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1.0 INTRODUCTION

A Natural Resources Information System was designed and developed for the Bureau of Indian Affairs and Bureau of Land Management. The computer based system stores, processes, and displays map data relating to natural resources. Details of the system are described in Reference 1.

The Natural Resources Information System was designed on the basis of requirements established in a user survey (ref. 2) and an analysis of decision flow within the two bureaus. This report briefly describes the design analysis effort and summarizes the rationale behind major design decisions.

2.0 METHOD

The starting point for system design was the contract work statement. The specifications for the system read as follows:

"An information system shall be designed to store, process, retrieve and display natural resources information required by BIA/BLM land managers. The system shall have the following features:

- Simple file design allowing ease of data entry and recall, as well as ease of updating the files as new information becomes available.
- Programming language compatible with existing BIA/BLM facilities (Fortran and/or Cobol).
- Use of UTM system for geographic grid location with provision for acceptance and conversion of data in State Plane Coordinate and United States Public Land Survey systems.
- Provision for variable size areal elements to allow flexibility in tabular and graphic output.
- Provision for inputting data on variable size areal elements to accommodate coarse analysis of large areas or detailed analysis of small areas.
- Tabular and graphic output of analyzed data keyed to the geographic grid system.
- Ability to list a library description and give the physical location of all data pertinent to the area.
- Provision to accommodate growth of files as new data needs or capabilities are identified in the future.
- Adaptability to various classes of terrain that exist in different parts of the nation."

With these specifications as a beginning, a data collection effort was accomplished in conjunction with the user survey. The objective was to acquire samples of all reports relating to natural resources used by the BIA and BLM. A listing of these reports, as well as general reference material collected at the same time, is presented as an appendix to this report.

Using the results of the user survey and data collection effort, a decision flow analysis was performed.

Decision flow charts were prepared for the BIA and BLM program elements and activities shown in Table 2.1. In each instance, a

TABLE 2.1

BIA and BLM Program Elements and Activities
Used in Decision Flow Analysis

BIA	BLM
Forest Lands	Timber
Range Lands	Livestock Forage
Dry Farm and Pasture Lands	Watershed
	Minerals & Energy (partial)
	Recreation
	Wildlife
	Lands
	Fire Protection & Rehabilitation

flow chart was begun at the top of the management chain and provided downward to the level of specific reports and planning procedures.

Figure 2.1 illustrates one of the flow charts prepared for BIA. At each level of the chart, a separate series of flow charts were developed.

Working at the data needs level of the chart, sources of data and methods of collection were next established. Refering to Figure 2.1, for example, commercial/non-commercial boundaries are available from the timber type map. To establish such boundaries, data are needed on species, market demand (for the species), and conditions which might make the stand nonoperable.

The final step of the analysis was the preparation of flow charts related to specific reporting requirements. For example, each BIA agency prepares an annual timber report. This report describes the actions (fires, treatment) that have taken place during the year and summarizes the condition of the timber area in terms of timber volume, type, and acreage. Flow charts established for the report worked through the report to identify basic data elements required, sources of these data (fire reports, check scale reports, timber type maps) and the processing of these data elements needed to complete the report.

After completing the flow chart analysis, the results were reviewed to establish system design requirements. This review was concerned with the categorization of data types and processing functions. Based on this review, a list of system performance requirements was established and each requirement given a general priority ranking.

