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PROCEEDINGS

Fifth National

MOSS USERS
WORKSHOP

May 2-5, 1988 • New Orleans, Louisiana

PROCEEDINGS

Fifth National MOSS Users Workshop

May 2-6, 1988

New Orleans, Louisiana

.

Compiled by

James D. Scurry

U.S. Fish and Wildlife Service

National Wetlands Research Center

Slidell, Louisiana

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PREFACE

The Fifth National MOSS Users Workshop was held at the Clarion Hotel, New Orleans, LA, May 2-6, 1988. It was hosted by the U.S. Fish and Wildlife Service and the Louisiana State University Office of Sea Grant Development. The over 120 participants represented Federal and State agencies, universities, and the private sector.

MOSS is a geographic information system (GIS) in the public domain, used by agencies of both the Federal and State government, and the private sector to aid in the spatial analysis of complex natural and cultural resource management issues. The MOSS family of software includes two data entry systems, ADS and AMS; a vector analysis system, MOSS; a raster analysis system, MAPS; and a cartographic production system, COS. In addition, these systems contain conversion routines to import and export data in a wide variety of formats including USGS-DLG3, ELAS, ARC/INFO, and SAGIS.

Enhanced and distributed under the auspices of the Bureau of Land Management, the MOSS family of software is a compilation of the efforts of several agencies and oversight committees. The AMS digitizing system primarily is maintained by the U.S. Fish and Wildlife Service, with significant contributions from Autometric, Inc., and the U.S. Army. ADS, MOSS, MAPS, and COS are maintained by the Denver Service Center of the BLM with coordination and recommendations from the multi-agency MOSS Configuration Management Team (MCMT).

The result is a flexible, user-oriented system which incorporates the conceptual and functional requirements of a wide variety of systems and applications specialists, and agency resource managers.

MOSS's uses are numerous; its functions have been successfully employed for more than a decade. It has proven its effectiveness in aiding managers to make resource management and land-use decisions. Products generated with this software have been used in legal proceedings and have supplemented testimony before several Congressional committees. The evaluation of MOSS, then, is not concerned simply with its successes, but with its improvements and its design for the future. This Workshop specifically was designed to incorporate data integration, software development, and data management issues generally not addressed at many conferences. Twenty-four papers and one video detailed the past year's accomplishments and the promises for the future.

The first session was designed to inform users of the status of the Prime software as well as prototyping initiatives on each of the hardware systems supported. The second session covered image processing and data integration techniques for GIS's. Data integration has become increasingly important with the proliferation of geographic information systems software and data base development clearinghouses. Session three presented overviews of current projects initiated for the Gulf of Mexico using MOSS and related software.

The fourth session detailed significant advanced geographic information systems applications by geologists, wildlife biologists, archeologists, and soils scientists from various research and resource management agencies. The fifth session allowed program managers, and those charged with justifying GIS within their respective organizations, the opportunity to present their perspectives on maintaining and using spatial data processing.

In addition to the technical presentations, individual meetings were convened by the User, Systems, and Management Groups of the MOSS Configuration Management Team (MCMT). These sessions were open to all Workshop participants and were designed to present the past year's accomplishments as well as make recommendations and chart new directions for 1989. Most discussions focused on the MOSS enhancement proposal prepared for the MCMT by the working committees of the User and Systems Groups. This proposal documented the state of the software in 1988, and outlined those enhancements and fixes necessary to bring the MOSS related software in-line with current state-of-the-art geographic information systems.

Similarly, technical representatives for Prime Computers, Inc., held an informal session to discuss system configuration alternatives, networking, software conversion, operating system support, and other issues not directly associated with MOSS, but which could have immediate impacts on system performance. For Data General users, Autometric, Inc. held a similar session to summarize parallel development and software standardization and portability from the Prime and VAX to the Data General.

A final, but vitally important, component of this Workshop was the exhibition of new GIS hardware and software currently under contract with the Department of the Interior. Six companies displayed equipment and software and provided demonstrations of their products' utility to resource management.

The enclosed are the Proceedings of the Fifth National MOSS Users Workshop. Included are all technical papers, with questions and comments on some; names and addresses of all attendees; summaries of the User, Systems, and Management group sessions; and a list and telephone number of GIS product vendors.

Additional copies of these Proceedings may be obtained from:

Louisiana Sea Grant College Program
Louisiana State University
Baton Rouge, LA 70803-7507

or

U.S. Fish and Wildlife Service
National Wetlands Research Center
1010 Gause Blvd.
Slidell, LA 70458

James D. Scurry
MOSS Program Chairman

PROCEEDINGS

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ACKNOWLEDGMENTS

Finally, special thanks are due to the session moderators, presenters, vendors, and participants who made the Fifth National MOSS Users Workshop a success. Only through sharing of data, ideas, and experiences will the GIS community realize fully the potential that these technologies offer both now and for the future. Thank you all.

James D. Scurry, Program Chairman
Fifth National MOSS Users Workshop

Fifth National Moss Users Workshop

AGENDA

Monday, May 2, 1988
Audubon Room E, 6th Floor

10:00 - 1:00 REGISTRATION

 1:00 - 1:10 WELCOME
              Robert E. Stewart, Jr.
              U.S. Fish and Wildlife Service

 1:10 - 1:20 VENDOR INTRODUCTIONS
              James D. Scurry
              U.S. Fish and Wildlife Service

 1:20 - 4:00 AGENCY OVERVIEWS AND GIS INITIATIVES

 1:20 - 1:40 Bureau of Land Management
              Robert R. Ader

 1:40 - 2:00 U.S. Fish and Wildlife Service
              Claude J. Christensen

 2:00 - 2:20 Bureau of Indian Affairs
              William J. Bonner, Jr.

 2:20 - 2:40 BREAK--Audubon Room E

 2:40 - 3:00 National Park Service
              Harvey Fleet

 3:00 - 3:20 U.S. Forest Service
              Gene Rockey

 3:20 - 3:40 U.S. Geological Survey

 3:40 - 4:00 PRIME Computer Procurement
              Charles Gish

 4:00 - 4:20 Peripheral Procurement
              William Battle

Tuesday, May 3, 1988
Grand Ballroom-Salon C

 8:00   REGISTRATION-2nd Floor Prefunction Area

 8:20 - 8:30 ANNOUNCEMENTS

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8:30 - 11:10   SESSION 1
               Status of Prime Software and Prototyping
               Initiatives
               Chairman, Bruce Morse, Autometric, Inc.

8:30 -  8:50   The Status of (W)AMS on the Prime
               Robin L. Gebhard, U.S. Fish and Wildlife Service

8:50 -  9:10   The Status of the MOSS and Related GIS Software
               One Year After Department of the Interior
               Acceptance
               Floyd O. Stayner, Bureau of Land Management

9:10 -  9:30   Current Development and Future Directions
               for MOSS on the Prime
               George Fuller, Autometric, Inc.

9:30 -  9:50   BREAK - Grand Ballroom--Salon B

9:50 - 10:10   Enhancement of the BLM's Cell Processing System
               (MAPS) Upon a Prime Mini-Computer
               Linus L. Smith, TGS Technology, Inc.

10:10 - 10:30  Interfacing MOSS with the Oracle RDBMS on the
               Prime
               Linnea Probert, Bureau of Land Management, and
               Lyn Price, TGS Technology, Inc.

10:30 - 10:50  Polygon Overlay:  In Theory and Practice
               John E. Heasley, U.S. Fish and Wildlife Service

10:50 - 11:10  Vendor Demonstrations - Grand Ballroom--Salon B

11:10 -  1:00  LUNCH ON YOUR OWN.

1:00 -  3:40   SESSION II
               Image Processing and Data Integration Techniques
               for Geographic Information Systems
               Chairman, L. Nelson May, Aero-Data Corporation

1:00 -  1:20   Comparison of Selected Level I Thematic Mapper
               Land Cover Classes with USFWS Ecological
               Characterization Maps
               DeWitt Braud and Henry Streiffer, Decision
               Associates, Inc.

1:20 -  1:40   Parcel Generation Techniques for Oil and Gas
               Mapping Jeff Nighbert, Bureau of Land Management
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1:40 - 2:00   The Naval Digital Mapping, Charting, and Geodesy
               Analysis Program--An Overview of the Navy's
               Coordination Efforts for Its Use and Development
               John Breckenridge, Naval Ocean Research and
               Development Activity

2:00 - 2:20   Using Side Scan Sonar in a Geographic
               Information System to Locate and Display Lake
               Trout Spawning Habitat in the Great Lakes
               Charles L. Brown, Barbara M. White, and Thomas
               A. Edsall, U.S. Fish and Wildlife Service, and
               Robert G. Waltermire, TGS Technology, Inc.

2:20 - 2:40   BREAK - Grand Ballroom--Salon B

2:40 - 3:00   The Bureau of Reclamation/Arizona Projects
               Office Uses MOSS on HP-9000/UNIX and VAX/VMS
               Computers and Shares Data with INTERGRAPH and
               ARC/INFO Systems
               Daniel H. Alberts, Autometric, Inc. and Mike
               McDonald and Stevan Augustin, Bureau of
               Reclamation

3:00 - 3:20   Integration of Legal Land Records with the MOSS
               Family of Geographic Information Systems
               Mike Kirby and Mike Thompson,
               Bureau of Land Management

3:20 - 3:40   Coal Volumetrics
               Patrick Madigan, Bureau of Land Management

3:40 - 4:20   SESSION III
               Application of GIS Technologies of Natural
               Resource Management in the Gulf of Mexico Region
               Chairman, James B. Johnston, U.S. Fish and
               Wildlife Service

3:40 - 4:00   Use of GIS Technologies in Addressing Resource
               Management Problems in Mobile Bay, Alabama
               Mary C. Watzin, Pasquale F. Roscigno, and E.
               Randy Roach, U.S. Fish and Wildlife Service

4:00 - 4:20   Application of GIS Technology to Monitor Barrier
               Island Change: Integration of SAGIS and MOSS at
               the Gulf Islands National Seashore
               Theodore Simons, National Park Service, and
               James D. Scurry, U.S. Fish and Wildlife Service

4:20 - 5:30   Vendor Demonstrations - Grand Ballroom--Salon B

7:00 - 8:30   Banquet - Grand Ballroom--Salon A
               An Evening with Mark Twain

Wednesday, May 4, 1988
Grand Ballroom--Salon C
Fleur De Lis Rooms 1 and 2

8:20 - 8:30   ANNOUNCEMENTS

8:30 - 11:40   SESSION IV
Advanced Geographic
Information Systems Applications
Chairman, Frank D'Erchia, U.S. Fish and Wildlife
Service

8:30 - 8:50   Running PC-MOSS in C-Language on a Network
Merlyn Paulsen and Douglas Pattie, Colorado
State University

8:50 - 9:10   Using MAPS to Emulate a Geographic Expert System
Solomon S. Katz, Bureau of Land Management

9:10 - 9:30   Subsurface Geological Mapping of the Greater
Blanding Basin Using a Geographic Information
System
Steve Jones, Bureau of Land Management

9:30 - 9:50   BREAK - Grand Ballroom--Salon B

9:50 - 10:10   Duck Numbers Estimated from MOSS Map Data,
Aerial Television, and Ground Counts
Lewis M. Cowardin, Philip M. Arnold, Terry L.
Shaffer, and H. Ross Pywell, U.S. Fish and
Wildlife Service, and Lee D. Miller,
MicroImages, Inc.

10:10 - 10:30   The Role of MOSS in Archeological
Predictive Modeling
Daniel W. Martin, Bureau of Land Management, and
James D. Scurry, U.S. Fish and Wildlife Service

10:30 - 10:50   Determining Soil Erosion: Problems and
Solutions of Work in Progress
Jacek Blaszczynski, Bureau of Land Management

10:50 - 11:10   The WODDB Tool Box
Robert Wright, Bureau of Land Management

11:10 - 1:00   LUNCH ON YOUR OWN.

1:00 - 3:00   SESSION V
Meeting Agency Needs: Management Perspectives
on Maintaining and Using Spatial Data Processing
Chairman, Robert R. Ader, Bureau of Land
Management

1:00 - 1:20   Workload Modeling and Capacity Planning for
              Resource Applications of GIS Technology
              Mike Garratt and Eric J. Strand, Bureau of Land
              Management

1:20 - 1:40   BLM Land Information System Field Test Site-
              Management Tool for System Development and
              Implementation
              James Gazewood, Bureau of Land Management

1:40 - 2:00   A Report: BLM Planning in Western Oregon for
              the 1990's
              Don Pearson, Bureau of Land Management

2:00 - 2:20   Configuration Management for Geographic
              Information Systems
              John Foster, Bureau of Land Management

2:20 - 2:40   BREAK - Grand Ballroom--Salon B

2:40 - 4:00   WORKGROUP SESSIONS

              User Group Meetings
              Session Moderators: James D. Scurry
              U.S. Fish and Wildlife Service

              System Group Meetings
              Session Moderators: Floyd O. Stayner and Wendy
              Tetley
              Bureau of Land Management

              Management Group Meetings
              Session Moderators: William J. Bonner, Jr.
              Bureau of Land Management
              Claude J. Christensen
              U.S. Fish and Wildlife Service

4:00 - 4:30   Data General User Group Meetings
              Session Moderator: Bruce Morse
              Autometric, Inc.

              Prime Computer User Group Meetings
              Session Moderator: Joseph Rowe
              Prime Computers

7:30 - 10:00 Evening Social Hosted by Autometric, Inc.
              Riverboat cruise on the sternwheeler Cotton
              Blossom. Dixieland Jazz band provided. Food
              and beverages will be available for purchase
              on the sternwheeler. Boarding begins at 7:30
              at Toulouse Street Wharf.

Thursday, May 5, 1988
Grand Ballroom--Salon C
Fleur De Lis Rooms 1 and 2

    8:30 - 9:30   User, Systems, and Management Group Meetings

    9:30 - 9:50   BREAK

    9:50 - 11:10   User, Systems, and Management Group Meetings

  11:10 - 1:00   LUNCH ON YOUR OWN.

    1:00 - 2:20   Group Presentations

    2:20 - 2:40   BREAK

    2:20 - 3:45   Group Recommendations, Discussions, and Action
                       Items

    3:45 - 4:00   SUMMARY AND CLOSE
                       James B. Johnston
                       U.S. Fish and Wildlife Service

Friday, May 6, 1988
Oak Room
Fleur De Lis Room 1

    8:00 - 12:00   Individual Agency Meetings

NOTE: Procurement updates were not presented at the Workshop
because of personal emergencies of the presenters.

Agency Overviews and GIS Initiative

Robert R. Ader, Bureau of Land Management, Denver, CO 80225-0047

The Bureau of Land Management's Task

The Bureau of Land Management (BLM) is an agency of the U.S. Department of the Interior. BLM manages approximately 272 million acres of public lands--about one-eighth of the land in the United States--and the mineral estate underlying another 300 million acres of land administered by other government agencies or owned by private interests.

Most of the public lands overseen by BLM are located in eleven western states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming. Significant BLM responsibilities also exist in the Midwestern and Eastern United States where the agency manages minerals on about 34 million acres and maintains the Federal survey system and land and minerals records system. Public land resources managed by BLM include rangeland, timber, minerals, watershed, fish and wildlife habitat, wilderness, recreation, and archeological and historical sites.

BLM's Commitment to Automation

BLM's earliest responsibility for maintaining land-based information originated from the establishment of the Public Land Survey System in the United States in 1785. Today, BLM maintains a vast records system, including public land survey information, Federal lands and minerals records, and natural resource data, which allows BLM to manage, lease, and protect the public lands.

In fulfilling its public land management responsibilities, BLM has looked for new solutions to handling land information. Historically, BLM's land information has been stored on paper and mylar. However, with the advent of computer technology, BLM began automating parts of its records functions in the late 1970's. BLM has made a long-term commitment to the implementation of a fully automated Land Information System. BLM will preserve historically valuable documents, and replace traditional paper records with more efficient automated procedures.

Why the Need for a Land Information System

The management of the nation's lands must be responsive to the needs and aspirations of American society. As the needs of society become more complex, so do the issues which our land managers face. For example,

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BLM prepares land-use plans in order to facilitate decision-making on the uses of resources for a variety of competing and often conflicting activities. In making these decisions, extensive public involvement is required and alternative actions must be considered. This entails weighing a large amount of data, opinions, and combinations of potential uses. Effectively evaluating land management requires automated methods and techniques.

As another example, BLM maintains more than one billion public documents on lands and minerals. These documents have been manually maintained, are beginning to deteriorate, and are accessible at only a few offices. Implementing an automated Land Information System can increase access to this data, providing better service to the public and more efficient decisionmaking.

Three Key Components of the System

The BLM Information System has three key parts:

1. The automated **Geographic Coordinate Data Base (GCBD)** is built upon data from the National Public Land Survey System. This provides the ability to link records and resource data to legal descriptions of land parcels, a first step in developing a comprehensive land information system.

2. The **Automated Land and Mineral Record System (ALMRS)** provides infor-

mation about ownership status, special designations (such as wilderness designation), and use authorizations, such as mineral leases, mining claims and road and pipeline rights-of-way. This data is typically represented on master title plats.

3. The **Automated Resource Data (ARD)** represents information about the natural and cultural resources and characteristics of public land administered by BLM. This data is the storehouse of information about resource values and uses of the BLM-managed public lands, and typically includes maps, tables, charts and reports (such as those showing wildlife habitat or the location of timber sales).

The BLM Land Information System will link these three parts for efficient land and resource planning and for management of the competing demands and uses on the public lands through use of computerized geographic information system (GIS) technology.

Moving to an Automated Environment

BLM is a leader in many areas of natural resource management. The agency's goal for information and data management is to be a leader in the effective use of automation to manage public lands and resources for multiple use. BLM will achieve this goal through an operational automated Land

Information System governed by these principles:

- BLM will manage information, as well as lands and resources as valuable public assets.

- To BLM, computers are tools to help employees do their jobs better.

- BLM will share its data with others in support of agency missions. This requires establishing common data standards and exchange capabilities with different organizations.

- Up-to-date, proved technology will be used.

Strategy for the Future

BLM's current activities in making the Land Information System operational include automating the data that now reside on paper by developing the organizational capability to process data differently than in the past through the acquisition of the necessary computer equipment and software.

A Bureauwide plan has been prepared that addresses all the actions needed to acquire and successfully implement the next cycle of data systems, thus ensuring that BLM goals and principles are followed. The plan establishes an overall framework for the general design of software, hardware, and communications necessary to effectively meet BLM's automation requirements in the 1990's, tieing together all the components and linking the Land Information System to BLM's administrative and office automation applications.

OVERVIEW OF GIS ACTIVITIES IN
THE U.S. FISH AND WILDLIFE SERVICE

Presented by
Claude J. Christensen

The following report sum-marizes the nature and extent of geographic information systems software and data base development and applications within the various research centers, refuge and ecological services, and regional offices of the FWS. The majority of the current activities are centered around the traditional Service GIS support facilities, the National Wetlands Inventory (NWI), the National Ecology Research Center (NERC), and the National Wetlands Research Center (NWRC); however, the number of field stations and research facilities using the technology increases monthly. Much of this has resulted from the development of high-speed microprocessors with ample disk storage and the transfer of GIS software and data bases to these systems. This is a trend supported fully within the Service and it is hoped that through forums such as the MOSS Workshop, the utility of geo-graphic information systems will become evident to a wider range of Service personnel.

NATIONAL WETLANDS INVENTORY

System Development

The National Wetlands Inventory has developed a new Version of (W)AMS on the Data General called Version 2.0. Work is currently in progress to convert Version 2.0 to the Prime. Several developments have also been made to the data reformatting programs that interface with (W)AMS files. A paper detailing all of NWI's program enhancement and development work is presented in these proceedings.

Data Base Development and Applications

NWI GIS applications include cooperative agreements with State and Federal agencies, with cooperators applying the funding for building Statewide and local wetlands data bases using the WAMS-MOSS-COS system. To date, Statewide data bases have been produced for New Jersey, Maryland, and Delaware, and work is in progress to complete data bases for Washington, Illinois, and Indiana. Local data bases are being built for parts of Alaska, California, Florida, Idaho, Kansas, Michigan, Minnesota, Nebraska, North Dakota, Oregon, Pennsylvania, and Utah.

Digital data files from either WAMS or MOSS are reformatted and supplied to State agencies for use in their GIS. These digital data are used for resource management planning, impact assessment, wetland trend analysis, and information retrieval.

NWI digital data have been supplied to the National Park Service, U.S. Forest Service, U.S. Navy, Corps of Engineers, other FWS offices, Ducks Unlimited, Inc., Bonneville Power Administration, and many State and county agencies.

NWI's production digitizing is contracted out through a service support contract with Martel Laboratories, Inc. A Prime model 9955A minicomputer has been installed at the NWI facility and is being used mainly for data transfer, MOSS data base construction, COS map generation, and acreage analysis, etc.

