(NASA-CR-127810) NATURAL RESOURCE INFORMATION SYSTEM, DESIGN ANALYSIS Final Report (Boeing Co., Seattle, Wash.) May 1972 31 p

CSCL 08G

N72-29294

G3/13

Unclas

36765

ACKNOWLEDGEMENTS

NATURAL RESOURCE INFORMATION SYSTEM

This was developed as a result of the combined efforts of the technical monitors of BIA and BLM, the environmental sciences staff of the Aerospace Group of The Boeing Company, graduate students from the University of Washington, and the Systems and Operations Research staff of Boeing Computer Services, Inc.

In the execution of Volume I we are indebted to Art Woll of the BIA-EROS Program and Grover Torbert, Cadastral Survey, technical monitors of the BIA and BLM for their valuable guidance, to Jon Leachtenauer, principal author of Volume I, to Bob Hirsch and Van Williams, geologists at the University of Washington, and Richard Tucker, Forester, The Boeing Company.

In construction of the base map we are indebted to the Arizona State Highway Department for the use of their excellent map series.

James F. Kenney, Ph.D.
Program Manager

Graham D. Clapp, M.S.
Technical Manager

TABLE OF CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The Bureau of Indian Affairs (BIA) and the Bureau of Land Management (BLM) are currently charged with the management of approximately 20% of the United States land area, some 475 million acres. Although the goals and methods of the two agencies differ, both are ultimately charged with the responsibility of insuring the maximum level of productivity for land under their control. Technological developments have improved the ability to increase land productivity, social developments have established a requirement for improved productivity and more intensive management. Increasing amounts of data are required to make increasingly complex decisions. The ability of the bureaus to collect and process required data in a form of maximum usefulness to the land manager has not kept pace with demand.

1.1 Background

In 1969, a study of potential EROS imagery applications to Department of Interior functions was performed (Ref. 1). A survey of potential remote sensing applications to BIA, BLM and Bureau of Reclamation activities was conducted and simulated ERTS-A imagery studied to determine the degree to which it could satisfy user data requirements. High altitude photography was also studied.

The study concluded that both ERTS-A and high altitude photos could be of value to the Bureaus' activities. Recommendations were presented for use of both types of materials.

A subsequent study was performed on applications of remote sensing data to BIA functions (Ref. 2). In this study, a more intensive analysis was made of BIA management functions and processes and a somewhat broader range of remote sensing applications considered. Again, it was concluded that there were several potentially feasible and cost effective applications of remote sensing to the Bureaus' functions. Plans were presented for development of a resource management information system.

Within BIA and BLM, a number of studies have been conducted on processing of natural resources data. The emphasis here has been on the development of resource data computer storage and processing. Processing requirements were largely established by reporting requirements. Many of the applications were of essentially a bookkeeping nature; e.g., dealing with mineral leases, property records, Indian land allotments, etc. Perhaps in part because of this background, there was a strong tendency to store and process data on a square or cell basis. Resource maps however, do not conveniently fit this approach; they generally consist of irregular boundaries and lines. Considerable difficulty was encountered in dealing with such data.

Like data portrayed on resource maps, data derived from remote sensing tends to consist of irregular lines and polygons. Although previous efforts had shown several applications of remote sensing data to the BIA and BLM, no means existed to conveniently handle such data.

1.2 Program Scope

Recognizing the need for development of a computer based information system which would handle remote sensing as well as conventional mapping data, BIA and BLM contracted with Boeing Computer Services for the design and construction of a prototype Natural Resources Information System. The primary objective of this effort was the design of a computer based system which would store, process and display data of maximum usefulness to land management decision making. The system was to include graphic input and display, the use of remote sensing as a data source, and was to be useful at multiple management levels.

Design of the system proceeded along two parallel lines. A survey was made to establish current decision making processes and functions, information requirements, and data collection and processing procedures. Concurrent with this effort, the application of remote sensing data to the decision making process was established and potential data processing requirements established. Based on these two analyses, an information system was designed. Processing software was constructed and a data base established using high altitude imagery and map coverage of selected areas of S. E. Arizona. A demonstration of system processing functions was conducted utilizing material from the data base.

1.3 Report Organization

This report is presented in two volumes. Volume I summarizes program activities and provides a brief description of the Natural Resources Information System. Volume II provides computer system operating procedures and instructions.

Section 2.0 of Volume I summarizes program activities. A description of the prototype system and a summary of operating experience are presented in Sections 3.0 and 4.0 respectively. Recommendations for further development and implementation are presented in Section 5.0.

Descriptions and results of the analyses leading up to final design of the system are presented in other References. Reference 3 presents the results of a user survey. A description of the studies relating to remote sensing which were performed under the contract is presented in Reference 4. A description of data analysis activities and a presentation of system design rationale are given in Reference 5, and Reference 6 covers the Demonstration of System Features and capabilities, presented in Washington, D. C., April 5, 1972.

2.0 SUMMARY OF CONTRACT ACTIVITIES

The development of the information system was conducted over a 12 month period and four major tasks were involved. In Phase I, a survey of system users was conducted. The results of the user survey were analyzed and a set of system design requirements generated in Phase II. The third phase of the effort entailed the construction and testing of software. In Phase IV of the effort, a data base was constructed, the data base entered in the system, and a demonstration of the system conducted.

2.1 User Survey/Data Collection

The objective of the user survey and data collection effort was to establish information requirements of BIA/BLM land managers and to collect data on organizational procedures and objectives. Reports, maps, and photos pertaining to the demonstration area were also collected as part of this effort.

Approximately 120 BIA and BLM employees were interviewed over the first few months of the program. Reporting forms, procedural manuals, maps, photos and reports were collected at the same time. Some 50 non-BIA/BLM personnel concerned with resources management or with computer applications to resource management were also interviewed. Detailed results of these efforts are described in Reference 3 - User Survey.

2.2 Data Analysis and System Design

The second major phase of the program led to a definition of general system requirements. Results of the user survey/data collection effort were cast in the form of decision flow charts (Figure 2.1). Data inputs, formats, and processing activities were specified for several decision hierarchies.

Concurrent with this effort, studies of remote sensing applications were initiated. An extensive literature survey was performed to document image quality requirements for each potential application.

Imagery available for the demonstration area was reviewed to form preliminary estimates of its utility for resource mapping. Interpretation of cultural features, range vegetation, and timber resources were performed and compared against available ground truth. The results of these efforts formed the basis for determining how and where remote sensing data might be employed in developing a data base for the prototype information system. Results of these efforts are presented in Reference 4 - Remote Sensing Studies.

Finally, data on existing computer systems and subsystems related to resources management were collected and analyzed. Several information systems or research programs designed to produce such systems were identified and reviewed. They are summarized in Table 2.1.

OBJECTIVE: Unit Resource Analysis

TASK: Provide a comprehensive inventory and analysis of resource problems, conditions, uses, production, capabilities and potentials for use in various planning processes

INFORMATION NEEDS:
- Location Map
- Base Maps: Cartographic Signature, Survey Grid Land Status
- Physical Profile of Area

DATA PROCESSING REQUIRED:
- Letter Size Map at any Scale
- Hand Base Map from Best Source Available (1/2 in. = 1 mile)
- Overlays, Tabulations and Narratives

DATA OR INFO NEEDS:
- BLM Standard Map Series

DATA:
- Climate
- Topography
- Hydrology
- Vegetation
- Soils
- Geology

Figure 2.1 Decision Flow Analysis: Example

Table 2.1 Land Inventory Computer Systems

SYSTEM	TYPE OF DATA
Canada Land Inventory	Land Capability and Land Use
CLARI	Land Use
Earth Resources Information System (University of California)	Forestry
BLM/Syracuse University	Forestry
BLM/Oregon State	Range Management
Minnesota Resource and Environmental Information System	Land Use
BLM/University of Oregon	Forestry
Illinois NARIS	Land Use
STORETS	Water Quality
PIOS (San Diego)	Soils and Traffic Zones
LUIS	Land Use

Approximately 30 subsystems, designed to perform discrete tasks related to resources management, were also reviewed.

Using the results of the data analysis, a preliminary system design was established. This design specified the general types and form of data to be stored, required processing functions, and information output. Details of the design are given in Section 3.0; the rationale leading to this design is presented in Reference 5.

2.3 System Development

In Phase III of the effort, software routines were written, tested, and assembled. All programming was done in FORTRAN IV. Testing was done on a CDC 6600. Details of the software packages are given in Volume II, Section 2.0

2.4 System Demonstration

Using data from the areas shown in Figure 2.2, a data base was constructed, entered in the computer system, and ten demonstration problems tested.

Reference 6 - Demonstration of System Features, provides a description of the demonstration problems and sample solutions, Volume II, Section 4.4 provides a detailed description of how one problem was executed.

The total data base consisted of 116 prepared overlays and associated attribute data. A land use map was prepared from high altitude color photography, the remainder of the data base inputs were derived from published maps. Table 2.2 lists the data base inputs and their characteristics. Details of the land use mapping effort are given in Reference 4.

