GEOGRAPHIC INFORMATION SYSTEMS: A REVIEW

SPECIAL REPORT 517

ENVIRONMENTAL IMPACT ASSESSMENT PROJECT

Oregon State University Extension Service

GEOGRAPHIC INFORMATION SYSTEMS: A REVIEW

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ENVIRONMENTAL IMPACT ASSESSMENT PROJECT

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as part of
"ENVIRONMENTAL IMPACT ASSESSMENT:
A FRAMEWORK FOR LOCAL PARTICIPATION AND DECISION-MAKING"

Oregon State University Extension Service
Corvallis, Oregon 97331

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Project Director

PREFACE

This report is one of several reports prepared by the Environmental Impact Assessment Project, Oregon State University Extension Service. This report is part of a study entitled "Environmental Impact Assessment: A Framework for Local Decision-Making" funded by the U.S. Department of Agriculture, Extension Service, Washington, D.C.

The objectives of the study are:

1. To improve the quality of environmental impact statement content;
2. To coordinate and streamline the environmental impact statement process;
3. To assist local communities, counties, and state agencies to comply with the letter and intent of environmental legislation; and
4. To contribute toward integrating impact assessment with land use planning goals.

The overall study is under the direction of Dr. James R. Pease, project director and land resource management specialist, OSU Extension Service. This report was written by Kris Brooks, research assistant, and James R. Pease.

Other reports prepared during this study are:

1. Environmental Assessment Manual and Form
2. Environmental Assessment Resource Handbook
3. Environmental Impact Education Program: Leader's Materials (Includes a slide-tape program entitled "The Role of Impact Statements in Public Decisions")
4. Final Report: Analysis and Evaluation

Information regarding these reports may be obtained from James R. Pease, Land Resource Management Specialist, Oregon State University Extension Service, Department of Geography, Corvallis, Oregon 97331, or Lawrence Heffner, USDA Extension Service, Room 5503 South Building, Washington, D.C. 20250.

We appreciate the assistance given us by Robert Keith, Bureau of Governmental Research and Services, University of Oregon, and Ralph Shay, Assistant Dean of Research, Oregon State University, in providing research materials. We are grateful to the individual staff members who reviewed and commented on the profiles included in the report. Our special thanks to Evy Wesley for her patient typing of several drafts and her assistance in the format.

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CHARACTERISTICS OF GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system is a computerized system designed to store, process, and analyze spatial data. Geographic information systems have been used for a variety of purposes, including land use inventories, environmental impact studies, forest management, water resources management, agricultural surveys, and socio-economic studies. In many respects, geographic information systems are similar to other automated information systems in that they involve:

1. data collection
2. transformation of the data into machine readable form
3. editing and updating of the data files
4. storage of the data
5. computer analysis or manipulation of the data
6. retrieval of entire files or selected portions of one or several files
7. generation of a variety of output including maps, charts, and statistical reports.

The most significant difference between a geographic information system and other information systems is in the spatial or geographic nature of the data. The data must be geo-referenced; that is, it is tied to locations on the surface of the earth.

DATA COLLECTION

Data for geographic information systems can be gathered from a variety of sources: maps, aerial photographs, field surveys, assessor's records, census tapes, etc. Geographic data can be divided into two basic classes: quantitative data and qualitative data. Quantitative data includes the geographic location, size, and shape of a unit of data, while qualitative data refers to the characteristics or attributes of the unit, such as land use codes, soil types, and demographic categories. One physical unit of data may have one or several attributes to describe it. The geographic location of a unit of data can be represented by an x y coordinate or georeferencing system.

Geo-referencing Systems

Four major geo-referencing systems have been used in geographic information systems, including: Universal Transverse Mercator (UTM), State Plane Coordinates, latitude and longitude coordinates, and land survey systems, i.e. U.S. Township and Range Survey. Each system has its advantages and disadvantages. UTM is used throughout the world, but the distortion of the projection near the poles creates calculation problems near the zone edges. The state plane coordinate systems use a combination of Mercator and Lambert projections to minimize distortions within a state, but the coordinates differ for each state, making calculations across state boundaries difficult. Latitude and longitude coordinates are potentially the most accurate and the most easily transformed, but they must be manipulated with spherical coordinates and distance calculations are difficult. U.S. Township and Range coordinates have been widely used in field surveys and resource records and, consequently, would be useful in systems utilizing this information; however, the survey pattern is irregular in certain areas making distance calculations difficult. The choice of a particular geo-referencing system depends upon the user's requirements and objectives and the data sources. A number of coordinate conversion subroutines have been developed by the U.S. Geological Survey, making it possible to use several geo-referencing systems within a geographic information system.

Data Accuracy

Data accuracy can be measured in terms of its validity and its resolution. Validity refers to the correctness or quality of the data and is largely dependent upon the quality of the data collection and editing procedures. The degree of validity depends upon the requirements of the system's users. A land registration system containing data for legal and tax purposes would require a higher degree of validity than a regional land use planning inventory containing aggregate land use classes. The degree of validity required will have an effect on the expense of the data collection phase of the system. Data resolution refers to the smallest data unit which can be identified and relates primarily to the scale of the data entered into the system. The resolution level required depends upon the requirements of the system's users. If several agencies use the same system, data must be entered at the largest scale or in the greatest detail necessary for the most demanding user. It is possible to aggregate data after it is entered into the system. However, data cannot be enlarged in scale and still retain accuracy. The resolution level required will have an effect upon the data transformation process and upon the storage requirements of the system as well as the data collection process.

Data Conversion

Once data has been collected, it must be converted into machine readable form for input into the system. Quantitative data is digitized, manually or automatically, according to the geocoding method utilized by the system.

Data Entry

Digitization is the process by which quantitative or spatial data is converted into machine readable form so that it can be stored and processed by the computer. Each geographic location or point on the map is identified by an xy distance relative to a predetermined point called the origin. Digitizing can be done by an operator, manually or with an electromechanical digitizer, or automatically, by an automatic line following digitizer or a scanning device.

Electromechanical digitizers are the most commonly used devices. The digitizer consists of a flat table with an internal xy matrix and a cursor. The cursor registers its xy position on the digitizing table through electrical sensors. Once a map is placed on the digitizing table and a point of origin is established, the cursor is used to trace an area of interest. When the cursor is centered over a point which is to be recorded, the operator pushes the "record" button on the cursor and the coordinates of that point are coded on key punch cards or magnetic tape or whatever recording medium is being used.

Automatic line following digitizers operate very much like an electromagnetic digitizer. The ALF traces the lines by sensing the contrast between the line and the background material. Scanning devices automatically convert the printed material into machine readable form by sensing the different intensities of reflected light. Both types of devices represent state of the art advances, but they are not at present technically or economically applicable to most operational situations.

GEOCODING METHODS

The geocoding method (point, line, grid, parcel, or polygon) is the dominating aspect of a system and provides the basis for classifying geographic information systems. The geocoding method influences the way data is collected, the resolution and validity of the data, the structure of the data base and storage requirements, the types of analyses which can be performed, and the types of products which can be produced.

Point and Line Systems

Point systems (Figure 1) are used to identify the location of features and activities which have no areal extent, i.e., waterfalls, wells, crimes, accidents, and fires. Points are usually identified by a single xy coordinate of a grid system.

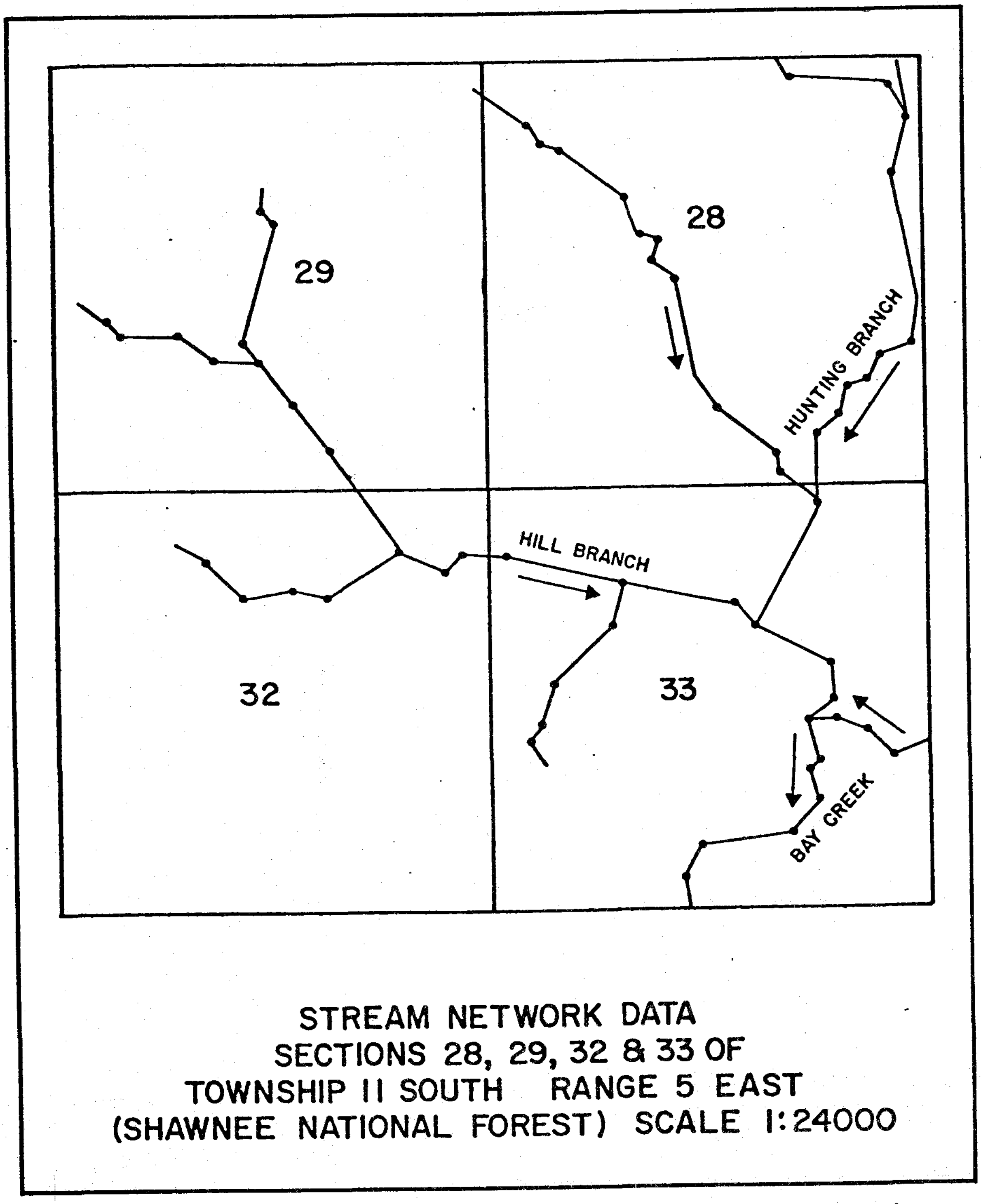
Line or network systems (Figure 2) are useful for linear data like streams, railroads, etc. The network segments are described by the xy point locations of the beginning and ending nodes of each line segment.

Figure 1: Point System

Geothermal springs in the Rocky Mountain states.

Source: E. R. Hill. Interactive Graphics Analytical Tool for Geoprocessing Richland, WA: Battelle Pacific Northwest Laboratories, 1975.

Figure 2: Line or Network System



Source: IRIS Illinois Resource Information System. Feasibility Study. Final Report. Urbana, IL: Center for Advanced Computation, University of Illinois, 1972.