NATIONAL ECOLOGY RESEARCH CENTER

System Development

ARC/INFO software has been acquired by the NERC on a three-month trial basis and is now installed on the Prime 9955-II superminicomputer. Potential applications of ARC/INFO include (a) a co-operative project with the FWS Vero Beach Field Station to formulate simulation models to evaluate hydrology, land use, and wildlife in areas that are under intense development between Miami and the Everglades National Park; (b) a cooperative effort with FWS Annapolis Field Office and EPA in planning GIS strategies for the Chesapeake Bay, including hydrological simulation model development to determine methods for reducing non-point source nitrogen and phosphorus from surrounding agriculture

into the Bay; and (c) a cooperative effort with the FWS Alaska Fish and Wildlife Research Center to use existing data in developing modeling techniques related to the effects of oil production on wildlife at Prudoe Bay on the North Slope of Alaska.

EPPL6 (Environmental Planning and Programming Language) software has been acquired by the NERC from the Minnesota State Planning Agency on a trial basis, and will be installed on the Prime 9955-II minicomputer. A PC-based version, EPPL7, is being acquired by the Great Swamp NWR, FWS Region 5, as part of a cooperative effort to test EPPL7 capabilities using Great Swamp NWR data previously digitized by the NERC. (Note: EPPL7 is a grid-cell-based GIS for use on IBM PC's and true compatibles running MS-DOS 2.0 through 3.3. EPPL6 currently runs on the Prime 9955-II minicomputer and has been in use for almost 20 years at the Land Management Information Center (LMIC), Minnesota State Planning Agency, St. Paul, MN.)

Data from MOSS are being integrated with other technologies in a decision support system called INFORMS (Integrated Forest Resource Management System), which is being developed by ATAS staff at the NERC. This system combines new and conventional information science technologies into one system and simplifies the use of these technologies in natural resource management. The system is currently being tested on the Red River Ranger District, Nez Perce National

Forest, and plans are underway for using INFORMS on the Deerlodge National Forest.

The NERC and Region 4 are continuing cooperative efforts to support the Region's operational activities and development of the Decision Support Manatees Project projection plans. NERC personnel are developing a system that can easily interface with other applications and focuses on data management, maintenance, and display (as opposed to analysis). This Decision Support System (DSS) is designed to run on standard IBM-PC compatible microcomputers so that many vendors and products are accommodated, rather than specific products being dictated.

Distinguishing characteristics of the DSS include:

- The underlying data structure is an arc structure that can accommodate arc/node constructs.
- A graphical user interface has been implemented to minimize training and simplify use.
- A device-independent standard has been implemented to increase hardware compatibility and to avoid responsibility of providing drivers for various hardware devices.
- Point data are handled more compactly.

FY88 accomplishments include:

- A prototype projection package running on an IBM-PC microcomputer that runs

in a single point mode or an ADDWAMS file.
- Successful import of AMSdata, MOSSdata, and SAGIS data into the prototype projection package.
- Arc data entry and editing package is 90% operational; the arc assembly into a map features component is in active development. Note: This is a semiautomatic process.

Data Base Development and Applications

A cooperative project with the U.S. Forest Service's, North Central Forest and Range Experiment Station in St. Paul, MN, and the Superior National Forest includes construction of a spatial data base using the MOSS family of software. Wetlands, timber, and home range data for a 16-quad study area in Superior National Forest will be used in MOSS to test and refine a Black Bear model that was developed by NERC in early FY88.

A cooperative project between the California Institute of Environmental Studies and the Advanced Technology Assessment Section (ATAS) of the NERC will result in a digital MOSS data base of thematic data for a Snow Leopard research project in Nepal. Rodney Jackson, a principle investigator for the Institute, is working with the National Geographic Society and the Government of Nepal on a long-term habitat modeling study of the Snow Leopard. AMS Version 2.0 software is being used to digitize the thematic map data provided by the Institute.

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Research personnel at NERC are using MOSS to assign cover types to telemetry data already collected for the Yuma Clapper Rail (endangered bird species) in two study sites along the Colorado River, at the CA-AZ border. The telemetry data, which was reformatted and transferred from a Radio Shack microcomputer to a Data General minicomputer, will be used to create point maps in MOSS for overlay with the surface cover type data.

GIS support to the U.S. Forest Service has continued throughout FY88 and data bases have been constructed for the Deerlodge National Forest and Lewis and Clark National Forest, Montana, and the Huron National Forest and Hiawatha National Forest, Michigan.

The Malheur National Wildlife Refuge (NWR), Oregon, has continued its efforts to expand its MOSS data base which now includes wetlands, transportation, and Public Land Survey (PLS) for the entire Refuge. Several other data themes have been added in FY88 for portions of the Refuge, such as crane territories, deceased pairs, nesting sites, and lake elevation. Wetlands data are being used with crane data in MOSS to analyze the wetlands in each crane territory, examine the condition of each territory on a year-to-year basis, and track nesting success. The data base is also being used to make decisions on land acquisition within the Refuge; identify the areas around Malheur Lake affected by extensive flooding; determine

how many acres of wetlands on private ranches along the lake are affected by flooding; estimate waterfowl pair density, conduct surveys on willow flycatcher nesting; and identify ditches and existing water management structures within the Refuge. The NWI wetlands data are also being used on a daily basis for habitat monitoring in the field.

In March 1988, several color COS maps were produced for a public meeting on the Blitzen Valley Management Plan. These maps were used to graphically illustrate the different conflicts that arise in treating adjacent areas with significantly diverse habitat types.

A DG-10SP microcomputer, loaned to the Refuge by the NERC, has been installed at the Refuge Headquarters and will be used to provide onsite training to staff biologists.

A cooperative project is underway to develop a digital data base of baseline information for the Middle Rio Grande Study, New Mexico. FY88 activities and mapping efforts are being focused on the River and adjacent riverine habitat within the historical floodplain region. The ultimate goal of this project is to assist the Region in developing a riverine and riparian habitat Resource Management Plan.

Approximately 21 data themes have been digitized for five grazing allotments in the Charles M. Russell NWR,

Montana, as part of a pilot study to evaluate the utility of a GIS for Refuge planning and management. A Prime 2450 microcomputer and associated peripherals have been installed at Refuge headquarters and staff are awaiting the final release of MOSS for the Prime. In the meantime, Refuge staff are using a DG-10SP microcomputer to continue the ongoing GIS evaluation.

Possible applications of GIS on the Refuge include road management programs, exploration of various grazing regimes, identification of prime habitat for the reintroduction of the black-footed ferret and swift fox, and sharptail grouse model development. If additional funding becomes available in FY89, the Refuge may add another eight grazing allotments to the existing data base.

Sixty-eight vegetation maps describing the upland plant communities on four of the major Hawaiian Islands were prepared by the Patuxent Wildlife Research Center, Maryland, as part of a survey conducted by the FWS Mauna Loa Field Station in 1976-1981 to determine the current status of native forest birds and their associated habitats. These map sheets have been digitized, added into MOSS, and will be used in COS to produce 1:100,000 black-and-white map separates for about 30 general vegetation types. These map separates will be fitted to six USGS composite base maps for Hawaii and Maui Counties and

used by GPO to produce final color 1:100,000 county base maps for inclusion in a published report on the project.

A GIS is one of the tools being used by the National Fisheries Center-Great Lakes, Michigan, to evaluate historically important lake trout spawning habitat in the Great Lakes. To date, lake trout spawning substrate data, collected via side scan sonar and a submersible television camera, have been digitized and added to MOSS for eight reef areas in Lake Michigan, Lake Huron, and Lake Superior. Color maps have been produced in COS and are being used by research personnel to determine habitat quality on these spawning grounds and to identify potential areas for future experimental studies on lake trout reproduction.

Two new reef areas will be completed in FY88 and bathymetric (depth contour) data, collected for the 10 reef areas mapped to date, will be digitized and added to the MOSS data base for each reef area.

As part of a Mountain Lion research project being conducted by the Wyoming Cooperative Fish and Wildlife Research Unit personnel, surface cover type (SCT) data for a 17-quad study area in Utah have been digitized and used in MOSS to identify the habitat types used by 52 individual mountain lions observed at the study site. In addition, the data are being used to determine the habitat types associated with observed mountain lion kills.

NATIONAL WETLANDS RESEARCH CENTER

The National Wetlands Research Center in Slidell, Louisiana, has initiated several new projects designed to augment and enhance the technical and resource management capabilities of geographic information systems and remote sensing technologies at the Center. These include the installation of specific applications software and initiation of three long-term data base development and research projects.

Systems Development

Version 4.0 of ARC/INFO, NETWORK, and TIN were installed on the Prime 9955. This software was acquired to support the FWS role in the San Joaquin Valley Drainage Program, but has been applied to a wider range of data base development, analytical, and modeling applications. Foremost among these are a five-year study of coastal erosion and landscape evolution in the central Gulf coast and a three-year study of potential contaminants impacts to Mobile and Galveston Bays.

Similarly, the Statistical Analysis System (SAS) quantitative analysis program was purchased for the Prime and for several IBM PC/AT stations. This software will be used on the Prime to interface with the GIS software to provide statistical support for the landscape and contaminants modeling. In addition, the Earth Resources Laboratory Analysis Software (ELAS) image processing system has been installed on the Prime

and similar satellite image processing systems currently are being evaluated. These systems are expected to provide wetland habitat classification update and raster processing/ modeling capabilities not present in the vector-based systems.

Data Base Development and Applications

NWRC, in conjunction with the Water Resources Division of the U.S. Geological Survey, began a study of coastal erosion and landscape modeling for Louisiana. This project includes the reinventory and digitization of wetland habitats for the Louisiana coastal zone as well as development of a multivariate data base of soils, hydrology, digital line graphs (DLG), erosion rates, storm events, sedimentation, and other relevant data. NWRC will provide permanent curation of this and all digital data associated with the study. These data bases are being developed in ARC/INFO and will be used to develop a comprehensive evolutionary model depicting future landscapes. Currently, the existing AMS wetland and upland habitat data are being converted to ARC format to serve as the initial data layers. The entire coast will be flown in December and color infrared transparencies developed for photointerpretation of wetland habitats.

Projects have been initiated to study the impacts of point source contaminants in Mobile Bay, Alabama, and Galveston Bay, Texas. These studies are

using both MOSS and ARC/INFO to develop data bases for determining concentrations, movements, and impacts from municipal, private, and corporate toxic disposal. Point-source data are being assembled from various State and Federal environmental monitoring agencies. Numerous GIS data layers are under development including soils, sediments, fish and bird concentrations (for all life cycle phases) as well as transportation and utility corridors, contours, bathymetry, and habitats. In addition, distributions of eight significant metals (nickel, chromium, tin, boron, etc.) are being interpolated from sample points within the bays. These data will be statistically and spatially correlated to determine the nature and extent of impact to local natural resources.

NWRC has been involved with GIS and data base support to the San Joaquin Valley Drainage Program for four years. This includes participation (with USGS and USBR) in a planning and coordination subcommittee to manage the extensive data bases developed for the Valley as well as provide data base development and GIS applications support. The Drainage Program is an interdisciplinary team assembled to deter the impact of contaminated agricultural drain water and develop management alternatives for disposal. During FY88, digitization began for land ownership parcels, easements, and wildlife management areas within the Grasslands Water District. Wetlands maps for this area have been photointer-preted and currently are being compiled. Siting location and ranges for 30 endangered species are being transferred from maps and field observation descriptions to stable base maps for digitization. These data are being used by Service and Bureau of Reclamation personnel in the development of alternatives for disposal of contaminated drainwater.

In addition to these long-term research projects, NWRC is continuing to provide data base development and analysis support to FWS Region, Ecological Services, Refuges, and to other agencies sharing common natural resource management goals. Included among these are photo-interpretation and digitization of 1986 habitats for the Gulf Islands National Seashore (with NPS), development of spatial and multiple attribute data for all major streams of the Tennesee-Tombigbee drainage basin (with Daphne ES), and a resource inventory of the Tyndall Air Base (with the U.S. Air Force). NWRC is also conducting numerous "in-house" studies related to wintering waterfowl habitat selection and loss within the Lower Mississippi River Valley, seagrass inventory and change in coastal Louisiana and Texas, and wetland changes analysis for the Lower Mississippi River Delta and coastal Louisiana.

Contributions by:

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THE ROLE OF GIS IN SPATIAL RESOURCE INFORMATION MANAGEMENT: A FOREST SERVICE PERSPECTIVE

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OVERVIEW

The Forest Service manages nearly 200 million acres of land nationwide. As a decentralized Agency, with 155 National Forests, 19 National Grasslands, and 653 Ranger Districts, the Forest Service must ensure a rapid, accurate flow and exchange of data and information about its resources. While much of the land is used for timber production, forest management also includes such natural resources as water, range, wildlife, minerals, and recreational sites under the overall objective of multiple use/sustained yield.

To manage this land effectively, the Forest Service requires information about the state of the land and the activities that relate to it. GIS is an information processing technology which helps the Forest Service to achieve its mission by improving program management, communications, and decisionmaking through reducing the time and costs involved in data access and display.

An effective corporate strategy is needed to employ GIS technology to achieve the objectives of managing and exchanging spatial resource information. These objectives require the establishment of a "corporate" or shared environment for spatial resource management predicated on the definition of a universal data standard, common data definitions, and a technological base to support the flow of data and information.

For best use by the Forest Service, GIS must be viewed as an information processing tool that will make project planning and implementation more efficient and effective. It can provide consistent information at various levels of our organization. Our job then is to plan and figure out what information we need for these processes, and remember that GIS will generate more tabular information than it does pictures.

Data are the building blocks from which information is developed. To be useful in developing a variety of information, data need to be simple, consistently defined, precise, and well-organized. We need to design our data requirements around those basic data elements that can be analyzed to generate 80% of the information needed for sound resource management decisions.

The Forest Service is developing a plan for implementing GIS Servicewide. This plan focuses on the basic principles of fostering a corporate information sharing environment and building on our existing computer and telecommunications network, which was designed for the communication of information.

NEED FOR CORPORATE DATA

The Forest Service is moving toward the concept of integrated land and resource management in place of management of individually identified resources. If basic resource and supporting data are organized around individual resources, it is far more difficult to produce integrated resource information than if the basic data were originally structured in a shared or corporate data base.

Corporate data, with appropriately defined data elements, support integrated resource management. The idea of corporate data implicitly suggests the need for a national strategy for defining, organizing, and using spatial data and their processing technologies. Such a national strategy is evolving, and is predicated on some basic principles of how the Forest Service views basic spatial data and the technologies which process this data.

Data Principles

The Forest Service deals with non-spatial data, which includes resource summary statistics, budget data, production targets, etc. We also deal with spatial resource data if its location on the ground is a fundamental component of the data description. GIS technology offers an opportunity to manage spatial resource information in an electronic medium consistent with the management of non-spatial information.

Common procedures for identification of the basic data elements and a uniform set of terms describing this data are needed to achieve consistency and reliability in information products. The types and quantity of required data should be determined by focusing on the answer to key questions about what information is needed to make resource decisions specific to given resource issues. Input data should be fundamental data, not interpreted information. Fundamental data are those parameters that are measured or directly observed. Interpreted information is the assumptions or conclusions of management response or consequences that can be derived from the fundamental data.

Resource information management requires that we improve our ability to communicate information about basic data consistently within and between units and organizational levels. In order to share resource information the Forest Service should have common data definitions and common terminology to consistently and accurately talk about basic data.

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Technology Principles

Technology refers to both hardware and software; and includes facilities and equipment used in preparing, collecting, analyzing, and displaying spatial data and information products. Together, hardware and software provide the mechanism to process data, to develop the information needed, and to display the effects of alternative management options to both the decisionmaker and interested groups.

Hardware should be integrated with the existing network of distributed processing facilities in the Forest Service. The selected technology should be easy to use in order to facilitate a wide range of employees accessing the GIS and utilizing the information in their work.

Buying hardware and software, and hiring or retraining people doesn't guarantee success. New tools have to be properly integrated into the whole work process, and not tacked on as an afterthought. GIS must be integrated into the Forest Service Information Management System and vigorously supported with commitment in time and dollars by management and staff alike. It's not "you make it work"; it's "we make it work."

CURRENT ACTIVITIES

The amount of resources required to implement a successful GIS are significant in terms of people and equipment.

A well thought out national strategy for using a GIS is needed to avoid costly mistakes, which may have a long-term impact and may prove ineffective in carrying out the Forest Service mission. To preclude this from happening, two efforts are currently underway at the national level.

The first is designed to develop common definitions for specific kinds of basic natural resource data for use in a Forest Service GIS. The emphasis is on those data that are directly observable and measurable without interpretation. Common definitions resulting from this study will form a starting point for establishing the corporate characteristics of basic, natural resource data. A similar approach is likely to be taken to set up corporate characteristics of location, facilities, and social data.

The second is an assessment of GIS technology, and how that technology can best be used to support the resource management work of forests in the local forest/ranger district environment while operating under the Forest Service overall information management policies. The study will be focused on obtaining information in four areas: resource data standards and structure, technical specifications (hardware software requirements), costs and benefits, and organizational implications. The study effort is an opportunity to learn about and experiment with automating and managing spatial data and information in an electronic environment. This

controlled evaluation is anti-cipated to take two years to complete and is taking place on selected units throughout the country. It is designed to identify the actions necessary to automate and manage spatial resource data and information within the Forest Service information architecture. The evaluation provides an opportunity to learn how GIS technology can assist in forest plan implementation and help to accomplish day-to-day resource work in an electronic environ-ment. The evaluation will also provide insights on what training and support needs are required for GIS.

The controlled evaluation units are: Tongass National Forest, Siuslaw National Forest, George Washington National Forest, Nicolet National Forest, Northern Region (District Level), Southeastern Station (Research and S&PF), and the Washington Office. The evaluation is expected to be completed by the middle of 1989; the results will help to guide future decisions and actions about GIS. Besides these "official" units, several other GIS projects are being looked at, and will add input to the evaluation effort.

SUMMARY

As an agency, we have to broaden public understanding, trust, and confidence in what we do. We can do this in part by communicating openly with the public, being attentive to public needs and values, and involving the public in the decisionmaking processes in a spirit of cooperation to achieve balanced natural resources management.

GIS technology is an infor-mation processing technology used to input, store, manipu-late, analyze, and display spatial resource data in order to support the decisionmaking and communication processes of an organization.

The GIS must meet your needs, our needs, not the vendors' needs. As we all know, tools are not cheap; the more things a tool can do, the more skills are needed to operate them. The more people to operate the tools, the more adjustments will be necessary in the work-place and in the work force. GIS could have some real im-pacts on the Agency; we've got to prepare for them and adapt.

This paper does not address hardware or software brand names. There are several software systems currently available and much hardware capable of handling GIS. It is more important to determine what the data needs are and what output products are needed to accomplish the analysis goals, than to spend a lot of time in the emotional arena of which software or which hard-ware is better than the other. Any procurement will have to specify desired performance specifications and to provide for long-term enhancement of the system to maintain it at a reasonable level of currentness with evolving technology.

SESSION I

Status of Prime Software and Prototyping Initiatives

Moderated by: Bruce Morse
Autometric, Inc.

THE STATUS OF
THE WETLANDS ANALYTICAL MAPPING SYSTEM

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ABSTRACT

During the past year, the National Wetlands Inventory in St. Petersburg has made significant enhancements to the Wetlands Analytical Mapping System (WAMS) on the Data General computer. The new Data General version, Version 2.0, was released in January 1988 and has the ability to capture data worldwide. Other changes improve the efficiency of the software, streamline directory structures, and reduce the amount of duplicate code and macros.

The version of WAMS currently operational on the Prime, Version 1.03, has remained unchanged since it was converted from the Data General last year. The National Wetlands Inventory is currently upgrading the Prime version of WAMS from 1.03 to 2.01P.

This paper details the status of WAMS on the Prime and Data General computers and describes the enhancements made to Version 2.0 on the Data General as well as what is currently being done on the Prime.

INTRODUCTION

During the past year, the National Wetlands Inventory in St. Petersburg has made significant enhancements to the Wetlands Analytical Mapping System (WAMS) on the Data General computer. A new Data General version, Version 2.0, was released in January 1988. One of the significant enhancements made in Version 2.0 is the ability to capture data worldwide. Other enhancements have been made to improve the efficiency of the software, streamline directory structures, and reduce the amount of duplicate code macros.

The version of WAMS currently operational on the Prime is Version 1.03. This version has remained unchanged since it was converted from the Data General last year. The National Wetlands Inventory is currently upgrading the Prime version of WAMS from 1.03 to 2.01P. In addition, several enhancements will be made to Version 2.01P. These include the implementation of color graphic displays, intelligent defaults,

and automated error evaluation from verification.

The National Wetlands Inventory is also supporting several data reformatting programs on both the Data General and the Prime. These include WAMS2PRIME, the data conversion program for transferring WAMS data-base files from the Data General to the Prime; ADDWAMS, the data reformatting program for importing WAMS data-base files to MOSS; AMS2DLG, the data reformatting program for converting WAMS data-base files to DLG3 format; and IGES, the data reformatting program for converting WAMS data-base files to the International Graphics Exchange System.