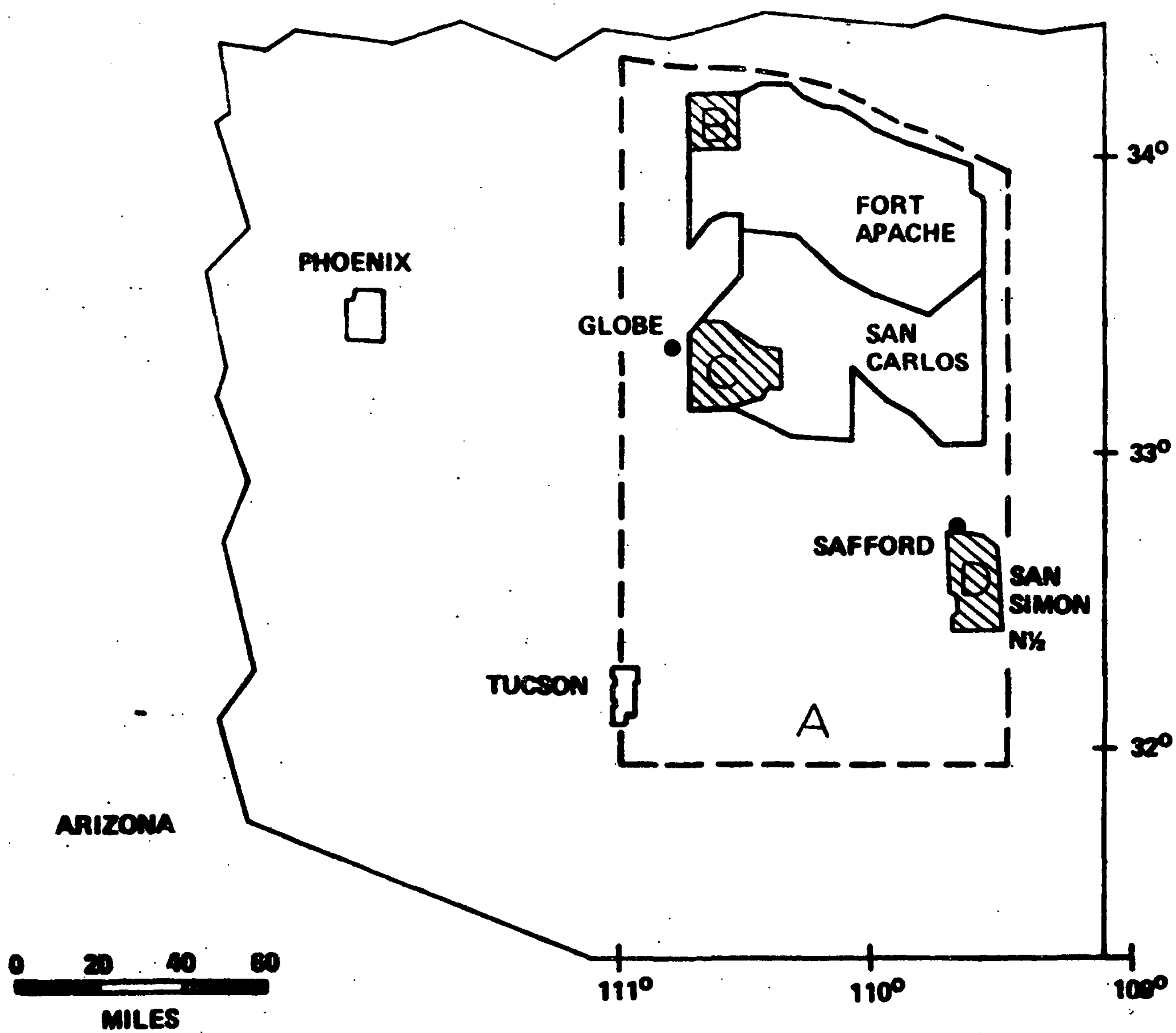


Figure 2.2 - Application Areas

Table 2.2

Maps Prepared for Digitizing

Map Type	Scale	No. of Sheets	Gd. Area*	Number of Polygons	Number of Lines	Number of Points
Land Use Polygons	1" = 2 mi.	29	A	1904		
Land Use Linear Features	1" = 2 mi.	28	A		126	
Administrative Boundaries	1" = 2 mi.	5	A	10		
Land Ownership	1" = 8 mi.	2	A	200		
Slope/Aspect	1" = 1 mi. 2-1/2"= 1 mi.	3	B,C	2154		
Elevation	1" = 4 mi.	2	B,C	28		
Physiography	1" = 4 mi.	2	B,C	101		
Geology	1" = 3 mi.	3	B,C,D	188		
Range Vegetation/Soils	2" = 1 mi	3	C	438		
Precipitation	1" = 8 mi.	1	B	5		
Range Improvements & Boundaries	2" = 1 mi	6	C	1	508	140
Timber Type	2" = 1 mi.	4	B		1274	
Timber Admin.	1" = 2 mi.	5	B	52	30	75
URA Overlays	1" = 2 mi.	26	D	268	84	307
		119		5349	2022	522

*See Figure 2.2

3.0 SYSTEM DESCRIPTION

The Natural Resources Information System was designed to be a computer based system to store, process and display land management data. Overall system flow and specific programming modules are described in Volume 2, (Reference 2). Development and demonstration of the system was conducted using a Gerber 2000 digitizer, a CDC 6600 computer and a CALCOMP 763 plotter.

3.1 Functional Description

The Natural Resources Information System is designed primarily to deal with maps or map-locatable data. Maps can be stored, two or more stored maps processed to make a map which combines or otherwise modifies the map data, and a map overlay prepared showing the results of the processing. Computations can be performed to establish the number of acres in a mapping unit, length in miles of linear features, and number of point features, and results presented in tabular form.

3.1.1 Data Input

Three general classes of input data are utilized: maps, delineated photo overlays, and field observational data. In each case, data are stored in terms of a geographic location or boundary as well as a resource descriptor and attributes of the descriptor. A resource descriptor is defined as a mapping unit designation, e.g., Fayette soil series. Attributes of a factor are items which further define the descriptor. In the case of soils, texture is one of the stored attributes. For a geologic mapping unit, rock type and age are stored as attributes.

Data input from maps and photos is normally accomplished using an optical digitizer and a keypunch. Each mapping unit is traced by the digitizer to a specified accuracy. The Gerber 2000 used for the demonstration can record data in increments as small as .001 in. to an accuracy of .005 in. over the full table (8 ft. x 16 ft.). Actual increments used ranged from 0.009 in. to 0.075 in. with 0.025 in. used predominately. Accuracy in terms of ground distance is a function of input scale. Locational data can also be entered manually to any desired degree of accuracy.

Each map entered in the system must show a minimum of three points whose coordinate locations can be specified. Each mapping unit is assigned a discrete number as well as a mapping unit symbol and the information pertaining to that unit is punched on a card. After the map or overlay has been digitized, an overlay is printed for comparison with the original, necessary corrections made, and the data stored for transformation. Field observational data are handled in a similar manner. Location of the data is plotted on a base map or photo and input in the manner described for photos and maps. Coordinates may also be entered directly.

The transformation process is required to place data in the map projection and coordinate system utilized by the base map. The base map used for demonstration is the Arizona State Highway Department 2 inch/mile series (Fig.3.1). This series uses a Transverse Mercator projection. The Public Land Survey grid and the Arizona State Plane coordinate systems are printed on the map. A UTM grid was placed on the base map, since the Natural Resources Information System is designed to operate with UTM coordinates.

Map transformation involves coordinate transform and a process called weeding. Curved lines are stored as straight line segments. In the initial digitizing process, a line is represented by many line segments; the weeding process reduces the number of segments (and coordinates) used to represent the line. Weeding is accomplished by specifying the maximum allowable deviation of the stored line representation from the original or digitized representation (Figure 3.2).

The system employs UTM coordinates but geographic coordinates may be entered. The transformation process entails geographic to UTM conversion. Other coordinate conversion routines are available in the public domain but were not used in the prototype system.

Table 3.1 lists the maps which were digitized and stored in the system for demonstration purposes. Input scales ranged from 1/24,000 to 1/500,000.

All maps were either in the Transeverse Mercator or Polyconic projection; no transform was performed.

3.1.2 Data Processing

Three general classes of processing functions are performed by the Natural Resources Information System. First, and most important, are those involving the analysis of mapping units. Map overlays can be created showing areas:

1) having specified levels of one or more factors (pine growing on slopes of 30% or more);

2) having common attributes of a single factor (sandy soils); and

3) having specified levels of one factor and not having specified levels of another (commercial forest not on allotted land).

In Boolean algebra terms, these are described as intersections, union, and complement operations. (Figure 3.3)