Uniform Grid Systems

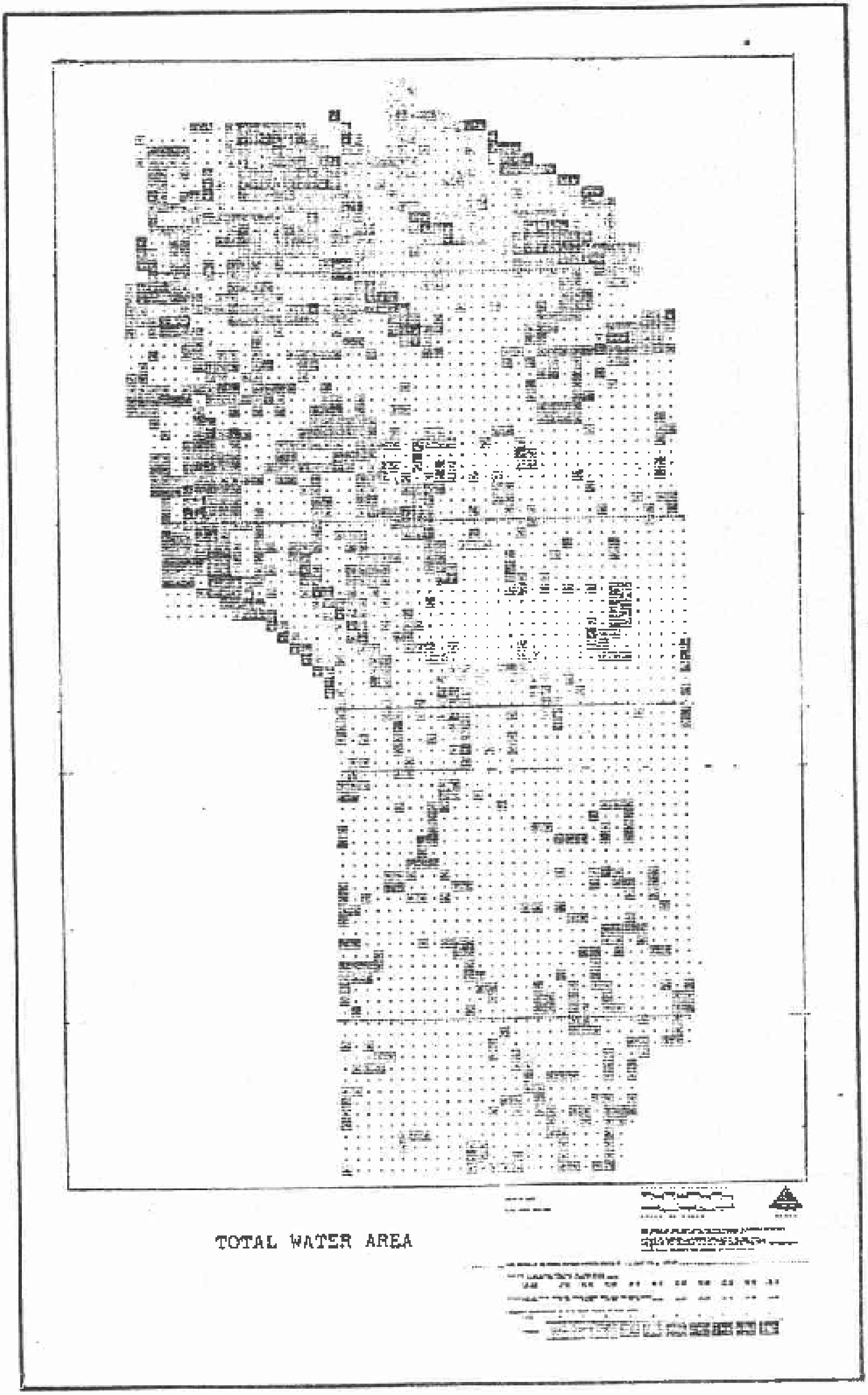
In the grid system (Figure 3) a uniform grid is superimposed over the study area and the attributes of each grid cell are entered into the system. The grid coordinates may relate to one of the referencing systems previously described or to an arbitrary xy matrix. Depending on the system used, it may be possible to enter one or several attributes or weighted values for each grid cell, but each cell can usually only represent one class for each attribute, i.e., one soil class, one species of tree, etc.

The resolution of the data in the system is a function of the grid cell size. If a high level of resolution is required, the grid cell size will be small. Conversely, if resolution requirements are not high, then it is possible to use a larger grid cell.

The grid system has a number of advantages. The system is relatively easy to develop compared to polygon systems because the grid structure corresponds to a conventional xy matrix and can be written in a number of programming languages and handled by a variety of computers. Digitization (see glossary) of coordinates of the cell is not necessary. Gridded overlays can be performed easily and efficiently without the difficulties of overlaying problem (slivering) experienced by polygon overlay programs.

Grid systems also have a number of disadvantages. Many political or resource boundaries do not conform to grid cells and, consequently, must be approximated. When only one class of an attribute is assigned to a grid cell, important information may be lost. If a particular cell contains 60% Douglas Fir and 40% Western Hemlock, the data for Western Hemlock may be lost. Even when both are coded, the exact location of the Douglas Fir and the Western Hemlock are not known. If one class covers a number of cells, the grid storage would be higher than that required by a polygon system because each grid cell must be coded. If each cell must be separately coded, the grid encoding process may be very time consuming when coding resource classes which cover a number of grid cells.

Figure 3: Uniform Grid System



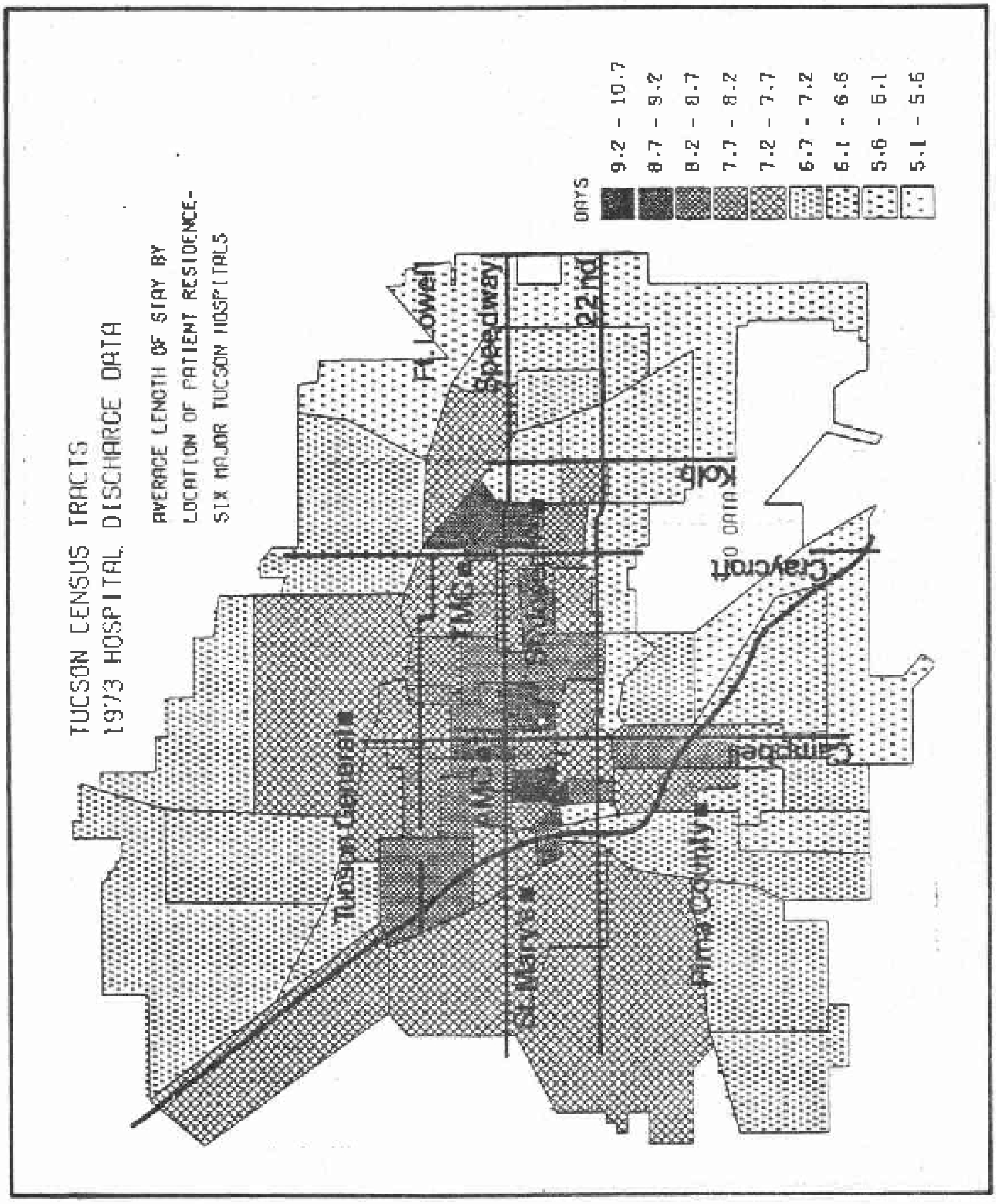
Source: New York State Land Use and Natural Resource Inventory Report. Ithaca, N.Y.: Center for Aerial Photographic Studies, Cornell University, 1968.

Parcel Systems

Parcel systems (Figure 4) permit the collection of data within naturally defined or politically defined cells, rather than uniform cells. Parcel referencing schemes include census tracts, township and range land survey, and political subdivisions. The parcel record may or may not include xy coordinates for the physical location of the parcel. Often, the record will include the attribute values and a geo-locator to provide access to a reference map. The geo-location may be a zipcode, township and range division, or an arbitrary number. The system was designed for users who were primarily interested in retrieving, aggregating, and tabulating data. Maps can be produced from the system, but it is usually necessary to digitize the parcel boundaries.

Parcel systems share some of the advantages and disadvantages of grid systems. Parcel systems are relatively easy to develop and file overlays can be done simply and efficiently. Parcel attributes, like grid cell attributes, cannot be broken down into finer detail than the original parcel input. Unlike grid cells, parcel boundaries correspond to natural or political boundaries which preserve some of the geographic realtionships. Most data, particularly resource data, is collected by parcel referencing schemes and consequently can be easily entered into a parcel system without any loss of accuracy or detail.

Figure 4: Parcel System



Source: U.S. Bureau of the Census. GBF/DIME System. A Geographic Dimension for Decisionmaking. Report GE 60, No. 7. Washington, D.C. GPO, 1976.

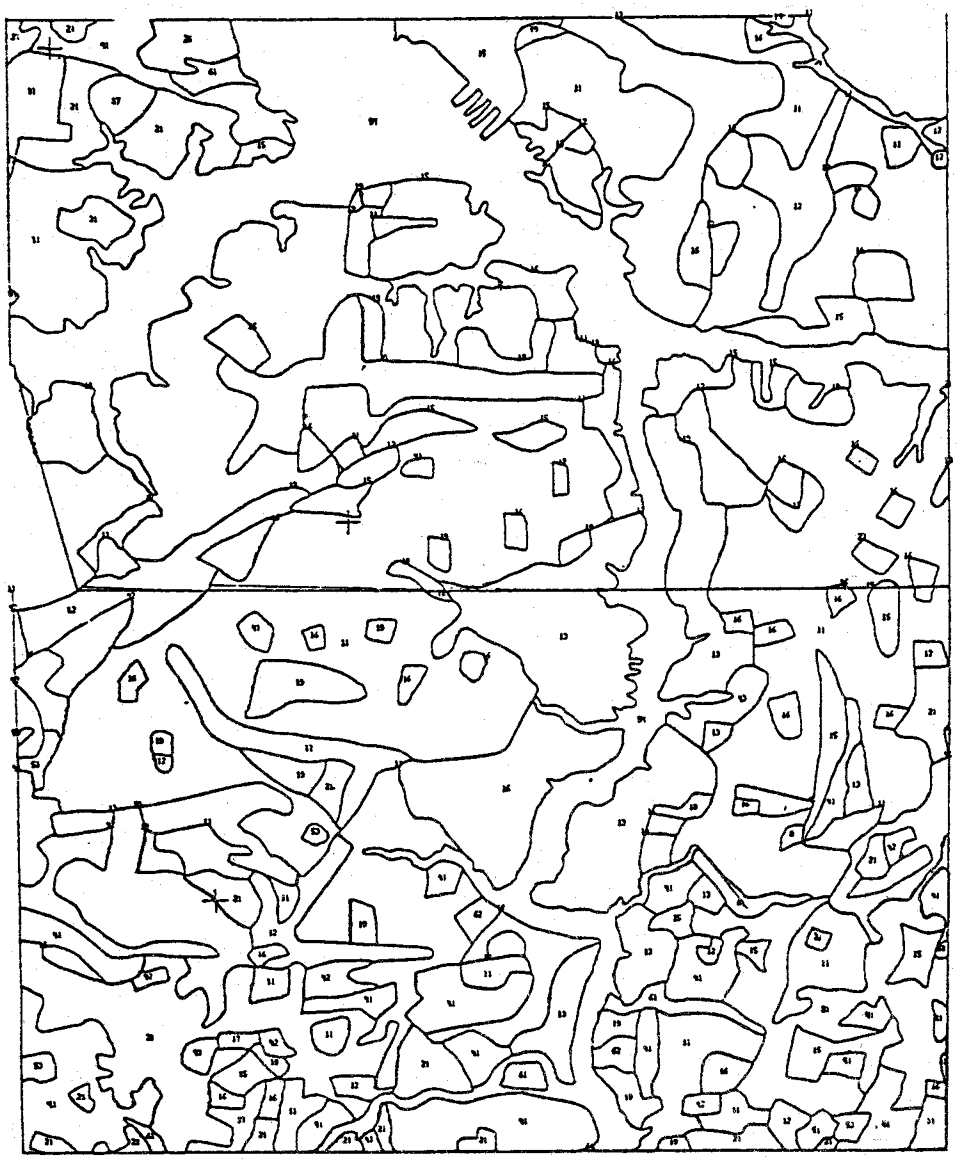
Polygon Systems

The principal difference between parcel systems and polygon systems is that data in a parcel system is stored separately from the maps whereas data in a polygon system is stored with its geographic locations.

Polygon systems (Figure 5) provide the most accurate representation of spatial data. The boundary of any geographic feature can be digitized and entered into the system regardless of the shape or the extent of the feature. Consequently, data can be entered initially at the finest resolution possible.