DATA GENERAL - VERSION 2.0

The Wetlands Analytical Mapping System (WAMS) Version 2.0 on the Data General was developed by the National Wetlands Inventory under contract to Autometric, Inc., and Martel Laboratories, Inc., during 1986 and 1987. Initial release tapes were distributed in January 1988 to the U.S. Fish and Wildlife Service, Bureau of Land Management, and the Bureau of Indian Affairs.

The most significant enhancement developed in this version is the ability to capture data worldwide. Previous versions of WAMS were limited to the northwest quadrasphere of the earth. Project data bases may now be created anywhere in the world. As a result of this enhancement all latitude and longitude values must be entered with the correct negative or positive signs for the quadrasphere in which they fall.

In the WAMS data base, map file names are ten characters in length, consisting of the geounit ID and a prefix indicating the file type (i.e. "A475610345" for the node file of geounit 47° 56' 15" latitude, 103° 45' 15" longitude). For Version 2.0 data-base files, this convention will continue to apply for projects that fall within one quadrasphere. For projects that cross quadraspheres, the data-base file name will be eleven characters long. In addition to the prefix and geounit ID, there will be a suffix to indicate in which quadrasphere the geounit falls. These suffixes are as follows:

A = Northeast quadrasphere
B = Northwest quadrasphere
C = Southwest quadrasphere
D = Southeast quadrasphere

Another enhancement made in Version 2.0 is the ability to utilize only a graphics terminal to emulate a WAMS workstation. By utilizing crosshairs on the graphics terminal, the user can perform all functions of WAMS, including digitizing, without having a digitizing tablet.

Other enhancements made in Version 2.0 include:

- The ability to use lower case letters for attributes. (For lower case attributes to be accepted,

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classification schemes must be created with lower case attributes).

- The ability to abort lengthy displays from the DISPLAY option. By typing 'AB', displays to the graphics terminal and the super-positioning device will be aborted.

- Segment numbers are now displayed to the graphics terminal when the EVALUATE or IDENTIFY options of the AMS DIGITIZING FUNCTIONS menu are selected.

- An option to generate geounit plots with border and interior tics as well as border annotation at 2' 30" intervals has been added to the WAMS plotting functions.

- An option to generate geounit plots within specified geographic windows has been added to the plotting functions.

- The ability to copy specific segments from the database into a job file has been added to the GEOCOPY option in the DATABASE FUNCTIONS menu. The segments to be copied must be known in advance. The segment attributes can be changed at the time they are being copied to the new user file.

- Point coordinates entered during map set-up in the LOCATE MAP POINTS function are now saved in the file $$CPCP in the user directory. This enables the user to perform multiple set-ups without having to re-enter the set-up points.

- An option to clean a dataset by eliminating all deleted segment records and the associated coordinate data records has been implemented.

Other enhancements have been made in Version 2.0 that are virtually invisible to the user. A new directory structure for the RUN, DATA, and PROCESSES directories has been implemented. Several subroutines have been rewritten to improve the efficiency of the code. Duplicate CLI's contained in WAMS to maintain two menu structures have been removed, Version 2.0 contains only one menu structure and one set of CLI's to support these menus.

Many known problems that existed in the code under earlier versions were corrected. Listed below are some of the more significant corrections and changes that have been made:

- The RESTART SET-UP option in the MAP SETUP/ DIGITIZING menus has been removed.

- The option to move in the actual number of records from a data base file to a job file during an update now works correctly.

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- The RESUME option of the INTERACTIVE VERIFICATION menu has been removed.

- A geounit with a status of "1" can no longer be brought in as a new job. The user will receive an error message if this is attempted.

- One apparent cause of ESORT and EMERG errors received during the update process has been isolated and resolved. The improper deletion of an edge node pointer that is the only node in a continuation record for a given side was generating these errors. Pointers are now properly reset in the Edge Node ($$0n04) and Restart ($$0n01) files.

- The UNLOCK option has been disabled.

- In the CREATE/EDIT/ DELETE SCHEME option of the DATABASE CREATE OPTIONS, when entering attributes for a standard classification scheme, if more than 16 characters are entered for an attribute, that attribute is truncated and a message notifying the user of this is reported.

- The "E" cursor button may now be used to change the node search criteria while digitizing. This function was previously assigned to the "F" cursor button.

- Due to modifications in the format of the PRDB,DT file in Version 2.0, it is not possible to update a geounit digitized in a project data base with a previous version without recreating the PRDB.DT for that project using Version 2.0. A "dummy" project data base should be created with the same boundaries as the original project (with attention to the appropriate signing of latitude and longitude) and the resultant PRDB.DT should be moved in to replace the existing file in the original project.

- A job must be verified (successfully or unsuccessfully) in order to generate a plot for the geounit. If the job has not been submitted to verification, the user will receive a GTDEF error from GTPOO in setting up the projection for the plotting process.

- The entry of the project name is now required for the plotting process as part of the worldwide data capture enhancement.

- The EDIT option from the "AMS side" (AMS.CLI) of the program has been installed in the "WAMS side" (WAMS.CLI) as option 7 of the TABLE DIGITIZING and APPS DIGITIZING SUBSYSTEMS.

- The output from the LOCATE AND PRINT MAP POINTS option of the LOCATE MAP POINT menu is now reported in decimal

degrees, as well as degrees, minutes, and seconds.

- The ADDWAMS program accessed through the IMPORT/EXPORT DATASET UTILITIES menu has been modified to accept world-wide data. Latitude and longitude of the geounit center must now be input on separate lines in the degrees, minutes, and seconds format (DDD,MM, SS.SSS). If appropriate, a negative (-) sign should be placed in front of the most significant non-zero value. Signs will be modified, however, to conform to the default values for the project if necessary.

- The creation of a new user, upon program entry, now requires the knowledge of a password. This is the same password used to access the RESTRICTED OPTIONS menus and is set to "PW" initially. The password may be changed inside the RESTRICTED OPTIONS area. The attempted creation of a user "0" will be ignored to facilitate program exit.

A user guide titled "User Guide to the Wetlands Analytical Mapping System Version 2.0, January 1988" was prepared by Martel Labs, Inc., under contract to the National Wetlands Inventory and was released with the software in January 1988. The "User Guide" is not a user manual, but documents in detail all of the enhancements, changes, and corrections that were developed and made in Version 2.0. It was prepared for the experienced WAMS user. The most recent WAMS user manual is titled The Analytical Mapping System, Version 1.03, Table Digitizing Subsystem and was prepared by the National Ecology Research Center in 1985. Version 1.03 of WAMS on the Data General is no longer operational or supported by the National Wetlands Inventory.

PRIME - VERSION 1.03

The current version of WAMS on the Prime is Version 1.03. This version was converted from the Data General to the Prime and delivered to the government in April 1987. Acceptance testing on the converted software was conducted by the National Wetlands Inventory and all identified problems were corrected by Prime Computer Company. The software was released in December 1987 to the U.S. Fish and Wildlife Service, Bureau of Land Management, and the Bureau of Indian Affairs. Although the program is fully operational on the Prime, the inefficiencies, such as Prime system dependency and Data General emulation, that were introduced in the code during the conversion still remain.

Currently, under contract to Autometric, Inc., the National Wetlands Inventory is upgrading Version 1.03 on the Prime to Version 2.01P. This effort involves four major tasks:

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1. Removal of Prime system dependencies in Version 1.03

2. Upgrade Version 1.03 to 2.01P

3. Conversion of CPL Macro's to FORTRAN77

4. Miscellaneous program enhancement

The removal of Prime system dependencies involves the removal of all input/output (I/O) functions within the main subroutines in WAMS. These will be isolated into a separate library module which will provide the ability to open, close, read, and write either sequential or direct access files. A channel manager will be developed to replace all hard-coded channel numbers in WAMS. The channel manager will be written in FORTRAN77 and will assign channels by returning a valid channel number for all I/O operations. An alternative path definition/searchlist capability will also be implemented. In version 1.03, search rules were implemented using a Prime operating system utility. The search capability in Version 2.01P will be based on a BLOCKDATA subroutine, specifying at compile time the pathnames for file searches. All of the work under Task 1 will be implemented using the same methods done for the ADS, MOSS, MAPS, and COS subsystems, which the Bureau of Land Management funded. This will ensure that all of the programs within the MOSS family of software remain compatible.

Task 2 requires updating Version 1.03 on the Prime to Version 2.01P. The enhancements made to the Data General Version 2.0 are not presently on the Prime. WAMS Version 1.03, modified under Task 1, will be the base for this task. The source code for the Data General Version 2.0 will be loaded on the Prime and a file-by-file comparison will be made. Differences between the source code will be identified and Version 1.03 will be modified to make it functionally similar to Version 2.0. This newly modified version of the Prime will be identified as Version 2.01P.

Task 3 involves the conversion of the CPL macros that drive the WAMS menus in Version 2.01P, now defined as the product of Task 2, to FORTRAN77. Presently, there are more than 150 macros in the user interface of WAMS. These macros are system dependent and tend to slow the execution of the software. Converting these to FORTRAN77 will improve the maintenance and portability of the software as well as speed its execution.

In Task 4, several enhancements that have been developed on the VAX version of WAMS are implemented. A color graphic display capability will be implemented using Tektronix PLOT-10 standards. Segments and nodes will be color-coded to distinguish between completed features, features being digitized, and features being edited. Intelligent defaults will be added to all user required prompts. This will allow the user to record the

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most commonly used responses and only have to enter a carriage return to execute the menu sequence. An improved error evaluation method will be implemented as part of the verification process. The evaluation of errors reported from verification will be automated. The error will be queried by the user, and the program will automatically zoom and display (with color if at a color terminal) the segments, nodes, and attributes involved. The error message will also be displayed to remind the user of the cause of the error. Corrections can be made to the data while in this program before moving on to evaluate the next error. This function should significantly improve the speed and efficiency of the error- correction process. By automatic display of the error reported, the often lengthy time involved in locating problem areas will be greatly reduced.

DATA REFORMATTING PROGRAMS

WAMS2PRIME

During the last year, a program to facilitate WAMS data file conversion from the Data General to the Prime was developed. This program, now fully operational, converts binary WAMS data-base files to ASCII on the Data General. The ASCII files are then loaded to tape and transferred to the Prime. The Prime component of this program reads the ASCII files from tape and converts them back to binary. This program was written by Prime

Computer Company and then modified by the National Wetlands Inventory to correct some sections of the code. The software was released in December 1987 to the U.S. Fish and Wildlife Service, Bureau of Land Management, and Bureau of Indian Affairs.

ADDWAMS, AMS2DLG

On the Data General, both the ADDWAMS and AMS2DLG programs have been modified to handle the worldwide data capture introduced with WAMS Version 2.0. They are fully operational and were released in January 1988 with WAMS Version 2.0.

The Prime versions of ADDWAMS and AMS2DLG are also operational and were released with the Prime version of WAMS (1.03). They do, however, contain the Prime system dependencies and Data General emulations that were introduced when they were originally converted to the Prime.

Work is currently in progress to remove these system dependencies using the same procedures for improving the maintenance and portability that was described above for WAMS Version 2.01P.

IGES

The International Graphic Exchange System (IGES) program has been operational on the Data General for several years. It was not affected by the developments in WAMS Version 2.0. Work is currently in progress to convert this software to the Prime.

SUMMARY

A new version of the Wetlands Analytical Mapping System, Version 2.0, has been developed for the Data General by the National Wetlands Inventory. This version has been in production in St. Petersburg, FL, since September 1987. Release tapes were distributed in January 1988. The National Wetlands Inventory is supporting and maintaining Version 2.0. WAMS Version 1.03, operational on the Data General prior to the release of Version 2.0, is no longer being supported.

The National Wetlands Inventory is funding the development of Version 2.01P, on the Prime.

This new version will be functionally similar to Version 2.0 on the Data General. The Prime system dependencies and Data General emulation that were introduced during the software conversion will be removed.

Several data conversion and reformatting programs are also being supported by the National Wetlands Inventory. The National Wetlands Inventory plans to continue to support these systems on both the Data General and the Prime.

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QUESTIONS AND ANSWERS

Q. Were the non-standard features of AMS fixed?
A. Yes. The corrected version was transferred to the Prime and part of Version 2.0 on the DG.

THE STATUS OF MOSS AND RELATED SOFTWARE ONE YEAR AFTER ACCEPTANCE BY THE DEPARTMENT OF THE INTERIOR

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ABSTRACT

Many problems arose when MOSS was converted from Data General to Prime computers. Specific recommendations were made at the Fourth MOSS Users Conference which were used by the Bureau of Land Management (BLM) as the guidelines for software maintenance and enhancement. This paper details the problems and their solutions through the current release, as well as lists future changes in a release scheduled for summer 1988.

INTRODUCTION

Last year the MOSS Users Conference ended with much uncertainty concerning the future of the MOSS software. The process of converting the software from Data General (DG) to Prime computers brought many existing problems to light. A number of these problems, both conceptual and technical, were identified by the Environmental Systems Research Institute (ESRI) (Guevara 1987). This provided the first comprehensive evaluation of the software; the numerous problems documented were very disconcerting to the user community. Many users had known of various problems but this was the first time they had been made cognizant of the number of defects throughout the system.

The general consensus was that some action should be taken to correct these defects or retire the MOSS software, permitting agencies to begin examining other alternatives for their Geographic Information Systems (GIS) application needs. As a result, very specific recommendations for the future of the software were made during the group meetings. These have been used by the BLM as guidelines for subsequent software maintenance and enhancement during the past year.

This paper outlines the various problems encountered and the accomplishments made in providing the Prime users with a stable and current version of the MOSS software. It is not a comprehensive list of all the problems encountered but is meant to give the users an idea of the complexity of the problems faced by the development staff and some explanation for the delay in releasing production software.

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ATTEMPTING THE FIRST SOFTWARE RELEASE

Preliminary Findings

During the acceptance tests, the government software conversion team observed some instability in the delivered software even though all specified tests functioned properly. With this instability in mind, the BLM decided to conduct another complete test of the software after its delivery and acceptance by the government team to ascertain what changes or fixes had to be made before the software could be released to the field. Early in the testing it became apparent that only the formal acceptance tests functioned satisfactorily. Any attempt to execute something other than a formal test resulted in system failure, returning the user to the operating system. Further testing demonstrated that only a small portion of the system functioned properly.

Another related problem was the limited obligation of ESRI to the government to provide software fixes. ESRI's assistance was limited to acceptance test failures, effectively eliminating the principal contractors from any further fixes or consultation.

Based on these preliminary findings and the demands from the field for software, a decision was made to fix as many problems within the general framework developed by ESRI and to release the software by late summer 1987.

In retrospect, this probably was the wrong decision because of the problems resulting from ESRI's attempt to emulate the DG operating system.

Problems and Solutions

Two major problems were identified during the first two weeks of testing. The first problem was the corruption of master data files. As testing progressed, users reported that system errors seemed to increase. Further examination determined that master data files were not being protected from unauthorized write access.

The problem originated from differences between DG FORTRAN 5 and Prime FORTRAN 77 and their respective methods of file access control. DG's FORTRAN 5 opened files without checking file access rights and only checked a user's rights when a write request was issued. The files could be opened for reading and writing, but they were protected at the system level against unauthorized write access by file access controls (i.e., Access Control Language). Prime's FORTRAN 77 checks the user's rights before opening a file. This prevents files from being opened for reading and writing unless the user has the necessary file access rights. Because all files were being opened for read and write access on the DG, ESRI's solution was to permit read and write access to master data files, permitting master data files to be overwritten. This solution was unacceptable to

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the BLM. Subsequently, the BLM changed the software to protect all data files from unauthorized writes.

A second major problem was the inability of the system to halt a process without returning the user to the operating system. This problem originated from differences between the DG and Prime operating systems. A swapped process or subroutine on the DG creates new processes as sons of the parent process. This allows the user to return to the parent process, while keeping all files closed in the event of an abort command (Control C on the DG). Thus a user can abort commands and remain in the main program (e.g., MOSS).

A swapped process on the Prime creates new processes as separate processes which cause the user to be returned to the operating system with all files left open if an abort is encountered (Control P on the Prime). This was a major problem because many times after starting a process a user realizes parameters for a command were entered incorrectly or the user just decides to do something else. A trap was inserted into all swapped processes to close all open files and return the user to the main program if an abort is received.

Another problem was the divide by zero. Formal assertions checking for divide by zero problems were never implemented in the DG software because FORTRAN 5 permitted

them to occur without error. However, FORTRAN 77 issues a fatal error at every occurrence. ESRI's solution was to emulate FORTRAN 5 in its conversion which meant if a divide by zero is encountered, the numerator is taken as the result and the analysis continues (Guevara 1987). This was unacceptable because a divide by zero is an error; therefore, an attempt was made to find all instances of divide by zero and flag them with error messages informing the user of input data problems.

Recompilation of the system highlighted the redefinition of common blocks. Redefinition can be a serious problem because it can corrupt memory and cause problems throughout the software. All redefined common blocks were examined and variable declarations changed to eliminate this problem.

All cursor input commands had to be changed because a carriage return on the Prime indicates the end of an instruction, yet cursor commands have no preceding text. This caused a system error and the user was returned to the operating system. This was a serious problem because carriage returns are often used for cursor input. The solution was to trap the carriage return and return a valid character to signal the cursor location.

A final system test was conducted before the release to identify as many errors as possible. As a result, over 80 errors specific to certain commands in MOSS and MAPS were

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reported and fixed. For example, the IMPORT command in MOSS did not check polygon coordinates for validity. This resulted in miscalculation of acreages. Checking was implemented to verify polygon and island closure as a minimum basis for topological validity.

Results of the First Release

The first software release was sent out in July 1987. Almost immediately, calls started coming in regarding the instability of the system. Apparently, any time an error was encountered, the user had difficulty returning to MOSS. A whole series of steps were required each time a user re-entered the system after an error, which led users to believe the system could not carry out production work. This caused great concern in the field because production software had been promised for over three months and it had yet to be delivered.

THE SECOND SOFTWARE RELEASE

General Approach

After continued testing and field use, it became apparent that many of the system problems emanated from ESRI's attempt to emulate the DG operating system. The BLM decided to strip all of the emulation software from the system before fixing any other software defects or implement any enhancements. After the emulation software was

eliminated, enhancement of the software and testing would be continued.

DG Emulation Software and Associated Problems

During the software conversion, ESRI developed a series of subroutines to emulate DG operating system functions in an effort to make the system perform as it did on the DG. The emulation software linking the GIS software with the Prime operating system intercepted DG-like commands and executed them on the Prime. However, this software caused numerous problems.

The environment was very complicated requiring initialization of 20 different global variables before the system could be operated properly. Anytime a hard error was encountered, users had to close down their environment (using ICE), run LEVINI to reinitialize all the global variables, and run DIRECTORY to reset the search list before returning to the system.

The environment when functioning properly required the system to be configured one specific way. All search lists were hardcoded in the software; no changes could be made in directory locations and the whole system was recompiled and relinked. This requirement made the software more system-dependent than it formerly was on the DG.

Another problem was channel management. Channels were

being improperly assigned to files causing fatal errors to occur and returning users to the operating system. Channel numbers were not tracked properly so attempts were made to assign files to channels that were already open.

The solution was to eliminate all the DG emulation software and substitute FORTRAN 77 routines in its place. This was beneficial in several ways. It eliminated the system dependencies introduced by ESRI, stabilized the system by eliminating the use of global variables and managing channels properly, and brought flexibility into the system by eliminating all the hard-coded paths throughout the software.

The two largest conversion efforts were the implementation of a channel manager and a pathblock routine. The channel manager was implemented to assign channel numbers to files after checking their validity. The manager checks an available channel before assigning it to a file, and then follows its status when the file is closed and the channel is made available again for use in the system.

The pathblock routine uses an ASCII file, named PTHBLK.DT, that specifies all the pathname prefixes to locate the necessary directories for running the system at the time of startup. The default is for all directories to reside at the Upper File Directory level (e.g., IS, MOSSDATA, ADSDATA, COSDATA). If a system configuration is different from the

default, the PTHBLK.DT must be used to define the new pathname prefixes.

Elimination of the DG emulation software and replacement with the FORTRAN 77 routines for channel management and pathnames stabilized the software and finally provided the development staff a base set of software that could be accurately debugged, fixed, and enhanced.

Other Problems, Solutions, and Enhancements

The first two major tasks to be undertaken after the elimination of the emulation software was the standardization of all input/output (I/O) subroutines and incorporation of all DG enhancements and fixes that were available in the February 1987 DG release.

All I/O routines were standardized and isolated in a separate library. Block I/O routines were standardized at 128 words (256 bytes). One problem found during testing was the writing of cell files as variable length records requiring file sizes to be calculated before any I/O could occur. Many times this caused read/write errors. The standardization and isolation simplified software maintenance and improved the portability of the software.

The software given to ESRI for conversion was a July 1986 release and contained many defects. In the interim between the conversion and delivery, the software con-

tinued to be fixed and enhanced causing the converted software to be outdated before it could be installed on the Prime. All software change reports used for the latest DG release were taken and incorporated into the Prime release. This finally provided the users with the capabilities present on the DG computers.