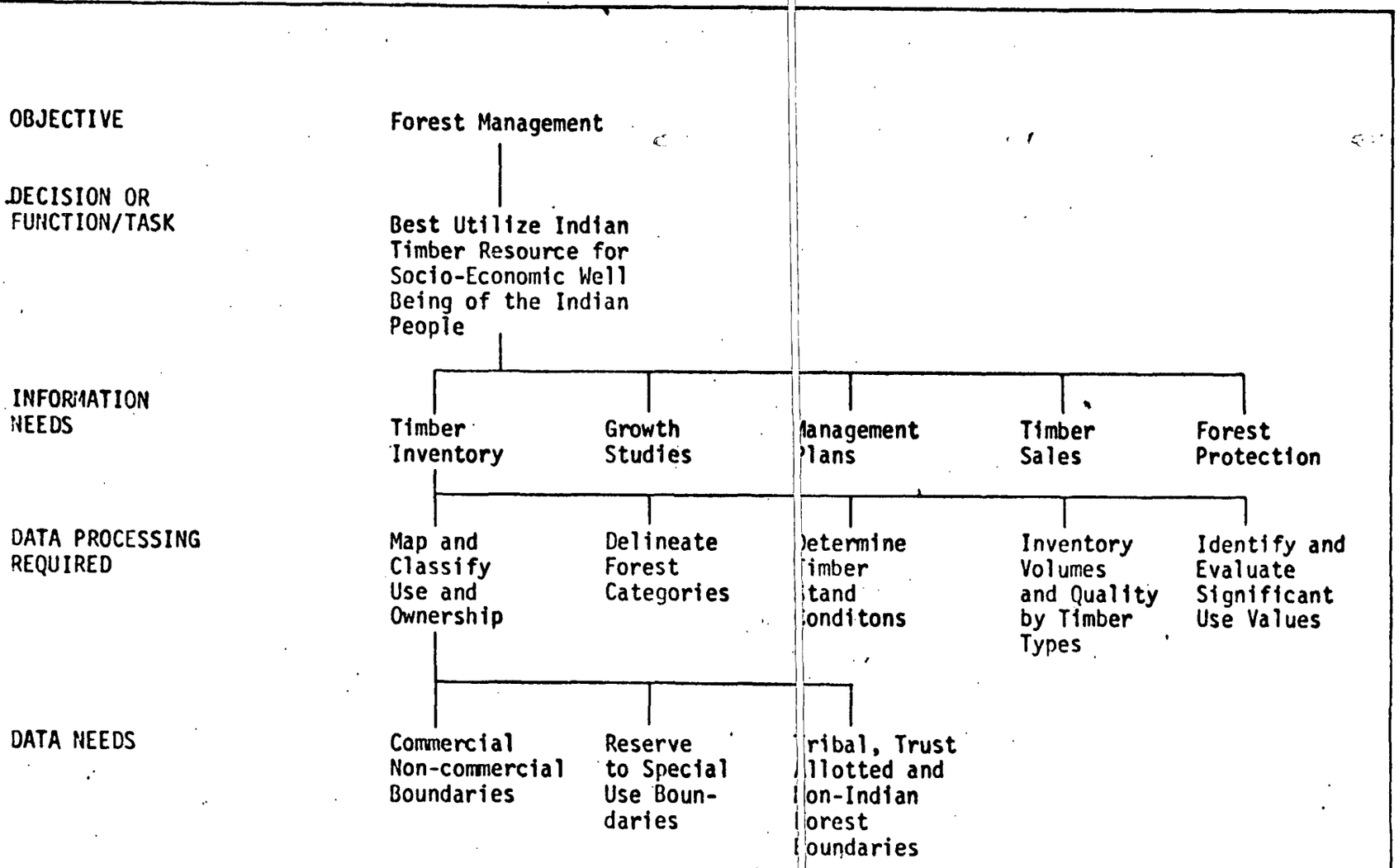

Figure 2.1 Sample Flow Chart - BIA Timber Management

3.0 DESIGN RATIONALE

In the design of the Natural Resources Information System, several key decisions were required regarding the nature of the final system. These included:

1) Emphasis on map processing;
2) Cell vs. polygon recording of data;
3) Method of recording and processing polygon data;
4) Use of the Anderson classification scheme for land use mapping;
5) Selection of resource classification schemes;
6) Accuracy of mapping;
7) Choice of coordinate systems;
8) Selection of base map; and
9) System hardware and software language.

The rationale behind each of these decisions is presented in the following paragraphs.

3.1 Map Processing

Maps have long been the means by which a land manager abstracts and records resource information. This is despite the fact that maps are often time consuming to prepare, may tend to generalize, are often inaccurate, and are difficult to analyze in a statistical manner.

No strong tendency to do away with maps has been noted, nor is there any strong reason to believe that such a tendency will develop in the future. There is every reason to believe that graphics analysis, providing it can be done quickly and conveniently, should be of considerable value to a land manager. For these reasons, a decision was made to emphasize the storage, processing and display of map information in the design of the system.

3.2 Cell vs. Polygon Approach

Several computer systems designed for handling resource data use a cellular approach for recording data location. The map area is divided into regular polygons which can be identified by a unique number, a numerical code, or four coordinates. Each polygon is described in terms of the attributes of the map unit on which it is located. This approach is appealing because of the limited data needed to store location information and the ease of data processing.