Polygon systems can be divided into two categories based upon the initial encoding process and the storage of the data: true polygon systems and area boundary systems. The boundary of each polygon in a true polygon file is digitized and stored as one record. Consequently, the boundaries of adjacent polygons are digitized twice. On the other hand, boundaries of an area boundary file are only digitized once, with modifiers indicating which polygon is to the left and to the right of the line segment. Each line segment is digitized only once, and the polygons are constructed by the computer after the file has been coded. Area boundary systems can take advantage of automatic line following digitizers and optional scanning devices.

Figure 5: Polygon System



PIOS plot of land use polygons.

Source: R. F. Tomlinson, H. W. Calkins, and D. F. Marble. Computer Handling of Geographical Data. Natural Resources Research Report No. 13. Paris: UNESCO Press, 1976.

EDITING AND UPDATING FILES

Geographic data can be classified by its persistence. Certain types of data, such as geologic features and soil classification are fairly stable, and, once entered accurately, can be left unchanged for long periods of time. Other types of data, such as demographic or employment data, change rapidly and must be updated frequently. The frequency of data updating should be considered in the design phase of the system, so that it will meet the requirements of the system's users.

Editing, like data entry, can be done in a batch mode or an interactive mode. Batch processing is usually far less expensive than interactive processing, but interactive processing allows changes in data to be immediately displayed so that further corrections can be made. Interactive data entry and editing requires more on-line computer storage than batch systems since interactive processing requires direct access to data files. Therefore, the data entry/updating method chosen will have an impact upon the system's hardware and software requirements.

DATA STORAGE

Data can be stored on a number of devices. It can be stored externally on key punch cards, paper tape, magnetic tape or disk, or it can be stored internally in the memory of the computer. Internal storage is quite expensive and is not normally used for data which is not in immediate use. External devices vary in storage costs, longevity, and ease of access. One of the greatest barriers to the development of statewide polygon systems has been the data storage requirements of such a system. Calkins (1976) has estimated that a high resolution encoding of all of the data contained in a U.S.G.S. 7.5 minute quadrangle would generate 38 line inches of data per square inch of the quadrangle. Although storage problems of this magnitude have not yet been solved, a number of software and technological developments have been made in methods of handling and storing data.

COMPUTER DATA ANALYSIS AND RETRIEVAL

The computer analysis of data is the primary function of a geographic information system and the characteristic which distinguishes a geographic information system from a computer mapping system. Application programs may retrieve, summarize, or tabulate data, develop mathematical models, or generate new data files by mathematically overlaying two existing data files.

Grid overlay is a very simple process as mentioned previously. Theoretically polygon systems would appear to be the most appropriate for data manipulation and analysis. Practically, however, the procedures for using polygon overlays are very complex and the computer processing is time consuming. Secondly, polygon overlays can generate finer distinctions than is justified by the data. Sliver polygons produced by the overlay of polygons with similar geographic extent may be significant; they may also be the result of imprecise boundary determination. Some polygon systems have been modified to deal with some of these problems. For example, PIOS II uses a polygon to grid overlay program in which parcels are digitized as polygons, converted to grid cells for overlay purposes and reconverted to polygons for map output. In this manner, the system is able to utilize some of the advantages of both polygon and grid systems.

Examples of some of the analyses which can be performed by geographic information systems will be presented in the descriptions of several operational geographic information systems.

SYSTEM OUTPUT

A variety of output products in a variety of formats can be generated from a geographic information system. Tabular reports, statistical models, graphs, charts, and maps can be generated. Output can be produced on line printers, drum and flatbed plotters, electrostatic plotters, cathode ray tube (CRT) graphic terminals, and computer output microfiche (COM).

The line printer is a high speed device used for printing maps as well as reports. Line printer maps are not as cartographically pleasing as plotted maps, but they are usually inexpensive to reproduce and can be satisfactory for displaying generalized data.

Drum and flatbed plotters operate in a similar manner to the digitizer. The plotter has a drawing arm instead of a cursor and draws lines rather than tracing them. Plotters may use felt tip pens, ball point pens, ink pens, or scribing tools. Sophisticated plotters have several pens and can scribe overlays for printing or produce inked maps in several colors with lines and lettering of different widths and sizes. The quality of some plotted maps would rival that of a skilled cartographer.

Electrostatic plotters operate on a xerographic process and produce copies of maps and graphs very similar to xerox copies.

The CRT contains an electron beam which actives a phosphorous material on the screen of the CRT. Wherever the beam moves on the screen, it leaves a visible trail and the final result is an image on the screen. The image is lost when the screen is erased.

Computer output microfiche is still an experimental medium, but its use is growing. Computer output microfiche devices are quite versatile and can produce gray scaled and color images with a high resolution. Computer output microfiche storage saving characteristic makes them an attractive alternative to conventionally sized maps.

PROFILES OF SELECTED GEOGRAPHIC INFORMATION SYSTEMS

The following profiles represent a sample of the kinds of geographic information systems which have been and are being developed. The systems differ in their sophistication, requirements, capabilities, and applications, but each was designed to meet the data requirements of the sponsoring organization. Each description includes a statement of the purpose and the scope of the system, data collection procedures, input procedures, retrieval capabilities and products, software descriptions and hardware requirements. Cost estimates were difficult to determine and cannot serve as a comparative measure of system cost effectiveness. A contact individual or organization and documentation have been included for readers interested in more information about the system. Comments have been made by the author to highlight some of the advantages, disadvantages, capabilities, and limitations of the system.

Information was gathered primarily from system documentation, indicated in the reference section of each description, and from published surveys described in another section of this report. Site visits were made only for San Diego's PIOS II and Lane County's Geographic Data System, although the description for each system was sent to the contact organization for comment, and corrections and additions were made to the final copy before publication. Samples of system products are included with each description if they were available.

GEOGRAPHIC DATA SYSTEM

Source: Lane County Council of Governments
Eugene, Oregon 97401

Scope and Coverage: The Geographic Data System was originally developed to handle ownership and land use information, but the system has been expanded to include boundary files for a number of public service zones and demographic and elections information. MAP/MODEL, a polygon mapping system, provides the basic set of geographic programs used in the GDS, but a number of other programs have been developed or adapted as components of the system. MAP/MODEL can be used to store, quantify, overlay, transform, select, summarize, or plot any geographic data represented by points, lines, or polygons. The system is limited to coverage of the Eugene-Springfield metropolitan area at the present time, but LCOG intends to expand its coverage to include the entire county and to include information on natural resources, soil types, geologic hazards, vegetation, and other planning data.

Data Collection and Referencing: Different types of data can be entered into the system. Maps are digitized for automatic processing, while tabular data which is geographically referenced may be directly entered into the system. Because MAP/MODEL is a polygon system, any data which can be spatially defined by points, lines, or polygons can be entered into the system as long as a common geographic reference base is used. LCOG utilizes the Oregon State Plane Coordinate System. Source maps of varying scales may be entered into the system and converted to a common scale for overlaying pruposes as long as each map utilizes or is converted to a common geo-referencing system. Data resolution is dependent upon the data that is being entered. Point data, i.e. sewer manhole covers, is quite specific. Land use information is based upon building permits and assessor's data; consequently resolution extends to the parcel level, whatever the size of the parcel.

Data Input and Retrieval: Most files are created in a batch process; maps are digitized and stored on magnetic tape, while non-geographic data is keypunched or entered via remote terminal and stored on magnetic tape. Some interactive capabilities are possible with the on-line manipulation of the stored files. Software is being developed to utilize the manipulative capabilities of a Tektronix graphics terminal which is connected to the system.

MAP/MODEL routines must be requested in PL/1, and consequently require some programming knowledge. However, frequent use is made of Cobol Architect Program (CAP) and the Statistical Package for the Social Sciences (SPSS) by the nonprogramming staff to generate a number of reports.

Output Products: Secondary machine readable files, tabular reports, maps and map overlays may be retrieved from the system.

System Software: MAP/MODEL is written in FORTRAN IV (G level) and PL/1 (Version 5). In addition to MAP/MODEL, LCOG uses several other software programs: Unimatch, developed by the Census Bureau; a point-in-polygon program developed by the staff to allow the geocoding of polygon "centroids" or points into boundary files; Cobol Architect Program, developed by the U.S. Department of Transportation, and SPSS, a statistical package.

System Hardware: MAP/MODEL requires an IBM series computer with 120-210 K of core storage with 4 tape or disk drives. LCOG utilizes the computer facilities at the Lane County Regional Information System (RIS) which operates two large IBM machines, a 370/155 and a 370/158. The machine size and storage (over 1000K of on-line storage) have not inhibited the development and use of the Geographic Data System. A Calma digitizer is used to digitize maps, a Calcomp drum plotter is used to generate the maps. As mentioned above, a Tektronix graphics terminal has been added to the system.

Costs: MAP/MODEL has undergone continuous development since its inception and, consequently, development costs are unavailable. The programs and manuals may be purchased from the Bureau of Governmental Research and Service at the University of Oregon. Robert Swank, LCOG, approximates the Geographical Data System Budget at $60,000 for 1973-1974. The cost is jointly shared by a number of agencies and governments.

Contact:

Robert Swank
Lane County Council of Governments
135 6th Avenue East
Eugene, Oregon 97401

For information concerning MAP/MODEL contact:

Robert Keith
Bureau of Governmental Research and Service
University of Oregon
Eugene, Oregon 97403

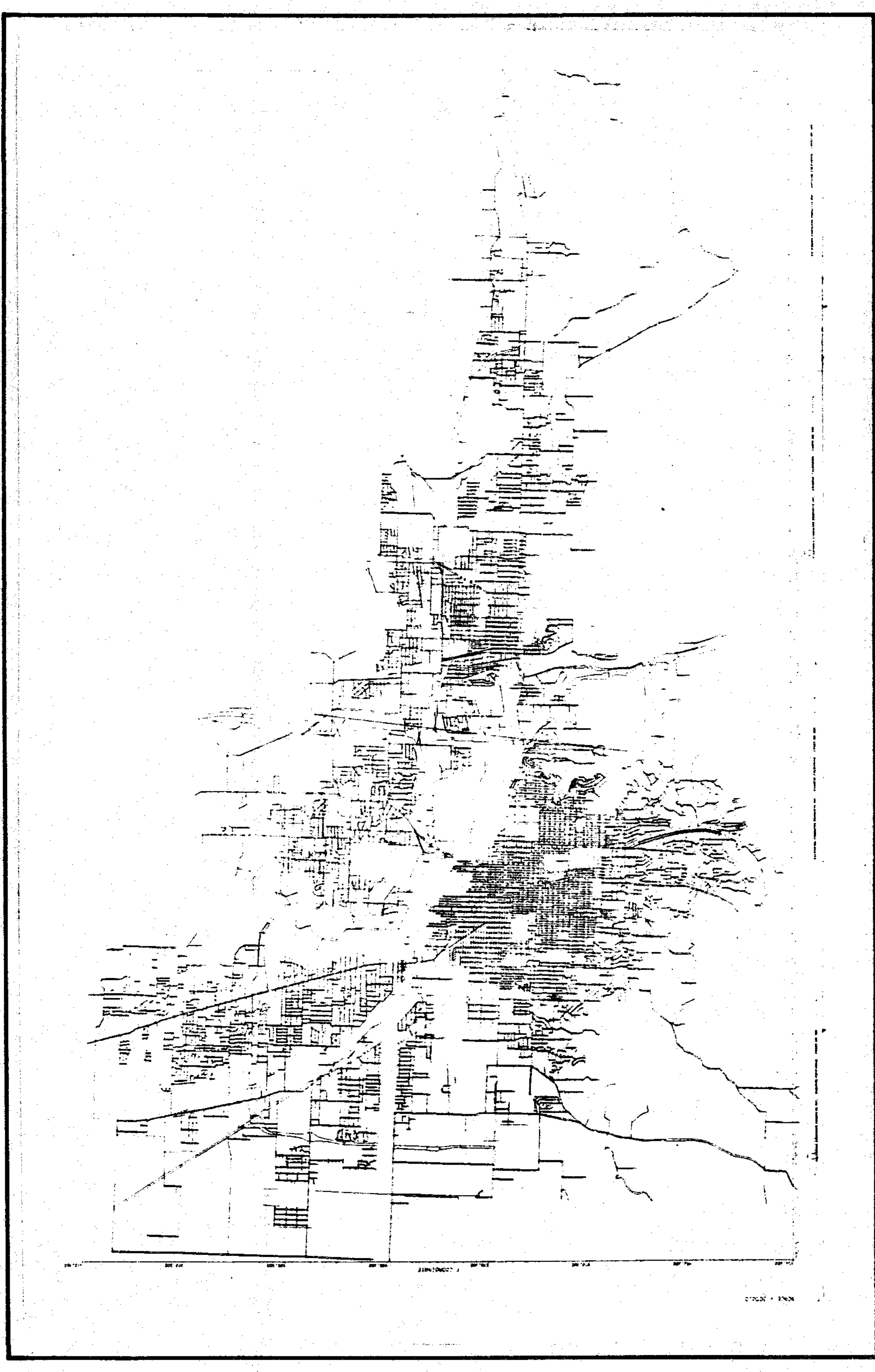
References: Swank, R., Description of Lane County's geographic information system, no title. (Draft copy) 1976.

MAP/MODEL System. Eugene: Bureau of Governmental Research and Service, University of Oregon. 1976.