The additional changes are too numerous to mention. Some examples are the modification of the OPEN command in MOSS to permit a user to change directories without terminating the present session; enhancement of the ASSIGN command in MOSS, providing users with rudimentary color capabilities for vector data (i.e., point, line, and polygon); the elimination of duplicate header information within MOSS (i.e., deletion of POINT.DT, and all .DH files), and the elimination of many duplicate commands within MOSS and MAPS (e.g., all duplicate raster commands were eliminated in MOSS).

After the above-listed enhancements and fixes were completed, the system was fully tested twice. As a result, numerous software errors were identified and corrected (e.g., over 200 in MOSS). In addition, some error checking was added to prevent users from entering illegal values. For example, if a user mistakenly entered a character instead of an integer, the system many times would return no error and the user would be given erroneous results. The second release has more error checking than the DG version of the software and is probably a more

reliable version than was previously available.

The Results of the Second Release

The software has been released for approximately two months and appears to function adequately. Considerably fewer problems are being reported than with the first release. The increased reliability of the second release has given users confidence in the capability of the software to be used in production environments.

CURRENT STATUS OF SOFTWARE

The numerous improvements in the software must not be interpreted as meaning that the software is error-free. A point has been reached where the software can be debugged and fixed with much less effort than previously. Problems do still exist and there is plenty of room for further progress. Improved testing and maintenance procedures will provide users with continually improving software. Some examples of existing problems are discussed below.

One long-standing problem is the OVERLAY command. At present, it should function better than it did on the DG because it has undergone extensive testing, but problems still exist. Users must be provided with an overlay processor that performs 100% of the time since it is the backbone of vector analyses. Some of the problems include

polygons and islands being left open, islands being processed incorrectly, and coordinates being miscalculated in special cases for small polygons.

The system still contains many inconsistencies. For example, a user can import maps with 1,280 islands into MOSS but no commands can handle more than 350. Formal assertions should be added, where appropriate, to trap illegal input values.

All system-related documentation must be improved. One example of the continuing problem with inadequate documentation is the conversion of COS files with DG2PRIME. COS files were not being transferred correctly and an examination of the problem showed that the second header record for component files was missing. Unfortunately, the only documentation on COS file formats available did not have any information on this second header record. These formats will have to be determined by examining the FORTRAN code.

The recent installation of a new revision of PRIMOS with its associated FORTRAN compiler highlighted a problem common with all systems: files are opened one way, and read and written another. The specific problem was the opening of files for unformatted, direct access, but attempting formatted reading and writing of the files. This had been allowed previously, even though it is not good programming practice, but caused no compiler errors. Now, all

files must be opened with respect to subsequent reads and writes.

Lastly, a recent error was reported concerning maps in units of feet being imported with incorrect results. An examination of the algorithm showed that the parameter designating feet or meters was being checked incorrectly. Further examination showed that the parameter was being entered two different ways depending on how the user responded (e.g., if input was defaulted with a carriage return, then an M or F was entered in the low byte of the word; if the parameter was typed in, then an M or F was entered in the high byte of the word). These kinds of inconsistencies will only be uncovered by further testing and field use.

These problems underscore the need for ongoing support and maintenance if the software is to continue to fulfill the application needs of various government agencies. Increased testing and better error reporting will benefit the user community as a whole.

FUTURE PLANS FOR A
SUMMER RELEASE

Preparations for a summer release that addresses some of the problems identified are currently underway. A few of the enhancements are listed below.

The BLM has installed a new revision of PRIMOS (REVISION 21), which is presently being

tested. Any problems will be corrected to permit the field to upgrade with the next release. For example, all the open statements will be made consistent with the reading or writing required by the command.

Many of the inconsistencies in the software will be addressed. The number of islands permitted in MOSS maps will be increased to 2,000 consistently throughout all commands. The number of ACTIVE ID's that can be used in commands will be increased from 30 to 40. The length of the command line has limited this number to less than 30 ACTIVE ID's in MOSS commands even though the documentation would lead users to believe otherwise. The IMPORT command in MOSS will be corrected to permit data in units of feet to be imported correctly.

The size of MAPS files will be increased from 9,999,999 to 9,999,999,999 cells to permit the use of satellite imagery (e.g., thermatic mapper, SPOT) in subsequent analyses. Color assignment will be added to MAPS shade tables to permit color shading of raster maps.

The system will undergo a full series of tests as occurred during past releases.

LESSONS LEARNED: A
GOVERNMENT PERSPECTIVE

Several important lessons have been learned during the software conversion process and through subsequent work that can be used for future conversions. These lessons concern government responsibilities in accomplishing a successful software conversion.

The most important lesson is the need for a government team that is exclusively dedicated to the software conversion. The members of the government team for the Prime conversion had everyday responsibilities as well as the conversion responsibilities. Agencies must realize software conversion is an expensive proposition and must provide adequate resources to successfully oversee the project.

One suggestion would be to assign a quality control team to work closely with the contractor during the conversion, and would have no other responsibilities. The team would have general oversight functions requiring a wide range of individual skills. Specific duties could include providing assistance in system installation; providing necessary documentation to keep the conversion running smoothly (e.g., file formats, subroutine descriptions and calling charts, use of device drivers); approving software changes to accommodate new hardware or software, developing adequate software tests; reviewing and approving all of documentation developed by contractor; and testing and approving converted software. Ideally, the team should be on-site with the contractor.

The tests developed by the quality control team must be extensive. An effort must be

made to test 100% of the data paths existing in the software. This would minimize any fixes necessary before general release to the field. All data types and modules must be tested. Development should be modularized so that portions of the converted system can be released to the quality control team for subsequent analysis and evaluation.

The conversion contract should be structured so that it includes a mandatory acceptance period (minimum of 90 days) during which the contract conversion team stays intact and provides fixes for identified problems. A series of acceptance tests can be used for initial approval but should not be used as the only criteria for final approval.

Documentation must be required for all new software developed during the conversion or for software that underwent extensive changes that altered the former appearance or parameters necessary for execution.

Finally, data conversion should not be forgotten. Part of the contract for conversion must include development of automated methods for conversion and transfer of all data bases to the new hardware.

CONCLUSION

MOSS has undergone extensive changes since its delivery to the Government from ESRI. During this period, BLM has invested a great deal of resources in stabilizing the software and fixing the numerous problems existing at the time of delivery. Several enhancements have been added and the software has been tested thoroughly, resulting in a much better version than any previously available to the field.

REFERENCES CITED

Guevara, J. Armando
   1987   MOSS PRIME Conversion
      Project.   pp.2-19.
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QUESTIONS AND ANSWERS

Q. Who is responsible for quality?
A. Everyone is. There is an independent group that has been measuring quality. Their report is being drafted and will be released with the summer release.

Q. Will the summer release come in late July?
A. Yes, late July. Overlay problems are being fixed.

Q. What about ADS, COS, and MOSS?
A. People are using them in the production mode. There're not many problems that have been reported.

Comment:

There are many more enhancements to ADS: X-track takes multiple quads and extracts townships; Merge and PCCS were added to ADS.

PCCS is Public Lands Survey Coordinate Computation System, which was converted to ADS and will convert to other coordinate systems.

The entire system is in better shape than it was a year ago.

CURRENT DEVELOPMENT AND FUTURE DIRECTIONS
FOR MOSS: THE 32-BIT VERSION OF MOSS

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ABSTRACT

Current versions of MOSS on the Prime and Data General computers store data as 16-bit integers. Now that MOSS is written in FORTRAN 77, 32-bit virtual memory offered by these computers may be utilized. This change improves the precision of coordinate data and eliminates the scaling of coordinate data, which created slivers in maps. The steps and methods employed in the conversion are discussed. Other changes to the program resulting from the conversion to 32-bit memory include: (1) increase in the limitations of MOSS map files; (2) increased processing speed within MOSS through the use of disk arrays; (3) implementation of a new 10/12-bit tektronix library; (4) changes in SELECT and AREA options, as well as DESCRIBE and DELETE; (6) BUFFER redesigned and rewritten; (7) simplification of OVERLAY (renamed to INTERSECT); (8) expansion of GENERATE command; and (9) reworked TEXT and ASSIGN. Discussion of possible future enhancements is also given.

INTRODUCTION AND BACKGROUND

The current versions of MOSS operating on the Prime and Data General computers store geographic coordinate data as 16-bit integers. The recent conversion of MOSS to FORTRAN 77 on Prime computers for the Department of Interior did not require implementing coordinate storage as 32-bit values. Now that MOSS is written in FORTRAN 77, the 32-bit, virtual memory environment offered by mini-computers may be utilized.

There are two major advantages in fully implementing MOSS in a 32-bit environment. The first advantage is to greatly improve the precision of the coordinate data. During the early years of MOSS use, the typical GIS user in the natural resources fields did not require highly accurate representation of their map data. The precision offered by 16-bit data was sufficient for resource data. In addition, during the late 1970's only 16-bit minicomputers were available to most MOSS users. The precision of data entered into MOSS, as measured in ground coordinates, was determined by and limited to the 16-bit environment. Actually the

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coordinate values may only range between 0 and 32,768 as negative coordinate values are reserved to flag islands within polygons. Therefore, the precision of MOSS data stored at 16-bit integers is about ±1 feet on a typical 7.5-minute USGS quadrangle located in Colorado, which is acceptable range of precision for many resource management applications. However, increased use of precise Geographic Coordinate Data Base (i.e., ownership and Public Land Survey) information requires that the original precision of the data be maintained. Through the implementation of 32-bit integer coordinate storage, the data precision maintained in MOSS is increased by a factor of over 65,000, since values between 0 and 2,147,483,650 may be used. This will allow data precision to be about ±0.0002 inch in a 7.5-minute quadrangle or ±0.1 inch within the lower 48 United States. This precision will be maintained throughout any analysis by MOSS through the use of double precision arithmetic within the MOSS algorithms.

The second benefit of MOSS operating in a 32-bit environment is the elimination of the scaling of coordinate data. The scaling of feature coordinates differently between individual features within a map has resulted in MOSS polygon data which contains slivers. Slivers are the overlaps or gaps between adjacent polygons or islands. They occur because the actual precision for 16-bit MOSS data is less than expected, since MOSS scales all coordinates by a

specific factor to allow for larger coordinate values (i.e., larger than 32,768). This scaling factor for coordinates within a particular feature is based on the size of that feature; features of different size have different scaling factors. Slivers are most prominent between two or more bordering polygons or islands that differ in size, and hence would have different scaling factors. Slivers have caused problems with the calculation of polygon areas and the performance of OVERLAY, BUFFER, MERGE, and other types of analysis operations. The coordinate values for bordering polygons/islands will, in fact, be identical in the 32-bit version of MOSS. This will facilitate conversion of MOSS data to a common data structure (i.e., arc/node), since the polygon borders may be directly formed into arcs.

The expected impact and proposed approach of implementing a fully 32-bit version of MOSS have been investigated through the use of a prototype, which was developed recently (March 1988) by Autometric, Inc., under a separate task order from the Bureau of Land Management (BLM). The approach and results of this prototype are fully documented in a report submitted to BLM on March 7, 1988, entitled, "32-bit Storage of MOSS Coordinate Data Prototype Study." Based on the understanding gained from the 32-bit prototype, the full implementation of a 32-bit version of MOSS was funded.

This document addresses the 32-bit storage of coordinates,

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as well as 32-bit analysis throughout the MOSS software. In addition, the reformatting and removal of slivers from existing MOSS data files are discussed.

TECHNICAL APPROACH

The technical approach taken by Autometric addressed a full implementation of the storage and the analysis of MOSS data in a 32-bit environment. Included were the design and consideration of the process necessary to reformat data into the 32-bit environment.

OVERVIEW

The full implementation of 32-bit MOSS began by taking the prototype work completed by Autometric and expanding it to include the remaining MOSS commands. Much of the prototype was modified to use double precision floating point (DPFP) calculations, as well as some of the MOSS library routines that were already converted to use the 32-bit structure. Once the prototype and library code were retrofitted with the DPFP calculations and retested, the other programs not addressed in the prototype were converted to use both the 32-bit data structure and more accurate calculations. At the same time, the record formats of MOSS files were significantly modified to permit storage and analysis of 32,512 items and subjects per map and 32,512 coordinate pairs per item.

Modifying the remainder of MOSS was simplified because the libraries had been completed and tested, such as converting ADS2MOSS and the routines EMOSS and EMOSS2 in COS. The most difficult portion of the task was the utility to convert old MOSS files into the new 32-bit format. Removing slivers, determining coincident features, and realigning islands also required considerable effort. To nullify the inaccuracies of the old 16-bit MOSS data, the polygon format was fit back into a "pseudo" arc/node format. This forced polygons with common borders to have exactly the same coordinates along that border and resulted in increase of reliability of many of the analytical functions within MOSS (i.e., BUFFER and OVERLAY).

METHODS

The methods used during the implementation of a 32-bit MOSS addressed both the conversion to the 32-bit environment and the reformatting of existing 16-bit data.

Conversion to 32-bit Environment

To finish the conversion of MOSS to the 32-bit data structure, each separate command and its supporting routines were copied to a new directory and modified. Disk arrays were replaced with virtual arrays and all coordinate computations were changed to double precision calculations. In addition, the file formats were significantly changed to increase the limit of items,

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subjects, and coordinates to 32,512. The specific changes to the records were documented in the file named :SU:MOSS:DOC: FILES.DOC. The coordinates were read from the import file into double precision floating point (DPFP) variables. After calculation of length or perimeter and acreage, the DPFP coordinates were multiplied by a scale factor (usually 100) to preserve the decimal place in an implied position. The DPFP coordinates were then converted to 32-bit integer values and along with the scale factor were incorporated into the MOSS map.

The two remaining changes entailed replacing the disk arrays and using DPFP arithmetic on coordinate calculations because (1) disk arrays are no longer needed nor desired on a virtual memory computer, and (2) the use of DPFP arithmetic will allow those MOSS routines that process coordinates to take advantage and retain the precision offered with the new 32-bit integer data. After all of the required MOSS routines were completed, the ADS2MOSS program was checked out of ADS and made compatible with the new 32-bit format. The COS routines EMOSS and EMOSS2 were then changed to accept the new format as well. Since COS is used for display purposes only, the DPFP coordinates were not implemented, but were changed to single precision floating point numbers (SPFP) so that they would not affect the entire COS program. MAPS will not require any changes since raster data will not be impacted with the conversion to 32-bit coordinates.

Reformatting Data

The 32-bit version of MOSS requires that all binary map files be formatted to 32-bit. This resulted in the development of programs to reformat new and existing data to be compatible with the 32-bit MOSS.

In a memorandum from Autometric dated November 18, 1987, the issues relating to reformatting 16-bit data to 32-bit were outlined to BLM. All MOSS data should be reformatted from the current 16-bit files. If the original data exist (i.e., ADS, AMS, DLG, or other "arc/node" structure), reformatting is then a simple matter of reimporting the data back into MOSS. This imported data will not contain slivers in the 32-bit version of MOSS. However, maps from polygon data that were generated or derived by MOSS will contain slivers. The slivers in MOSS data cannot be removed without a rigorous reformatting verification software program, which will address all cases where slivers may exist.

The data reformatting program named 'old to new', alias O2N, addresses the two major areas where slivers occur in MOSS polygon data: (1) between an island and its parent polygon and (2) between two or more adjacent polygons, especially those polygons that differ radically in size. Removal of slivers in the first case is accomplished by simply identifying the parent polygon and replacing the island coordinates with the respective polygon coordinates, but in

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reverse order. Removal of slivers between adjacent polygons of different sizes is much more complex. The software decides which coordinate point from which of the polygons should be honored. This process may change the location of polygon borders, but generally not significantly.

Basically, the conversion program takes the imprecise 16-bit data with slivers, and edge-matches all coincident lines and all islands to their respective polygons. In this way, two polygons with a common boundary (arc) have exactly the same coordinates along that boundary. This has been confirmed by comparing coordinates from IMPORT and EXPORT files.

Some general rules about the function of the software needed to be set, so that optimum precision is retained from the 16-bit data. The first rule is to use the coordinates from the smaller polygon where two polygons touch because the coordinates of small polygons are more precise in 16-bit data since coordinate scaling was based on maximum feature extent. This also applies to islands. All island coordinates are replaced by the coordinates of the polygon which fill the island. Since the program needs a tolerance to decide which lines are coincident and which are not, the tolerance is calculated for each of the two polygons being evaluated based on the difference in size (scaling) of the polygons. This rule is necessary because a general tolerance (fudge factor) for

the whole map has been tried before with generally poor results. MOSS maps are not reformatted "on-the-fly," since this process is not fast and most users will not have write access to the master data base. The program O2N may reformat multiple maps as a batch process.

The general algorithm for the reformatting program is as follows:

1. Open the old 16-bit map and create the new 32-bit map file.

2. Process each item in the old map, making a list of each other item that touches it, sorted from largest to smallest.

3. Process this list (largest first), checking for coincident lines.

4. If a coincident set of lines is found, determine which polygon is smaller. Pull the coordinates from the smaller to the larger along the coincident arc. (This will also work for islands).

5. Repeat Step 3 until the list for this item is exhausted.

6. Set a flag in the header of the map to indicate that it has been reformatted to a 32-bit data file.

7. Finish processing, rename the 16-bit map, and replace it with the 32-bit map.

8. Exit from program.

Point and Line File Structure

In addition to merely reformatting data to 32-bit, Autometric investigated the impact of changing MOSS point-and-line data files during the data reformatting process to eliminate wasted file space, thus reclaiming space in MOSS point data files. The rationale was that file sizes could be reduced for point maps through the elimination of 256 bytes of space reserved for each coordinate pair. In the reformatting process, the points would be referenced instead to each point's minimum bounding rectangle (MBR). Currently feature MBR's are stored as real numbers. There is no additional room in the file header to store MBR's as double precision floating points without significantly changing the data file structures. In addition, MBR's as real numbers are less precise than point coordinates stored as 32-bit integers, resulting in loss of precision of point data if the MBR's were used instead. It would be counter productive to increase the precision of MBR's, since a tolerance factor is often added to the MBR during many analysis operations, such as occurs when the juxtaposition of two features is checked. One final argument against changing the MBR is that the Tektronix graphic library currently uses the MBR to window; this library uses real numbers, and, thus, a double precision floating point MBR would have to be changed back to real numbers.

The major reason both point-and-line data files were not modified to eliminate file space reserved for non-existent islands, however, was that significant changes would have to be made throughout MOSS to account for exceptions concerning these data types.

Significant Enhancements

The 32-bit version of MOSS contains some significant enhancements above and beyond the capabilities of the 16-bit version on the Prime. These enhancements were funded in large part by Los Alamos National Laboratories for implementation on Data General MV series computers. In addition, Autometric programmers have further improved the software. The enhancements to MOSS which may be realized by users of the Prime, Data General, and Tektronix UNIX version of the software are listed below:

- All fixes/enhancements made by BLM and Autometric to the 16-bit Prime version during the development of the 32-bit Prime have been implemented. These include, but are not limited to, the 2,000 island limitation, FEET/ METER consistency check, and use of 40 active ID's.

- The limitation of the MOSS map files have been increased to: 32,512 subjects per map; 32,512 items per map; and 32,512 coordinate pairs per item.

- Full use of virtual memory through the elimination of disk arrays. This significantly increases the processing speed within MOSS.

- Implementation of a new 10/12-bit Tektronix library to support the entire line of Tektronix compatible terminals. MOSS now supports Color, Color Patterns, Flood, Rubberbanding, Mouse, Segments, and Views.

- SELECT supports wildcard and template matches for both mapname and subject search strings. The AREA option allows selection of items contained within a user defined area.

- DESCRIBE and DELETE supports mapname templates.

- BUFFER has been redesigned and rewritten to correctly form item buffers and island formations.

- OVERLAY has been renamed to INTERSECT, and has been simplified to remove tolerance checking of 32-bit coordinates.

- GENERATE allows 32,512 coordinates per feature, automatically generates curved lines, undoes previous points, and supports rubberbanding.

- TEXT was reworked to increase functionality and ease of use.

- ASSIGN allows the assignment of line fonts to polygon borders. Polygon borders may also be assigned by individual item.

Integration and Testing

As each module in MOSS was completed, Autometric tested the unit using the data sets that had been included in the prototype, as well as more complex data sets, to verify that the module still worked as expected. Acceptance testing by the the BLM, U.S. Forest Service, and Los Alamos National Laboratories addressed all commands and the reformatting of all types of MOSS vector data. All other MOSS, ADS, AMS, MAPS, and COS programs remain unchanged as far as the user is concerned, except, of course, the addition of any new enhancement made to a command. In these cases, the on-line help file should be consulted. The Data General and Tektronix version of 32-bit MOSS has been in use in a production environment since October 1988 within the Los Alamos National Laboratories and the U.S. Forest Service. All problems reported have been minor and have been fixed.

