 5. IDIMS/GIS Summarized

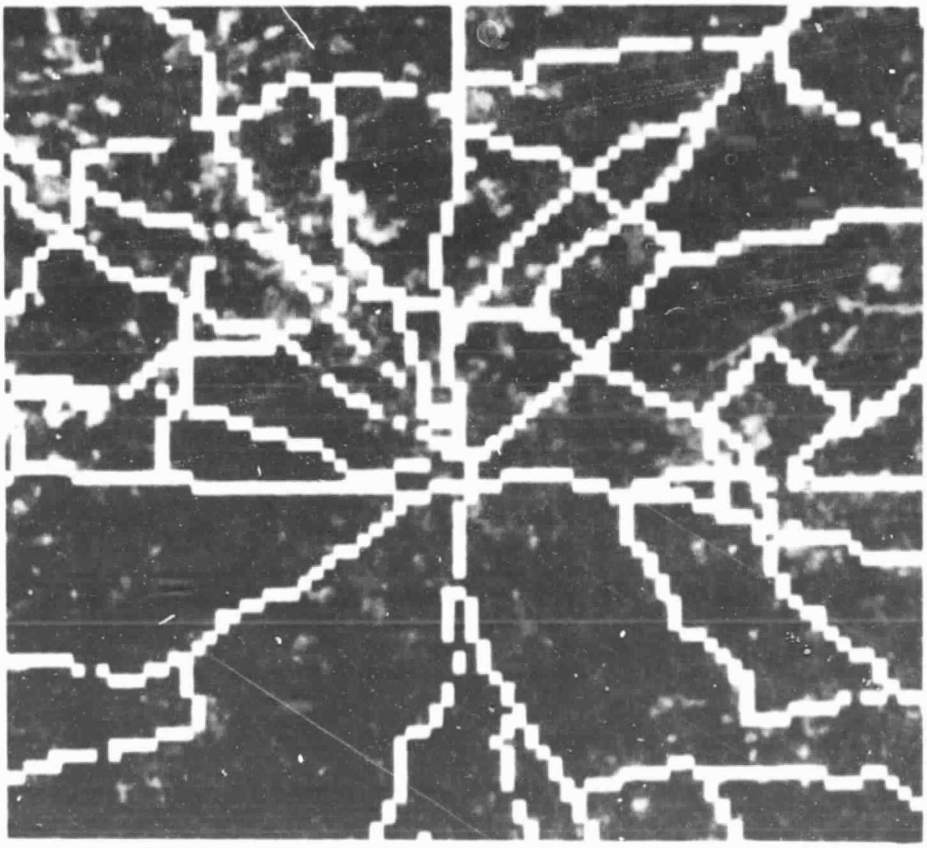


Figure 6. Highways Overlayed on Landsat Imagery. To create this image, highways were digitized from a road map, converted into grid format, registered to a Landsat image, and overlayed. Digitization and conversion were performed by GRID/PIOS. Registration and overlay were performed by IDIMS/GIS. The area shown is Lancaster, Pennsylvania.