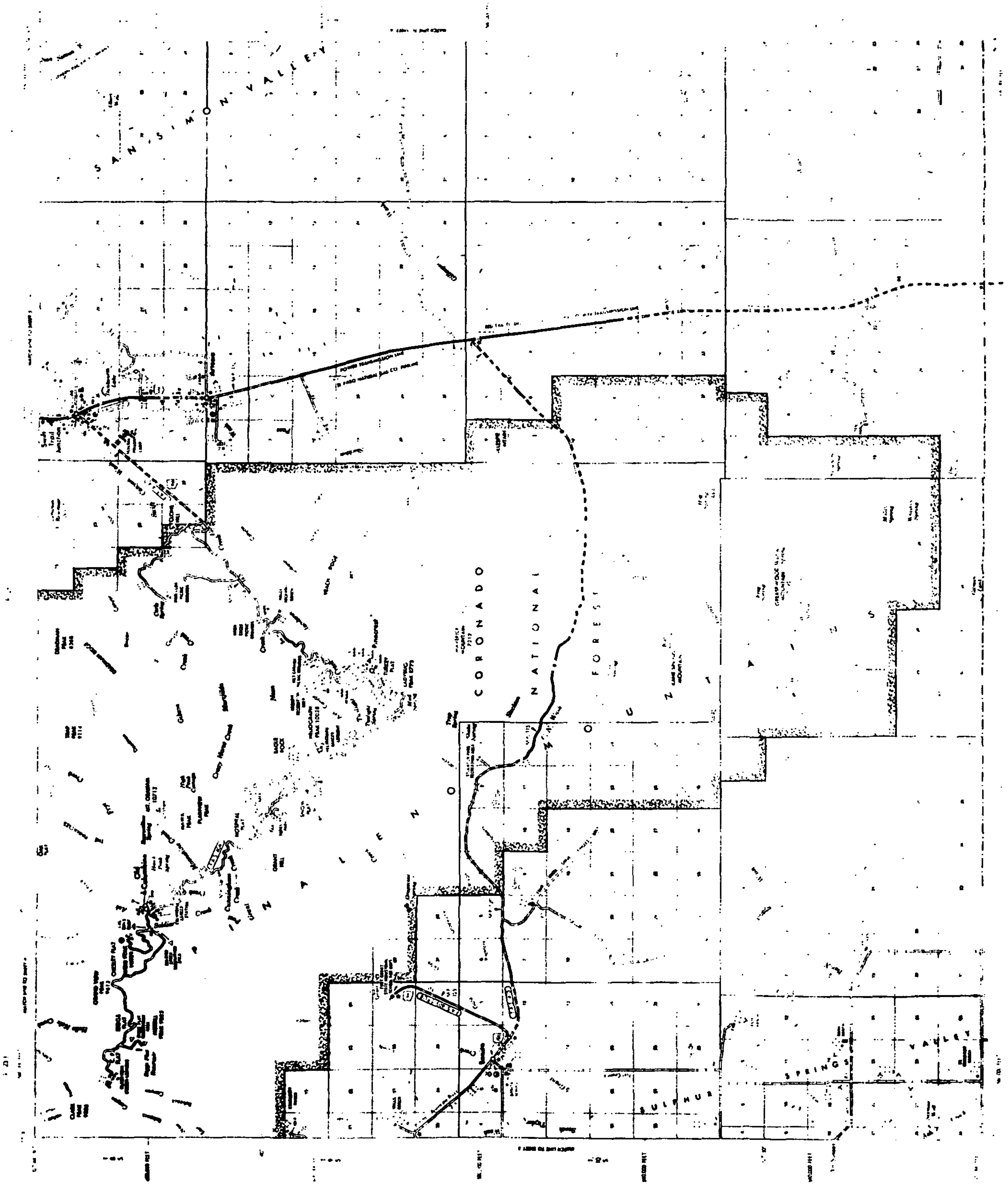


Figure 3.1. Arizona State Highway Department Map

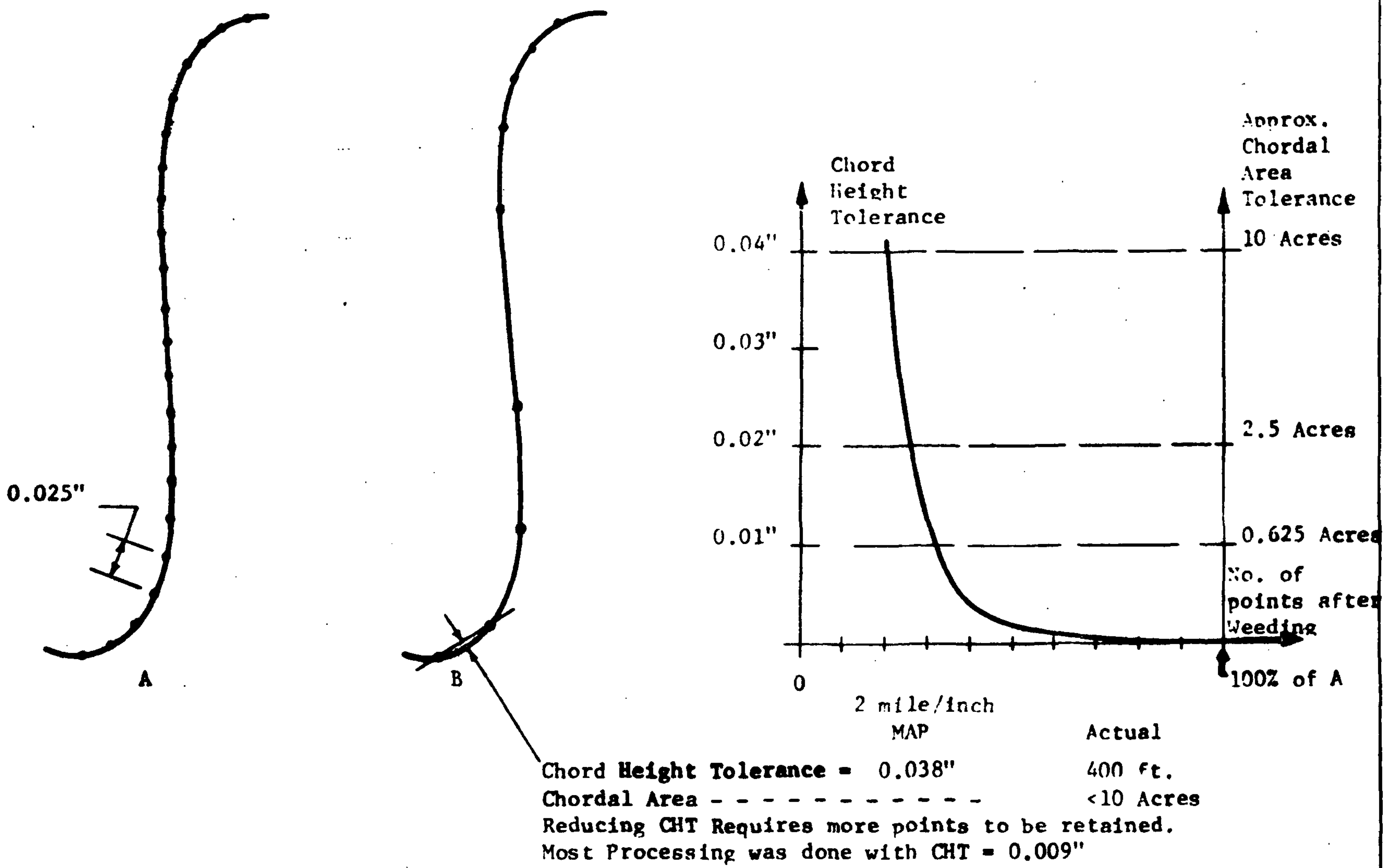


Figure 3.2. WEEDING PROCESS. The original line can be digitized according to 3 options: - (1) Evenly spaced points (2) Area tolerance, (3) Angular tolerance, where the latter options perform selective weeding by the digitized software. Line (A) shows option (1) with spacing at the most commonly used value. Further weeding is done by software in the file building process to reduce the number of points to be stored. This process uses a chord height tolerance method which also guarantees area tolerance requirements (B).

Table 3.1 - List of Digitized and Stored Maps

Map Identification	Description
03010000672	URA/ Soils & Parent Geological Formation
03020000672	URA/ Land Classification & Market Value
03030000672	URA/ Recreation - Present Resource & Opportunities
03040000672	URA/ Erosion Hazard
03050000632	URA/ Range Condition
03060000672	URA/ Vegetation (Species)
03070000672	URA/ Allotment Boundaries & Grazing Systems
02010100482	BIA/ Slope (Fort Apache)
06010104692	BIA/ Timber (Fort Apache)
01031500622	Land Use/ Streams
01041500622	Land Use/ Roads
01041700622	Land Use/ Roads
01051500622	Land Use/ Railroads
01061500622	Land Use/ Utilities
01071500622	Land Use/ Canals

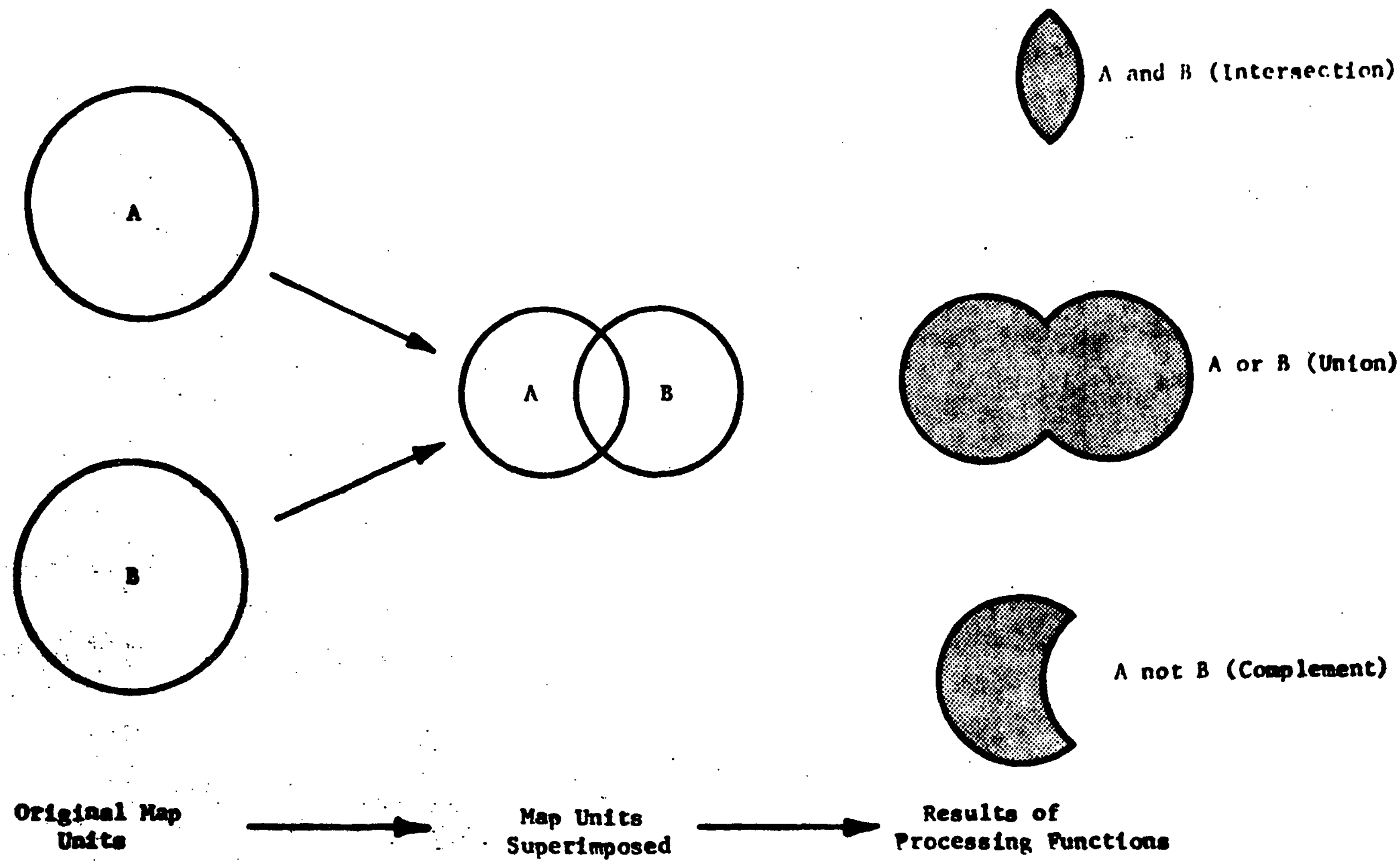


Figure 3.3 Basic Map Unit Processing Functions

The number of factors, attributes, or map overlays used in preparing an overlay is unlimited so long as the logic structure of each file is followed.

Using, for example, a timber map and soils map, it is possible to prepare the following overlays:

1) all ponderosa pine growing on sandy soil;

2) all ponderosa pine not growing on sandy soil;

3) all ponderosa pine and/or spruce growing on sandy soil;

4) all areas on the timber map where site quality exceeded a given value;
and

5) all areas which have high quality merchantable timber and a soil of a type known to favor timber growth.

The overlays produced by any of these operations could then be combined with a slope map, an allotment map or an administrative boundary map to produce a further set of overlays.

The second class of processing operations involves counting or tabulation. The number of acres occupied by a mapping unit or group of units, number of miles of a boundary (e.g., lake shoreline) or linear feature (roads or streams), or number of features (stock ponds) can be calculated. Results of the calculation can be multiplied by a value or a value added or subtracted from the computation. It is thus possible, for example, to prepare an overlay and tabulation showing the money to be received from logging each unit on a timber type map.

The third class of processing functions involves reporting. A series of programs are available to store and process data required for the BIA Annual Forestry Report. Inventory data, monthly scale reports and individual fire reports are stored and processed to provide an annual record of timber accretion and depletion.

3.1.3 Data Output

Two principal output formats are utilized; map overlays and tabulations. The tabulations are conventional computer printouts; the overlays are prepared on a CALCOMP Model 763 drum plotter and can be generated at any scale for which a base map in the proper projection is available. For the demonstration, a base map scale of 1/125,000 was used. Map sheet size is limited to 29.5 inches in width and 120 feet in length. Machine accuracy is ± 0.010 inches excluding paper shrinkage or expansion.

3.2 Equipment

There are four basic hardware components utilized by the prototype Natural Resources Information System. They are:

1) Gerber 2000 Optical Digitizer
2) IBM 360-40
3) CDC 6600
4) CALCOMP 763 Drum Plotter

The Gerber digitizer is used to input map feature coordinate data and identifying information onto punched paper tape. The Gerber is an automatic line following machine. A TV camera scans the input map and provides a 10X magnified view of the map to the operator. The operator depresses a foot pedal which drives the camera along a line. When a line intersection is reached, the operator must manually adjust the scanner to follow the correct line, otherwise he simply monitors the progress of the machine. A small computer program performs the automatic tracking.

The Gerber can accommodate copy up to 8 ft. by 16 ft. in size. It operates most efficiently on high contrast copy with minimum line weight.

The IBM 360-40 is used to read the paper tape of the digitizer and convert values onto a magnetic tape. This step could be eliminated if the digitizer were equipped to input data directly onto magnetic tape. The software capability to go directly to magnetic tape exists and the cost to add this feature is modest.

The 6600 is a large multi-processing computer. BCS operates it under the Kronos II operating system. The combination of this operating system and the computer is used by BCS to perform the functions of file building, logical operations and printed and plotted output tapes for off-line processing.

The machine is configured with 131K decimal 60 bit computer words. This word size amounts to about 15 significant digits of accuracy in any numbers stored or computed. There are 12 input output data channels connected to 7 input output tape drives.

There are also:

1 card punch
1 card reader
4 1200 line/min. line printers
2 high speed discs) 34.4 mill 60 bit words
2 "low" speed discs)

The Natural Resources Information System is operational on the CDC 6600 computer and is designed to use no more than about one-third of the machine's capacity. The programs on the 6600 will read the converted magnetic tape from the digitizer, create data files, produce printed output and write plot files that may be plotted on the CALCOMP 763 Drum plotter.

The CALCOMP 763 Drum Plotter is used to plot output overlays. Maximum sheet size is 29-1/2 inches by 120 feet. The machine plots straight lines connecting stored coordinate points. Maximum accuracy is ± 0.005 inches, by manufacturer's specification. In practice, especially over large drawings, accuracy would be about ±0.01 inches.

3.3 Program Description Summary

The Natural Resources Information System was designed to be adaptable to a wide variety of applications. The user controls the type of data that is stored, retrieved, processed or displayed. A diagram of the program layout is given in Figure 3.4.

The system software is organized into five program modules. The CONVERT module is used to read digitized data and write a coordinate file. PLOTMP contains the routines used to plot overlays. Included in this module is a program providing for plotting of digitized data in an exploded view. Successive map features can be shifted by some user-specified distance to facilitate map edit.

EDITOR is used for file editing and the creation of attribute files. Coordinate transform is also included in this module. The EXTRACT module contains software used for overlaying map files to establish set intersections and unions. It also provides a capability of setting area and linear tolerances for interaction of data files.

Finally, the REPORT module contains software routines used for such things as area computation, point counting, and computation of linear feature length. Writing of timber and fire reports and file data listing is also accomplished under this module.

Further details on system software are provided in Volume II.

3.4 File Design

The files set up for the demonstration system were for the most part based on the information available in the demonstration areas. A file entry consisted of an arbitrarily assigned unique number designating a specific polygon, line, or point, a string of coordinate values providing the location of the mapped unit, and a character string providing the attributes of the mapped unit. An open-ended file design was used. It was concluded that file design, in the sense of establishing the specific data elements to be included in each file, should be accomplished by the user agencies. As a starting point for this effort, however, several prototype designs were established.