FUTURE CONSIDERATIONS

The 32-bit version of MOSS is a significant improvement over the 16-bit version. The users will notice improvements in speed and performance, while the support staff will realize improvements in the ease of maintenance and support. In the long run, the entire user community, whether they are Department of Interior or other agencies, or, for that matter, Prime computer or Data General/ Tektronix computer users, will benefit from this version of MOSS.

The 32-bit MOSS is compatible with the BLM current system

plans, i.e., the Prime version contains all enhancements requested by BLM during FY88. The 32-bit precision of the data will maintain all of the accuracy necessary for the Geographic Coordinate Data Base. The quality of the 32-bit code has significantly improved, which will allow BLM to devote fewer resources to maintaining this code, primarily because the source code is more robust and less redundant, and contains very few system dependencies (the software has gone through three additional conversions—to the Tektronix, Data General, and back to the Prime). Furthermore, the elimination of slivers has isolated many algorithmic deficiencies since problems with the data are no longer evident.

The 32-bit MOSS is also compatible with the BLM's Interim LIS plans: the software is very portable as it operates under the UNIX operating system. More importantly, the reformatting program (O2N) removes all slivers in the data, thus providing polygon data which may more easily be converted to a common data structure (i.e., arc/node). Finally, many enhancements which have been made to existing commands such as BUFFER could realistically be implemented into the interim LIS at great cost savings to BLM.

The 32-bit code was developed under strict configuration management guidelines imposed at Autometric. This effort was made to facilitate the long-term support of all government

agencies (USFS, DOE, etc.) using this software. Support and cooperative funding between agencies and departments is feasible since the 32-bit version of MOSS on the Prime, Data General, and Tektronix computers are identical. This software may remain the same as long as minimal Configuration Management and Quality Assurance procedures are adhered to by the one organization maintaining the software. This will help to insure that all government agencies using MOSS benefit equally.

An example of enhancements done by one government agency on the Data General version of 32-bit MOSS, which may benefit other groups using the Prime version of 32-bit MOSS, is the current effort to develop a SQL interface to MOSS. Although this work is being performed on the Data General using DG/SQL, the design and much of the software can easily be implemented on the Prime and/or Tektronix version using any other SQL data base, such as Oracle.

There are two other long-term considerations which should be addressed. The first is that information in the MOSS binary files is now stored as integers, except the map MBR, which is still stored as a floating point value. The fact that integers are treated similarly across different hardware provides the potential for inter-computer transfer of binary MOSS files between a network of different brands of computers (i.e., between Prime and Tektronix workstations if

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MBR's are stored as 32-bit integers). This capability may be of value to BLM during the interim period.

A second consideration that 32-bit MOSS users should be aware of is the difference in precision of coordinates stored and analyzed by MOSS versus those coordinates displayed by the various graphic libraries. Simply put, the graphic libraries (Tektronix, Calcomp, etc.) are not currently capable of using the same precision as that found within MOSS. Since these libraries are single precision, all coordinates are rounded to the nearest whole number before displaying softcopy and hardcopy output. This will impact users who would like to accurately display very small features contained in a large map.

ENHANCEMENTS TO THE GEOGRAPHIC INFORMATION
SYSTEM CELL PROCESSING SYSTEM (MAPS)

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ABSTRACT

The Bureau of Land Management (BLM) maintains a
Geographic Information System (GIS) to assist in the
management of public lands and mineral holdings. The GIS
is made up of a number of subsystems, including the Map
Analysis and Processing System (MAPS), which is used for
raster (cell) map processing. The MAPS system is used
to conduct complex GIS processing tasks and Digital
Elevation Model (DEM) processing. This paper presents
software enhancements to the MAPS system that assist GIS
and DEM processing. The enhancements include those
implemented into the software, those that are currently
in development, and those under consideration for
development. The paper includes a section in which the
new enhancements are used in a DEM processing application
with two different sources of DEM data (1:250,000-scale
and 7.5-minute). The DEM processing session includes
discussions of (1) system differences between entering
the two sources of data into MAPS, (2) data manipulation
required before DEM processing, and (3) DEM processing
in which three dimensional perspectives are generated
and slope and aspect analyses are conducted.

INTRODUCTION

The Bureau of Land Management
(BLM) is responsible for
managing nearly 300 million
acres of public land and
mineral holdings in the United
States. To assist in the
management of these lands the
BLM maintains an automated
Geographic Information System
(GIS) on a PRIME minicomputer.
The GIS is a software tool used
for encoding, analyzing, and
displaying map information, and
is made up of various systems.
These systems consist of the
Automated Digitizing System
(ADS), used to convert analog
data to digital form; the Map
Overlay and Statistical System
(MOSS), used to manipulate and
perform analytical operations;
and the Cartographic Output
System (COS), used to produce
enhanced cartographic products.
The MOSS system has the
capability to manipulate both
vector and raster (cell) data.
The raster data are manipulated
by a MOSS subsystem called the

Map Analysis and Processing System (MAPS).

The MAPS computer system processes maps having an array of grid cells. These maps are also commonly referred to as raster maps. Raster map processing is often preferred over vector processing because of its technical expedience for undertaking complex operations, such as map overlays, map combinations, and spatial analysis (Burrough 1986). Raster processing also is particularly advantageous for conducting complex cartographic modeling procedures, handling image-based data (i.e, classified satellite scenes, such as LANDSAT), and digital terrain processing.

The BLM is making use of the raster processing capability of MAPS to assist projects involving spatial analysis, including resource and land-use analysis, and environmental assessments. Raster processing has also provided the automated support to assist the BLM in completing Resource Management Plans (RMP's), Environmental Impact Statements (EIS's), Environmental Assessment Reports (EAR's), and Cultural Resource Management (CRM) assessments (Calamia and Martin 1986; Zulick 1986).

The intention of this paper is to present software enhancements to the MAPS system that have been completed or are currently in development by the Branch of GIS Implementation (D-155), now the Interim Management and Operations Group (D-155), at the BLM Service Center (SC), Lakewood, CO. The paper is divided into four parts:

- enhancements that support GIS processing,
- enhancements specifically related to Digital Elevation Model (DEM) processing,
- status of the enhancements, and
- enhancements used in DEM processing to compare and contrast two DEM sources.

It is worthy to note that the enhancements discussed in this paper are not the only enhancements to the MAPS system that the SC has recently developed.

GIS PROCESSING ENHANCEMENTS

Re-Projection

Currently available in MOSS, the vector portion of the GIS, is the capability to re-project a map in various ways. The re-projection capability allows the GIS user the luxury of selecting a number of map projections that retain either area, conformity, scale, or direction. The re-projection capability allows the user to obtain digitized map data from various map sources and re-register the data to one preselected projection. For example, the user may need to combine data from a BLM surface and mineral map (scale 1:100,000) with hydrologic data from a 7.5-minute quadrangle (scale 1:24,000). The two sources of information are registered to the earth by two different projections (UTM and State Plane). To allow inte-

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gration of this data, both or one of the sources is usually re-projected to a common projection. This is normally accomplished using the PRO-JECTION command in MOSS (Consult MOSS Users Manual, Version 8706).

The MAPS system is often used for analytical operations involving map combinations, overlays, and modeling. Normally to use the analytical functionality of the MAPS system, a user transforms data from a vector structure to a raster (cell) structure, by using the RASTERIZE command in MAPS. If a problem exists with differing projections, a GIS specialist would re-project a map in MOSS before rasterizing it. In this sense, the GIS specialist did not require a capability to re-project a map in MAPS.

Recently GIS specialists have recognized the potential use of image-based satellite data and DEM's in assisting natural resource management. These sources of data are already in cell format and, hence, do not require the use of a digitizer to extract the data, nor a vector-to-raster conversion to place data in MAPS. However, these sources of digital information are affixed to a projection system. Digital

Elevation Models are either UTM or Geographic (latitude/longitude). In these cases the digital elevation data may have to be re-projected to a different projection to allow integration with other data sources. Because the data are inherently raster in format, a re-projection of the elevation data needs to be accomplished in MAPS. To meet this need, a re-projection capability is being developed for the MAPS system. The enhancement will be comprehensive and will allow re-projecting of either continuous or categorical raster maps to a variety of map projections. The enhancement incorporates the NOAA/USGS re-projection software which resides in MOSS.[1]

Re-sample

Most cell processing systems (LAS, ERDAS, IDIMS, etc.) have the capability to take a cell map and transform it to a new map that has cells of a different dimension. This capability in MAPS would be applicable for a number of situations including (1) alter cell size of maps directly entered into MAPS (function IMPORT), thereby allowing integration with other cell maps of a project; and (2) obtain complete coverage of a

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[1]One would argue that a DEM could be re-projected with the existing software by (1) creating a linear contour file by use of CONTOUR in MOSS, (2) re-projecting the contour file in MOSS (PROJECTION) function, (3) re-converting the re-projected file to a cell elevation file in MAPS (function RASTERIZE). The problem with this method is that it requires needless processing and may be inaccurate.

study area. Currently the MAPS software limits the size of one map to a total of 9,999,999 cells, or an array of 3,162 x 3,162 cells. The maps within a project could be re-dimensioned to a larger cell size to encompass a larger geographical area. This capability has been recently built into MAPS as the RESAMPLE function. The RESAMPLE function allows a user to alter the cell size of a continuous or a categorized cell map (dichotomous, discrete, or continuous cell map).

Array Expansion

One of the limitations of MAPS is its inability to support large project areas. The internal software limit of 9,999,999 total cells, or about an array of 3,162 x 3,162 cells, is an area of roughly 58 merged 1:24,000-scale quad-rangles with a cell size of 30 meters by 30 meters.

Currently in development is an expansion of the array size in MAPS to 8,192 x 8,192, or roughly 67,100,000 cells. This expansion will support a study area of 386 merged quadrangles at a cell size of 30 meters by 30 meters, which will eliminate the need to break resource study areas into separate blocks.

Raster Edit

Currently MOSS (vector processor of GIS) has an interactive editor (EDMAP) that permits a user to edit vector data such as point, line, and polygon data. A similar editing capability is needed in MAPS that will permit editing of raster cells. This capability is needed if MAPS is going to support manipulation of entered image-based products, such as classified satellite scenes. To meet this need, a comprehensive raster editing capability is currently being developed for MAPS. The edit function will support editing of single cells, subsets of rows and columns of cells, diagonal line segments, and a group of line segments.

Raster-to-Vector Conversion

Currently, MOSS has the capability to convert a vector data structure to a raster data structure (vector-to-raster conversion) in MAPS, but its counterpart, a raster-to-vector conversion, is lacking. The capability to convert data residing in the MAPS system to the MOSS system would enable the transfer of classified satellite image data (i.e., LANDSAT, SPOT). A raster-to-vector conversion would also eventually create products (maps) that are more carto-graphically sound. Following the conversion of a cell map to vector, the "jagged" appearance of polygons and linear features of maps caused by the outlines of individual raster cells could be removed by line smoothing operations available in MOSS. Following the smoothing, the maps could then be sent to a vector pen-plotter.

The Service Center is investigating the possibility of developing software to perform a raster-to-vector conversion between MAPS and

MOSS. The raster-to-vector conversion will have the capability to not only convert polygon data with associated attribute labels, but also to convert linear and point data. Examples of raster polygon data include land cover, land-use, and soil and vegetation classifications obtained from raster-based satellite imagery. Conversion of linear data would consist of features such as hydrologic and transportation networks (highways and gravel roads), and pipelines. Point features may consist of gas and oil well locations.

ENHANCEMENTS FOR DEM PROCESSING

1:250,000 DEM Entry

The requirement to have an alternative digital elevation source other than the USGS 7.5-minute DEM's has been documented (Foster 1987; McKinley 1986). This requirement has resulted from the need for (1) more complete digital elevation coverage within BLM resource areas; (2) larger geographical coverage with a single digital elevation map; and (3) elimination of pre-processing on another system, which is costly and inefficient. The 1:250,000 DEM maps cover a geographical space of a one-by-one degree block. This coverage results in a map of 1,201 by 1,201 cells, with three arc-second spacing between each cell. Normally the 1:250,000 DEM files are preprocessed on the IDIMS system before being brought into MAPS. The map is registered to a geographic (latitude/longitude) coordinate system.

A new enhancement to the MAPS package allows the direct entry of a DEM arc-second map into the GIS. This was accomplished by modifying the existing IMPORT routine. Also included in the enhancement is the capability to subsection a portion of the map for entry. This is done through the IMPORT command line during execution, by indicating a latitude/longitude subsection. This capability will permit the fitting of a DEM arc-second Map to a particular study area, and will reduce processing time during execution. Before the map can be used with other existing maps, the map will have to be re-projected from a geographic coordinate system to a plain (rectangular coordinate system).

Slope and Aspect

The MAPS software package has the capability to generate slope and aspect maps from continuous elevation data. The SLOPE function enables a user to generate a gradient percent (rise over run) for each cell of a map. The ASPECT function enables a user to determine the direction the surface slope faces, or its azimuth or exposure. These existing functions often produce erroneous slope and aspect values for cells near the edge of a DEM. This is caused by fill data (value zero) existing along the edge of DEM's, because of the variable angle between true north and grid north of the UTM projection. The erroneous slope and aspect values result because of the inclusion of zero values in the

roving matrix when calculating slope and aspect values. To rectify this problem, the SLOPE and ASPECT functions were enhanced to allow the user the option to mask-out certain values during calculations. These enhancements are extremely useful for ASPECT and SLOPE calculations involving 1:24,000 scale USGS DEM's.

STATUS OF ENHANCEMENTS

The Service Center is responsible for maintaining, updating, and enhancing a GIS system with primary data manipulation and analytical operations within the MOSS/MAPS software. The Service Center periodically (usually semi-annually) releases software to the field; the next scheduled release is the summer of 1987.

Table 1 provides the status of the enhancements.

APPLICATION USING THE ENHANCEMENTS
(1:250,000 versus 7.5-minute DEM processing)

Entry of DEM's into the MAPS system

The 1:250,000 DEM entry enhancement will give BLM field personnel an alternative digital elevation source other than the traditional 7.5-minute DEM. The existing IMPORT function was modified to allow the entry of a 1:250,000 DEM into MAPS.

Figure 1 depicts the command flow of entering a 1:250,000 DEM (denoted as an ARC-SECOND DEM) and a 7.5-minute DEM into MAPS, and the required data

Table 1. Status of MAPS enhancements.

Enhancement	Status	Release Date
GIS processing		
Re-projection	In development	Winter 1987-88
Resample	Implemented	February 1987
Raster edit	In development	Summer 1987
Raster-to-vector conversion	Requirements	T/D
DEM processing		
DEM arc-second entry	Implemented	Summer 1987
Slope and aspect	Implemented	February 1987

Note: In development indicates the software code is currently being developed. Implemented indicates the software has been developed, tested, and loaded into MAPS. Requirements means that the needs of the users are being determined. T/D indicates that the release date has not been determined.

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manipulations needed to alter the cell elevation data to a format compatible with other data sets of a study area. A few differences exist between the entry and manipulation of the two sources of DEM's. Because of limited geographical coverage of the 7.5-minute DEM's, a number of adjoining DEM's may have to be entered into MAPS individually. This requires the user to execute the IMPORT function a number of times, depending on the desired coverage, and to verify that each IMPORT is successful and that the elevation data is correct. This verification is normally accomplished by producing a contour or three-dimensional perspective of the entered DEM's. Once the verification is completed, the adjoining 7.5-minute DEM's can be joined by using the MERGE command in MAPS.

The 1:250,000 DEM's differ in that they must be entered once because of their extensive geographical coverage. Once a 1:250,000 DEM has been entered into MAPS, the map must be projected from a geographical coordinate system latitude/longitude) to another system, depending on the needs of the project. When both DEM sources have been entered into MAPS, the DEM's can be re-sampled to a different cell size and cut to fit a particular study area. The DEM's are now ready for digital terrain processing (i.e., calculation of aspect, slope, and viewshed analysis).

The major trade-off between using 7.5-minute DEM's and 1:250,000 DEM's is processing time and accuracy. The 7.5-minute DEM's are more accurate, but they require more computer processing through the multiple use of the IMPORT command and the MERGE command. A GIS specialist can reduce inter-active processing by using the READ command in MAPS or by creating a CPL (Command Procedure Language) program that allows batch entry of DEM's. The READ command is a program control command in MAPS that allows a sequence of commands to be executed. In this case, a series of IMPORT functions could be executed to allow a number of DEM's to be entered into the system. The READ function or a batch job will make more efficient use of the computer by (1) reducing interactive time on the computer, (2) by reducing computer processing through more efficient use of the CPU (Central Processing Unit), and (3) by allowing job entry during non-peak user hours.

1:250,000 Versus 7.5-Minute DEM.

Following the MAPS command flow depicted in Figure 1, a 1:250,000 DEM and a 7.5-minute DEM that cover the same geographical area (near Kanab, Ut) were brought into MAPS with IMPORT. The 1:250,000 DEM was re-projected to a UTM projection and resampled to a 30-meter grid. The map was then cut to fit an area of 350 by 400 cells. The 7.5-minute DEM was entered into the system and cut to the same area. For comparison, three-dimensional perspectives were generated, and slope and aspect class maps were created.
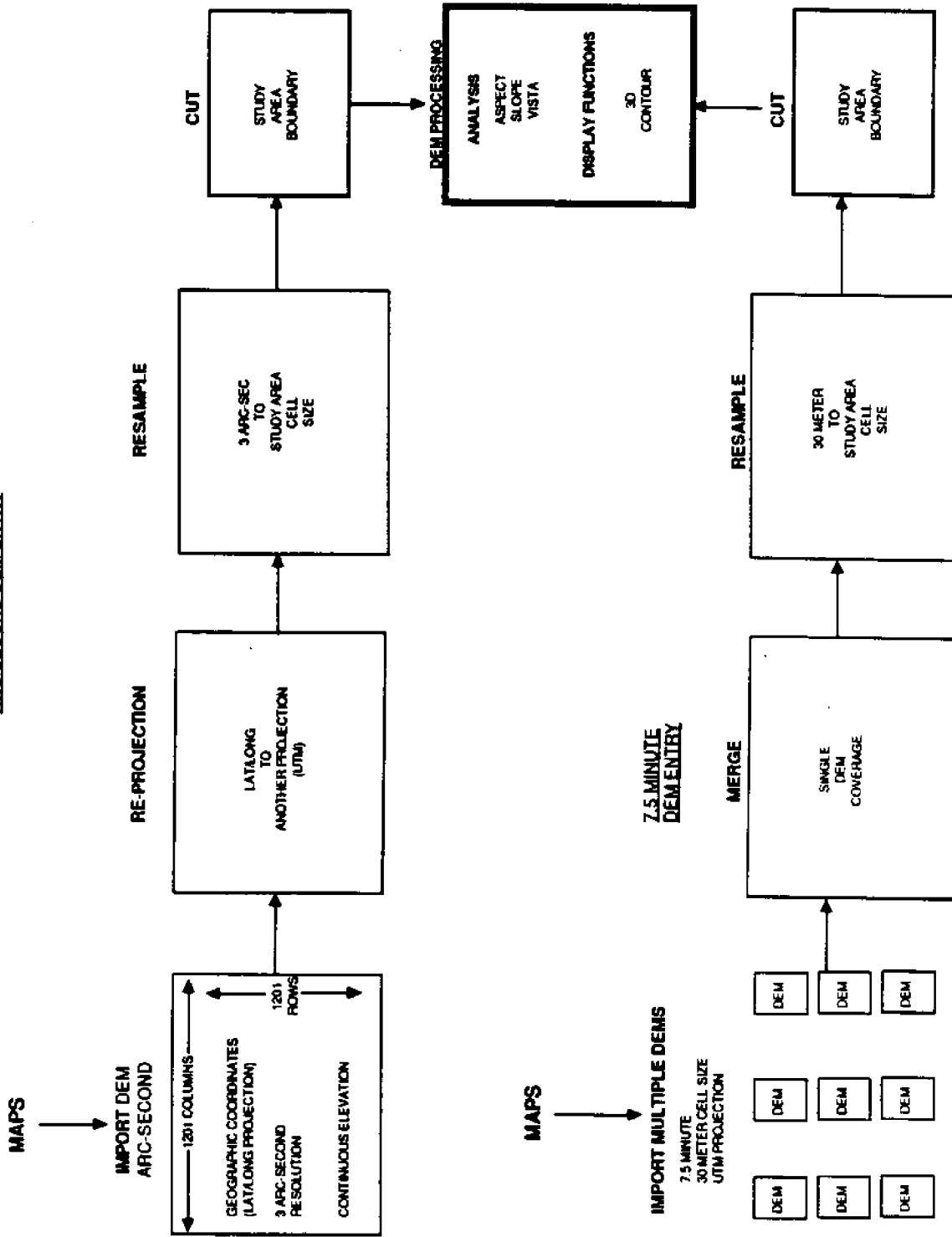
Figure 1. Arc-second DEM and 7.5-minute DEM entry.