Comments

In many respects, the Geographic Data System used by Lane County is very similar to the PIOS II system employed by the Comprehensive Planning Organization of San Diego County. They have the same advantages: flexibility of polygon display, large hardware systems with large storage capacity, and some of the same limitations: programming restrictions, batch entry, and time consuming and costly editing procedures. Robert Swank maintains that the programming restriction is not a complete disadvantage in that it insures the presence of an interface between the system and the end user, presumably an operator who understands the capabilities and the limitations of the system and of the data. The GDS is not operated entirely in a batch mode. Some on-line capabilities are available at the present time through remote terminals located in a number of participating agencies, and these will be increased with the addition of the graphics terminal. Perhaps the most unique aspect of the system has been the close cooperation which has been demonstrated by participating agencies in the shared use of data files as well as programs. This cooperation has been largely responsibile for the cost effectiveness of the system and its utility for the participants.

Figure 6: Geographic Data System



GRIDDED RESOURCES INVENTORY DATA SYSTEM (GRIDS)

Source: Department of Natural Resources
Olympia, Washington 98504

Scope and Coverage: GRIDS, a uniform grid sampling system, was developed to replace the conventional map inventory used to inventory lands administered by DNR and to provide the information base for a vigorous management program. The majority of the 3,000,000 acres administered by DNR are in forest, but recreation sites, sharecrop grain lands, orchards, grazing lands, and urban areas with industrial sites are also included. GRIDS has been operational since 1972 and was designed with the following capabilities:

1) the actual resource and its condition are described
2) a statistical data base is provided for resource analysis and planning
3) management activity sites (timber sale areas, reclamation sites, etc.) can be located
4) information can be easily edited and updated
5) additional definitions of existing information can be added to records
6) new types of information can be added to existing records

Data Collection and Referencing: Data are collected primarily through air photo interpretation, although other available information is also used (previous field work, ground sampling, maps, etc.). Data are based upon a circular one acre "grid point" within a 10-acre "data cell" or parcel. Therefore, data resolution of the 10 acre data cell is limited by the one acre sample. The data is kept current by recording the effect of management activities and disasters as they occur. Complete revision of the data is accomplished on a 10-year schedule. Grid point locations are controlled by the Washington State Plane Coordinate System. Grid points are referenced by coordinates within a section, providing data output by township, range, section, and section coordinates.

Data Input and Retrieval: Data are input by keypunch or remote terminal. Access is primarily by batch process at the present time because only one file can be processed on-line at one time, although several files can be created at the same time. Users access GRIDS through several "canned programs." These programs cannot accommodate requests or information which has not been specified in the system. Users must be trained to input information, but it is not necessary to be a programmer to use the system. Information may be requested in several ways: it may be listed in tabular form, it may be summarized, or maps which graphically illustrate the data can be generated, although graphic displays are limited to township format. Each print position represents a grid point.

Output Products:	Maps and statistical reports can be generated from the GRIDS files, and both are displayed on a line printer. The map displays are limited to township and range sections which are used with Land Base Record maps (LBR). The LBR is diazo copy of the photo with the grid points marked and a copy of a USGS quad topographic map at a scale of 1:12,000.
System Software and Hardware:	GRIDS is written in FORTRAN and consists of two basic systems: System 525, an editing system, which allows the user to create files and edit and update existing files; and System 527 which allows the user to select data from the files and produce maps and/or reports of the data. GRIDS operates on an IBM 360/30, a relatively small computer, and uses magnetic tape and disk storage. It requires 84K of storage on-line.
Costs	It is estimated that GRIDS costs approximately $390,000 annually or 13¢ per acre per year to operate, a cost that is comparable to the manual inventory which was previously used.
Contact:	Roger A. Harding, Resource Inventory Supervisor Department of Natural Resources Olympia, Washington 98501
References:	Harding, R.A., GRIDS Works for DNR. DNR Report No. 25 Olympia: Department of Natural Resources, March 1973.

Comments

GRIDS is an operational system which is some testimony to its success. It operates on a small computer at reasonable cost, and new information can be added to the system without a great deal of reworking, but only within the existing spatial framework. Data cannot be defined at a finer level than the 10 acre data cell, and map displays are simple and are limited to township format.

Figure 7: GRIDS

A

ACTIVITY AND GRIDS INPUT

FES 20-1804 (2-76)

Use a separate form for each activity. Complete blanks and check appropriate boxes for the activity. Draw a boundary on the photomap making sure only the grid points affected are inside the boundary. See shop manual.

S. No. / Project No. or / Contract No. / Lease No. / Reforestation Unit } No. ________ (9 Spaces)

Project Name ________ (28 Spaces)

Historical Activity ☐ Input ☐

Map Acres of One Activity In This Section
By DNR ________
Contract ________
Camp ________

Date Activity Completed [1] ________

Further Maint. Needed ☐ Yes ☐ No

Add To Activity Plan ________
Specify Need and Date Mo. Yr.

B

ACTIVITY CODES

TIMBER SALES

Code

Conifers
- ☐ 531 01 Clearcut
- 531 02 Selective Cut
- 531 03 Shelterwood

Hardwoods
- ☐ 532 01 Clearcut

Thinnings
- ☐ 533 04 Commercial Thin

Forest Products
- ☐ 534 05 Christmas Trees

RECREATION
- ☐ 193 10 IAC Construction

FOREST LAND MANAGEMENT

Code

Reforestation
- ☐ 321 20 Seeding
- ☐ 322 21 Planting
- ☐ 322 22 Container Plant

Site Preparation
- ☐ 330 23 Scarification
- ☐ 330 24 Hand Slashing
- ☐ 330 25 Hand Chemical Treat.
- ☐ 330 26 Mass Ignition Burning
- ☐ 330 27 Regular Burning
- ☐ 330 28 Browning
- ☐ 330 29 Aerial Foliar Spray
- ☐ 330 30 Aerial Dormant Spray

Code

Plantation Maintenance
- ☐ 340 24 Hand Slashing
- ☐ 340 25 Hand Chemical Treat.
- ☐ 340 29 Aerial Foliar Spray
- ☐ 340 30 Aerial Dormant Spray
- ☐ 340 31 Tordon Pellet App.
- ☐ 340 32 Animal Damage Con.

Reprod. Survey
- ☐ 350 33 2 Yr. Establishment
- ☐ 350 34 5 Yr. Verification

Stand Management
- ☐ 360 35 Pre-Commercial Thin
- ☐ 370 36 Fertilization

LANDS

Code

Geol., Agr. and Comm.
- ☐ 910 40 Grazing
- ☐ 910 41 Grazing Lease
- ☐ 910 42 Permit Range
- ☐ 930 43 Geology
- ☐ 930 44 Mineral Prospecting
- ☐ 930 45 Mining
- ☐ 950 46 Agriculture
- ☐ 950 47 Orchards
- ☐ 950 48 Reclamation Proj.
- ☐ 950 49 Irrigation
- ☐ 971 50 Commercial Lease
- ☐ 991 51 Water Rights
- ☐ 992 52 Site Resource Eval.
- ☐ 994 53 Abandoned Pit Site
- ☐ 995 54 Weed Control

C

COMPLETE FOR APPLICABLE ACTIVITY CODES

Material Used

________ (20 Spaces)
____
____
____
____

Quantity/Acre

1. Lbs. ________
2. Stems ________
3. Spot Treat ________
4. Gallons ________
5. Ft. in Thousands ________
6. ________

Seed Source

1. Nursery Code ________ (7 Spaces)
Zone (3 Sp.) Elevation (2 Sp.)
2. Nursery Code ________
Zone Elevation
3. ☐

D

NEW COVER TYPE OR CORRECTION[2] INFORMATION

For thinning and reprod. surveys, complete information describing the cover type after activity is accomplished.

Act. Code or Stand No. ________ (From Above)

	Species	Avg. D.B.H.	BA or Stem/Ac.
Primary (Major)			
Secondary			

Cover Type Group ____ Land Mgt. Base ____
Origin ____ Site Index ____ 50 Yr. ____ Other ____
Damage Type ____ Intensity ____

Act. Code or Stand No. ________ (From Above)

	Species	Avg. D.B.H.	BA or Stem/Ac.
Primary (Major)			
Secondary			

Cover Type Group ____ Land Mgt. Base ____
Origin ____ Site Index ____ 50 Yr. ____ Other ____
Damage Type ____ Intensity ____

Grid Point Nos.	Data Subject	Old Data	Correction Data

[1] For Timber Sales, Report Date Sold
[2] To Update or Correct Erroneous Data

Submitted By: ________ Date: ________

Figure 8: GRIDS

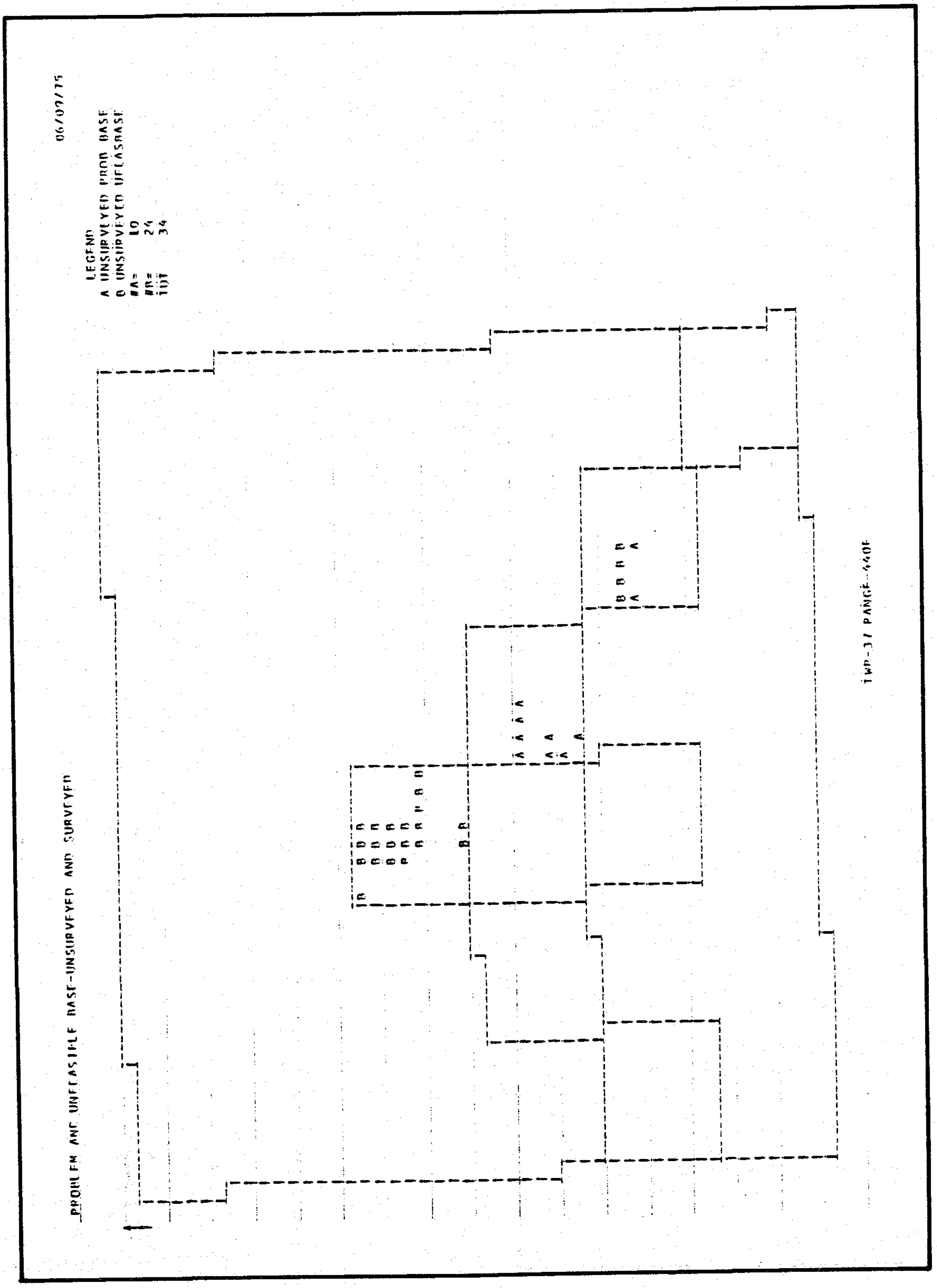


Figure 9: GRIDS

PROBLEM AND UNFEASIBLE BASE-UNSURVEYED AND SURVEYED.