Early attempts to store map data on other than a cellular basis generally found that storage requirements were not feasible (ref. 3). With advances in storage capacity, software

techniques and digitizing equipment, however, polygon storage is now possible.

In the course of the study, three major systems employing the polygon approach were reviewed (ref. 4, 5, 6). In all three systems, problems with data entry were reported. However, the inherent flexibility of the polygon system coupled with uncertainty as to what data should be stored led to selection of the polygon approach.

3.3 Recording and Processing Polygon Data

Two general methods exist by which polygon data may be stored and processed. In one, a polygon is treated as a complete entity (figure 3.1). Each polygon is stored as a string of coordinates. In this method, all sides of a polygon must be digitized. This means that lines common to two polygons are digitizied twice.

The second method treats a polygon as a string of line segments. In this method, each line is digitized only once.

The line segment approach offers easier digitizing at the expense of difficulties in defining a polygon and in computer processing. A decision was made not to employ the line segment approach because of the higher computer processing costs associated with the method, and relatively low storage costs.

After the system had been set up and experience acquired in digitizing, it became evident that the complete polygon approach might not be the best choice because of digitizing expense. It appears that the data input problem can best be resolved by an automatic scanning process whereby point data would be input and processing then performed to form lines and/or polygons. Effort is underway to continue research in this area.

3.4 Land Use Classification System

The selection of the Anderson Land Use classification system (ref. 7) was made on the basis that it would be employed in the EROS program. The system as originally proposed is not particularly well suited to use with remote sensing data. The classification categories are not all interpretable with equal accuracy. The revised classification system used for mapping in this study was an attempt to alleviate this problem.

Prior to selection of the Anderson System, several other land inventory and land use classification schemes were reviewed. These included the CLARI system (ref. 8), the Canada Land Inventory system (ref. 9), the Poulton system (ref. 10), and