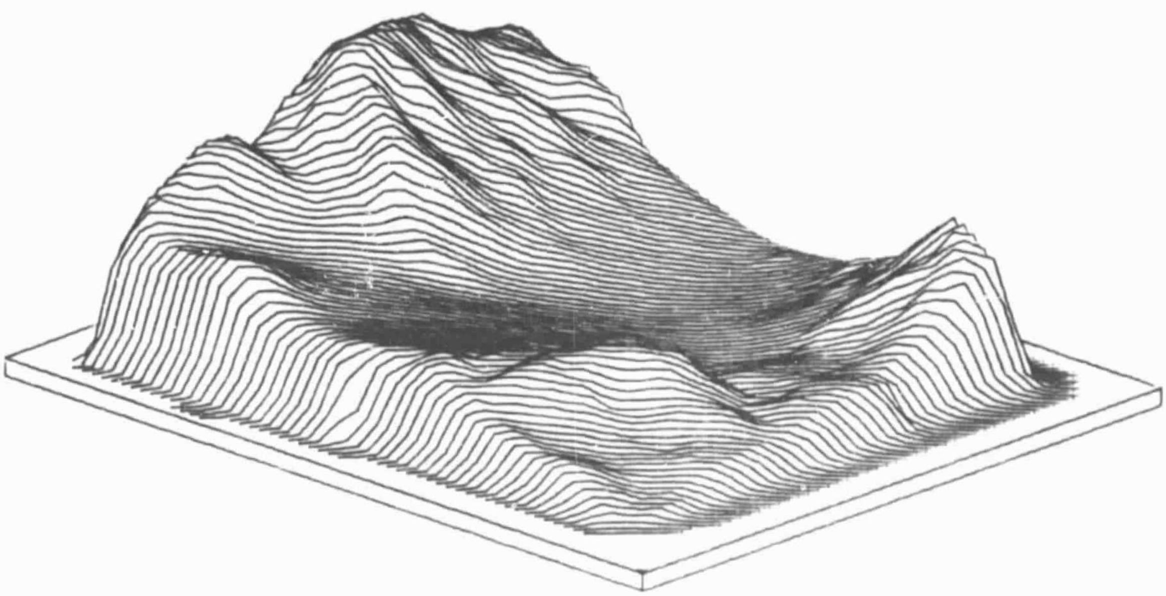
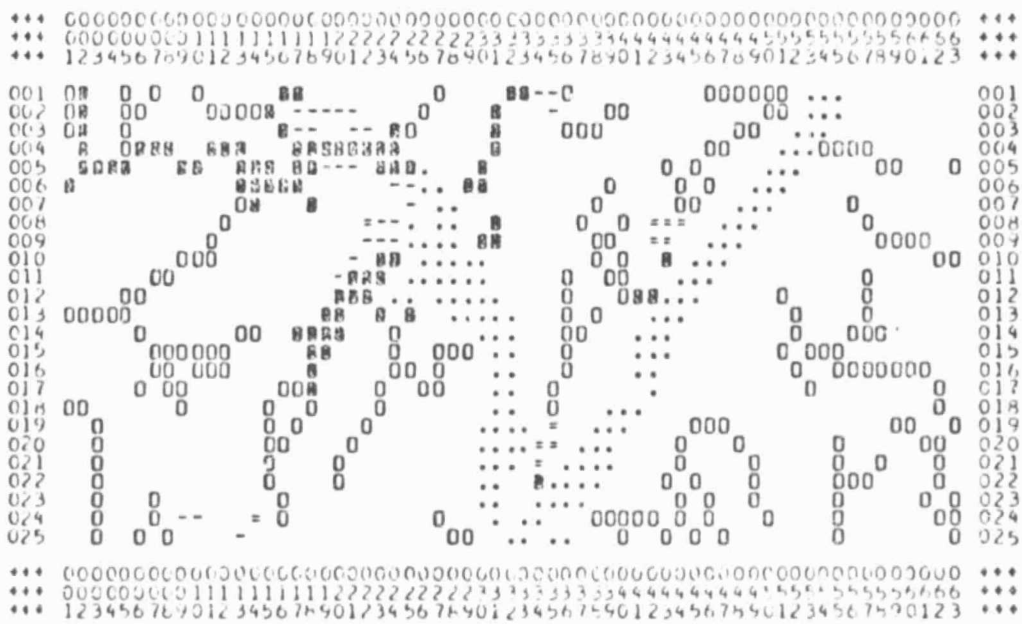


Figure 7. Perspective View of Elevation Data. A CALCOMP line plotter was used to draw this three dimensional projection. The GRID/PIOS VIEWS program translated the topographic data stored in grid format into plotter commands.



WATER

	0	DRY LAND	1095 CELLS	69.5% COVERAGE
----------	1	MARSH	28 CELLS	1.8% COVERAGE
==========	2	POND OR LAKE	11 CELLS	0.7% COVERAGE
0000000000	3	CREEK	224 CELLS	14.2% COVERAGE
8888888888	4	STREAM	80 CELLS	5.1% COVERAGE
....	5	RIVER	137 CELLS	8.7% COVERAGE

Figure 8. A Sample M.A.P. Output Map. M.A.P. produces printer plots at the user terminal. Overprinting can be used to create varying shades of grey.