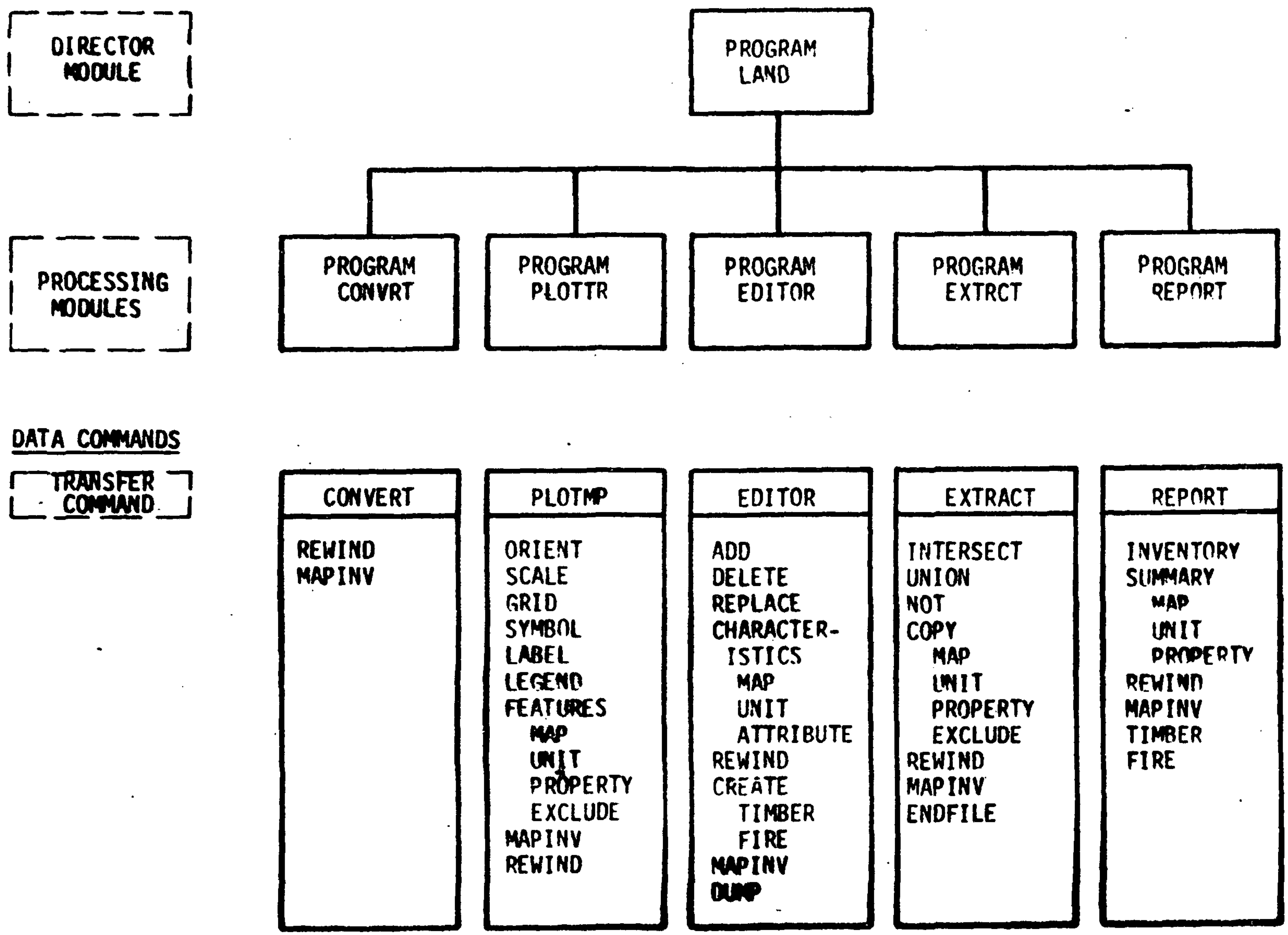


Figure 3.4 - Program Layout

3.4.1 Map Identification

Data within the system is currently organized on the basis of the input maps from which data were derived. In general, every map overlay entered into the file generates a discrete file and every map has a unique identifying number. An 11-digit number describes the type, origin, date and geographic location of the map data as shown in Figure 3.5. Table 3.2 lists the codes assigned for the demonstration system. Additional digits could be assigned to provide greater specificity in terms of map area location if desired by the particular user application.

3.4.2 Forestry File Design

The forestry file was designed to store information on forest inventory mapping units (Fig. 3.6). Types of information stored include cover type (tree species, non-commercial land classification), age, condition, crown density, site quality, growth rate, and value. Value is defined in terms of commercial versus non-commercial, dollars, or any combination of stand condition data. For example, a classification can be created which takes into account species, age, and site quality. Table 3.3 shows the layout of the file system.

3.4.3 Slope/Aspect

The slope/aspect file records slope in percentage categories and direction of slope (Figure 3.7). Up to nine slope and nine aspect categories can be employed. For the prototype system, six slope and five aspect categories were used as follows:

Slope	Aspect
1 = 0 - 4%	N = North
2 = 5 - 8%	E = East
3 = 9 - 16%	W = West
4 =16 - 32%	S = South
5 =33 - 50%	X = No determination; etg., flat land, knob of hill.
6 = > 50%	

Slope mapping was accomplished using 1/24,000 and 1/62,500 scale U.S.G.S. topographic maps.

Data Type & Location — Sheet Number — Source of Data

0 6 0 1 0 1 0 4 6 7 2 e.g.

06 = Timber
01 = Ft. Apache
01 = Sheet #1
04 = April
67 = 1967
2 = man

Month Year
of
Data Collection

Figure 3.5 Map Identifier System

Table 3.2

Map File System Codes

Category	Code	Meaning
Data Type (1st two digits)	01	Land Use
	02	Slope/Aspect
	03	URA Overlays
	04	Soils/Range (BIA)
	05	Elevation/Physiography
	06	Timber
	07	Geology
	08	Range Improvement (BIA)
	09	Precipitation
Data Type (2nd two digits)	0101-0107	Specific land use overlays; e.g. 0102 for administrative boundaries
	0301-0319	Specific URA overlays
	0501	Elevation
	0502	Physiography
	0601-0607	Specific Timber Data categories; e.g. 0604 for fire map
	0801-0806	Specific data types; e.g. 0806 for natural boundaries

34°17'15"
110°46'56"

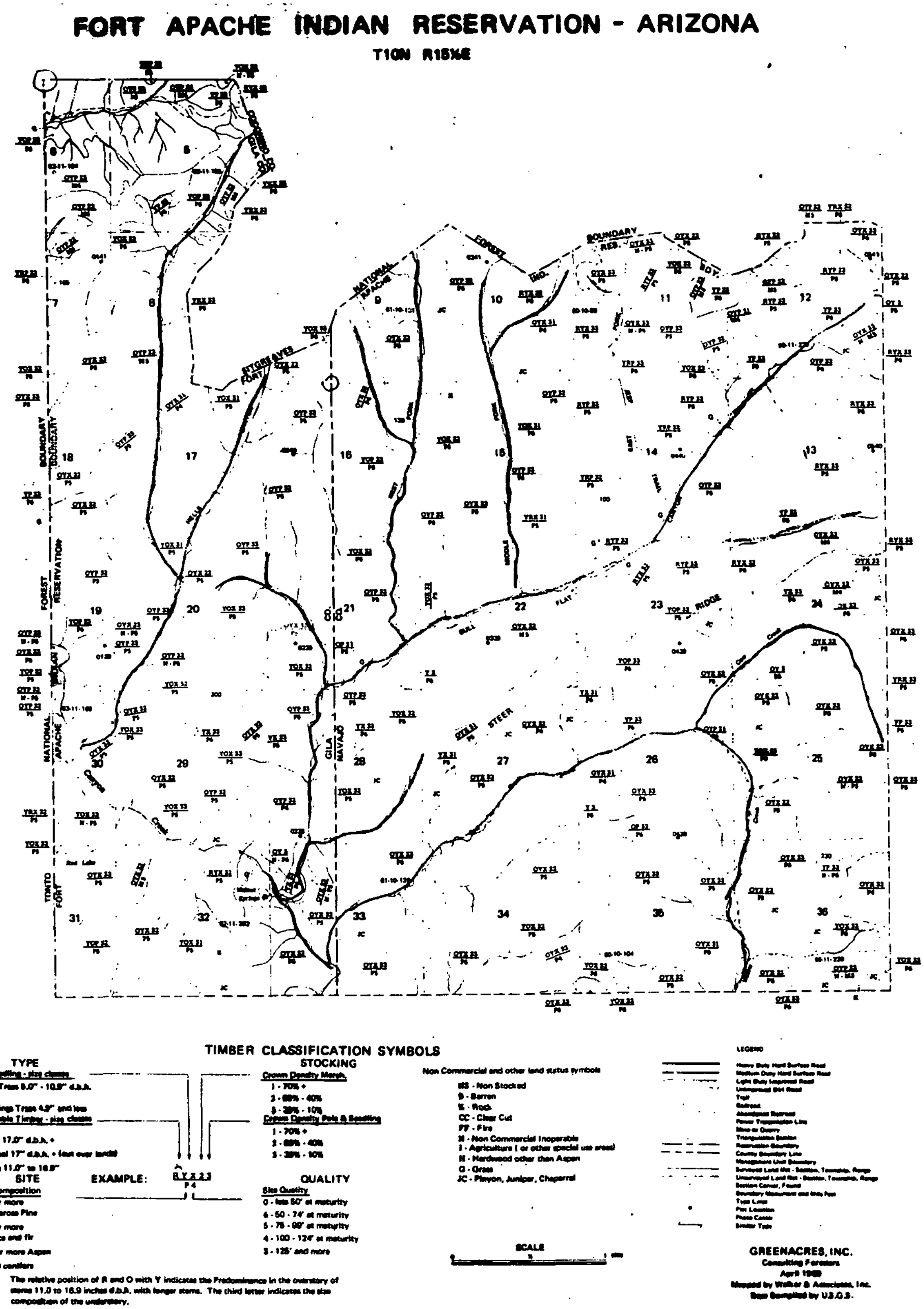


Figure 3.6. Forest Inventory
Mapping Units

Table 3.3

Forestry File Design

Data Category	Levels
Value-1	Commercial, Non-commercial
Value-2	Up to 9 categories based on sorting of other data
Value-3	Up to 9 ranges of dollar values
Status-1	Vegetation Other land
Status-2	Vegetation type/species, e.g. ponderosa pine, mixed conifer, grass, etc.
Condition	Virgin Residual/cut over Young
Age	Seedling/sapling Pole Saw timber
Crown Density	High 70% + Medium 40-69% Low 10-39%

(Note: each area may have two ages and two crown density values)

Site Quality	0 = 50' at maturity
	6 = 50-74' "
	5 = 75-99' "
	4 =100-124' "
	3 =125' + "
Growth Rate	MBM per year in up to 10 categories
Inventory Plot	4 digit number identifying inventory plot