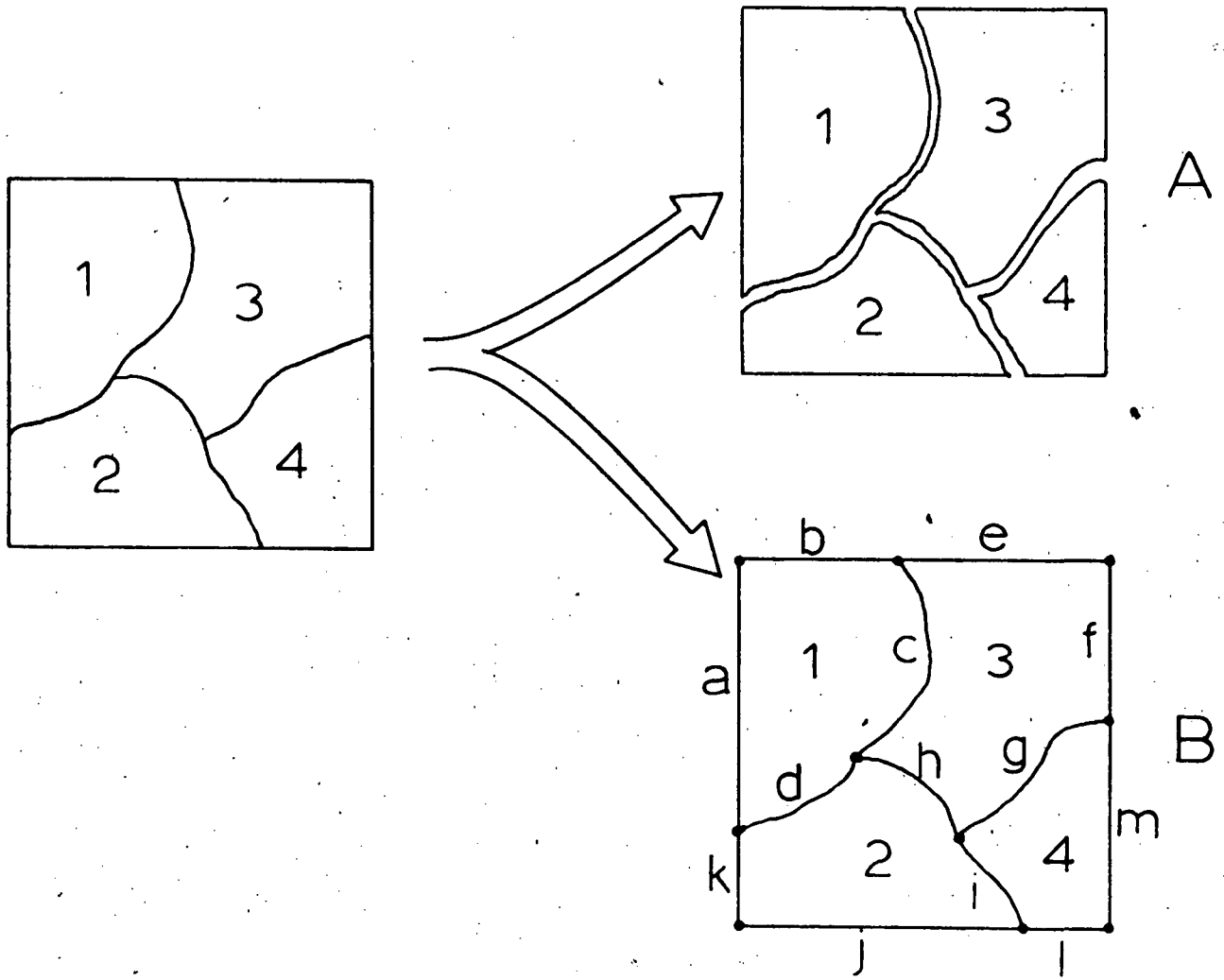

Figure 3.1 Alternative Methods of Polygon Representation--In method A, polygon 1 is described by a string of coordinate values around all its boundaries. In method B, polygon 1 is described by lines a, b, c, and d, each of which is then described by a string of coordinates.

the URA/BPA system (ref. 11). The Canadian system, which emphasizes use potential, appeared to be the most useful from a land management viewpoint. The URA/BPA system requires extensive ground checking and is more urban-oriented than most other systems.

3.5 Resource Classification Systems

In the initial stages of the program, some thought was given to devising one or more standard resource classification schemes for use with the system. An adaptation of the Canadian system or use of Poulton's system appeared to be reasonable possibilities. After interviewing a sampling of BIA and BLM users, however, it became apparent that tying the system to a single classification system would be unnecessarily restrictive at this stage of development. Little agreement was found within and between BIA and BLM as to what constituted relevant and important data. To have systematically tackled the problem would have required resources far beyond the scope of the program. Further, the imposition of a single scheme on the users would probably have met with considerable resistance. Accordingly, it was decided to treat each data set used for the demonstration as a separate case and to design the system to deal with a wide variety of classification schemes.

3.6 Mapping Accuracy

At the initiation of the contract effort, the system was conceived as cellular in nature. Requirements relating to mapping accuracy were expressed only as follows:

1) The system shall deal with mapping units as small as 40 acres; and

2) the system shall be capable of storing variable size mapping units.

After the decision was made to employ a polygon approach, some redefinition and expansion of requirements was needed. A survey of users indicated a general tendency to accept maps as completely accurate. Discussions with cartographic personnel in BLM indicated that BLM maps were generally, but not always, prepared to National Map Accuracy standards. Reliability data are generally not printed on map issues.

Given the lack of firm accuracy standards on the one hand and the requirement for dealing with units no smaller than 40 acres on the other, it was necessary to generate some type of accuracy standards. These were as follows:

1) Collection of original input data would be accomplished in units no smaller than 40 acres; and

2) digitizing and data entry would be accomplished to a chord height tolerance of ± 400 feet.

The chord height tolerance related to the maximum allowable deviation between a curved line and the straight line used to represent the curved line. Any single such deviation introduces an area error of no more than 9 acres, an error of less than 2 acres was more common. In general, there is a tendency for such errors to average out over most complex polygons.

In actual practice, it became necessary to reduce this tolerance considerably. In working with large scale maps, use of the 400 foot tolerance totally eliminated some polygons and caused considerable confusion in the data entry process. For this reason, it was generally necessary to employ a chord height tolerance expressed in inches at the digitizer. The tolerance used was 0.009". Map accuracy then can be expressed only in terms of the error added to that in the original map digitized.

3.7 Coordinate Systems

The selection of the UTM coordinate system was made on the basis that it had been selected for use in the EROS program. From a computing viewpoint, it is somewhat less desirable than a geographic coordinate system and in fact geographic coordinates were used for initial data entry because UTM coordinates were not carried on most of the maps used in the program.