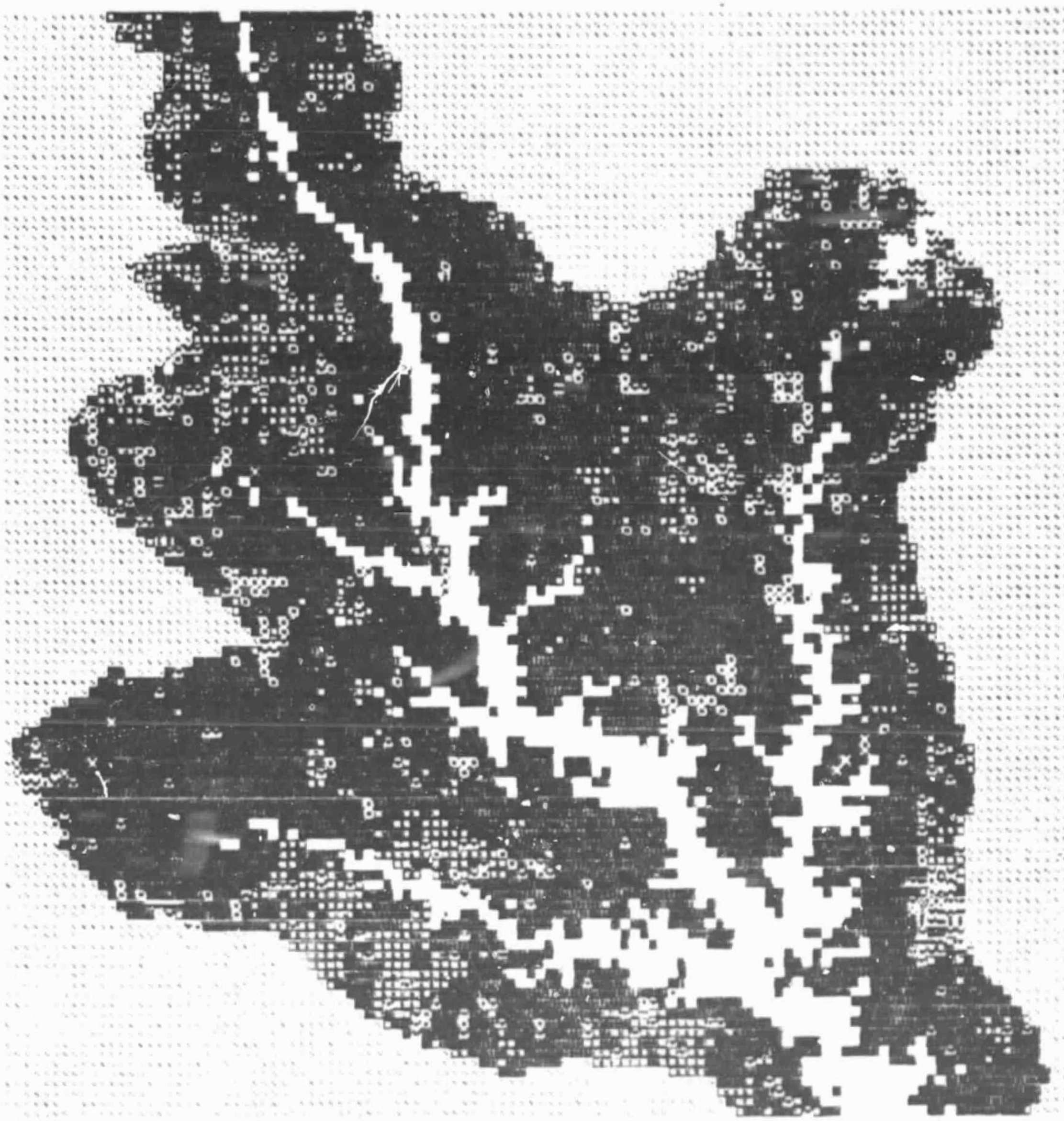


Figure 9. Dot Matrix Printer Watershed Map. Matrix printers can produce detailed imagery relatively inexpensively. This map was generated by ERDAS 400.