AREA	TWP	RANGE	SECTN	CWNIR	CCUNTY	CNPUIMDRFR	LPR	CTG	ETYPE	MTYPF	FCOPRIEGSITN	STIATRELF	SIINIDFFX	PSRPIEC	PDRPIH	PBRAI/ST	SSEPCEC	SDEPCH	SBEAC/ST	CBOAN/IAFCR	HBRAD/WAUC	TBOAT/AALC	CSOTN/IAFCR	HSRTD/WADC	TSOTT/AALC	DTAYMPACGE	DMINT
23	37	440F	16	03	27	0124	05C	45		1	1002	08	050	08	10	6				6		6					
23	37	440F	16	C3	27	0125	05C	45		1	1002	08	050	08	10	12				12		12					
23	37	44CF	16	C3	27	0424	050	45		1	1003	08	05C	08	6	10				10		10					
23	37	44CE	16	C3	27	0425	050	45		1	1003	08	05C	08	8	4				4		4					
23	37	440F	16	03	27	0426	050	44		1	1003	08	050	08	3	4							4		4		
23	37	440F	16	03	27	0427	050	46		1	1002	08	050	08	14	5				5		5					
23	37	440E	16	03	27	0428	05C	46		1	1002	08	05C	08	14	6				6		6					
23	37	440F	16	03	27	0523	050	45		1	1003	08	05C	08	8	3				3		3					
23	37	440F	16	03	27	0524	05C	45		1	1003	08	050	08	8	4				4		4					
23	37	440E	16	03	27	0525	05C	45		1	1002	08	060	08	8	12				12		12					
23	37	44CE	16	C3	27	0623	050	45		1	1002	08	06C	08	8	14				14		14					
23	37	440F	16	03	27	0624	050	45		1	1002	08	060	08	6	8				8		8					
23	37	440F	16	03	27	0625	050	45		1	1002	08	06C	08	6	10				10		10					
23	37	440F	16	C3	27	0723	050	45		1	1002	08	060	C8	10	10				10		10					
23	37	440E	16	03	27	0724	050	45		1	1002	08	06C	08	6	14				14		14					
23	37	440E	16	03	27	0725	050	45		1	1002	08	060	08	8	8				8		8					
23	37	440F	16	03	27	0821	050	44		1	1003	08	050	08	3	4							4		4		
23	37	440F	16	03	27	0823	050	45		1	1002	08	06C	08	6	10				10		10					
23	37	44CF	16	03	27	0824	050	45		1	1002	08	060	08	8	12				12		12					
23	37	44CE	16	03	27	0825	05C	45		1	1002	08	06C	08	8	14				14		14					
23	37	440F	22	03	27	0122	040	23		1	1003	08	10C	12	8	3	65	1	7	3		3		7	7		
23	37	440F	22	03	27	0221	04C	20		1	1003	08	100	65	1	10								10	10		
23	37	440E	22	03	27	0321	040	20		1	1003	08	10C	68	1	5								5	5		
23	37	440F	22	03	27	0322	040	20		1	1003	08	10C	65	1	5								5	5		
23	37	440E	22	03	27	0521	040	24		1	1002	08	060	08	12	2	65	1	3	2		2		3	3		
23	37	440F	22	03	27	0522	040	24		1	1002	08	C6C	08	12	3	65	1	5	3		3		5	5		
23	37	440E	22	03	27	0523	040	24		1	1002	08	080	12	14	3	08	6	1	4		4					
23	37	44CE	22	03	27	0524	04C	23		1	10C2	08	C8C	08	6	2	65	1	4	2		2		4	4		
23	37	440E	2C	03	27	0521	040	20		1	1003	08	08C	55	1	13								13	13		
23	37	440F	26	03	27	0524	040	24		1	1002	08	090	30	14	2	62	1	5	2		2		5	5		
23	37	440F	26	03	27	0621	050	45		1	1003	06	080	26	6	14				14		14					
23	37	440E	26	03	27	0622	050	45		1	1003	06	080	26	6	10				10		10					
23	37	44CE	26	03	27	0623	05C	44		1	1003	06	C7C	26	4	4	55	1	6				4	6	10		
23	37	440F	26	03	27	0624	050	44		1	1003	08	080	12	4	3	55	1	6				3	6	9		

METLAND/COMLUP

Source:	University of Massachusetts Amherst, Massachusetts 01002
Scope and Coverage:	METLAND is a resource assessment model developed at the University of Massachusetts to determine the effects of urbanization on the resources in the Boston metropolitan region since World War II. Three assessment models have been developed: a special value resources variable (water supply and quality, wildlife and agricultural production, visual complexity and visual compatibility), hazard variables (flooding, noise, and air pollution), and development suitability variables (physical, climatic, aesthetic and amenity factors). The ultimate purpose of the system will be to develop a planning model which integrates the three assessment models.
Data Collection and Referencing:	Data for 25 landscape variables has already been gathered from existing maps and studies and manually digitized for entry. METLAND is using the COMLUP computer mapping system developed by the U.S. Forest Service. Data is entered into the system in grid or polygon form and converted to a grid format for overlay purposes and reconverted to line form for map display. Therefore, the mapping system is a polygon/grid system which contains x y references to a local coordinate system. The map boundaries of the study area were entered into the system, eliminating the need to re-enter the boundaries as new data is entered into the system. The cell size or data resolution is arbitrary due to the nature of the mapping system, but the COMLUP resolution in the Burlington test study equalled .02 acres.
Data Input and Retrieval:	Map data is digitized on a CALMA digitizer and is computer checked for miscoding. The system operates in a batch mode due to the constraints of the University of Massachusetts computer hardware.
Output Products:	COMLUP can produce composite polygon maps as grid matrix or line plots. Reports of net acreage can also be generated.
System Software and Hardware:	COMLUP is written in FORTRAN IV and operates at the University of Massachusetts on a CDC 3600. It was originally developed on a CDC 3100.
Costs:	Software program to a university - $200. Software program to an agency/firm - $400.

Contact: Dr. Spencer A. Joyner, Jr.
Department of Landscape Architecture & Regional Planning
Wilder Hall
University of Massachusetts
Amherst, Massachusetts 01003
413-545-0930

References: Ferris, K. H. and J. G. Fabos. The utility of computers and landscape planning: the selection and application of a computer mapping and assessment system for the Metropolitan Landscape Planning Model (METLAND). Research Bulletin 617. Amherst: University of Massachusetts Agricultural Experiment Station, December 1974.

Comments

METLAND is an attempt to develop an operational landscape resource assessment model which integrates all of the measurement and rating techniques developed for each of the 25 landscape resource variables identified. An existing computer mapping system, COMLUP, was incorporated into the system because it was compatible with U Mass. computer hardware, it was capable of producing overlays, it was capable of associating identifiers with areas on the source maps (eliminating the need to redigitize source maps each time data is entered). It was capable of plotting maps at any stage of the process, and it was capable of generating new maps. Most of the conversion problems were minor and were associated with the constraints of the U Mass computer hardware. The location of identifiers also became a problem. As maps are scaled up and down from the same source map, the identifier does not retain its relative location to parcel boundaries. Consequently, it is necessary to re-lable parcels when the scale changes. This may present serious problems if final map scales are radically different from that of the source map.

Figure 10: METLAND/COMLUP

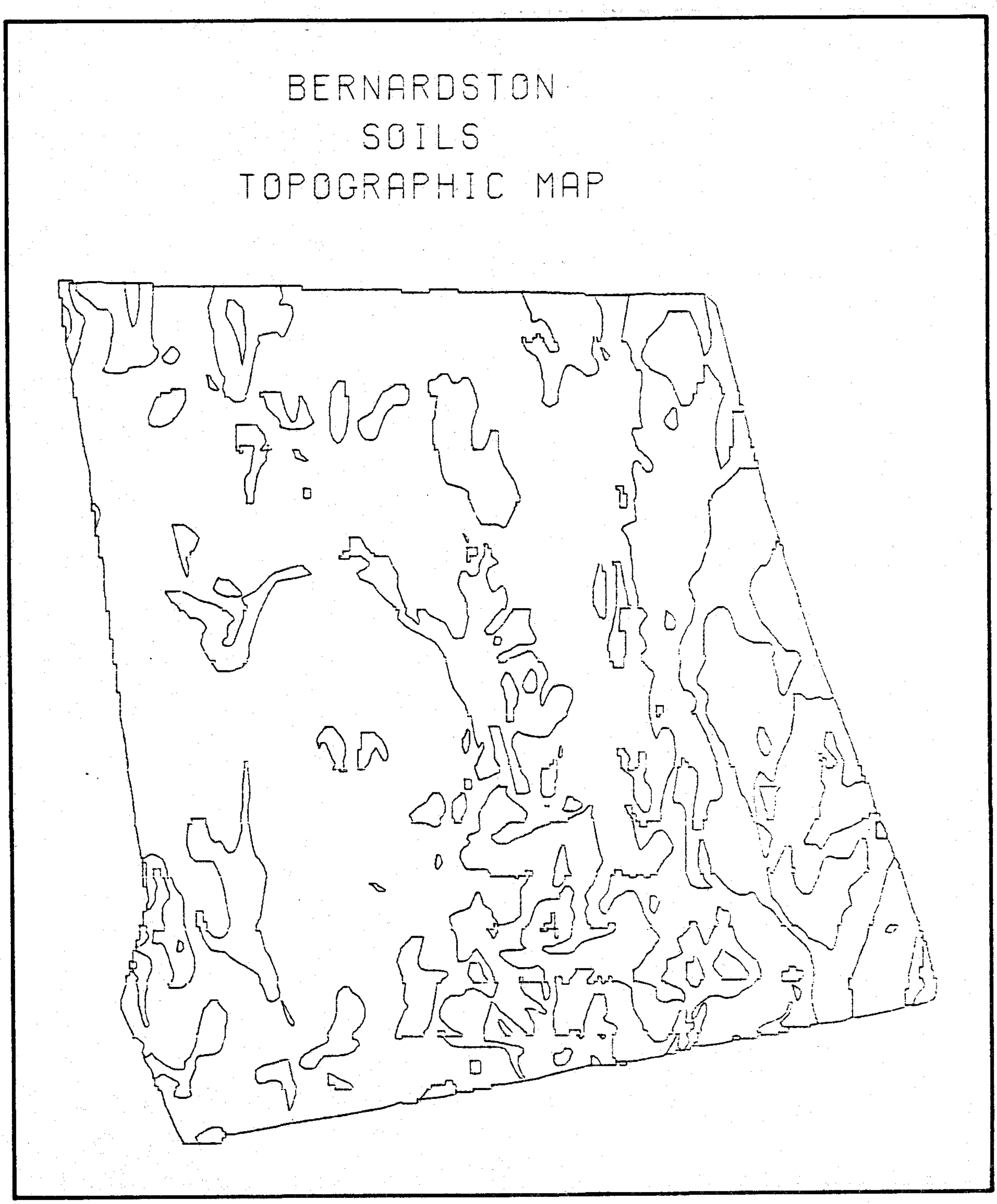
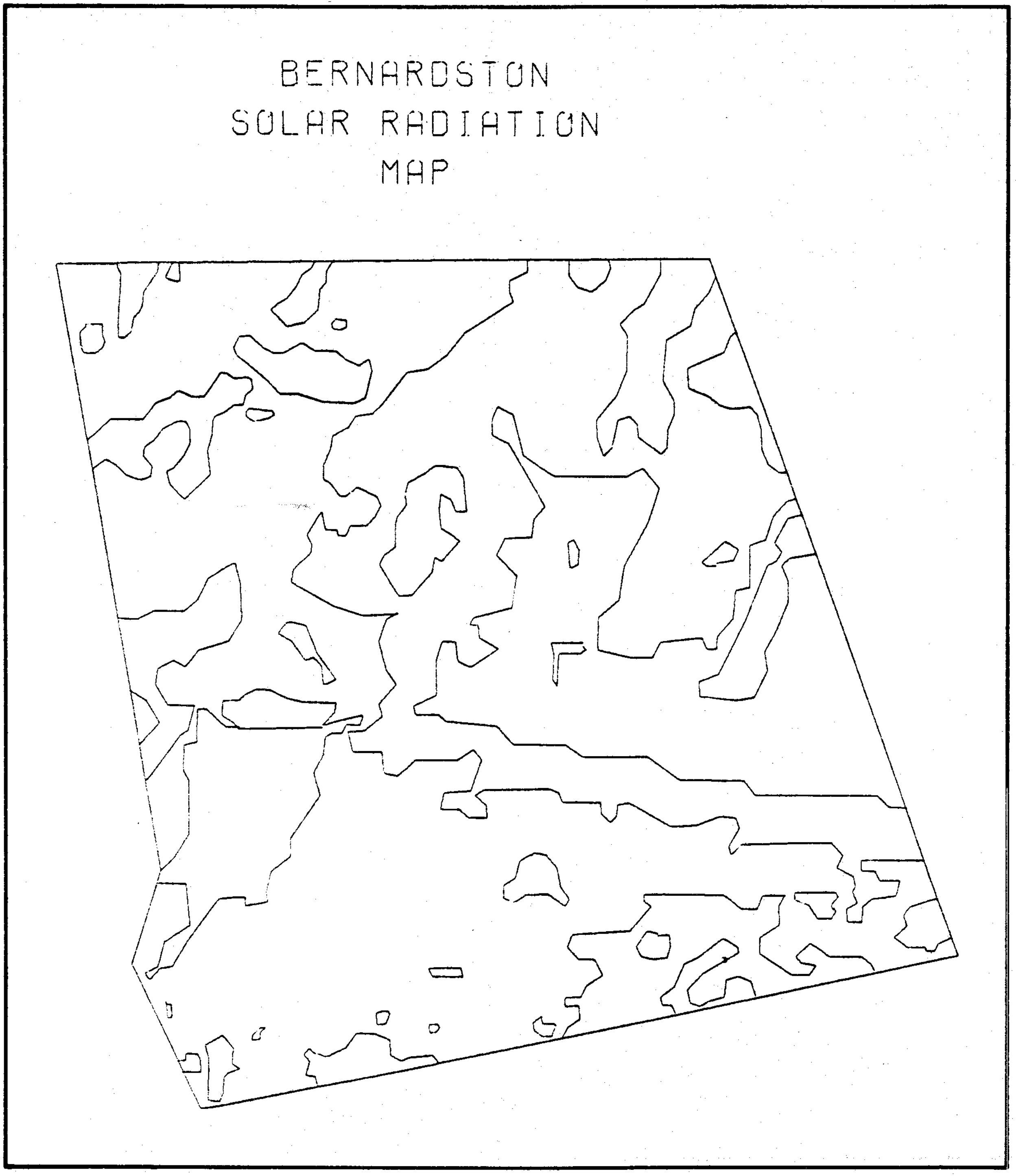