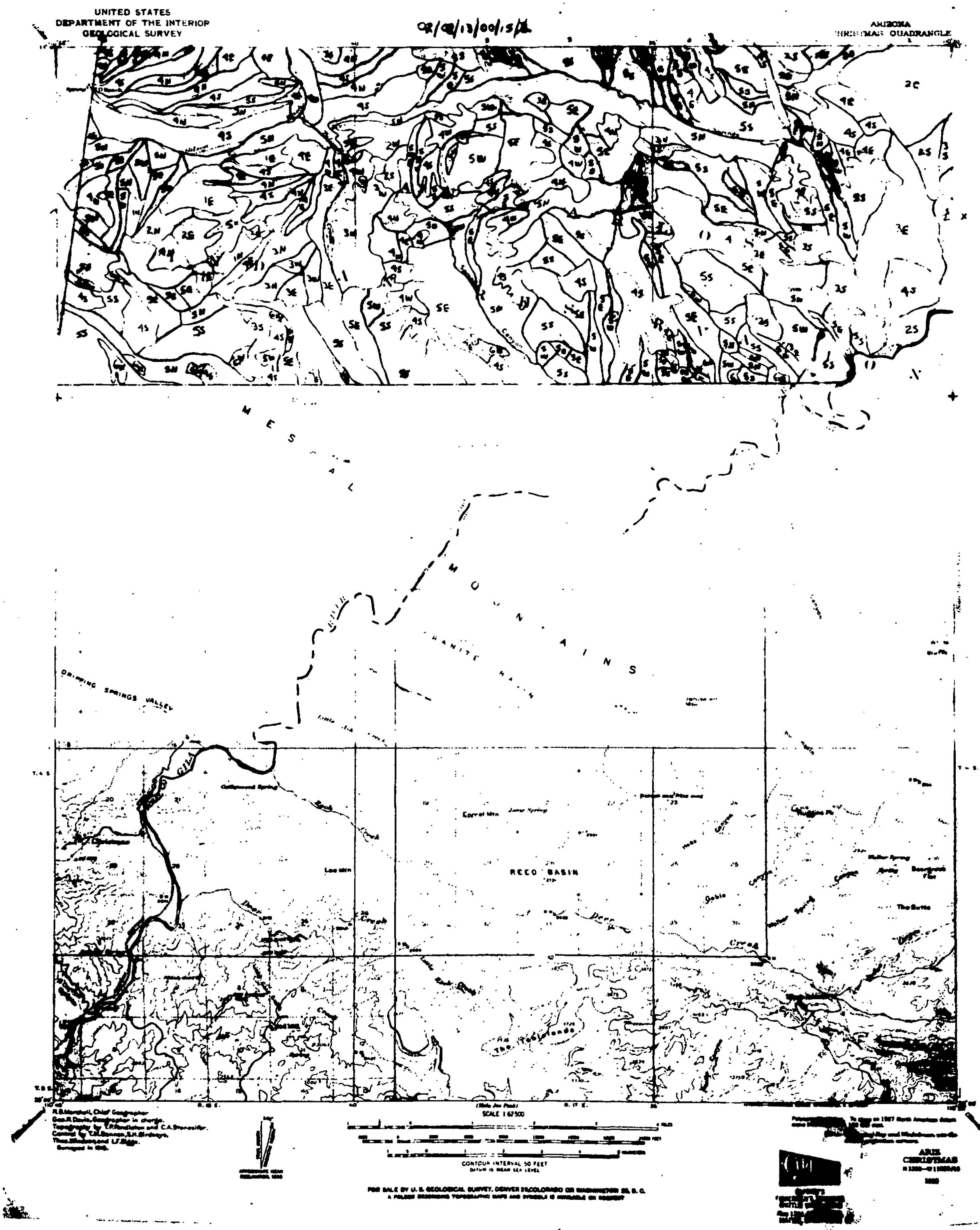


Figure 3.7. Slope/Aspect Map

3.4.4 Geology File Design

The geology file was designed to store information extracted from geologic maps. Types of information stored include age, rock type, and rock characteristics. Table 3.4 lists the information classifications. Provision was made for adding linear data (fault lines, etc.) and point data (dip and strike, etc.). These data, however, were not included in the prototype file.

3.4.5 Soil File Design

The soil file was designed to accommodate BIA soil classification data as well as SCS and BLM soil description data. BIA data may be entered using the descriptive terms shown in Table 3.5 or the depth/texture/permiability classes shown in Figure 3.8.

3.4.6 Physiographic File

The physiographic file stores data on elevation and macro features. Elevation was recorded in 1000 foot contours, macro features in six level classification systems ranging from mountainous to flat (Poulton's macro features classification system, (Ref. 7) as follows:

1) Flat
    a. Not dissected
    b. Dissected

2) Rolling (10-25% slope)
    a. Rolling or hilly
    b. dissected

3) Hilly/Submountainous

4) Mountainous

3.4.7 Land Use

The land use system (Table 3.6) was based on Anderson's land use classification system (Ref. 8). In addition to the use categories, which were coded as 4-digit numbers, provision was made to store land ownership (state, private, federal agency) and municipal boundaries.

Table 3.4

Geologic File Design

Date Category	Levels
Age	9 levels, PreCambrian to Quaternary
Type	Igneous Metamorphic Sedimentary
General Characteristics - 1	Sed. - Consolidated Unconsolidated
	Met. - Meta-sediment Meta-volcanic
	Ig. - Glassy/Fragmental Fine grained Coarse grained
- 2	Sed. Consol. - Clastic Non-clastic
	Sed. Unconsol. - Well sorted Poorly sorted
	Met. - Contact Regional Mixed or unknown
	Igneous - Basic Acidic

Type - Total of 67 types; e.g., limestone, gabbro, etc.

Example: 21113

Paleozoic siltstone
2 Paleozoic
1 Sedimentary
1 Consolidated
1 Clastic
3 Siltstone

Table 3.5

Soil File Design

Data Category		Levels
Land Cover - 1		Cropland
		Former Cropland
		Woodland
		Grassland
		Barren
		Other
Land Cover - 2		Rough
		Broken
		Stoney
		Gullied
		Badlands
		Active sand dunes
		River wash
		Thin breaks
		Rough breaks
Productivity		High
		Moderate
		Low
Soil Depth - 1		Deep 36" +
		Mod. Deep 21-36"
		Shallow 10-20"
		Very shallow 9"
Soil Depth - 2		Less than normal thickness surface layer
		Normal thickness surface layer
		More than normal thickness surface layer
Texture - 1		Loam
		Organic
		Fine
		Moderate
		Coarse
Texture - 2	(fine)	Clay
		Clay silt
		Silt clay
		Silt
	(moderate)	Silty sand
		Sandy silt
		Fine sand

Table 3.5 (continued)
Soil File Design

Data Category	Levels
(coarse)	Coarse sand Gravel Cobbles
Permeability	Very rapid Rapid Moderate Slow Very slow
BIA Soil Description (Depth, Texture, Permeability)	(See Figure 3.8)
Erosion - 1	Wind accumulation Wind removal Slips & landslides Water
Erosion - 2	Slight Moderate Severe
Inhibitory Factors - 1	Alkalinity Salinity Calcareous Caliche Claypan Zone of lime accumulation in soil Gypsum Stoniness Chert Gravel Non-restricting usable strata 10-20" Non-restricting usable strata 20-36" Non-restricting usable strata 36" +
Inhibitory Factors - 2	Wet Slight Moderate Severe
Parent Material - 1	Residual Alluvial
Parent Material - 2	Igneous Sedimentary Metamorphic

Table 3.5 (continued)
Soil File Design

Data Category	Levels
Parent Material - 3	Sandstone
	Limestone
	Shale
	Acidic
	Basic
	Mixed Alluvium
	Siltstone
	Mixed parent rock
	Calcoreous mixed alluvium
	Mixed alluvium

CO 1000 0080 ORIG. 4/71

Depth	Deep					Moderately Deep					Shallow					Very Shallow
	36" - plus					20-36"					10-20"					5-10"
	Permeability					Permeability					Permeability					
Texture	VSP	SP	MP	RF	VRP	VSP	SP	MR	RP	VRP	VSP	SP	MP	RP	VRP	
Fine	1	2	3				13	14	15			25	26	27		36
Medium	4	5	6	7	7	16	17	18	19	19	28	29	30	31	31	37
Coarse	8	9	10	11	12	20	21	22	23	24	32	33	34	35	35	38

Figure 3.8 Standard Symbols for Making Soil Surveys

TABLE 3.6

ANDERSON LAND USE CLASSIFICATION SYSTEM (MODIFIED)

LEVEL 1	LEVEL 2	LEVEL 3
I. Resource Production & Extraction	A. Agricultural	1. Crop Production a. Irrigated b. Non-Irrigated 2. Fruit/Nut Culture a. Irrigated b. Non-Irrigated
	B. Grazing*	
	C. Forestry	1. Non-Commercial* 2. Commercial*
	D. Mining & Quarrying	
II. Transportation, Communication & Utilities	A. Roads B. Railroads C. Airports D. Communications & Utilities	
III. Urban Activities**	A. Urbanized Livelihood Areas (1970 Census Bureau Definition)	1. Industrial 2. Commercial 3. Residential 4. Institutional* 5. Other Urban Land
	B. Other Urban (Population > 2500 but not urbanized)	Same as III A*
IV. Towns & Other Built-up Areas**		Same as III A* plus 6. Residential Development
V. Recreation	A. Mountain Oriented B. Water Oriented C. Desert Oriented D. Other(Golfcourses, parks, etc)*	
VI. Low-Activity Areas	A. Marshland Oriented B. Tundra Oriented C. Barren land Oriented	
VII. Water Using Activities	A. Standing (Lakes, Oceans, etc.) B. Flowing (Rivers)	

*Indicates changes from the Anderson system.
**Mapping of urban and built-up areas will not be beyond Level 1.

3.4.8 URA Overlays

In the BLM, administrative areas known as planning units are graphically described on a series of up to 36 Unit Resource Analysis overlays. For the demonstration area, 18 such overlays were available (Table 3.7). Provision was made for storage of the information contained on each of these overlays in a separate file. For the most part, it was necessary to treat each as a separate case except for those instances where one overlay showed current conditions and a mate showed projected conditions. Figures 3.9 through 3.11 show examples of these overlays.

3.5 Input Requirements

The Natural Resources Information System in its present form will accept any type of data which:

1) can be located on the base maps; and
2) can be classified or described in terms of one of the existing file systems.

The base map carries State Plane, UTM, Geographic and Public Land Survey coordinates. The Public Land Survey is not complete over the total area, however. Existing file systems are described in Section 3.4.

The normal method of data entry is by digitizing. Any map or map overlay in a Transverse Mercator or Polyconic projection can be handled in this manner. Maps utilizing other projections may require projection transform. Software required to perform these transforms is available in the public domain but has not been incorporated in the current system.

Digitizing is performed on a specially prepared manuscript or overlay. Three types of data can be entered; points, lines (linear features) and mapping unit boundaries (polygons). Each type of data is entered from a separate manuscript.

Point data are recorded on the manuscript as a point or a cross so that the digitizer operator can readily determine the precise location to be digitized. If all point features to be entered are identical, they need only be symbolized on the manuscript. If they differ in some manner, different symbols can be used or the points can be numbered and their characteristics listed on a separate sheet. Figure 3.12 illustrates the three methods of portraying point features on the digitizing manuscript.

Linear features are portrayed as solid lines; dashed, colored, or cross-hatched lines cannot be used. For this reason, a linear feature manuscript can normally show only one type of feature. Roads and railroads, for example, must usually be shown on separate overlays. If descriptive information on the linear features is to be stored, each line must be numbered. A number is applied to every line between all intersections and the characteristics listed on a separate sheet.