Use of an overlay/base map system made it possible to display State Plane and Public Land Survey coordinates without actually storing or processing data in those systems. Programs exist for State Plane conversion, and the use of the Public Land System merely requires storage of each corner point.

3.8 Base Map Selection

The Arizona State Highway map series was selected for use as a base map (figure 3.2). This series, prepared on a transverse mercator projection at a scale of 2 miles/inch, covered most of the area of interest and had also been used as the base for the BLM/URA overlays. The Public Land Survey grid and Arizona State Plane coordinates are shown on the map.

After developing the system and preparing several map overlays, it was concluded that the base map was not adequate for detailed management planning. In future work, a topographic map or an orthophoto map at 2 inches/mile scale would be recommended for such work.

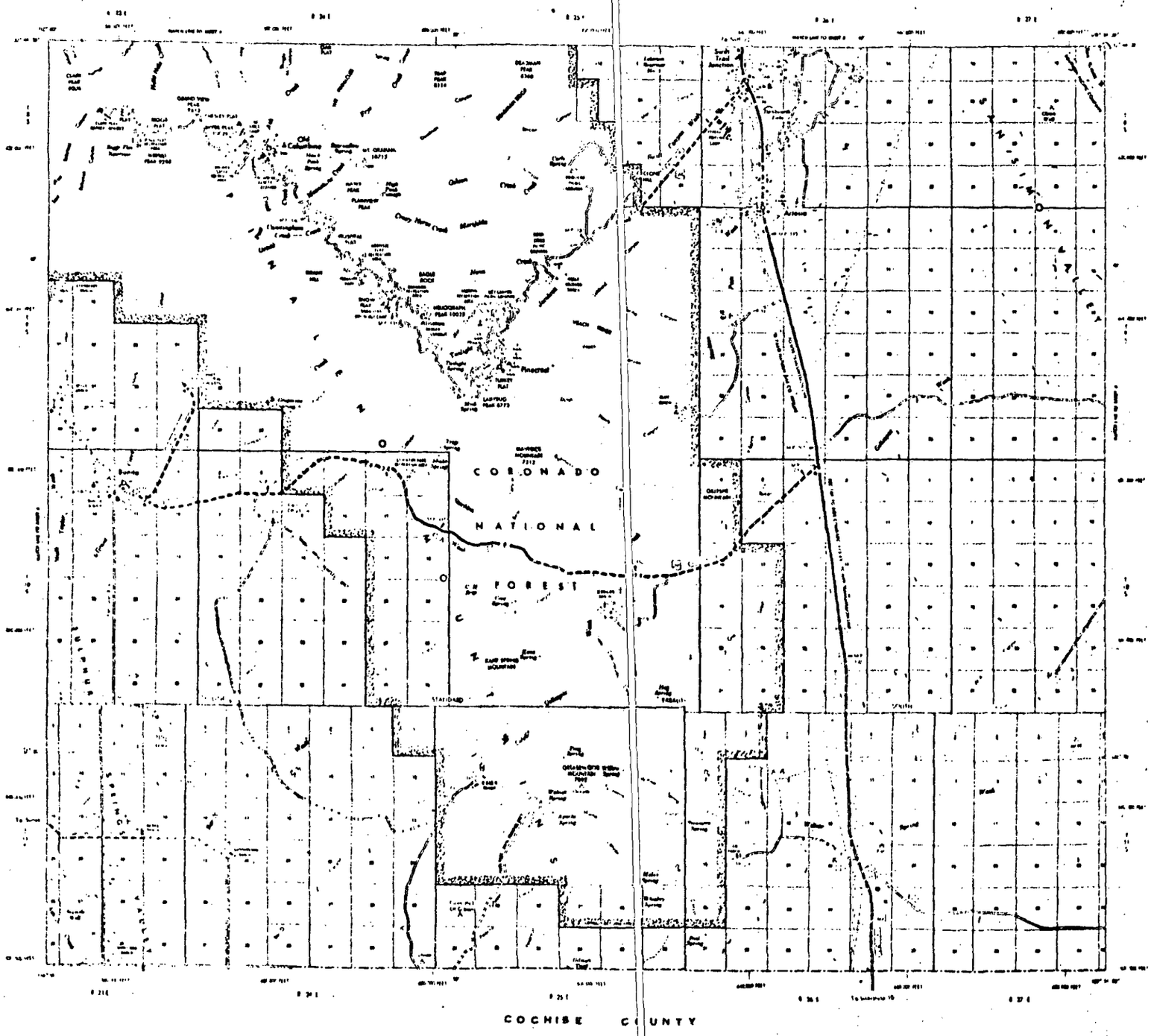

FIGURE 3.2 ARIZONA STATE HIGHWAY DEPARTMENT MAP

3.9 System Hardware and Software Language

The final series of decisions relating to design of the Natural Resources Information System were those concerning software language and the hardware used to demonstrate the prototype system.