Figure 11: METLAND/COMLUP



MULTIPLE INPUT LAND USE SYSTEM (MILUS)

Source:	Jet Propulsion Laboratory California Institute of Technology Pasadena, CA 91103
Scope and Coverage:	MILUS is not exactly a geographic information system, but it presents a method for using digital image processing technology to interface existing information systems with thematic maps and remote sensing imagery. Initially, MILUS is being interfaced with Los Angeles' LUMIS system (Land Use Management Information System), an interactive graphics display information system developed by the Jet Propulsion Laboratory in cooperation with the Los Angeles Department of City Planning.
Data Collection and Referencing:	LUMIS, a polygon system, uses census data as a primary source of information, and interfaces the census tapes with existing maps and interpreted aerial photographs. Data is referenced by the California State Plane Coordinate System, but the most common cell size is the census block. MILUS, as an interface to LUMIS or similar systems, consists of satellite imagery (LANDSAT) and other digital data. Digitized information is converted to an image format, similar to a black and white television image. Each pixel of information from the imagery is identified as a grid cell or polygon node, allowing the interfacing of the LANDSAT image and the digitized information.
Data Input and Retrieval:	Once the digital image information is converted into a usable tabular file format, it is entered into the system (primarily by magnetic tape) and manipulated in the same manner as other types of data. MILUS serves as a general data handler which can interface with other information systems like LUMIS.
Output Products:	Computer maps and tabular reports are generated by the system.
System Software and Hardware:	MILUS requires some special purpose image processing hardware systems in addition to a general purpose computer. Information about system software was not available.
Costs:	MILUS is still in the testing stages and no cost data are available at this time.

Contact:	Nevin Bryant MILUS Task Force Jet Propulsion Laboratory California Institute of Technology Padadena, CA 91103

References:

Bryant, N., Zobrist, A.L., and Landini, A.L. "MILUS Multiple Input Land Use System" Pasadena: Jet Propulsion Laboratory, November 1975.

Billingsly, F.C. and Bryant, N. "Design Criteria for a Multiple Input Land Use System" in Proceedings of the NASA Earth Resources Survey Symposium. Volume IB technical sessions presentations: geology information systems and services. pp. 1389-1393. Houston: Lyndon B. Johnson Space Center, June 1975.

Bryant, N.A. and Zobrist, A.L. "IBIS: A Geographic Information System Based on Digital Image Processing and Image Raster Datatype," Proceedings, LARS Symposium on Machine Processing of Remotely Sensed Data, p. 1A-1-7, LaFayette, Indiana, Purdue University, June 1976.

Comments

JPL's proposal to develop an automated data gathering mechanism from satellite generated remote sensing imagery faces the usual problems associated with very fine data resolution requirements. For some types of information and purposes, these problems make the satellite generated data unacceptable. However, automatic processing of LANDSAT data does provide a fast and efficient way to collect an enormous amount of information on a regular basis and allows users to process the information much more quickly and cheaply than manually encoded data. JPL's proposal to supplement existing systems with remote sensing data would appear to be a useful alternative, allowing the use of remotely sensed data and relying upon manually interpreted or gathered data for baseline surveys.

NATURAL RESOURCE INFORMATION SYSTEM/
ILLINOIS RESOURCE INFORMATION SYSTEM (NARIS/IRIS)

Source: Center for Advanced Computation
University of Illinois
Urbana, Illinois 61801

Scope and Coverage: NARIS is an irregular grid (parcel) system which contains resource information for portions of eight counties in northeastern Illinois. NARIS was designed by the Center for Advanced Computation in cooperation with the Northeast Illinois Natural Resource Service Center and the Northeastern Illinois Planning Commission. IRIS was designed to extend NARIS coverage to the entire state, and is currently being tested in a six county area in Northeastern Illinois. Each tract included in the system contains 18 classes of information under the following headings: geology, land use, vegetation (native and planted), soil characteristics, water, natural resources, employment, and population. Each class is subdivided into several subheadings or data elements; i.e., soil characteristics include soil type, slope, erosion state, and other characteristics. The system was designed to be used in making planning decisions; users may perform weighting function analysis by assigning different weights to different factors (up to 50), summing the weights for each tract and comparing the resulting totals to determine the most suitable tracts for particular land uses.

Data Collection and Referencing: Information for NARIS is gathered on quarter quarter sections (40 acre tracts) and for IRIS on quarter sections (160 acre tracts). Each tract is identified by the Rectangular Survey (based on township and range units) coordinates. Information is gathered for each parvel and data element from field data, maps, and other sources.

Data Input and Retrieval: Each element is manually encoded and entered into the system in a batch process from card image files through a preprocessor program. NARIS is unique in that it is accessed in the interactive natural language mode. The language format was specifically designed for the regional planner. NARIS requires no programming experience and only a short training period. The conversational and tutorial capabilities of the system allow users to access NARIS data in an exploratory fashion through a remote terminal.

Output Products: Tables, arithmetic analyses, overlays, and maps.

System Software and Hardware: NARIS is written in ALGOL. It contains three main files: the data base file, the symbol table, and the parcel dictionary. NARIS operates on a Burroughs 6700, a fourth generation computer. The system is accessed through remote terminals and maps and reports are produced on line printers and electrostatic plotters.

Costs: NARIS was designed by CAC for approximately $200,000. Annual operating costs are not available, but an experimental analysis of the weighting function was performed.

Contact:
Calvin Corbin
Senior Research Programmer
Center for Advanced Computation
University of Illinois
Urbana, Illinois 61801
(217) 333-0707

References:
NARIS, a Natural Resource Information System
CAC Document No. 35. Urbana: University of Illinois Center for Advanced Computation. 1972.

Alsberg, P.A., McTeer, W. D., and Schuster, S.A.
IRIS/NARIS A Geographic Information System for Planners
Urbana: University of Illinois Center for Advanced Computation n.d.

Comments

NARIS is one of the most sophisticated systems available in terms of its interactive and natural language capabilities. The large size of the data cells (40 acres) limits the usefulness of the data that is contained, and the parcel geocoding system is not as appropriate for some of the data elements, i.e. soil characteristics, as would be a polygon system.

NARIS/IRIS users can perform statistical analysis, aggregate data to higher geographic levels, and produce township maps on remote terminals by using MONICA, an interactive statistical program developed by CAC, on data stored in IRIS.

Figure 12: NARIS

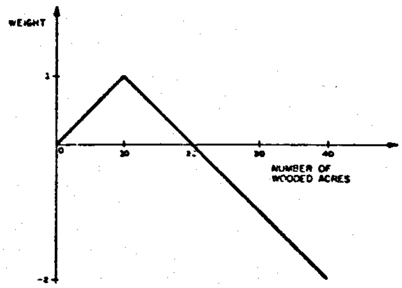
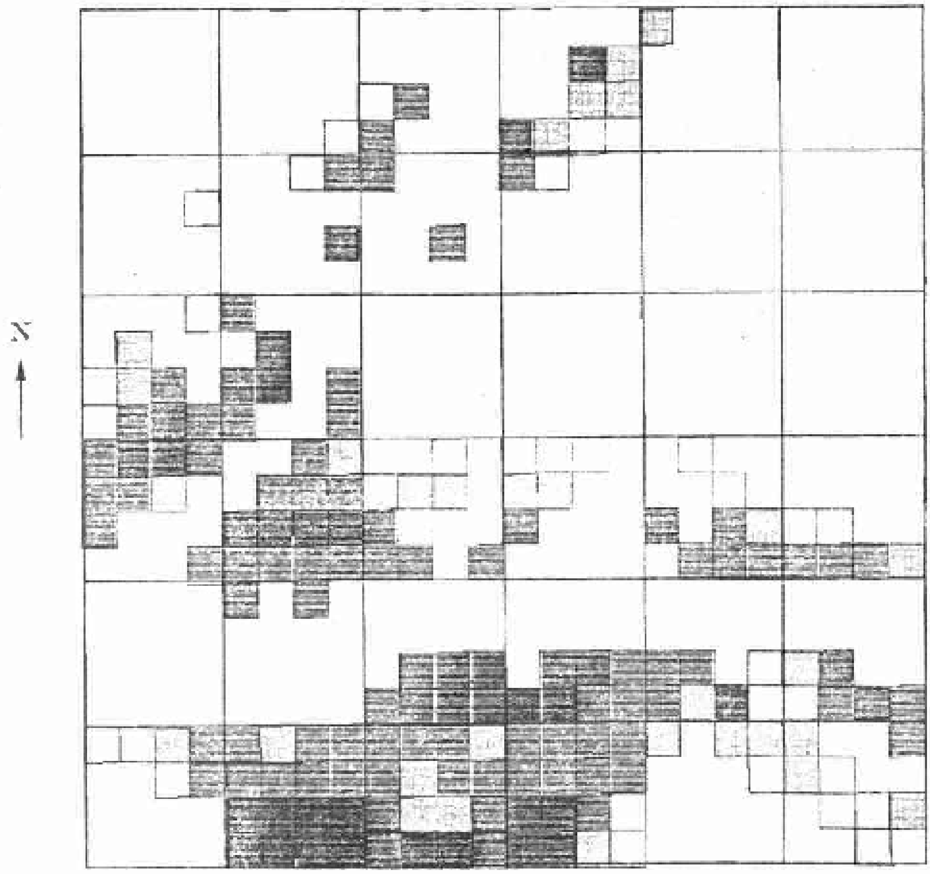
NARIS Request	Interpretation
REGION FLOOD IS MARENGOTWP WHERE STREAMS FLOODACRES IS NEQ 0 ■	→Find all tracts in Marengo which are subject to flooding.
REGION NOFLOOD IS MARENGOTWP EXCLUDE FLOOD ■	→Look only at those tracts not subject to flooding.
REGION SUBDIVISION IS NOFLOOD WHERE GEOCONSTRUCT TYPE IS ONE OF (G2, G3) AND SLIGHTSEPTICLIMIT. AND SLIGHTURBANLIMIT. ■	→Region SUBDIVISION consists of all those tracts which have good geological construction characteristics and good septic and urban soil interpretations.
FOR SUBDIVISION MAP AT 1:40000	→Map region SUBDIVISION at a scale of 1:40,000. The following parameters determine the shading of the map:
(2* SUM LANDUSE1 ACRES WHERE CODE IS 81.0	→Relatively open land is desired;
+ 2* FUNCTION [(0,0) (10,1) (40, −2)] (SUM FORESTRY ACRES)	The FUNCTION graphed below is used to assign weights based on wooded acres — ten wooded acres is most desirable (greatest positive weight is assigned) — if more than 20 acres, the assigned weight becomes negative; 
+ 2* SUM GEOWATER ACRES WHERE TYPE IS G1	→Good drainage characteristics are desirable;
+ (−100)* SUM LANDUSE1 ACRES WHERE CODE IS ONE OF (33.0, 64.0, 71.0, 72.0, 94.0)	→Mines, cemeteries, sewage disposal works, refuse dumps, and marshlands are extremely undesirable;
+ (−2)* SUM GEOSANDGRAVEL ACRES WHERE TYPE IS G1 AND ACRES GTR 10	→Tracts with sand and gravel resources are not desirable;
+ (−2)* SUM IMPOUNDMENT ACRES) ■	→Tracts with lakes and ponds are not desirable.

Figure 13: NARIS

The four NARIS requests, culminating with the MAP verb, will cause NARIS to generate the following map:



This map shows which tracts in Marengo Township of McHenry County are most attractive for housing construction based on the NARIS requests. The darker the shadings, the higher the desirability.