Table 3.7

URA Overlays

Overlay Title	Types of Information
Soils and parent geologic formation	4 character designator of each mapping unit
Land classification and market value	Land value and indication of whether or not land was classified for retention.
Recreation	Boundary and identification of recreation areas
Erosion hazard	3 level classification of erosion potential
Range condition	5 level classification of range condition, location and identification of photo stations and line transects, 3 level classification of range trend
Vegetation	5 level classification of vegetation type, listing of 3 most dominant species in each mapping unit
Range Management	Grazing system type and location, allotment boundary, allotee identification, utilisation (CYL/Sec.)
Range Improvement	Location and identification of all fence lines, corrals, and water facilities
Mineral Status	Location of all areas where minerals owned by Federal Government
Mineral Occupancy	Location and identification of all mineral resource areas, leases, patents, etc.
Proposed exchanges	Location of land suitable for disposal by exchange, land BLM needs to acquire by exchange

(continued)

Table 3.7

URA Overlays

Overlay Title	Types of Information
Wildlife, Present	Location and species identification of watershed habitat areas; location of watering facilities
Wildlife, Potential	same
Found Section Corners	Location of all found section corners
Roads	Location and identification of all roads and road markers
Rights of Way	Location, width and file designation of transportation and utility rights of way
Watershed	Location and identification of all watershed improvements
Watershed Potential	same for planned improvements

Figure 3.9
Range Condition and Trend

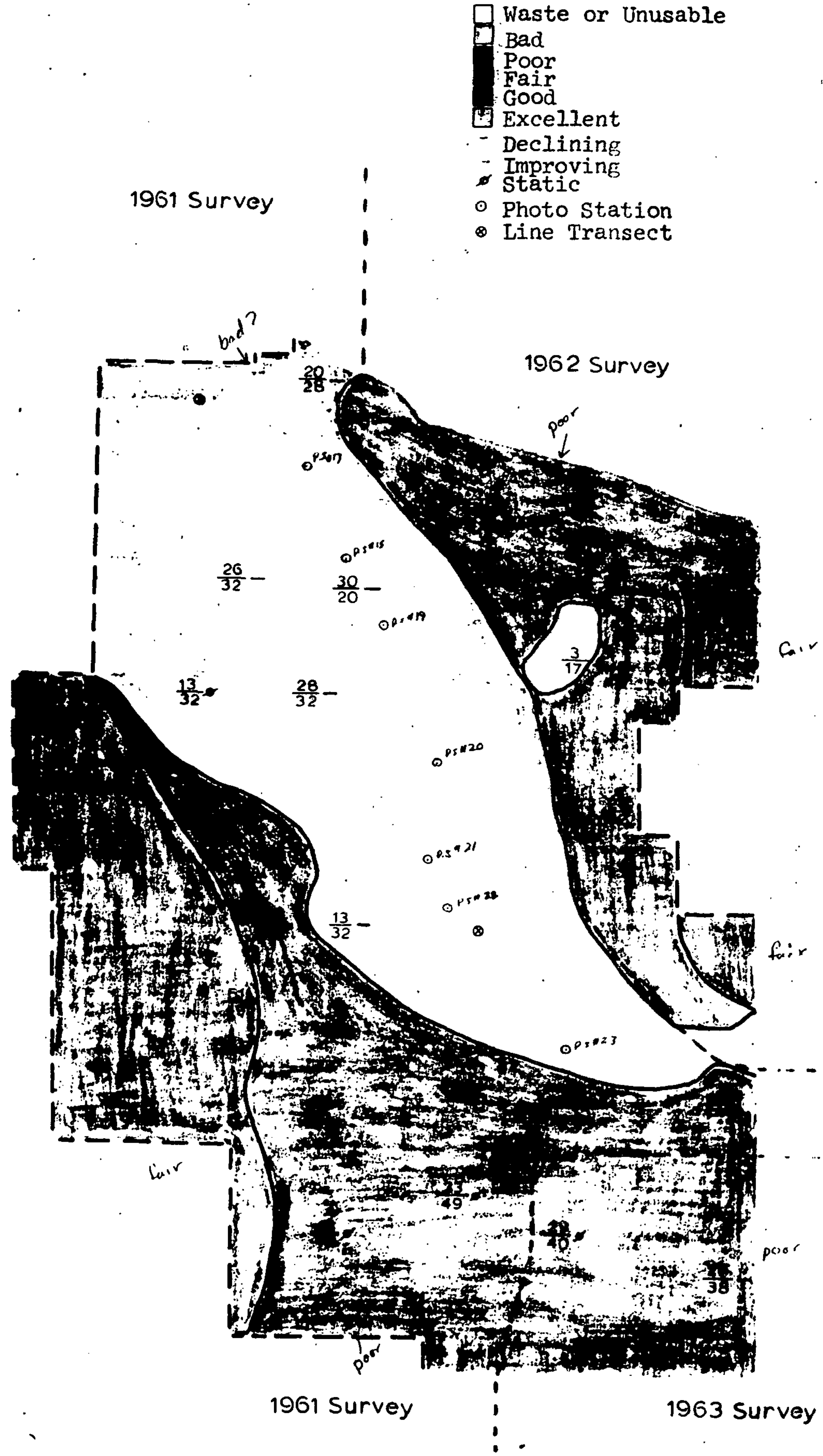
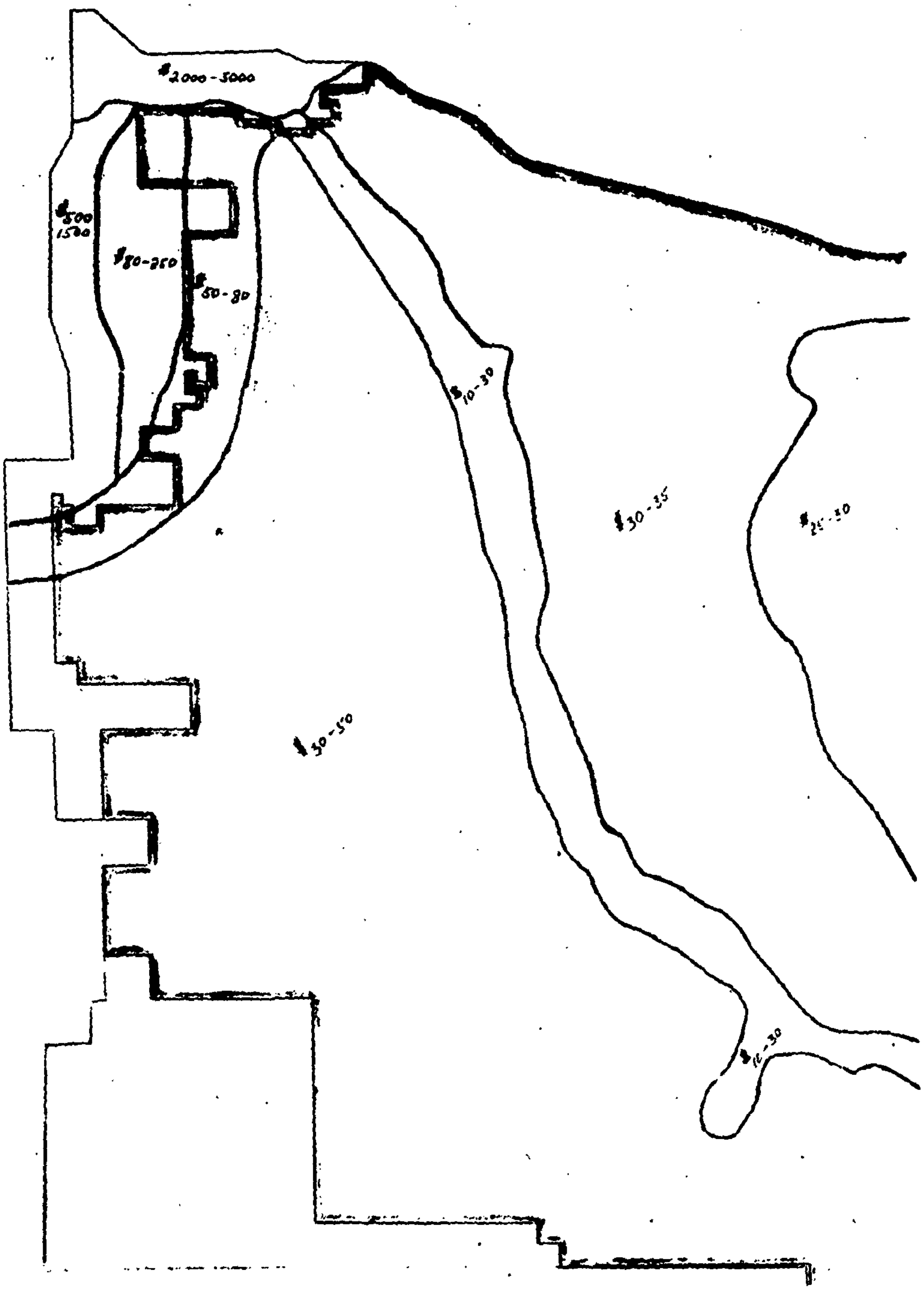


Figure 3.10
Land Classification
and
Land Market Values

Area Classified for Retention
Estimated Fair Market Value



F3q West San Simon Slopes
F3g3 Gila Valley Farmland
F3n6 Gila Mountain Slopes
F4i6 Gila-Peloncillo Mountains
F4k2 East Chiricahua Footslopes
F4b11 Pinaleno Foothills
F4i3 Fisher Hills
F4s3 Whitlock Valley