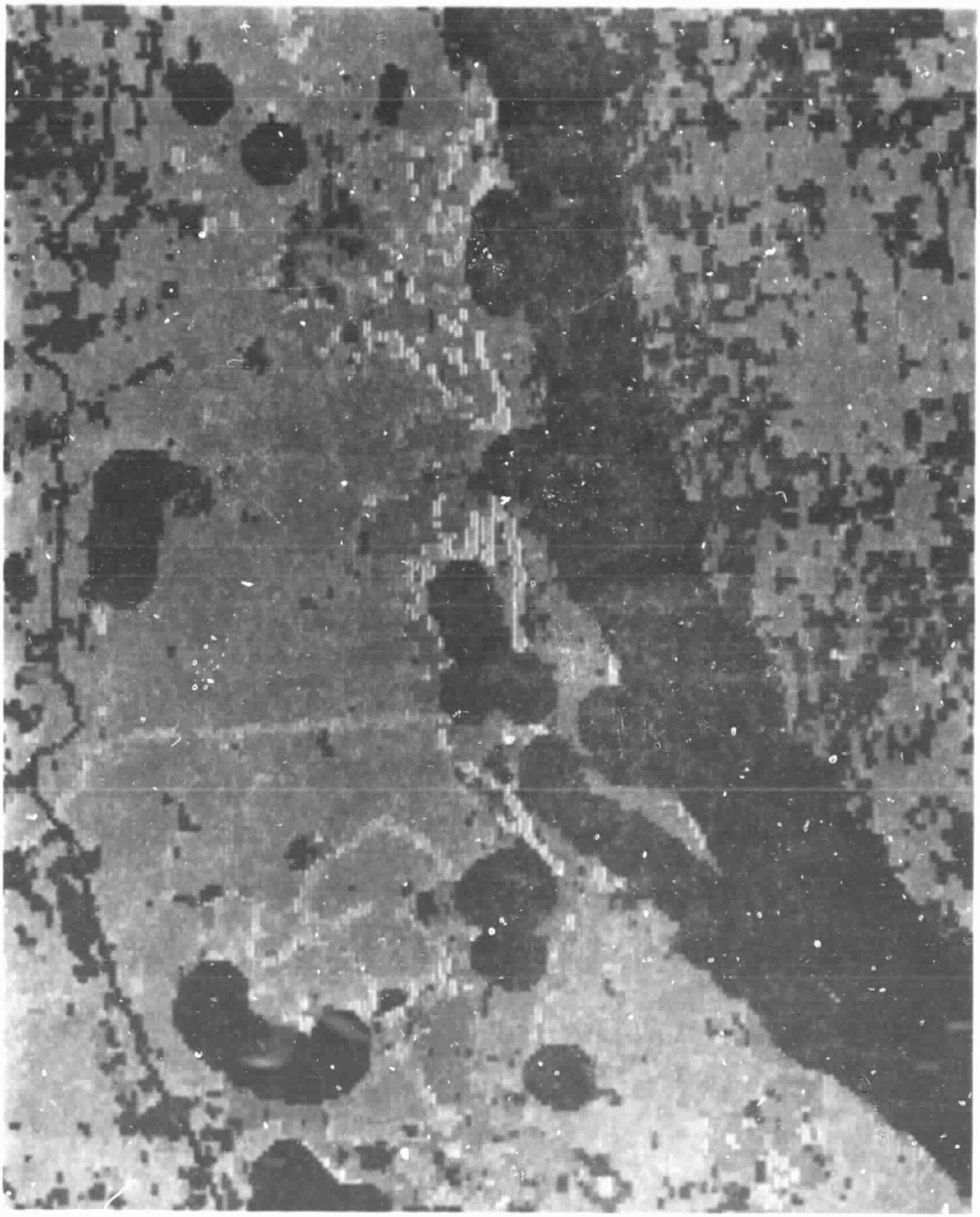


Figure 10. Five-Cell Distance Search from Water. Areas within 300 meters (5 cells) of the nearest water were masked in this map created by IDIMS/GIS. The area shown is the Mississippi River just north of St. Louis.

REFERENCES

1. G. Nagy and S. G. Wagle. "Geographic Data Processing." ACM Computing Surveys. Vol. 11, No. 2. 1979.

2. C. D. Tomlin and J. K. Berry. "A Mathematical Structure for Cartographic Modeling in Environmental Analysis." Proceedings of the American Congress on Surveying and Mapping, 39th Annual Meeting. March 1979. pp. 269-284.