POLYGON INFORMATION OVERLAY SYSTEM (PIOS II)

Source:	Comprehensive Planning Organization San Diego County, California
Scope and Coverage:	The Polygon Information Overlay System was originally developed for the San Diego Comprehensive Planning Organization by the Environmental Systems Research Institute of Redlands, California. The system was designed and implemented in 1971 to digitize soil types and analyze the types within a given study area, the Traffic Analysis Zone. The revised system, PIOS II, has been used for a number of projects: quantification of land uses in the San Diego region, the evaluation of the impact of aircraft noise around various airport site alternatives, and the evaluation of development in floodplains in the area. The geographic analysis capabilities of the system have been expanded to include population and demographic data.
Data Collection and Referencing:	Data is collected from maps, overlays, and/or aerial photograph Census tapes are used to associate population and demographic data with digitized polygon information. Geographic referencing is controlled by the California State Plane Coordinate System.
Data Input and Retrieval:	PIOS II is primarily a mapping system which produces map overlays from digitized polygon data. Collected data are manually digitized and the digitized coordinates are stored on magnetic tape or disk. The system operates in a batch process. The routines are written in FORTRAN and ALGOL; therefore, some user knowledge of these languages is required. Files can be updated to generate new maps and two files containing different attributes can be overlaid to create a third file which contains the intersected polygons. A number of attributes may be compared by repeating the overlay process.
Output Products:	Tabular reports, statistical summaries, and map displays of individual attributes or overlays of two attributes can be generated by the system.
System Software:	PIOS II is written in FORTRAN IV and consists of four main programs: a Polygon Edit Program which processes the output from the digitization of the base maps and constructs the "system compatible polygon records" and detects input errors during the polygon structuring process; the Polygon Update Program which provides the capability of adding, deleting, changing or shifting information in the files; the Plot Program which provides for the display of the digitized polygons; and the Overlay Program which provides the capability of overlaying two attributes and calculating and displaying the common areas.

System Hardware: PIOS II operates on a Burroughs 6700, a fourth generation computer which has far more capabilities than the IBM 360 upon which PIOS was developed. A digitizer is used to digitize the polygons, and maps are generated on a pen plotter and a graphic CRT.

Contact: Comprehensive Planning Organization
Suite 524 Security Pacific Plaza
1200 Third Avenue
San Diego, CA 92101
(714) 233-5211

References: Proposed Information System for Planning, Volume I. San Diego: Comprehensive Planning Organization, May 1971. (Available from NTIS, Springfield, VA 22151)

DeBerry, Terry B. PIOS II, General System Description. San Diego: Comprehensive Planning Organization, July 1974.

DeBerry, Terry B. PIOS II, Technical User's Manual. San Diego: Comprehensive Planning Organization, January 1975.

Comments

PIOS II, a polygon overlay system, is more sophisticated than the grid systems which have been described; the polygon boundary display is more useful in representing a variety of data, i.e. soils, slope, vegetative cover. Although only two attributes can be overlaid at any one time, the process can be repeated to determine the intersection of a number of attributes. One drawback to the system is the programming requirement, which restricts the number of users that can directly interact with the system. Some planners may not consider this a drawback, since it may be preferable to have operators with an understanding of the system and its limitations to serve as intermediaries between the system and the end users. The batch operation of the system is limiting; an interactive or on-line system would allow users to retrieve data rapidly and manipulate the files to analyze possible alternatives.

Polygon overlay systems are generally more expensive to develop than grid systems, but they have greater flexibility in the types of data which can be entered into the system. Secondly, polygon systems are more expensive to operate than grid systems, because they require more computer time to input data. However, as computer time decreases in cost and human labor becomes more expensive, polygon systems may gain an economic advantage over grid systems.

PTOLOMY

Source:	Battelle Pacific Northwest Laboratories Richland, Washington 99352
Scope and Coverage:	PTOLOMY is an experimental mapping system designed by Battelle as an interactive computer graphics program to manage geographic information. The geographic retrieval capabilities and the file structures were adapted from the Des Moines Geographic Information System. The polygon overlay technique was adapted from the MAP/MODEL program. PTOLOMY operates on a minicomputer and is consequently restricted to rather small files, but it is a very flexible system which operates in a real time frame (see glossary).
Data Collection and Referencing:	Data can be collected from a variety of sources. Map data must be digitized before being entered in the system. A coordinate conversion program is used to convert the digitized coordinates (referenced by the State Plane Coordinate System) to geodetic latitude longitude coordinates.
Data Input and Retrieval:	Data are initially entered onto magnetic tape. Once it is loaded into the system, the user may query the files in a real time frame via a video display unit (CRT). Commands may be entered in a natural language format by keyboard or graphically identified by means of a lightpen. By using the lightpen, it is possible to zoom in on a particular area. Therefore, it is possible to examine a large area at an aggregated level of detail and subsequently zoom in to a specific site at a more detailed level. Users may zoom in as many times as desired, or to any level of detail, within the limits of disk storage space. Technical information (non-digitized data) may be entered into a separate report file and referenced to geographic locations depicted on the CRT. Files may be overlaid to determine the intersection of different attributes.
Output Products:	Maps, overlays, tabular reports and charts.
System Software and Hardware:	PTOLOMY operates in FORTRAN on a 48K minicomputer with two disk drums for on-line storage. A digitizer operating on a PDP 11/35 is used to enter graphic data into the system and a CRT is used to access data within the system.
Costs:	The software development costs are estimated at $20,000 while the hardware investment equalled $96,000 ($36,000 for the computer and disk drum storage and $60,000 for the CRT).

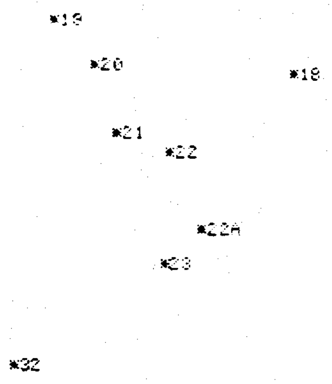
Contact: E. Richard Hill
Battelle Pacific Northwest Laboratories
Battelle Boulevard
Richland, Washington 99352

References: Hill, E. R., Interactive Graphics: Analytical Tool for Geoprocessing. Richland: Battelle Pacific Northwest Laboratories, October 1975. (BNWL SA 5517).

Comments

PTOLOMY is an experimental system which is restricted to handling small files due to its limited storage capacity, but it offers some exciting possibilities in the development of a total geographic information system. It could be interfaced with a larger system, drawing on the storage capacity of a large computer while retaining its manipulative capabilities.

Figure 14: Ptolomy



3. Springs in the area of interest with labels included.

MINERVA(PTOLEMY) BATTELLE-NORTHWEST JUNE 1975

HOT SPRINGS DATA

STATE	FIG	LABEL	REF	TEMPERATURE LOW	TEMPERATURE HIGH	FLOW LOW	FLOW HIGH	LAT DEG.MIN	LONG DEG.MIN
COLD	2	18	1	69	69	0	0	38.42	105.31
COLD	2	19	1	120	144	150	150	38.53	106.19
COLD	2	20	1	99	150	50	50	38.44	106.10
COLD	2	21	1	88	155	500	500	38.31	106. 6
COLD	2	22	1	94	94	150	150	38.27	105.56
COLD	2	22A	1	101	101	0	0	38.12	105.50
COLD	2	23	1	116	122	50	50	38. 6	105.57
COLD	2	32	1	100	120	50	50	37.46	106.27

4. Data listing corresponding to retrieved springs.

OAK RIDGE REGIONAL MODELING INFORMATION SYSTEM (ORRMIS)

Source:	Regional Environmental Information Systems Analysis Program Oak Ridge National Laboratory Oak Ridge, Tennessee 37830
Scope and Coverage:	ORRMIS was developed by Oak Ridge as a regional modeling program for the East Tennessee Development District (ETDD), a 16 county area surrounding Knoxville. It is a uniform grid system which has a variable size grid structure ranging from 40 acres to 2.7 acres. When fully developed, ORRMIS is expected to contain information on land use, zoning, physical characteristics (soils, vegetation, geology, etc.), census data, tax records, and other socio-economic data. One of the functions of the system will be to develop a land use simulation model based upon an analysis of the data that is collected.
Data Collection and Referencing:	The program does not include a "data-gathering" component, so existing data from a variety of sources including maps, census tapes, tabular reports, field studies, and tax reports are used. Data referencing is tied to latitude and longitude coordinates.
Data Input and Retrieval:	Data are input in a variety of ways; manual digitizers and automatic scanning devices are used. Information is entered and hard copies are retrieved in a batch process, but files may be manipulated in an interactive mode. ORRMIS does not use a fixed amount of core space but allocates space to itself on the current capacity of the computer system. Data sets are packed which decreases disk storage by 50% to 75%. The "nested hierarchy" of grid cells allows data to be input, stored, and analyzed at the level or levels appropriate to their content, and requires less storage space because only data at the proper level of aggregation needs to be processed. Factor and cluster analyses may be performed on a number of attributes: land use relationships relating to accessibility, land value and public services have been identified.
Output Products:	Five types of output products can be generated: spatial plots of single attributes, graphs or histograms showing changes over time, density plots, overlays of two or more variables, contour or isotherm plots, using line printers, mechanical plotters, and video display units (CRT's). Not all types of spatial displays are equally appropriate for each product. Line printer maps are quick but they are not as accurate or as aesthetically pleasing as plotter maps; CRT's allow interactive manipulations, but they do not provide hard copy (unless they have an attached copier).

System Software and Hardware:	ORRMIS programs were developed by the computer staff at Oak Ridge and are written in FORTRAN. ORRMIS operates on an IBM 360. A Hough-Powell flying spot scanner/digitizer controlled by a PDP 9 is used to automatically scan data for entry into the system and a digitizer is also used. Output devices include line printers, CRT's and mechanical plotters.
Costs:	No data is available on the development costs for ORRMIS, but R.F. Tomlinson prepared a study comparing a number of systems in a data encoding experiment. There were some differences among the systems which made exact comparisons difficult, but the ORRMIS project cost \$289.45, while the PIOS project cost \$273.85. Neither figure includes personnel costs.
Contact:	Richard C. Durfee Regional Environmental Information Systems Analysis Program Oak Ridge National Laboratories Oak Ridge, Tennessee 37830
References:	Durfee, R. C., ORRMIS. Oak Ridge Regional Modeling Information System. Part I. Oak Ridge, Tennessee: Oak Ridge National Laboratory, 1974. ORNL-NSF-EP-73. Tomlinson, R. F., Calkins, H.W., and Marble, D.F. Computer Handling of Geographical Data. Natural Resources Research Series No. 13. Paris: UNESCO, 1976.

Comments

ORRMIS may be one of the most sophisticated geographic systems yet developed in terms of data entry and computer storage. The initial system design called for three phases of development: the first phase, development of the basic input storage and retrieval capabilities, has been accomplished, and the second phase, the development and use of generalized record structures to support complex hierarchical data structures, is underway. The third phase will be the development of a user oriented search language so that users can more easily analyze and retrieve information.

Figure 15: ORRMIS

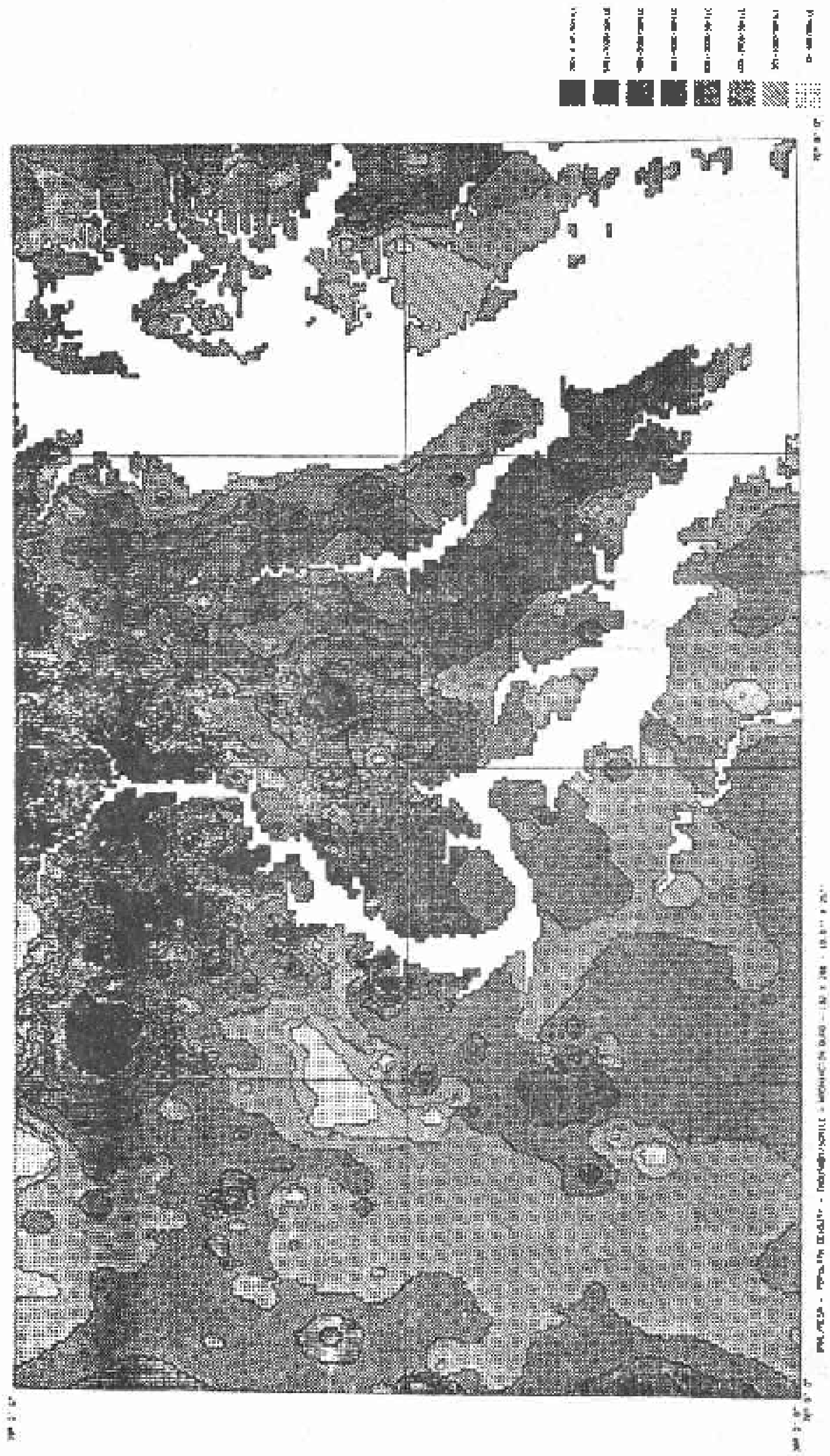


Figure 19 - Shaded Map of Population Densities for the Washington Quad (Calculated from 1970 MED-X Census Data using a weighted Interpolation Procedure, 1° by 2°, Polyconic Projection at 1:250,000, 19.8" by 25" cells = 90 acres)

ANNOTATED BIBLIOGRAPHY OF GEOGRAPHIC INFORMATION SYSTEM SURVEYS

IRIS Illinois Resource Information Systems, Feasibility Study, Final Report. Urbana, IL: Center for Advanced Computation, University of Illinois, 1972. 204 p. (Available from the Center for Advanced Computation, University of Illinois at Urbana, Urbana, IL 61801. $9.00)

This volume presents the findings and recommendations of a study to determine the feasibility of an Illinois resources information system. The study team examined the availability of geographically referenced data, the uses of such data in Illinois, and the production and exchange of this information between and among various state agencies.