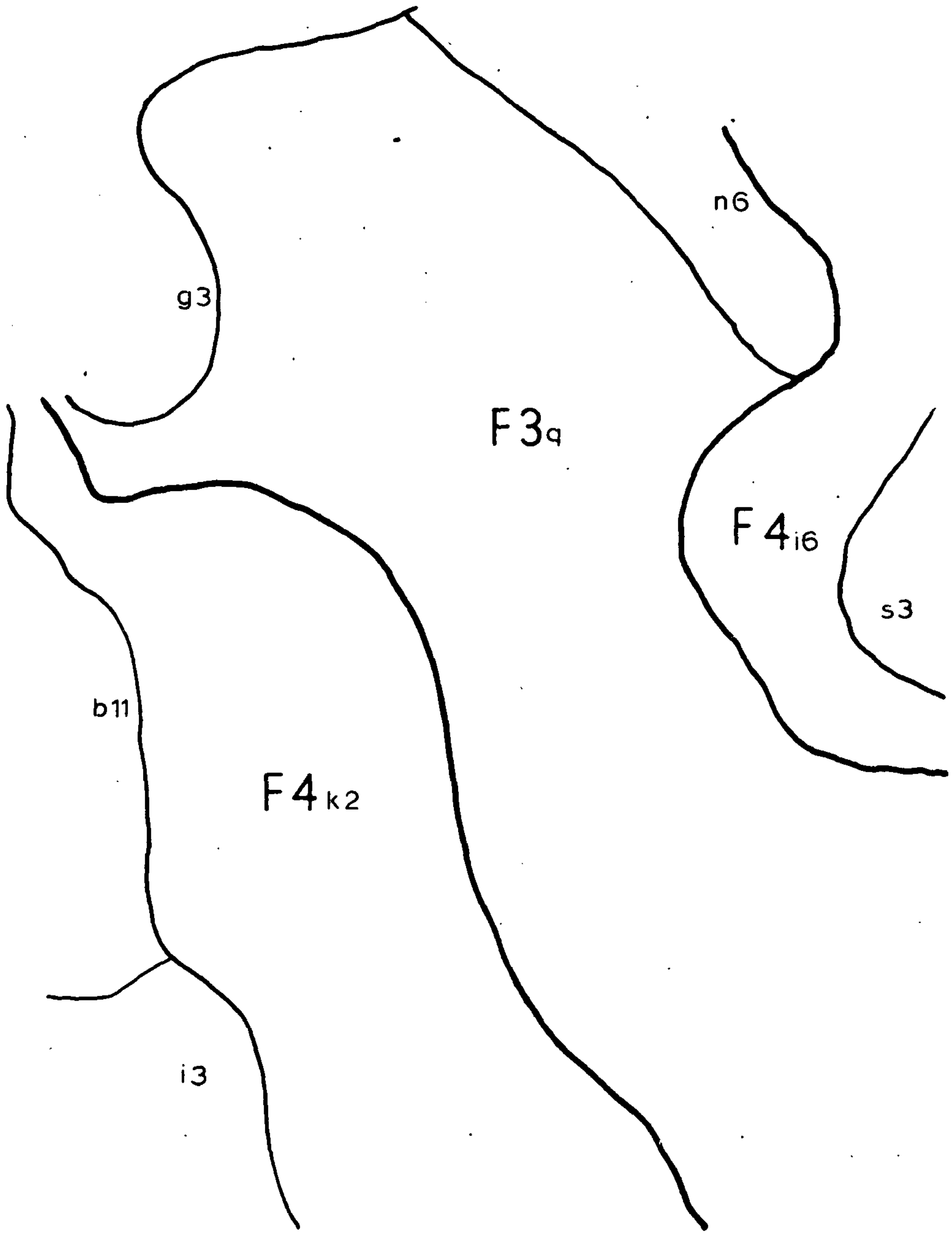


Figure 3.11. Soils and Parent Geological Formations

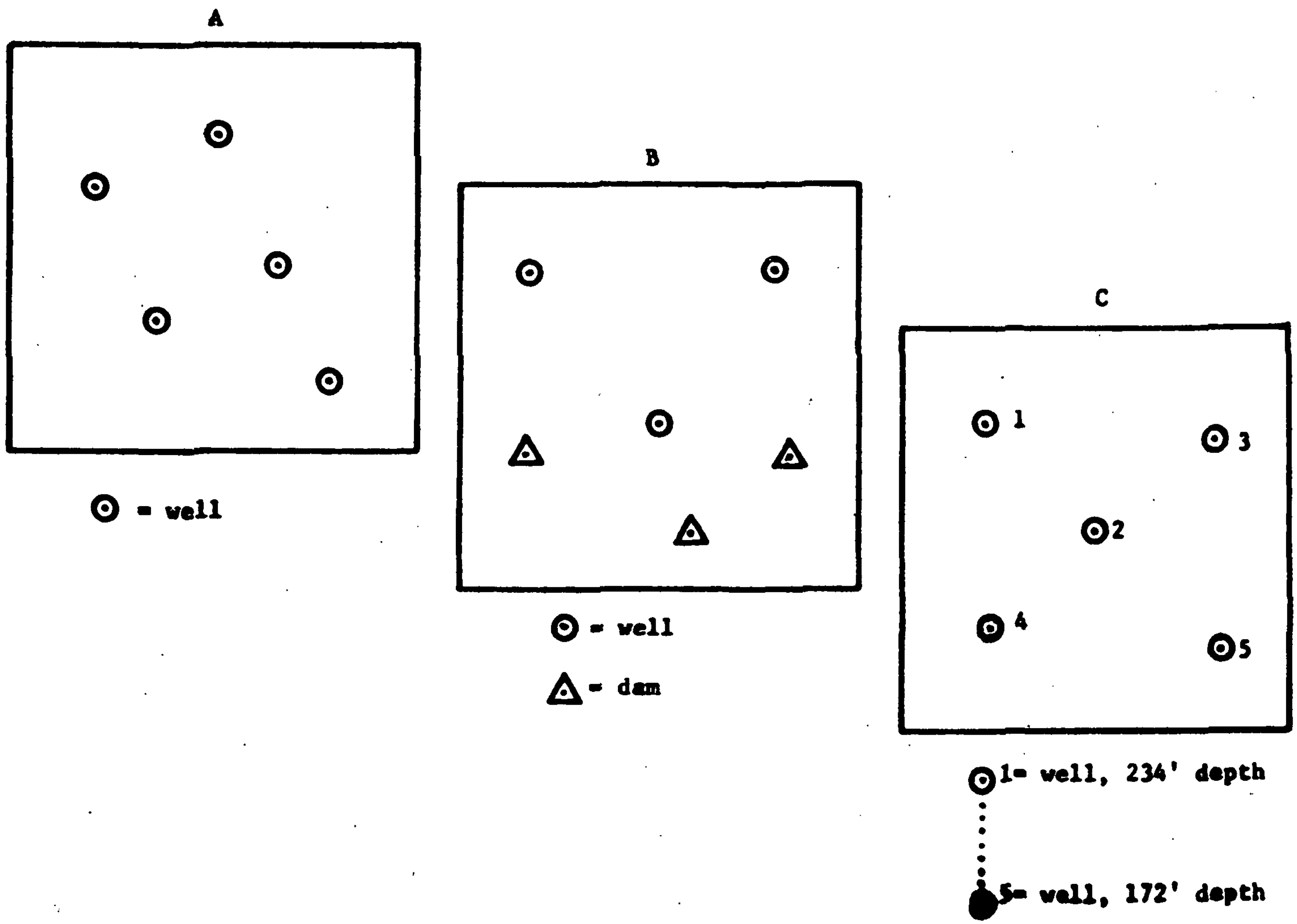


Figure 3.12. Alternative methods of portraying point features on digitizing manuscript.

CO 1000 0080 ORIG. 4/71

Figure 3.13 illustrates three permissible methods of showing linear features.

Map unit boundaries or polygons are also shown as solid lines. All polygons must be closed and all must be numbered (Figure 3.14). Descriptive information on each polygon is listed on a separate sheet. Digitizing with an optical line following attachment is fastest and most accurate when line weight is at a minimum and all lines are of high and equal contrast. All of the data entered in the system to date has been prepared using a Number 0 or 00 Rapigograph pen on chemically frosted mylar. Pencil was found to be unsatisfactory because of line contrast variations. Mechanically frosted acetate is unsatisfactory because erasures remove the surface and cause reflection problems with the digitizer.

It is also possible to use photographically prepared map separations rather than inked tracings for the digitizing manuscript. This method is particularly useful with items such as timber type maps, where a separation showing only the type boundaries is normally available.

All digitizing manuscripts must show a minimum of three coordinate point references. In this application, six such points were used. These references are used to adjust scale and relate the data to the base map. The geographic or UTM coordinates of the points are recorded on the overlay. The map identifier is also recorded on the manuscript.

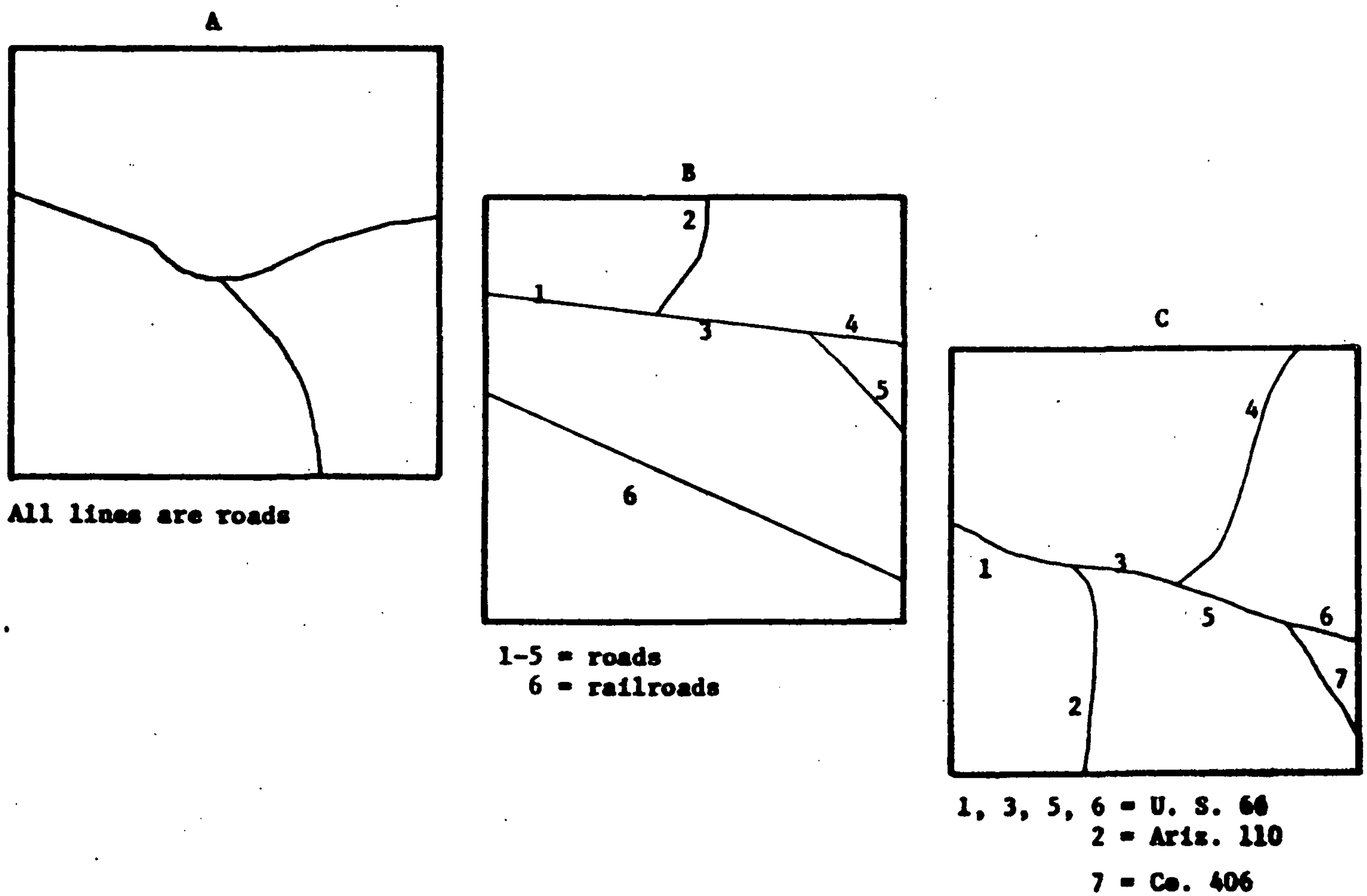


Figure 3.13. Alternative methods of portraying linear features on digitizing manuscript.

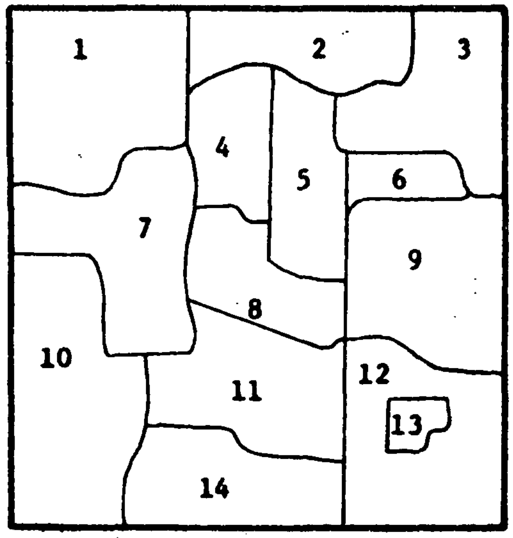


Figure 3.14. Method of portraying polygons on digitizing manuscript. Each polygon must have a unique identifying number and all polygons must be closed.

4.0 SYSTEM OPERATION

At the present time, 119 map overlays have been prepared for digitizing, 49 map overlays have been digitized, and overlays entered into the data base. Ten problems exercising the processing functions of the system have been run. Details of this experience are described in the following sections.

4.1 Data Input

All materials were prepared for digitizing as inked mylar overlays. Most of the overlays were traced from existing maps. Each overlay consisted of a series of numbered polygons, points or lines. A separate coding sheet was prepared at the same time to record attributes of each mapping unit.

The time required to prepare and number an overlay ranged from .25 to 10 hours depending on number of features, complexity of features, and scale. Rectangular features required much more time to trace than irregular polygons.

Recording of attribute data required from .25 to 4 hours per overlay. Time was affected principally by the amount of data to be recorded. Representative time samples are given in Table 4.1.

Land-use mapping was accomplished from 1/117,000 scale photos. Approximately two hours per stereo model were required for initial delineation and one hour per model for radial line plotting on a base map overlay. The plotter used pencil and it was subsequently determined that the digitizer would not handle pencil lines without constant readjustment. Overlays were therefore replotted in ink. This, plus numbering and coding of polygons, required from 2 to 4 hours for each of the 29 map overlays.