Three-dimensional perspec-
tives. Figure 2 shows the
three dimensional perspectives
generated from the 1:250,000
DEM and the 7.5-minute
quadrangle using the 3D
function in MAPS. The major
differences between the two
perspectives is the level of
accuracy depicted. The
1:250,000 DEM appears smooth
and is absent of detailed
landform features. The smooth
appearance of the 1:250,000 DEM
is due to two reasons. First,
the 1:250,000 DEM has been re-
sampled from a three arc-second
(90 meter in the vertical di-
rection and 60 to 90 meters in
the horizontal direction) cell
size to a 30-meter cell size.
Second, the original level of
accuracy of the 1:250,000 DEM
does not match that of the 7.5-
minute DEM. The 1:250,000
DEM's are produced by inter-
polating elevation at intervals
of three arc-seconds from
1:250,000-scale topographic
sheets. Accuracy throughout
the 1:250,000 DEM depends on
the accuracy of the original
topographic sheets, which are
50 feet in flat terrain, 100
feet in moderate terrain, and
200 feet in steep terrain. The
7.5-minute DEM's are inherently
more accurate because a 30-
meter horizontal sampling
interval is used throughout
the map (Elassel and Caruso
1985).

Slope and Aspect Class Maps.
Slope and aspect class maps
were generated from both DEM's,
by using the SLOPE and ASPECT
functions in MAPS, and then
using the CATEGORIZE function
to place the results into
distinct classes. To compare
the two DEM types, south facing
aspects were extracted (135 to
225 degrees), and 20%-25%
slopes. Maps were generated to
allow visual comparison of the
results, and area determina-
tions were calculated (function
AREA in MAPS). Table 2 sum-
marizes the results of the area
calculations for the slope and
aspect class maps.
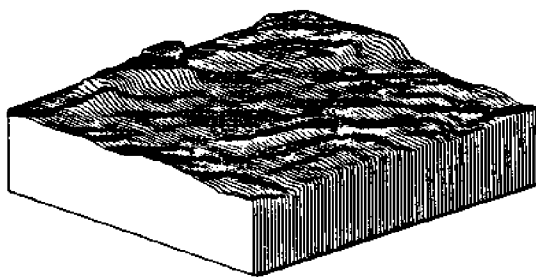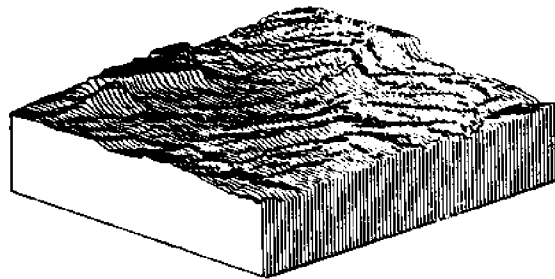
1:250,000 DEM   7.5-minute DEM

Figure 2.   Three-dimensional perspectives of elevation data
produced in MAPS using the 3D command.

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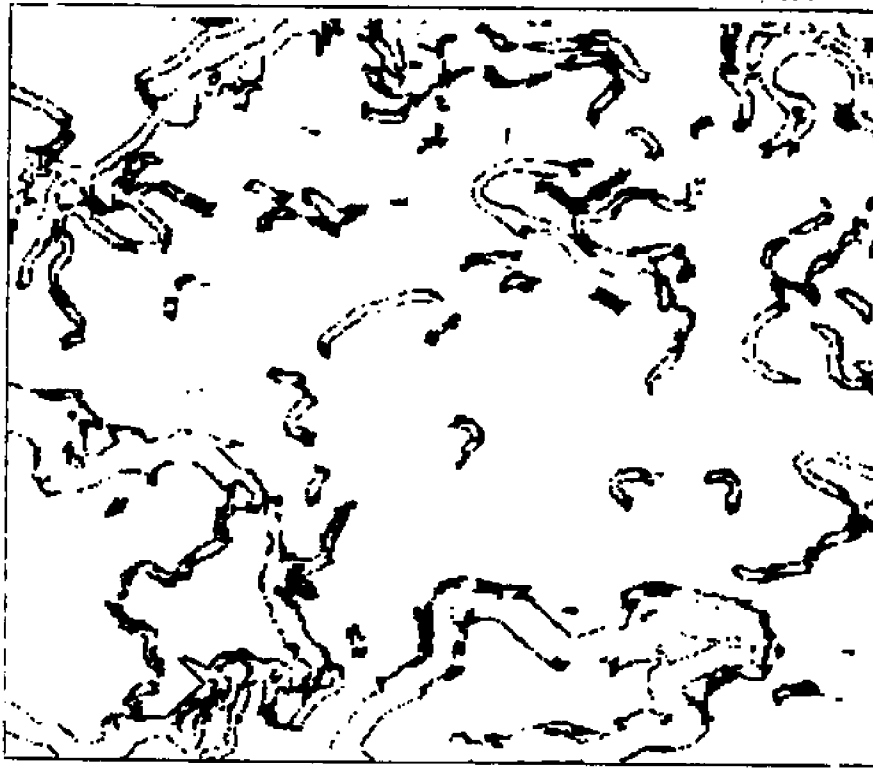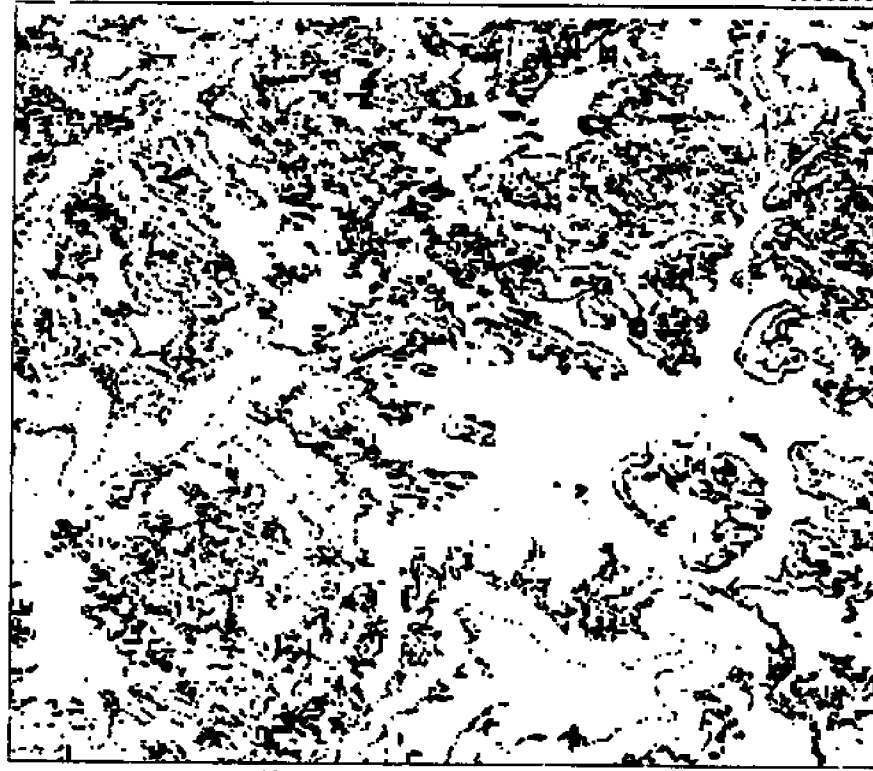KANAB. UT DEM ARC-SEC CAT SLOPE MAP   KANAB, UT DEM 1:24,000 CAT SLOPE MAP

1:250,000-scale DEM   7.5-minute DEM

Figure 3. Illustration of classed (categorized) 20%-25% slope maps.

Results indicate the large difference between the elevation sources, most notably the difference between the 20%-25% slope areas extracted from the two DEM's. This is again due to the accuracy of the elevation data. A number of the cells of the 1:250,000 DEM will have a zero slope value because adjacent cells have identical cell elevation values from earlier resampling. Figure 3 illustrates the dramatic difference between the geographical coverage of the two categorized slope maps.

Table 2. Area calculations. ASPECT (135-225 degrees); SLOPE (20%-25%).

7.5-minute DEM	7,413.3	3,933.4
1:250,000 DEM	7,525.4	2,417.2

Note: Area given in acres.

Applying Results to Field Operations

The comparison of the two DEM's indicates the large differences between three-dimensional perspectives and classified slope and aspect maps. The 7.5-minute DEM generally provides more accuracy, but it requires more computer processing because of its limited geographical coverage. The 1:250,000-scale data do not require as much processing, but their accuracy is questionable. Generally 1:250,000 DEM's should only be used for generation of visual products, such as three-dimensional perspectives, relief maps, and contour maps.

The 7.5-minute DEM's should be used for extracting slope and aspect information, undertaking viewshed analysis, and supporting complex analytical operations such as map overlays, maps combinations, or predictive modeling.

SUMMARY

The BLM identified a requirement to improve the capability of the MOSS/MAPS software to perform raster (cell) processing for GIS and DEM processing. GIS processing was improved by the inclusion of the RESAMPLE function with the latest MOSS/MAPS release, the present development of the reprojection and raster edit capabilities, and the determination of the requirements for a raster-to-vector conversion. DEM processing was also improved by the release of the SLOPE and ASPECT enhancements, and the capability to directly enter 1:250,000-scale DEM's into MAPS.

The enhancements allowed the direct entry of a 1:250,000 scale DEM that fulfilled· the needs of the field GIS specialist by providing coverage where 7.5-minute DEM's were lacking, and by reducing processing time. GIS specialists should be careful in applying this data to slope and aspect analysis and applications involving complex modeling procedures. The 250,000-scale DEM data are more effective for three-dimensional perspectives and contour maps. If 7.5-minute DEM coverage is lacking, there may be no alternative but than to use this source of

data. If so, the specialist should be aware of its accuracy and, hence, its limitations.

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QUESTIONS AND ANSWERS

Q. Is the ARC-SEC different cell sizes?

A. Yes. The 1:250,000 scale is roughly 90-100 m while the 1:24,000 DEM is 30 m.

Q. What method did you use to smooth output?

A. Resampled by bi-linear interpolation.

Q. What about processing time without the Array Processor?

A. It's already on the Prime. Use the memory on the Prime to process more arrays.

Q. Are there improvements for display stations for quality control?

A. Yes, the implementation of color into MOSS and MAPS should help quality control.

INTERFACING MOSS WITH THE ORACLE RDBMS ON THE PRIME

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ABSTRACT

An interface between MOSS and the Oracle RDBMS has been prototyped on the Prime at the BLM Denver Service Center. The interface is handled via C language subroutines in which Oracle Host Language Interface statements are embedded. It comprises MOSS, Fortran 77 subroutines that process MOSS, and multiple attribute data previously stored in the ".AT" file. The result is more efficient handling of MOSS attribute data. Changes to user interfaces are minimal. Several commands have been modified and others have been eliminated.

INTRODUCTION

Over the last ten years the capabilities of geographic information systems (GIS's) have increased dramatically due to user demands for greater functionality and flexibility. A GIS is now expected to provide, at a minimum, the following capabilities: capture, storage, and display of numerous data types, conversion of data into different formats, modeling of spatial phenomena, derivation of new data, and production of various hardcopy outputs.

Simultaneously, data base management systems (DBMS's) have become more and more sophisticated, with capabilities that extend beyond inputting, outputting, modifying, and maintaining data. Many DBMS's now provide English-like syntax for querying and retrieving data. Many support development of user interfaces in the form of menus and screens that guide users through applications. Many have strong error and help facilities, and provide security and audit facilities. Many also allow interfaces with other software via host language interfaces.

A major drawback for many GIS's is that they lack the data handling capabilities that would make them more efficient and secure; on the other hand, no DBMS's provide the graphic and analytic capabilities required by a GIS. Interfacing a GIS with a DBMS could

provide the best of both worlds.

Several organizations have recognized the possibilities offered by a marriage of the two technologies. Kork Systems, Inc., has a product called "GIS" which integrates attribute and coordinate data via a topological data structure (Ingram and Philips 1986). In this system, attribute and coordinate data are handled by separate DBMS's (a design aspect invisible to users).

PURPOSE

The purpose of the MOSS/Oracle interface project at BLM's Denver Service Center was to examine the benefits and problems of interfacing MOSS with a commercial DBMS. The scope of the project was limited to multiple attribute processing; it was defined in this way to reduce the amount of software required to be restructured or created. The primary constraint was that user interfaces be changed as little as possible so that impacts to users would be minimized. Final impacts to software, data input and processing, and data structures were to be reported.

THE ORACLE DBMS

What is a DBMS Anyway?

In a "flat file," data are stored as a collection of information delimited by physical location. In order to find a particular piece of data, the file must be laboriously searched, comparing values given by the user against values stored in the file. In the worst case, the file must be searched sequentially, checking each word in each record. Comparisons can be the slowest and most expensive of computer processes. If the user is not careful, or if the program the user is running is poorly designed, the wrong data may be retrieved. In any event, retrieval times may be poor, worsening as the file grows. In addition, it may be difficult to update and maintain the file in a manner that ensures its integrity. In addition, any user who has access to the file has access to ALL of the data in the file, creating a potential security hazard.

A DBMS is a means of storing data that goes far beyond "flat files." In fact, the word "file" may not be used in the vocabulary of a particular DBMS because it has no relevant meaning to users. DBMS's allow flexible queries, rapid access to data, update and maintenance capabilities, integrity checking, and access control. In addition, common query languages are being developed and standardized so that users and software can be carried from one DBMS to another with minimal impact.

Data managed by a DBMS may be described in terms of entities and attributes. An entity is a type of object or phenomenon that can be represented by an attribute or

set of attributes.[1] An attribute is the smallest piece of descriptive information about an object or phenomenon.[2] An example of an entity is "LAKE"; for this entity, attributes might include: "LAKE_ID," "LAKE_NAME," "SURFACE_AREA," "SHORE_LENGTH," "MAX_DEPTH," "NUMBER_OF_INLETS," "NUMBER_OF_OUTLETS," etc.

In a DBMS, there can be multiple items corresponding to an entity, each item representing an individual object or phenomenon. Values are assigned to all applicable attributes. If there is no value for a particular attribute, it is assigned a null. Attributes such as "LAKE_ID" may be designated as key attributes, because their values are used to uniquely identify individual occurrences of the entity "LAKE." Key attributes must be assigned a value (often this is done automatically to ensure assignment). Other attributes are non-key and may or may not be assigned a value. If a value is assigned, it need not be unique. For example, there may be more than one lake having a value for "MAX_DEPTH" of 23 meters.

During the design of a data base, analysts reduce redundancy and capacity requirements and increase efficiency by normalizing relationships be-tween entities and attributes. First, entities and attributes are identified, then key attributes are defined. Relationships between entities and attributes are structured in such a way that key attributes do not point to non-key attributes of more than one entity. Finally, attributes whose values can be computed from other attributes are eliminated. Once this goal is reached, the data base is said to be in "third normal form."

Oracle as a Relational DBMS

There are three basic types of DBMS's: hierarchical, network, and relational. At the logical level, a hierarchical DBMS can be represented by hierarchy charts, one chart for each entity, with each box in a chart corresponding to an attribute. For a network DBMS, charts of entities might show the boxes scattered in space with one or more lines linking boxes to each other. A relational DBMS is viewed in a completely different way: as tables in which attributes are represented as columns and items as rows. There is one table for each entity (all items corresponding with the entity "LAKE" would be stored in a table called "LAKE"). Thus, in a relational DBMS, attributes are defined in terms of their

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[1] In MOSS, "subject" corresponds roughly to "entity."
[2] In MOSS, an individual point, line, or polygon is equivalent to an "item," or occurrence of an "entity."

relationships to entities, rather than by their links to each other.

In order to retrieve data, hierarchical and network DBMS's require knowledge of the locations of attributes relative to each other, making them somewhat difficult to use; in addition, changes to the data base design can be cumbersome and require numerous changes to associated software. Relational DBMS's are far more flexible in both query capabilities and design changes.

At the physical level, the exact means of storing and processing data are dependent on the particular DBMS and system being used, and are invisible to the user.

Querying the Data Base

Oracle data bases may be queried on an ad hock basis, with the user logging into Oracle, entering statements in response to Oracle prompts, and getting almost immediate results. Oracle data bases may also be queried via computer programs containing Host Language Interface statements.

Oracle utilizes Standard Query Language (SQL) which provides an English-like syntax that is fairly easy for computer-literate users to learn. SQL allows the creation of tables, addition of columns to existing tables, deletion, insertion, and update of data, and many other capabilities. Originally developed by IBM, SQL is becoming the most common query language used by DBMS's.

Users familiar with Oracle should be able to use other SQL-based DBMS's with little trouble. Programs containing SQL statements should be recompilable if an organization changes its DBMS.

The following is an example of an ad hoc SQL statement:

```
SQL>  SELECT KILLS
   1  FROM MDWLFRG
   2  WHERE SUBJECT LIKE
      "%WINTER RANGE%"
   3  AND KILLS > 10;
SQL>
```

"SQL>" is the Oracle SQL prompt. "SELECT" initiates the statement and ";" terminates it. The prompts "1", "2", and "3" are line numbers that tell the user that the statement has not yet terminated. In this example, "KILLS" and "SUBJECT" are attributes for which values are stored in Oracle; "MDWLFRG" is the name of the MOSS map and the name of the Oracle table; "%WINTER RANGE%" is a string. Oracle will search the table "MDWLFRG" for all items having attribute values that match the given selection criteria and display those items.

Interfacing Oracle
With Other Software

Oracle may be interfaced with programs written in Cobol, Fortran, and C via the Oracle Host Language Interface (HLI). In order to create the interface, the programmer inserts Oracle HLI statements into host language routines.

Following is an example of an Oracle HLI statement:

```
EXEC SQL SELECT KILLS INTO
:var1
     FROM MDWLFRG
     WHERE SUBJECT LIKE
       "%WINTER RANGE%"
     AND KILLS > 10;
```

In the example ":var1" is a host variable. Host variables are declared in the host language routine and are used to pass values between it and Oracle. Data read from user input to the host routine can be passed to Oracle for use in querying the data base, and data retrieved from the data base by Oracle can be passed to the host routine for processing.

Since the host language compiler will not recognize "EXEC SQL" statements, resulting in errors, source code containing such statements must be precompiled. The Oracle HLI precompiler converts the "EXEC SQL" statements into host language calls that can be compiled.

Since the "EXEC SQL" statements are standardized, source code containing them should be precompilable by any SQL-based DBMS.

THE MOSS/ORACLE INTERFACE

MOSS Attribute Data

MOSS attributes are descriptive information assigned to digital geographic features (map items). MOSS attributes may include any category of information and may be assigned values of any data type, including dates, text, and real or integer numbers. They fall into two categories: subjects and multiple attributes. Subjects are mandatory and are treated separately from other attributes. Multiple attributes are optional and are used to provide additional information about map items. MOSS attributes may be used as selection criteria, for reports, for generation of new attributes, and for statistical analysis.

Components of Interface

The MOSS/Oracle interface consists of Oracle HLI statements embedded in C language routines that are called by MOSS Fortran 77 subroutines. In order to accomplish the interface, MOSS was analyzed to determine all references to MOSS attributes and what software changes would be needed to accommodate the C routines. A design document was produced (Price 1987) and submitted to peer review to identify any technical flaws. (None were found.)

The MOSS/Oracle interface utilized the Fall 1987 version of MOSS and Version 5.0.20.1 of Prime Oracle, both of which ran under Primos Version 20. C was used instead of Fortran because preliminary tests revealed bugs in the Oracle Fortran HLI precompiler.

Design Limitations

Because the scope of the project was limited to multiple attributes, the only commands that were redesigned were ones that handle multiple attributes; other commands remained

as they were. Thus, files required by those commands were not changed in data duplication--the same data stored both in MOSS files and in MOSS/Oracle tables.

Because of the constraint that changes to user interfaces be minimized, the design of MOSS/Oracle tables could not be normalized nor could data be stored in a "seamless" geographic data base. A new table is generated for each new map and a new column is generated for each attribute name entered by the user. Thus, the MOSS/Oracle data-base structure is partly dependent on users. Also, queries are not as flexible and the data base is not as efficient as it could be.

In addition, there was no requirement that MOSS/Oracle handle both the MOSS ".AT" files and the MOSS/Oracle attribute tables, nor was there a requirement to automatically import MOSS ".AT" files. Attempting to access multiple attributes not stored in a MOSS/Oracle table resulted in an error. Thus, a distinction needed to be made between maps having multiple attribute data in a MOSS attribute file and maps with multiple attribute data in MOSS/Oracle tables. This was done via a flag in the MOSS map file; the flag that indicates existence of multiple attributes is set to 1 for MOSS ".AT" files and 2 for Oracle tables. (It is possible to port MOSS ".AT" files into Oracle using the original MOSS "report" command in order to write MOSS attribute data into flat files. Then, from MOSS/

Oracle, the utility to add attributes must be run. If a user wishes to use MOSS/Oracle with an existing map, it is highly recommended that this procedure be performed.)

Since Oracle has a limit on the number of columns per table and total number of characters for all columns, users are allowed 246 attributes and 60,960 total characters for all attributes per map. The original MOSS allows 200 attributes with a total of 14,400 characters for all attributes.