Fortran IV was selected as the programming language. The principal reason for selection was compatibility with BIA and BLM systems.

Choice of a digitizer was made between a Gerber 2000 optical line follower and hand digitizers normally used for inputting strip chart recorder data. The Gerber was selected on the basis of accuracy and speed. Subsequent experience indicated that the accuracy of the device exceeded requirements and was slower than expected. The Gerber also required input prepared to critical standards in terms of line density and annotation. Its use would not be recommended in an operationaly system.

Choice of computers was made between a CDC 6600 and an IBM 360/75. The CDC 6600 was selected primarily on the basis of better access within BCS.

Finally, choice of a plotter was made between a CalComp 763 drum plotter and the Gerber 2000. The CalComp was selected because of its higher speed and lower cost.

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APPENDIX

REPORTS AND REFERENCES

Results of a data collection effort are listed in the following paper in bibliographic form. The listed BIA and BLM forms and reports represent those used in the management of natural resources.

BUREAU OF INDIAN AFFAIRS

PUBLICATIONS

FORM NUMBER		TITLE	DATE
New	Old		
5-5201	5-100A	Appraisal Report (Legal Description)	12-56
5-5202	5-100B	Appraisal Report (Neighborhood Analysis)	12-56
5-5203	5-100C	Appraisal Report (Detail Description of Land)	12-56
5-5204	5-100D	Appraisal Report (Detail Description of Improvements)	12-56
5-5205	5-100E	Appriasal Report (Market Data)	12-56
5-5209	5-100J	Appraisal Report (Tract Map)	12-56
5-5210	5-100K	Appraisal Report (Vicinity Map)	12-56
5-5214	5-130	Sales Data and Analysis	2-57
5-5215	5-110C	Semiannual Report of Real Estate Appraisals	
5-5301	5-473	Scale Report	
5-5302	5-473a	Transmittal & Reporting Sheet	
5-5303	5-477	Tree Tally for Timber Estimate	
5-5304	5-478A	Forest Topographer's Large Map Sheet	
5-5305	5-480	NE/4 of T No. --R -- etc. Map	
5-5309	5-486	Report of Timber Cut	
5-5310	5-486c	Check Scale Report	
5-5311	5-487a	Timber Sale Data	2-59
5-5313	5-490	Agency Annual Report	8-67 Rev.
5-5314	5-490A	Area Annual Report	10-67 Rev.
5-5316	5-492	Analysis of Expenditures	6-68
5-5317	5-493a	Lookout Report	
5-5319	5-500A	Statement of Completion of Timber Contract and Summary of Operations Report	3-66
5-5324	5-611	Timber Contract for the Sale of Estimated Volumes	3-60
5-330	5-615 (A-D)	Cumulative Fire Record	8-63
5-5331	5-924	Timber Cutting Permit	4-49
5-5334	5-928	Scale Sheet Summary	3-62
5-5337	5-928C	Scale Sheet	1963
5-5341	5-1474	Individual Forest and Range Fire Report	8-63