Digitizing of the prepared overlays required from .25 to 40 hours per overlay. A timber type map consisting of some 200 polygons at a scale of 1/24,000 required 40 hours to digitize. A total of 91,000 points were recorded. A soils map at 1/125,000 scale consisting of 9 polygons required 1.9 hours to digitize; 3500 points were recorded. Weeding to a 400 foot chord height tolerance reduced the number of stored points to 600.

After an overlay was digitized, additional time and cost was required to place the data in a computer file. On an average, for every 20 hours of original digitizing time, 16 hours of programmer, keypunch and redigitizing labor was required plus approximately $110.00 of machine time.

A reduction in digitizing time was exhibited as the job progressed. It was concluded, however, that the automatic line

TABLE 4.1

Preparation Time for Digitizing Overlays

Map	Scale	No. of Polygons	Preparation Time
Timber Type	1/29,000	260	6 hrs.
Soil/Range	1/24,000	200	10 hrs.
URA Soils	1/125,000	9	1.3 hrs.
Administrative Boundaries	1/500,000	11	2 hrs.

Follower used for the job is not a practical means of data entry except where high accuracy is paramount. A hand operated digitizer which could be used on maps as they are received appears to be the best interim solution; a completely automatic line scan input device appears to be the best long term solution.

4.2 Data Processing

Ten processing problems were performed, eight using URA overlays and two using a timber type map. The problems performed with URA overlays (files) consisted of a three-file intersection, union of attributes, area computation, object counting, overlay revision and file sorting. The timber problems involved file sorting to locate and plot all polygons having specific attributes.

Processing time is recorded in Computer Resource Units (CRU's), a measure which takes into account both central processor and peripheral equipment time.

The URA problems required about ten CRU's each to run. Roughly 80 seconds of central processing time were required for each problem. Approximately 3 of the 10 CRU's were required for loading; in a stable operating system, the time would be reduced or eliminated. The timber problems required approximately 25 CRU's, which included loading time.

Several of the problems were also run by hand as a check against the computer solutions. The URA-type problems required from .5 to 4.0 hours to perform by hand; the timber problems were estimated to require from 8 to 16 man-hours for performance.

5.0 SYSTEM RECOMMENDATIONS - BIA

The Natural Resource Information System developed under this contract is a prototype system and as such needs to be implemented and used by BIA personnel on a trial basis. Many computer systems already exist within the BIA; some of these should be integrated with the Natural Resources Information System. Based on experience with the system to date and the results of the user survey conducted in the beginning of the contract, several recommendations for system implementation and growth have been developed.

5.1 System Implementation

It is recommended that the Natural Resources Information System be set up for joint operation and analysis at the Albuquerque Data Center and Area Office. It is understood, however, that the CDC 3150 at the center is used to capacity. For this reason, it may prove more cost/effective to continue to operate the system on BCS facilities.

Within BIA, three general areas of system utilization are foreseen. The first is in the basic inventory and planning process as exemplified by the initial phases of the Natural Resources Development Program. The BIA data entered in the prototype system is mostly of this type. To test and develop the system in this utilization, the Phoenix Area Office is recommended.

A second area of system utilization is in the detailed analysis and planning stage; e.g. development and updating of timber management plans. For development of the system in this area, it is recommended that two or more reservations involved in detailed planning be selected and the system tested in these areas.

The third major area of system use is in the monitoring and reporting area. This type of utilization is exemplified by the Annual Timber report and PBE analysis and reporting. It is recommended that this type of application be evaluated in each of the Natural Resources Development Program component areas (Forest, Range, etc.).

5.2 SystemsResearch

The system developed under this effort is a prototype and additional research is recommended to increase cost/effectiveness. The major problem area encountered with the prototype system is in the area of data input, both polygon and attribute data. The digiting process was time consuming and subject to errors which could not be discovered until after data had been entered in the computer. When the errors were discovered, it was necessary to redigitize and re-enter the data. Problems of a similar nature were reported in the development of a similar polygon overlay system (Ref. 9).

Potential solutions to this problem include:

1) Digitizing polygons as liniar features with subsequent computer assembly of polygons;

2) Use of a drum scanner for data entry with subsequent computer assembly of polygons;

3) Development of automatic error detection and correction routines; and

4) Elimination of the paper to magnetic tape conversion process.

The drum scanner technique is utilized with the Canada Land Inventory System.

Simplifying attribute data entry can be simplified in two ways. In this effort, a two stage process was used whereby data were extracted from the map and recorded, the recorded data transcribed to the coding format, and each numeric or descriptive property with its identifying number input as a data card. This approach was used as an expedient since file designs had not been finalized at the time of original data encoding. At the point where final designs are established by the users, programming techniques to automate the entry process should be investigated. Card punching directly from the map or even scanning and direct entry of map symbols might be investigated.

Further research is also needed to more fully define and simplify the user interface. Many of the processing functions currently included in the system require a series of user decisions and commands for implementation. This provides a maximum of flexibility. As experience with the system is acquired, and standardization is achieved, many of these functions can be more fully automated.

5.3 Processing Functions

Softwave developed for the prototype information system was concentrated in the area of mapping unit measurement and manipulation. There are a number of niceties which were not included because further input from system users is needed or because programs already exist. To have included these existing programs in the prototype system would have entailed a needless duplication of effort.

The following subroutines are recommended for consideration as potential additions to the current softwave package:

1) Coordinate conversion - Conversion between State Plane and UTM, State Plane and geographic,

2) Projection transform - Transform of map projections to a Transverse Mercator or some other agreed upon projection,

3) Photo transform - Provide ability to input data directly from photo overlays,

4) Line and point selection based on distance - Provide ability to select points or lines at some predetermined distance from other known linear or point features,

5) Contouring - Draw contours based on point date; e.g., precipitation isohets.

The addition of a statistical module is also recommended. As a starting point, the UCLA BMD and BMDX Series is recommended for review. Additions should include Chi Square analysis and other non-parametric statistic and various sampling statistics.

Additional display capabilities including shading, variable line forms, and point symbols appears useful. Modifications to the program permitting output on other display devices such as the SC4020, the Gerber, or cathode ray tube may also prove desirable.

The current system was designed to prepare the BIA Annual Timber Report. As users gain experience with the system, additional reporting functions might be added. For most efficient use of the system, however, extensive redesign of current forms will probably be required.

A number of software packages designed to perform various record keeping and analysis functions currently exist within BIA. It is recommended that these packages be inventoried and analyzed with the objective of possible incorporation in the Natural Resources Information System. It should be noted however, that many of the available programs were developed for specific user applications and have little generality.

Finally, it is recommended that work be initiated on expanding the system to socio-economic areas. Of particular importance are data and analyses relating to cost/benefit studies relating to the PBE process.

5.4 File Design

As indicated previously, the files set up for the prototype system were established largely on the basis of information contained on available maps. Standardization of file design and data requirements is needed for most efficient utilization of the system. A hierarchical system, capable of collapse or expansion to different levels of detail is recommended.

5.5 Equipment

Because of the problems with digitizing previously expressed, it is recommended that a digitizer not be purchased at this time. Additional research is required to resolve the data input problem. In the interim, data input might best be handled on a contract basis.

The CDC 3150 operated at the Albuquerque Service Center is heavily loaded. Furthermore, use of this system on a computer of this size would require a great deal of conversion and would result in very inefficient operation.

At the output side, a plotter similar to the CALCOMP 763 is recommended as a compromise between speed and accuracy. The CALCOMP appears sufficiently accurate to handle planning type applications. If the system is extended to applications such as lease mapping and billing, a higher order of accuracy such as provided by the Gerber may be desirable. At such time as the system is extended to all BLM offices, the use of remote CRT terminals should be investigated. It is anticipated that user access to the system will require 24-hour turnaround or less.

5.6 Data Collection

One of the major problems existing in BIA is the lack of accurate and timely data regarding resource condition and location. This problem appears to result from three major factors. First, and perhaps most important, data and information needs are not well established nor are they consistent from one location to another. For example, what information is really needed to best manage timber for maximum dollar-return? Without an answer to this type of question, one is faced with the problem of collecting a large variety of detailed information in the hope that some of it will be of use.

A second factor involved in the data collection problem is a lack of ability to collect large amounts of detailed information. The number of people available to collect data cannot keep pace with data requirements. As a result, either the data is not collected or it is collected in only a few locations over a long period of time.

Finally, the ability to analyze available data, particularly map data, is lacking. Without the ability to collect and analyze data, it is difficult to establish what data are needed and thus to reduce the collection and analysis problem.

Data and information requirements expressed by BIA users have evolved over a number of years and are largely indirect approximations of the information really desired. It is also apparent that information is often carried beyond the management level at which it is of value or is presented in an indirect manner such that considerable value is lost.

The problem is not unique to BIA; it exists with many management systems. As an example, a timber type map carries information on species, site quality, crown density, and size. In actual fact, management is based on timber volume, growth rate and mortality. It would appear that a more useful timber map might show timber species and volume with the capability of quickly producing revisions to reflect natural or management actions. It would also appear that for many applications, the level of detail shown on a 1/29,000 scale timber map is far too fine and that broad generalizations of data are permissible for many applications.

The annual timber report appears, in some cases, to present data which requires extensive processing to fill an expressed or implied information requirement. The report records the number of fires occurring during the year by size, class and cause. Although this information may be of some use in its own right, it would probably be of much greater value if it were expressed as trend or comparitive data. For example, is a total of 109 fires in one year unusually high? How does fire loss in dollars compare to fire protection cost? The data to perform such analyses are available from the report but there is no formal indication that such analyses are actually performed on a consistent basis.

Because of problems of this nature, it is recommended that considerable emphasis be placed on analyzing upper level management information requirements with the view of either reducing reporting requirements or of carrying data analysis beyond its current point.

At lower management levels; i.e., area and below, it is suggested that emphasis be placed on achieving consistency of data collected and also a coarser level of data collection. To achieve this latter objective, however, will require several tests using up-to-date fine detail data. Such data was generally found not to exist at any single site.

To further alleviate data collection requirements, it is recommended that research be pursued in two other major areas. The first is remote sensing. Numerous potential applications of remote sensing exist within BIA's activities but in general these are not being fully exploited. It is recommended that a central organization be established to provide training, guidance, research and analysis capabilities in remote sensing.

In addition to conventional uses of imagery for mapping, particular attention should be directed to automatic data collection through remote instrument packages. This approach would alleviate current difficulties in obtaining timely and accurate weather data. A second approach which might be emphasized is the use of vegetation sampling using low altitude aerial photography. The use of such photos, obtained from a light aircraft and not flown to cartographic standards, could provide a considerable amount of useful data at a minimum of cost.

It is clear that ERTS imagery will not satisfy all remote sensing requirements. Its maximum value will be in the areas of change detection and sample stratification. Both applications appear to offer substantial benefits but they are as yet unproven. It is recommended that remote sensing research related to high altitude or satellite imagery concentrate on these applications.

REFERENCES

1. Raytheon/Autometric, Applications of Space and High Altitude Photography to Interior Department Functions, Final Report, United States Department of the Interior, Geological Survey, Washington, D.C., 1970.
2. North American Rockwell, Space Division, A Study for Natural Resources Management Information System and Remote Sensing Application, SD 70-351, June 18, 1970.
3. User Survey
4. Remote Sensing Studies
5. Data Analysis/System Design
6. Demonstration of System Features and Capabilities
7. Poulton, C; Faulkner, D; Martin, Niels; Application of Ecology and Remote Sensing to the Analysis of Range Watersheds--Final Project Report, Oregon State University, Corvallis, Oregon, 1971.
8. Anderson, J. "Land Use Classification Schemes", Photogrammetric Engineering, Vol. XXXVII, No. 4, April 1971.
9. Polygon Information Overlay System, Comprehensive Planning Organization, San Diego, September 15, 1971.
10. McCormack, R. Land Capability Classification for Forestry, The Canada Land Inventory, Rept. No. 4, Department of Regional Economic Expansion, Ottawa, Canada, 1970.