A large portion of the study is devoted to the state of the art in geographic information systems. The basic types of systems are identified and discussed and a number of planned or operating systems are described. Several operational systems are examined with respect to the applicability for Illinois. This report represents one of the most comprehensive studies of geographic information systems published, covering over thirty operational or implemented systems, but much of the detailed information concerning specific systems is out of date.

Marble, Duane F., Director, Computer Software for Spatial Data Handling. Draft review, International Geographical Union Commission on Geographical Data Sensing and Processing. March 1976. (Contact Dr. Marble, Geographic Information Systems Laboratory, State University of New York at Buffalo in Amherst, New York 14226 (716-831-1611)).

The first version of this inventory was developed by the International Geographical Union Commission for the U.S. Geological Survey and the Office of Land Use and Water Planning, U.S. Department of the Interior, as a supporting document to Information/Data Handling: A Guidebook for Development of State Programs. The guidebook and inventory were never published, although draft copies were issued in 1975. The inventory presents descriptions of a number of computer programs for spatial data handling. The programs are divided into five categories: full geographic information systems, data manipulation programs which provide for the initial structuring of spatial and other data, data analysis programs which provide statistical and analytical processing of the data, mapping and graphics programs which display the data using a variety of devices and supporting programs. Each description includes, if available, information identifying the program, its purpose and capabilities, operating requirements, origin documentation and availability.

Power, Margaret A. Computerized Geographic Information Systems, An Assessment of Important Factors in their Design, Operation and Success. St. Louis: Center for Development Technology, Washington University, December 1975. 168p. (Available from the Center for Development Technology, Washington University, Box 1106, St. Louis, MO 63130).

A brief history of the development of geographic information systems is presented, and the key decisions in the design of a system are discussed: user needs, geocoding and geo-referencing, accuracy, and modes of access.

A number of information systems are described, but detailed descriptions are limited to 11 systems: SAROAD, STORET, LUNR, MLMIS, NARIS, ORRMIS, UDIS, LUMIS, IMIS, WRIS, and COMLUP. The information presented is based upon interviews, correspondence, and an examination of the literature. The status of information system development in each of the 50 states is briefly reviewed. The report concludes with an assessment of the quality of the systems described and a description of an idealized system synthesized from the best features of the systems studied.

This report was funded by NASA and leans toward systems which use or are capable of using remote sensing data. The report is well written and very readable.

Tom, Craig and Miller, Lee D., A Review of Computer-Based Resource Information Systems. Land Use Planning Information Report No. 2. Fort Collins, CO: Colorado State University, December 1974. 51 p. (Available from Dr. Miller, 6208 Feldspar Court, Bellvue, Co. 80512. $2.00)

The authors have identified five types of resource related information systems: resource information collection and analysis systems, information storage and retrieval and display systems, resource response simulation systems, resource facility design and operation planning systems and multiple use and environmental planning and decision systems. Each of the five categories is generally described and illustrated with examples of specific systems. Several tables are included to facilitate comparisons between the systems described. The descriptions of individual systems are particularly comprehensive for systems utilized by the U.S. Forest Service.

Tomlinson, R. F., Calkins, H. W., and Marble, D. F., Computer Handling of Geographic Data, an Examination of Selected Geographic Information Systems. UNESCO Natural Resources Research Series No. 13. Paris: UNESCO Press, 1976. 214 p. (Available from UNIPUB, Box 433, Murray Hill Station, New York, N.Y. 10016. $15.30)

The report contains a detailed examination of five information systems and digitizing methods which represent different methods of encoding spatial data as well as different encoding procedures. The report is rather technical and is intended for specialists who have some familiarity with the principles and the vocabulary of geographic data handling. The systems studied include: CGIS, the Canadian Geographic Information System, PIOS, the Polygon Information Overlay System, MLMIS, the Minnesota Land Management Information System, LUNR, the Land Use and Natural Resources Inventory of New York, and ORRMIS, the Oak Ridge Regional Modelling System.

The authors conducted a data encoding experiment to assess the suitability of the various approaches for other system designers. Several of the desired objectives were achieved, but the systems differed sufficiently to limit the authors' ability to directly compare system capabilities.

Tomlinson, R. F. ed., Geographical Data Handling, Symposium Edition. Volumes 1 and 2. Ottawa: International Geographical Union Commission of Geographical Data Sensing and Processing, August 1972. 1387 p. (Available from NTIS, Springfield, VA 22151. Report No. PB 234 308 and PB 234 309. $34.00)

This massive two volume work contains the proceedings of the International Geographical Union Commission on Geographical Data Sensing and Processing held in Ottawa in August 1972, and it was prepared as a set of working papers for the symposium participants. The assembled papers are primarily concerned with the design, organization, and display of machine handled geographic data. The papers include background papers written for the conference and state of the art reviews prepared by the five "working groups" established at the first symposium in 1970. These working groups include: geographical data sensing (including photointerpretation and remote sensing), geographical information system definition and review, geographical data manipulation, geographical data communication, display and dissemination, and geographical information systems use and economics. Several operational systems are described, but the descriptions are limited to structural details. A catalog of hardware, descriptions of available software programs and a directory of people involved with geographical information systems or data handling are included in the appendices. Most of the papers are very technical in nature, but this represents a most comprehensive examination of the theoretical bases of computer and machine handling of geographic data.

Catalog of Geography Program Exchange, Michigan State University, East Lansing, Michigan. (Contact Dr. Robert Wittick, Geography Program Exchange, Computer Institute for Social Science Research, Michigan State University, East Lansing, MI 48824 (517-353-2042).

While not a geographic information system survey, the Geography Program Exchange is sponsored by the International Geographical Union (IGU) Commission on Geographic Sensing and Processing and has been collecting and distributing geographic computer software for a number of years. The catalog lists the computer programs available from the Exchange.

GLOSSARY

Access	The act of fetching an item from or storing an item in any computer memory device.
Address	An identification, represented by a group of symbols, that specifies a register or computer memory location.
Auxiliary Memory	Any computer memory or memories used to supplement main memory.
Batch Processing	A method in which a number of data items or transactions are coded and collected into groups and processed sequentially.
Bit	Acronym for Binary Digit, the smallest unit of information which can be stored in the computer.
Boundary	General term for the division between two mapped areas.
Buffer	The internal portion of a data processing system which serves as an intermediate storage between two different storage or data handling systems with different access times or formats.
Byte	A group of adjunct bits that are operated on as one unit.
Card Image	A representation in computer storage of the hole patterns of a punched card. The holes are represented by one binary digit and the spaces are represented by the other binary digit.
Cathode Ray Tube	An electronic tube with a screen that is used in computer terminals to display input and output data. Also referred to as a CRT.
Cell	The smallest region in a grid.
Central Processing Unit	The central processing unit or CPU of the computer is that portion of the computer which is used to control the components of the hardware system.
Centroid	The center point of a mass or polygon.
Character	A letter, digit or other special symbol used for the representation of information.
Data Base	A set of data files organized in such a manner that retrieval and updating can be done on a selective basis and in an efficient manner.

Data Tablet	A flat tablet which will output the digital position of a pointer placed at any position on its surface.
Digitization	The process of converting analogue or graphic data into digital form. Manual digitization involves the transformation of data by an operator with or without mechanical or computer processors, while automatic digitization requires the use of an automatic device, i.e. scanner, pattern recognition, character recognition.
Digitizer	A device which converts maps into a digital format for computer input.
Direct Access	Interactive systems employ direct or random access in which the access time is not related to the location of the data in the computer memory, i.e. data does not have to be serially or sequentially searched.
Editing	The detection and correction of errors
Encode	The process of applying a set of unambiguous rules to transform data from its original form to some coded representation, usually digital.
Field	A group of characters that is treated as a unit of data.
File	A variable number of records grouped together and treated as a main division of data.
Fixed Length Record	Relates to a file in which various records must contain the same number of characters.
FORTRAN	An acronym for FORmula TRANslation, a procedure-oriented computer programming language.
Geocoding	The geographic coding of the location of data items.
Geographic Base File	A coded network
Geographic Coordinates	A spherical coordinate system for defining the position of points on the earth.
Geo-referencing System	Planimetric coordinate system which identify points on the surface of the earth. Systems include latitude-longitude universal transverse mercator, stable plane coordinate and land survey systems, etc.
Grid Coordinates	Euclidean coordinate system in which points are described by perpendicular distances from an arbitrary origin, usually on an x y axis.

Hardware	The physical components of a computer and its peripheral equipment.
Hard Copy	Printed or paper copy of computer output. Commonly a paper copy of the information displayed on a computer video terminal.
Information Retrieval	Methods and procedures used for storing and retrieving specific data and/or references based on the information content of documents.
Interactive Mode	Allows users to directly interact with the information system to input and/or manipulate and retrieve information in a real time framework.
Interface	The junction between components of a data processing system.
Intersection	The region containing all of the points common to two or more regions or polygons. See also union.
Light Pen	A device the size of a ball-point pen which is used for pointing to a location on a CRT screen. One of several types of interactive positioning devices including a mouse, joystick and tracking ball.
Line Printer	An output device for computers which prints one line at a time. It can be used as a high speed listing or, by spacing symbols, as a plotting device.
Magnetic Disk	A computer memory medium on which data is available by random access.
Magnetic Drum	A computer memory device on which data is available by random access.
Magnetic Tape	A computer memory or storage device which will store a large amount of data, but this data is only accessible in a sequential search.
Natural Language	A user-oriented language which can be used to search the computer files by operators who have no programming experience.
Network	A connected set of segments and nodes.
Node	A point which is common to two or more segments.
Off-line	Processing is not directly under the control of the central processing unit.
On-line	Processing is directly under the control of the central processing unit. All interactive systems operate on-line.

Optical Character Recognition	The process by which printed characters are read by light sensitive devices for computer input. Also referred to as OCR.
Overlay	The superimposition of one map or digital image over another of the same area in order to determine data combinations or intersections and unions.
PLI	A computer language intended to combine the most useful features of the scientific (FORTRAN) and business (COBOL) languages.
Plotter	An x y mechanism controlled by a computer, generally for the recording of location or spatial information. Lines are drawn as a series of vectors.
Polygon	Plan figure consisting of three or more vertices (points) connected by line segments or sides.
Program	The implementation of a procedure by the use of a computer programming language. A program consists of a set of instructions which direct the CPU in the performance of a specific task.
Random Access	The process of obtaining information or data from a computer storage device where the time required for such access is independent of the location of the information most recently obtained.
Raster Scan	A line by line sweep across a display surface to generate or record an image.
Real Time	Processing which appears instantaneous to the person or the device controlling a computation.
Resolution	Measure of the ability of an imaging system to separate the images of closely adjacent objects. Also the smallest area at which data can accurately be identified.
Software	The set of programs used to instruct the computer in problem solving; consists of the operating system programs and applications programs.
Terminal	A device used to input or output data from a computer, often from remote sites.
Time Sharing	The concurrent use of a computer system by more than one user or program by allocating short time intervals of processing to each active user. The response time is usually so fast, that each user is given the impression that the computer's resources are totally designated to his task.

Uniform Grid	Square rectangular or hexagonal lattice grid coordinate system for recording geographic data.
Union	The region containing all of the points in two or more regions or polygons. See also intersection.
Variable-length	Relates to a file in which the various records may contain a different number of characters.