MOSS Data Affected

Attribute data previously stored in a MOSS ".AT" file is stored in a MOSS/Oracle attribute table named after the associated map. The columns of the table are defined as shown in Table 1.

If columns are not used due to the map type (for example, AREA is not used for line maps), they are not defined.

Subject and item data continue to be stored in MOSS map files because they are accessed by commands not dealing with attributes. Not affected in MOSS/Oracle are cell maps from MAPS or maps produced by PI2MOSS.

MOSS Commands Affected

General changes to subroutines that process MOSS commands include:

1. Code for opening and closing MOSS ".AT" files has been eliminated.

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Table 1. Attribute table column definitions.

Name	Definition
ITEMID	-- the number of the corresponding map item
SUBJECT	-- the subject of the corresponding map item
LENGTH or AREA	-- The length if the map is a line map; the area if the map is a polygon map
PERIMETER	-- the perimeter of a polygon if the map is a polygon map
MINX	-- minimum X value of bounding rectangle
MAXX	-- maximum X value of bounding rectangle
MINY	-- minimum Y value of bounding rectangle
MAXY	-- maximum Y value of bounding rectangle
attribute_1	-- the name of attribute 1 as entered by the user
attribute_2	-- the name of attribute 2 as entered by the user
attribute_N	-- the name of attribute N as entered by the user

2. C language routines containing Oracle HLI statements ("EXEC SQL" statements) have been added.

3. Some variables used by MOSS as parameters have been changed.

Table 2 summarizes changes to specific commands.

RESULTS

The result of the MOSS/ Oracle interface prototype is the streamlined handling and efficient storage of MOSS multiple attribute data. In addition, the security and report generating capabilities of MOSS are enhanced. To date no performance problems have been noted.

Due to the scope and constraints of the prototype,

Oracle's capabilities could not be used to their fullest. This would have required much more work than was actually done.

MOSS/Oracle is currently awaiting formal testing. Due to the installation of Primos Version 21 and a new revision of Prime Oracle, a number of changes will probably need to be made in order for MOSS/ Oracle to run properly. In addition, changes must be made to bring MOSS/Oracle up to 32-bit capability. When these steps are accomplished and Quality Assurance passes MOSS/ Oracle, it will be released for public use.

CONSIDERATIONS FOR
FUTURE APPLICATIONS

As previously stated, the scope and the constraints of

Table 2. Changes to MOSS commands.

Name	Status	Comments
BSEARCH	deleted	functionality incorporated into select command
SUB2AT	deleted	subject is automatically stored in the attribute table
SELECT	new syntax	uses Oracle compatible operators for querying (is similar to BSEARCH syntax)
COMPUTE	new syntax	functions requiring two arguments now require arguments to be enclosed in parentheses
REPORT	new syntax	connects directly to Oracle in order to use its editing, formatting, and reporting capabilities

The following commands have been modified to accommodate internal I/O changes:
CALCOMP, HEWLETT, VERSATEK, ZETA, GRID, LEGEND, STATISTICS, AREA, PERIMETER, FREQUENCY, VARIOGRAM, PENPLOT, DELETE, LIST, DESCRIBE, RENAME, OVERLAY, POLYCELL, QUERY, EDITATT, SAVE, EDMAP, ATTRIBUTE.

the prototype placed limits on the capabilities of MOSS/Oracle. In order for the interface to be made more efficient and to standardize handling of all non-coordinate MOSS data, many MOSS routines would need to be restructured. While such a task would be time-consuming, the result would be a very streamlined and powerful version of MOSS. Potentially this work could be done in conjunction with the Common Data Structure development.

CONCLUSIONS

The interface between MOSS and the Oracle RDBMS prototyped on the Prime at the BLM Denver Service Center has demonstrated the possibilities for efficient data handling offered by a DBMS. These possibilities can be well utilized by MOSS. However, the scope and constraints of the prototyping effort imposed several design limitations that prevented full utilization of Oracle. Future work on the interface may require considerable change to MOSS, but may be well worth the effort in streamlining MOSS's data handling and allowing more powerful querying of MOSS data.

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POLYGON OVERLAY: IN THEORY AND PRACTICE

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ABSTRACT

The process of polygon overlay is simple in theory. Its implementation, however, has been fraught with problems for developers of geographic information systems. This paper describes the theory of polygon overlay for vector data structures and some of the difficulties in putting it into practice. The problems encountered during the development of the overlay processor of the Integrated Forest Resource Management System (INFORMS) are presented along with their solutions. These problems are (1) computational precision, (2) determining if a point is inside a polygon, (3) handling of coincident lines, and (4) resolution of slivers. Factors that influence the speed of execution of the INFORMS overlay processor are also discussed. Solutions to these problems include (1) the use of double-precision variables and tolerances in critical calculations; (2) the development of rules for counting intersections of a scanline with a polygon; (3) resolution of coincident lines by checking a point that is a short distance inside a polygon, perpendicular to the segments in question; and (4) the use of an area tolerance to avoid processing slivers.

INTRODUCTION

In the past, vector formats have been the most common data structure used in geographic information systems and cartography. This structure is especially advantageous where spatial conditions can be represented as lines or edges (Maffini 1987). The process of logically combining two maps of different data themes continues to be important in the analysis of geographic or spatial data. For vector data structures, this process (polygon overlay) has always posed a problem for developers of geographic information systems. A variety of approaches have been taken with varying degrees of success (Berry 1987, Burrough 1987, Iyenger and Miller 1986). Some polygon overlay processors perform well for simple polygons but fail when islands are added. Others do not always handle cases with coincident lines. Often the resultant map might have incorrect acreages, missing polygons, or the process may fail to complete.

Wetlands maps are especially difficult to handle.

Four years ago the Forest Pest Management group of the U.S. Forest Service decided to develop a system that would integrate the technologies of simulation modeling, spatial analysis, and data base management into an easy-to-use-problem-solving environment (Daniel et al. 1983). The National Ecology Research Center of the U.S. Fish and Wildlife Service was employed to design and implement this system. A result of this effort is the Integrated Forest Management Resource System (INFORMS). INFORMS employs a library of spatial functions, one of which is a polygon overlay processor. Because of the limitations of available overlay processors and the need to invoke the library functions from within other programs, it was decided to develop a new overlay processor. The overlay function in INFORMS has been tested on a wide variety of maps in the Data General environment and has proven successful. In this paper, I will describe the theory behind this processor and some of the difficulties encountered during its development.

THEORY

The polygon overlay processor developed for INFORMS uses a geometric approach to the problem (Tseng et al. 1986). Between two maps, three logical variations of polygon overlay can be performed: intersection, union, and difference

(Berry 1987, Burrough 1987). The intersection of two polygons results in a polygon or polygons that define the area belonging to both of the input polygons. The union of two polygons is a polygon that defines an area belonging to either of the input polygons. The difference of two polygons is a polygon or polygons containing the area of one input polygon while excluding any area of the other. Figure 1 illustrates these logical variations.

The intersection (A and B) of two maps is the most common type of overlay used in spatial analyses. Because a polygon overlay processor is applied to vector maps, sets of coordinates that define the boundaries of polygons are manipulated. The algorithms must determine which portions of the boundary of A are also contained within the boundary of B and which portions of the boundary of B are also contained within the boundary of A. Conversely, the union (A or B) operation dictates that the overlay processor determines which portions of the boundary of A are not contained within the boundary of B and which portions of the boundary of B are not contained within the boundary of A. The difference function (A not B or B not A) combines the procedures of the intersection and the union. That is, the overlay processor determines which portion of the boundary of A is not contained within the boundary of B and which portion of the boundary of B is contained within the boundary of A. The theory behind the overlay of two

INTERSECTION
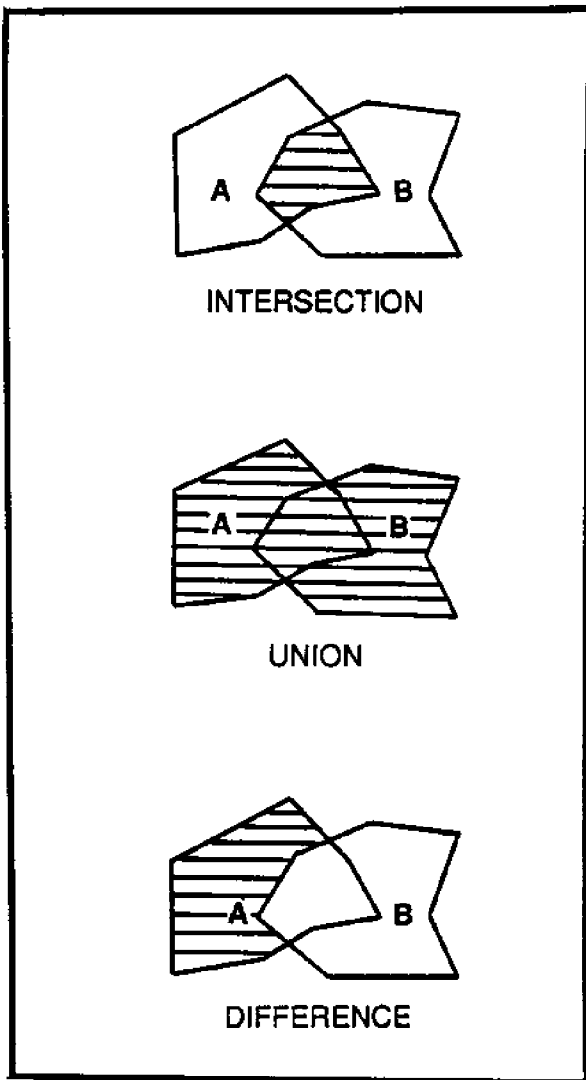
UNION

DIFFERENCE

Figure 1. Logical 6 variations of polygon overlay depicting intersection (A and B), Union (A or B), and Difference (A not B).

geometric features can be concisely stated as follows:

Intersection - the intersection of two geometric features, A and B, is the concatenation of the arcs of A that also belong to B (within the boundary of B) with the arcs to B that also belong to A.

Union - the union of two geometric features, A or B, is the concatenation of the arcs of A that do not belong to B (within the boundary of B) with the arcs to B that also do not belong to A.

Difference - the difference of two geometric features, A not B, is the concatenation of the arcs of A that do not belong to B (within the boundary of B) with the arcs to B that also belong to A.

IMPLEMENTATION

Although the theory behind polygon overlay is simple, its implementation is not without difficulty. To compute the intersection of two polygons (A and B), the overlay processor must perform the following tasks:

1. Process each line segment (pair of points) of polygon A to see if it or part of it also belongs to polygon B.

2. If it does, store it or the part that belongs to B for later use.

3. Repeat the same process for polygon B, discarding any arcs that coincide with those determined for polygon A.

4. Concatenate the arcs to form new features.

5. If some of the resulting features are wholly contained within others, merge them to form complex polygons (polygons with islands).

Five algorithms or routines are critical to successfully computing the intersection of two geometric features. These include a line intercept routine, point-in-polygon routine, boolean arc generator, feature-formation routine, and polygon-merge function. The most fundamental of these is the line intercept routine. It is a critical element of the point-in-polygon routine and the boolean arc generator. Line intercepts are computed in the boolean arc generator to determine where the two features intersect. The computations must be precise; the intersections computed for polygon A should match those computed for polygon B; and the routine must be able to distinguish between intersections in the interior of a line segment and its endpoints.

The point-in-polygon routine is very important because it determines whether or not to keep a line segment. A failure in this routine results in a failure to form a polygon. The algorithm in the INFORMS overlay processor uses a scanline technique (Artwick 1984, Foley and VanDam 1984, Monmonier 1982). In this method, a line is constructed from the search point to the outside of the polygon (see Figure 2). The number of intersections with the boundary of the polygon is then computed. If the number is odd, the point is inside the If it is even, the point is outside the polygon. The routine also checks to see if the point lies on the boundary of the polygon.
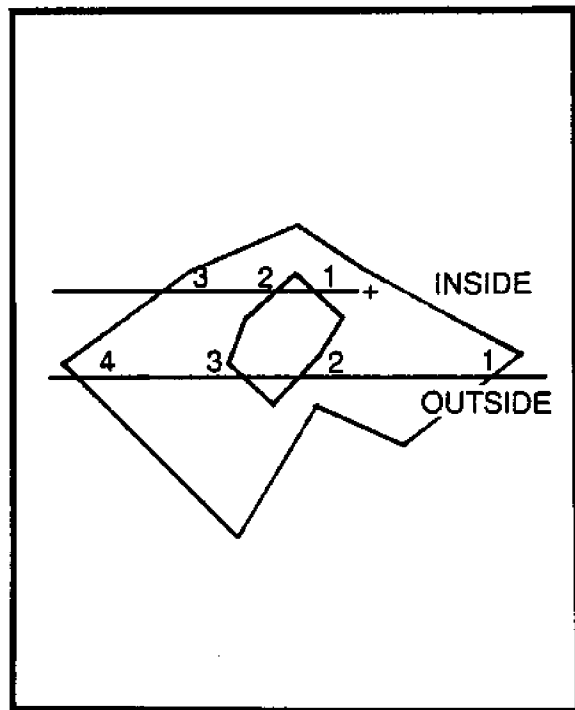
Figure 2. Point in polygon scheme in which a scanline is constructed from the point in question to a point outside the polygon. The numbers indicate the intersections of each scanline with the polygon.

The boolean arc generator contains the rules and book-keeping software for generating and storing the arcs resulting from the intersection, union, or difference of two features. This routine implements the following rules for intersections:

1. Compare each line segment of A to see if it intersects with a line segment of B. Intersections split a line segment into subsegments.

2. Each segment or subsegment of A is processed to

determine if a point immediately inside of it is also inside polygon B.

3. The point is defined as the midpoint of the segment. If the point lies on the border of B, move a specified perpendicular distance to the inside of polygon A and check it again.

4. Parent polygon points are stored in a clockwise direction. Therefore, an inside point would lie to the right of the segment. Because island points are stored counterclockwise, an inside point would also be to the right of an island segment.

5. If the point is inside polygon B, store the segment as an arc of the intersection. If not, skip the segment.

6. On the second pass (comparing B against A), skip any qualifying segments if they have been previously stored during the first pass (comparing A against B).

The union and difference operations are logical variations of these rules. For example, the rules for unions are the opposite of those for intersections. That is, segments of A that are outside of B are kept. The feature formation routine matches the endpoints of arcs to form lines or polygons. Coordinates are stored in a clockwise manner. The polygon merge function merges polygon islands that are

formed with their parent polygons. The point in polygon routine is critical here also.

INFORMS OVERLAY PROCESSOR IMPLEMENTATION PROBLEMS

In the development of the INFORMS polygon overlay processor, several implementation problems were encountered. Because the geometric approach involves exact calculations, computational precision is of critical importance. Double-precision variables, however, require more memory to implement than single-precision variables. Thus, a trade-off was made between computational precision and memory requirements. Coordinates were converted to double precision for the calculation of line intersections, point-in-polygon determinations, arc formation, and area calculations only.

Real number comparisons are made throughout the software. These types of comparisons are not always reliable and therefore necessitate the use of tolerance values. These tolerances were determined by trial and error (processing many maps of varying complexity) and differ from one algorithm to another. Tolerance values vary from 0.00001 to 0.001 (meters or feet).

The majority of the problems experienced during development occurred with the point-in-polygon routine. Figure 2 illustrates the following basic premise, upon which this algorithm is based:

If a line from the point in question to the outside of the polygon intersects the polygon an odd number of times, the point is inside the polygon. If the number of intersections is even, it is outside the polygon (Foley and VanDam 1984).

There are several cases, however, in which this theory breaks down. When a point lies on the polygon boundary, the number of intersections may be odd or even. Therefore, the point-in-polygon routine must always check for this condition. When the scanline passes through a point that defines the polygon boundary, a double intersection occurs (one with the end of one segment and one with the beginning of the next). Only one of these intersections can be counted. If the point is a peak or valley, as shown in Figure 3, neither of the inter-

sections can be counted. If just one of them is counted it will result in a false indication. Repeated points such as the first and last points of a polygon or island must be discarded, counting only one intersection.

In the case of large complex polygons, the scanline may overlap a line segment. If this segment is skipped, the number of intersections that are counted might or might not be correct. The only way to solve this problem is to eliminate it by rotating the scanline slightly and restarting the process.

One of the most common problem areas with polygon overlay processors is in the handling of coincident lines (two lines have the same coordinates or overlap). Figure 4 illustrates two

+ SCANLINE OVERLAPS
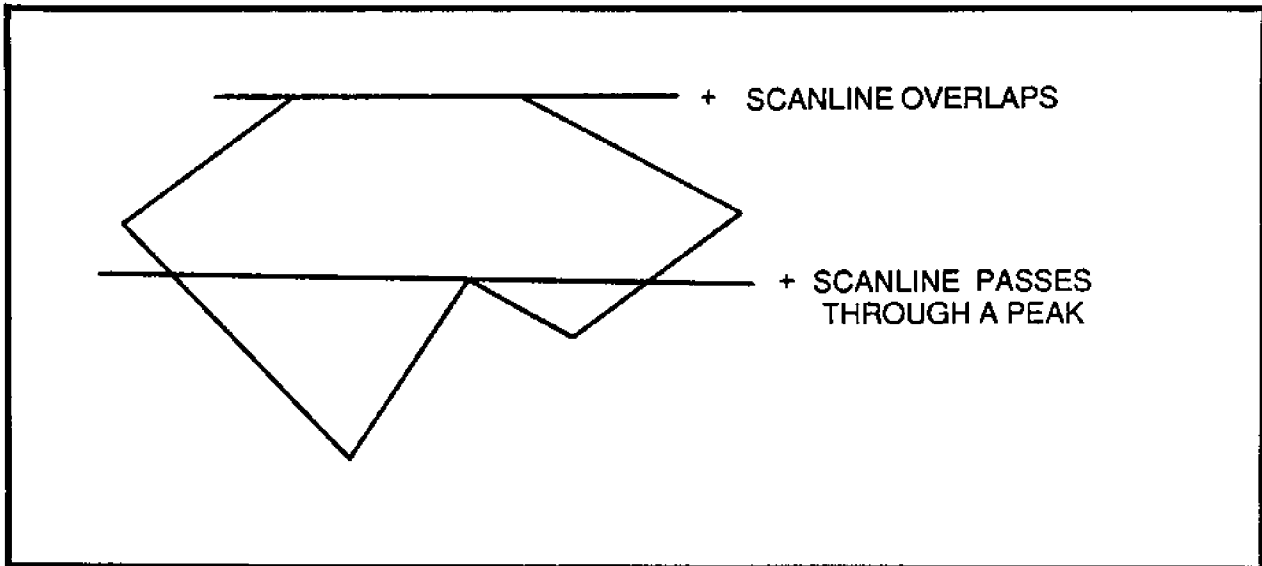
+ SCANLINE PASSES THROUGH A PEAK

Figure 3. Point-in-polygon special cases depicting the problem of the scanline overlapping a segment of the polygon and the problem of the scanline passing a point that forms a peak.
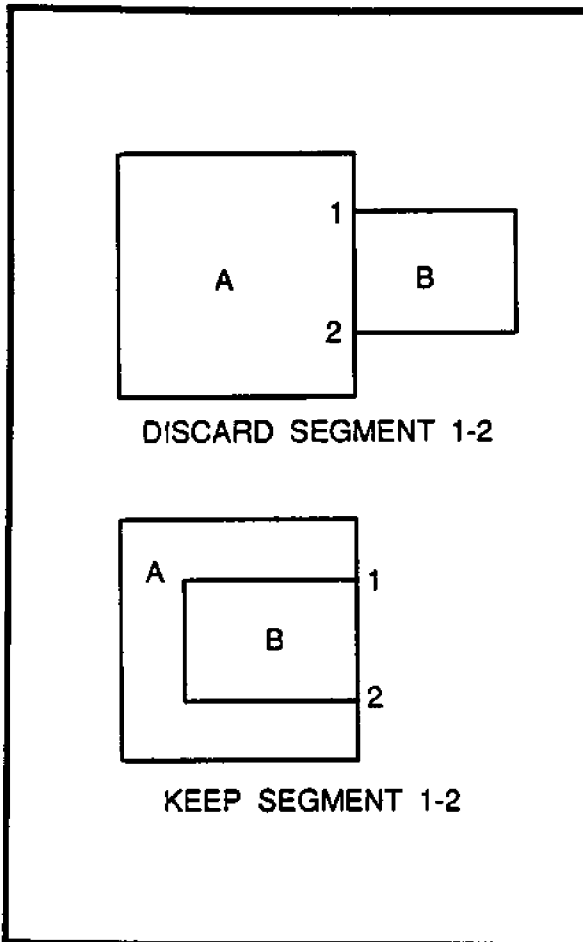
DISCARD SEGMENT 1-2

KEEP SEGMENT 1-2

Figure 4. Coincident lines formed by the points 1 and 2. In the top case segment 1-2 is discarded because a point moved to the inside of B is outside of A. Segment 1-2 in the bottom case is kept because a point moved to the inside of B is also in A.

examples of coincident lines. In both cases, segment 1-2 of polygon A is coincident with segment 1-2 of polygon B. Two difficulties arise from this condition. The number of intersections of overlapping lines is infinite. The problem, therefore, is how to form arcs from these lines--that is, what points are used as segment end points. This is solved by dividing the composite line segment (the sum of the two overlapping lines) into two subsegments defined by the endpoints of the original lines. The second problem with coincident lines is deciding whether to keep a segment that lies on the boundary of the other feature. This is solved for intersections by computing a point perpendicular to the midpoint of the segment in the direction toward the inside of the polygon. This is always to the right of the direction of the boundary. If this point is inside the other polygon, the segment is added to the arcs already formed. If not, it is discarded (see Figure 4). Islands are handled in a manner identical to parent polygons. The fact that their coordinates are stored in an opposite direction from parent polygons obviates the need for specialized code.