FORM NUMBER		TITLE	DATE
New	Old		
5-5415	5-110N	Report on Sale of Indian Land	5-55
5-5418	5-118	Annual Report of Mineral Leasing Activities, June 30, 19__	
5-5419	5-124	Land and Title Document Extract Sheet	
5-5420	5-125	Land Index	
5-5425	5-152	Annual Report of Caseloads, Acreages under BIA, and Surface Leasing	
5-5433	5-154j	Sand, Gravel, Pumice, Building Stone Permit	6-56
5-5437	5-155b	Mineral Prospecting Permit (Exclusive with option)	10-57
5-5440	5-159	Mining Lease Indian Lands (for minerals other than Oil and Gas)	10-57
5-5451	5-188a	Title Status Report (Description of Realty Services)	12-60
5-5452	5-188b	Title Status Report (Individual or Tribal Ownership and Shares)	12-60
5-5501	5-162a	Project Data - Irrigation Construction	10-63
5-5502	5-162b	Project Data - Rehabilitation & Betterment	10-63
5-5503	5-167	Irrigation Program of Work (Appropriation Analysis)	1-68 Rev.
5-5505	5-205A 5-205B 5-205B	Annual Range Management Report	9-67 Rev.
5-5506	5-206	Annual Outdoor Recreation & Wildlife Report	10-65
5-5507	5-210	Land Use Inventory & Production	1-68
5-5508	5-300	Soil & Moisture Conservation Annual Estimate	9-62
5-5509	5-302	Soil & Moisture Conservation Annual Report	9-62
5-5510	5-210a	Gross Value of Products Grown and Harvested by Means other than Livestock	1-66
5-5511	210b	Pounds of Livestock Products Produced from Crops Harvested by Livestock	1-66
5-5513	-	Sale of Grazing Privileges	5-70
5-5514	-	Bid for Grazing Privileges	5-70

FORM NUMBER		TITLE	DATE
New	Old		
5-5515	-	Grazing Permit	5-70
5-5701	5-1125	Annual Road System Inventory	12-60
5-5704	5-1128	Work Program Status	8-61

BUREAU OF INDIAN AFFAIRS

PUBLICATIONS

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PUBLICATIONS

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BUREAU OF LAND MANAGEMENT

MANUALS

No.	Release	Date	Title
1220	1-195	1-17-66	Paperwork Management Function Classification Chart. Appendix 1
1222	1-519	2-11-69	Reports Management
1222.3	1-508	1-21-69	Index of Reports
1601	1-547	6-17-69	Planning System
16-2	1-653	7-9-70	Basic Guidance
1603	1-653	7-9-70	Supplemental Guidance Appendix 1 - Program Outlook Guide
1604	1-561	7-1-69	Management Environment Analysis
1605	1-562	7-3-69	Unit Resource Analysis
1606	1-563	7-9-69	Economic Profile
1608	1-570	8-6-69	Land Use and Development Planning
1634	1-627	5-5-70	Work-Job Code Handbook
1734	1-435	5-20-68	Impact Studies
1791	1-697	12-28-70	Environmental Impact Statements
2031	2-49	9-8-70	Environmental Quality and Natural Beauty
2063	2-37	1-7-69	Land Reports
MINERALS			
3030	3-14	9-9-70	Minerals Resource Inventory
RANGE			
4110	4-29		Grazing Administration (Inside Grazing Districts)
4410	4-31	12-12-68	Management Studies

BUREAU OF LAND MANAGEMENT

MANUALS

No.	Release	Date	Title
WILDLIFE			
6600	6-19	10-22-70	Wildlife Habitat Management System
6610	6-9	7-19-68	Habitat Inventory and Analysis
6620	6-13	10-14-68	Habitat Management Plans
SOILS			
7312	7-36		Soils
7317		4-14-71	Erosion - Manual + Illustrations + Appendices 1-3
WATERSHED			
7322	7-33	8-14-70	Watershed Conservation and Development System (Instruction Memo No.70-426, 12-30-70)
ROADS			
9110-2		5-68	Maintenance Inventory - Roads
FIRE CONTROL			
9213	9-30	5-6-66	Presuppresion
9213.2	9-30	5-6-66	National Fire Danger Rating System - Spread Phase
9213.3	9-36	9-16-66	Fire Weather
9218	9-70	2-17-71	Reports and Statistics

BUREAU OF LAND MANAGEMENT

FORMS

No.	Release	Date	Title
RANGE			
4115-3		8-64	Annual Grazing Statistical Report
SOILS			
7310-9		12-70	Vegetation - Soil Description
7310-10		10-69	Ground Cover Transect Data Sheet Paced Transect Method
7310-12		6-70	Determination of Erosion Condition Class - Soil Surface Factors
7310-14		7-70	Erosion Inventory
7330-11a & 11b		7-70	Job Documentation Report Selected Codes
7330-12		6-70	Watershed Conservation and Development Field Data - Phase I
7330-15		11-70	Watershed Conservation and Development Field Data - Productive Capacity
ROADS			
9110-1		6-64	Inventory Record - Roads and Trails
9110-3		11-66	Construction and Maintenance Schedule Trails
MANAGEMENT			
	1-569		Standard ADP Codes
DSC-1265-457 to 464		4-70	Land Survey Records

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