Slivers are another problem common to polygon overlay routines. They are small polygons formed during the polygon overlay process (see Figure 5). Slivers might be caused by failure to insure that common lines between data themes are identical; they might be precision errors introduced in computations; or they might be a true intersection of polygons in close proximity (Burrough 1987). They can be undesirable cosmetically as well as analytically.

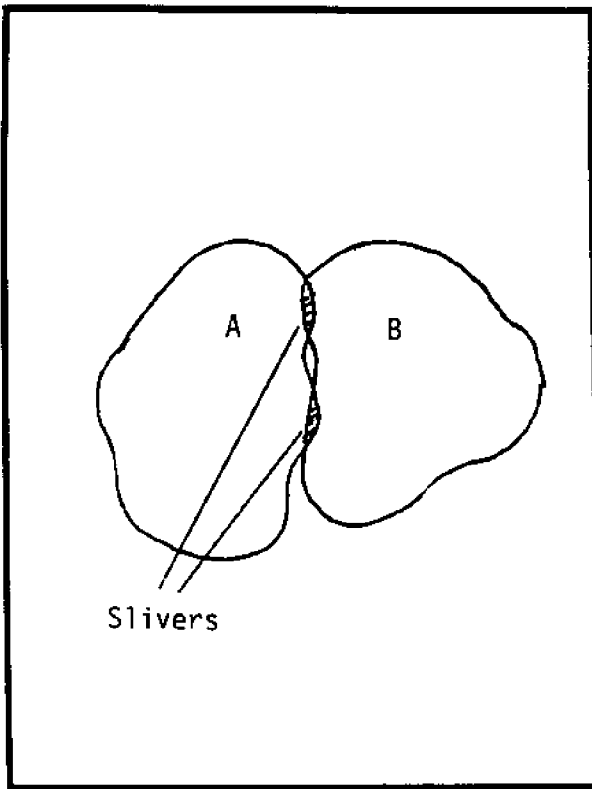Slivers are handled in two basic ways. The first is to

Figure 5. Polygon slivers. Here polygons A and B slightly overlap. These small polygons may be real or an artifact of the digitizing process.

adjust the borders of adjacent polygons so that the slivers no longer exist. This is very difficult to accomplish in an automated fashion and most likely would require manual intervention. The second approach is to set an area tolerance below which polygons are not stored in the resulting map. This will eliminate the need for excessive processing of insignificant polygons but will not remove them from the map plot. Depending on the scale of the map and the size of the tolerance, they might still be visible as holes. For the INFORMS application these

small holes are acceptable and it is this latter approach that has been implemented.

SPEED OF EXECUTION

The geometric approach to polygon overlay is inherently computationally intensive. In the worst case, the execution time is directly proportional to the product of the number of points in the polygons processed: two maps are nearly coincident and have a large number of points. This requires that every segment in each map be processed and orthogonal points (points a small perpendicular distance from each line segment) be checked. The most obvious way to reduce processing time is to reduce the number of points that define polygons. Several techniques are used to screen polygons and segments before processing. They all use minimum bounding rectangles (the minimum rectangle that will enclose a polygon). The effectiveness of this screening process is dependent upon the shape of the polygons. Minimum bounding rectangles do not work well for narrow polygons that diagonally traverse the map because they cover a much larger area than the polygon itself. Thus, many polygons that do not intersect with this polygon might be unnecessarily processed. Improved screening techniques could also improve execution speed.

The ability to handle a large map with large polygons necessitates the use of a large amount of memory. The INFORMS overlay processor employs the

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use of several scratch files to reduce the memory required. This increases execution time due to the relatively slow input/output operations. Elimination of the scratch files should reduce execution time but at the expense of memory requirements.

SUMMARY

A polygon overlay processor was developed for use in the Integrated Forest Resource Management System (INFORMS) of the U.S. Forest Service. Although the theory of polygon overlay is simple, many difficulties arose in the implementation of this theory for INFORMS. In the development of the software, many of the problems common to other polygon overlay processors were addressed and acceptable solutions found. These problems include computational precision, determining whether a point is inside a polygon, coincident lines, and slivers. Solutions to these problems range from the use of double precision variables and tolerances to the development of rules for handling specific cases. INFORMS currently runs in the Data General computing environment. The overlay processor has been ported to the PRIME environment, and plans have been made to integrate it into the PRIME version of the Map Overlay and Statistical System.

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1986 Polygon Overlay Processing: A Comparison of Pure Geometric Manipulation and Topological Overlay Processing. Pp. 102-119 Proceedings of the Second International Symposium on Spatial Data Handling, Seattle, WA.

QUESTIONS AND ANSWERS

Q. Does it work on the DG and the Prime?

A. The intersection portion appears to be working on the Prime. There are some plans to incorporate MOSS to the Prime.

Q. Do you throw out the slivers?

A. They produce a hole in the map which will calculate to a lower acreage tolerance. They don't process anyway.

Q. Are you claiming full success with the basic three Boolean Arcs?

A. Yes. We've done 200-300 maps with 18 failures and 17 bad maps.

Comment: We used USGS data set overlay killers to test MOSS and ARC INFO and ran Boolean Arcs against them, and had no problems.

SESSION II

Image Processing and Data Integration Techniques for Geographic Information Systems

Moderated by: Nelson May

Aero-Data Corporation

COMPARISON OF SELECTED LEVEL-1 THEMATIC MAPPER LAND COVER CLASSES WITH USFWS ECOLOGICAL CHARACTERIZATION MAPS

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ABSTRACT

A recent project for the Louisiana Department of Resources (DNR) Coastal Management Division resulted in a classified Landsat Thematic Mapper (TM) data base for Louisiana using 14 modified Level-1 categories. These data were then compared to an existing 1978 habitat data base in order to check for changes. The major problem encountered was the identification of open water and broken marsh, since landsat data does not differentiate between the two; floating aquatic vegetation is also sometimes misidentified and classified. Attempts were made to incorporate an arithmetic factor that would correct for the discrepancies, but all attempts were unsuccessful. More studies will be needed in order to accurately compare TM and habitat data.

INTRODUCTION

There have been a few attempts to relate the U.S. Fish and Wildlife Service (USFWS) Ecological Character-ization Habitat Maps to satellite imagery, particularly to Landsat MSS (May 1985). The resolution and spectral discrimination of Landsat Thematic Mapper (TM) data offer further incentive to attempt this comparison. A recent project for the Louisiana DNR Coastal Management Division (CMD) resulted in a classified TM data base for the entire Louisiana coast using 14 modified Level-1 categories (Braud and Streiffer 1987). With the project accomplished, there were many questions about whether this substantial data base could be compared to the existing 1978 habitat data for change detection. To know if this were possible, we had to first determine if comparable results were obtainable for the two distinctly different methodologies using data obtained in close temporal proximity.

Selected areas of the Louisiana coast were recently mapped for habitat using 1983 aerials, digitized and stored in a MOSS GIS. The TM data base was derived from 1984 satellite imagery and pro-cessed with the ERDAS system. The closeness of the dates, less than a year apart, provided an opportunity to relate classified TM data to habitat classes. The results

of the comparison should show discrepancies within an acceptable margin of error, if the data sets are indeed comparable, particularly with regard to water acreages.

To relate the USFWS habitat maps to the Level-1 land cover categories developed for the TM classes, several steps were required:

1) Classification and geographic rectification of TM data;
2) Collapse of habitat classes to Level-1 categories;
3) Gridding of MOSS habitat vector maps to create cell maps;
4) Overlay intersection of the two data sets for test areas.

TM CLASSIFICATION OF THE LOUISIANA COAST

Landsat TM 1984 imagery was used to classify the entire coastal zone of Louisiana for 14 Level-1 land cover categories (defined below) in a 1986 project. This required the acquisition and processing of portions of 14 quarter scenes of data and was one of the most extensive applications undertaken with TM data. It is also the first time the whole Louisiana coastal zone was inventoried and classified with satellite data of this quality. The product establishes a new baseline of land cover data for the endangered Louisiana coast that is at minimum suitable for comparisons to acquisitions of future satellite imagery.

Additionally, the 30-meter spatial resolution and the refined spectral discrimination is potentially sufficient to detect small area (10 acres) changes such as land loss, development, encroachment, forest and agricultural loss, and land accretion.

The project required the processing of an extremely large amount of data, and a number of innovations and automated procedures were designed and developed to complete the project within a seven-month period. The classification process could not rely solely on standard techniques, such as supervised training, due to the nature of TM data (high spatial resolution and spectral discrimination). We consequently had to develop techniques to reduce the complexity of the process. Other procedures were automated to speed up repetitive tasks.

Cluster analysis was used on 512x512 screens of data to develop a maximum of 50 classes per screen. Of the seven bands available on the TM, the following three bands were used: Band 3 (red) 0.63 – 0.69 microns; Band 4 (near IR), 0.767 – 0.9 microns; and Band 5 (mid IR) 1.55 – 1.75 microns (Sheffield 1985). There are approximately 36 screens in a full quarter scene. Portions of screens were recoded to correct mixed-class errors. The classified screens were reduced to 14 standard Level-1 categories for the project and photo verified and field checked when necessary. The finished screens were mosaicked to complete each quarter scene,

and each quarter scene was rectified to geographic co-ordinates. The rectified quarter scenes were mosaicked to complete the Louisiana coastal zone. Screen and scene match errors were corrected. Data for each USGS 7.5-minute quad was then cut from the master coast file. The quality control was good enough so that match lines between adjacent screens and even overlapping scenes are not evident.

The land cover categories selected were based on previous experimentation that helped to identify land cover types most useful to CMD and most easily detected in the Louisiana coast with the Thematic Mapper Sensor. The chosen categories constituted a modified Level-1 land cover scheme as defined in the Geological Survey Profes-sional Paper 964 (Anderson et al. n.d.). Each category is defined below with qualifi-cations given to help reduce interpretation errors that may arise from the broadness of the Level-1 categories, or from environmental conditions that may produce situations in which spectral signatures of certain classes are mimicked by dissimilar subclasses. The definitions are abbreviated for space economy. Complete definitions can be found in Braud and Streiffer 1987.

Land Cover Definitions

Out. This is the background class that is outside the study area but in the rectangular file space. It has a value of zero that is not counted or included in area calculations.

Water. It includes all open-water bodies detected by the 30-meter resolution of the scanner regardless of salinity, turbidity, or origin.

Broken Marsh. This is an especially difficult category because there are a number of environmental conditions that generate spectral signatures resembling broken marsh. Specifically, broken marsh is defined as areas of marsh that are not continuous and are interspersed with water that constitutes approximately 40%-60% of the surface area. These areas of marsh typically have a low stem count. The characteristic spectral reflectance for this land-cover class will have values lower than values for continuous, healthy marsh and greater than for open water. The nearly uniform mixture of marsh and water for this category will generate a distinct signature.

Marsh. This is a solid, non-forested wetland dominated by herbaceous vegetation, and includes fresh, intermediate, brackish, and saline types.

Forest. Forest lands have a tree-crown areal density of sufficient percentage to produce uniform signatures over broad areas. Forested areas include deciduous, coniferous, evergreen, mixed, bottom-land hardwood and upland forest types, and tree-like shrubs.

Swamp. These are forested wetland areas that include some bottomland hardwoods, but are primarily deep water and wooded swamps of cypress/tupelo and shrubs.

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Shrub/Scrub. This includes shrub land, brush land, and scrub vegetation in better drained or elevated environments and vegetated spoil banks.

Agriculture/Pasture. This is primarily crop land and land used for grazing. Crop land includes all cultivated lands used for growing food and fiber and can be in many different stages. Also included in this category is land used for pasture and grazing, including drained and reclaimed marsh land. Other land covers commonly classified as pasture include utility right-of-ways, golf courses, parks, cemeteries, and open or vacant lands. Difficulties arise in these categories due to distinctions between land cover and land use.

Developed. This is urban and built-up land or disturbed areas. It includes cities, town and strip developments, transportation, power and communications facilities, shopping centers, industrial, mining and commercial complexes, institutions, residential areas, some recreation areas, and waste disposal sites.

Inert. This is typically barren land that is dry and very reflective in all bands and supports little or no vegetation. The category includes sand-and-shell deposits and bars, shell middens, levees, rock jetties, spoil banks and deposits, mineral deposits, exposed mines, tailings, gravel pits, landfill and waste areas, cleared land and clear-cut forest sites, some roads, and mud flats.

Beach. Beaches along shorelines are distinguished from the inert class where feasible.

Cloud. It is not always possible to acquire cloud-free imagery. Since it is not possible to know exactly what is under clouds except over large water bodies, clouds are identified as a distinct category so that the user is at least aware of the reason that land cover is not distinguished in such areas.

Floating Vegetation. This is typically aquatic vegetation mats such as water hyacinths and duckweed occurring in shallow-water bodies. It is also possible that in some cases, the class will include submerged vegetation in shallow water when the vegetation is very close to the surface.

Mixed Vegetation. This is another difficult class because there are a variety of mixed land-cover types that constitute this category. These are generally areas where no specific vegetation type dominates and areas where tree crown density is low. The mix could be between marsh and trees, trees and pasture, shrubs and marsh, marsh and agricultural land, or any combination of land-cover classes that could, within reason, spatially co-occur. Other environmental conditions that generate a mixed vegetation signature are areas in transition, interfaces between land-cover types, right-of-ways, and roads through

forested regions. This category can also include small regions of undetermined vegetative types.

Unclassified. This class represents pixels of unknown land cover type that could not be identified with the best available information. Unclassified pixels do not fit in any of the categories discussed above. These could be interface and edge pixels, unusual ground conditions, or data anomalies. Most of the unclassified data in this project were caused from cloud shadows, which have a tendency to spectrally represent water or broken marsh.

Land Use versus Land Cover

It is important to distinguish between land cover and land use though it is not always possible to distinguish between the use of the land and the associated land cover with remote sensor acquired data. The TM sensor detects reflectance from the surface of the Earth. Although modulated by the atmosphere, the pattern of reflectance is in response to the physical properties of earth-surface features, i.e., the cover of the land, and environmental conditions at the time of data acquisition. The sensor, then, is responding to land-cover conditions, which is not always a direct corollary to what the land is actually being used for; i.e., land use. For example, pastureland (land use) is actually composed of grasses (land cover). Grass land cover could be designated for a broad range of land uses: grazing, preservation, parks,

golf courses, football fields, etc. It may be called prairie, pasture, marsh, rangeland, or urban.

RELATION OF LANDSAT TM CLASSES TO USFWS ECOLOGICAL HABITATS

Collapse of Habitat Codes to Level-1 Classes

Initially, the MOSS system was used to query the subject categories from every habitat map stored on disk. The map subjects related exactly to the habitat codes. As the subjects for each map were determined, they were saved and compiled in a separate sequential file for each year. This ensured that we had an exact list of every habitat type actually coded on all the maps and helped to find habitats incorrectly coded (that is, not matching any of the valid code combinations) so that these spurious codes could be accounted for in any automated process subsequently derived.

The sequential lists of all subjects were sorted, eliminating duplicates, so that what remained was a comprehensive, alphabetical list of all subjects for each year. Using the Chenier Plain region ecological characterization habitat mapping guide by Karen Wicker (Wicker 1980) to obtain detailed habitat descriptions, we categorized each code into one of the Thematic Mapper cover classes. Wicker provided help for spurious or confusing codes. The table derived from this classification process presents each habitat code

grouped into its equivalent Level-1 class. A list of the habitat categories follows. (See Braud and Steiffer 1988 for the code assignments.)

Water (Natural)
Water (Artificial)
Fresh Marsh
Intermediate Marsh
Brackish Marsh
Saline Marsh
Forest (Upland)
Forest (Bottomland Hardwoods)
Swamp
Shrub/Scrub
Shrub/Scrub (Spoil)
Agriculture/Pasture
Developed
Aquatic Vegetation (Floating,
    Submerged, Undistinguished)
Inert (Unvegetated)
Beach
Unassigned

Gridding of Habitat Maps

Selected 1983 habitat maps were gridded to 25x25 meter cells to match the resampled, classified TM data cell size. Several test quads were chosen for comparison. Each gridded habitat map was exported to ERDAS and recoded to match TM Level-1 classes using the categories discussed previously. This recoding process provides the capability to directly compare the habitat classes to TM classes. The georeferenced TM data were extracted for each quad to compare to the habitat data.

Comparison of 1983 Habitat Data to 1984 TM Data

Before deriving a complex matrix of class intersections, we wanted to determine if water-to-water comparisons were

possible. Using a USGS quadrangle as a unit of comparison, we initially contrasted water acreages from the two data sets. The TM classified data were characterized by a broken marsh category that was partly composed of water; this marsh class occurs in complex areas of marsh/water interface and along canals and small water bodies (see definition for broken marsh). We included a percentage of the broken marsh category as water, although the amount was unknown. The purpose was to determine if and how much of the broken marsh should be included as water. This was thought to be necessary since the TM consistently estimated less water than the habitat maps. This phenomenon has been noticed on many occasions when comparing water acreages derived from TM with that derived from habitat data. For a 7.5-minute quadrangle, the TM water acreage was typically more than 1,000 acres less than the USFWS habitat maps, which is equivalent to an error greater than 10% of the total water area for the given quad. An error of this magnitude is unacceptable.

The process to accomplish reliable comparisons is somewhat complex, not only because certain water categories in the habitat data, such as small canals and borrow pits, do not show up as water in the TM classified imagery, but also because floating and submerged vegetation in both data sets have to be considered as water due to their transient and intermittent nature. Errors in the habitat data

(infrequent errors related to misnamed, misinterpreted, unnamed classes, generalization of overly complex areas, and digitization mistakes), edge pixels in the TM data, recent rainfall history prior to acquisition of TM data, and tidal stages further complicate water-to-water comparisons.

Methodology

The 1984 classified TM GIS file for selected quadrangles was intersect-overlaid with its 1983 habitat counterpart. Each pixel for the selected TM quadrangle file was compared to the spatially equivalent cell for the habitat quadrangle. Difference categories were generated via this comparison process and recorded as a difference map with accumulation of acreages. Differences of particular interest for this project were water-land and land-water. In addition to the type of comparison, other difference characteristics determined were:

1. Geographic location (where is it);
2. Spatial distribution (geographic areal extent);
3. Spatial density (measure of concentration); and
4. Amount (acreage of each category).

From a comparison map that was produced for a given quadrangle, we visually learned the location and areal extent of each type for which acreages are routinely calculated and reported. The location and distribution of the differences were further elaborated with

UTM coordinates and, more importantly, displayed with geographic references such as are found on base maps. We used as references the existing 1978 habitat boundaries to provide a base reference.

A comparison map was typically characterized by numerous difference pixels occurring throughout the area. Most of these were false positives generated by inexact alignment of the overlays, particularly around water bodies for land-water comparisons. Since it is virtually impossible to get the overlays to precisely match, false changes are usually generated along water bodies and across the image where there are land-water interfaces. These discrepancies should not be reported for two reasons: (a) They are likely not real, and (b) The acreage of a single 25x25 meter cell of the resampled, georeferenced image is only 0.15 acres, less than that of the actual spatial resolution of the scanner. We are not able to detect disparities this small and they will very easily bias the results in favor of more differences than are actually present.

The density analysis was used to filter the false positives and find areas of concentrated disparity that we were more sure were due to real differences rather than registration problems. The change map was scanned with a 3x3 roving window to determine density across the area. The procedure operated as follows: (a) All pixels of a common difference were isolated; (b)

the 3x3 nine-pixel window began in the upper left corner of the data set and the total number of difference pixels in the window were counted and the value of the center pixel then assigned this number; (c) the tabulation established the concentration of a discrepancy type within the window, with the lowest amount, zero, and the maximum amount, nine; (d) a difference map was generated for each disparity of interest so that only one change was scanned at a time.

All cells with a value of one were counted and the value of

the center cell received the total count value on a newly created density map, in this case, 6. In this example, 0 represents no difference, 1 represents a difference of a given type.

Using this technique, a new map (termed a density map) was created. This map reported the density or concentration of disparity surrounding each cell in the image with the difference being isolated for each type since we were not interested in complexity, but in uniformity. Excluding zero, the density values can range
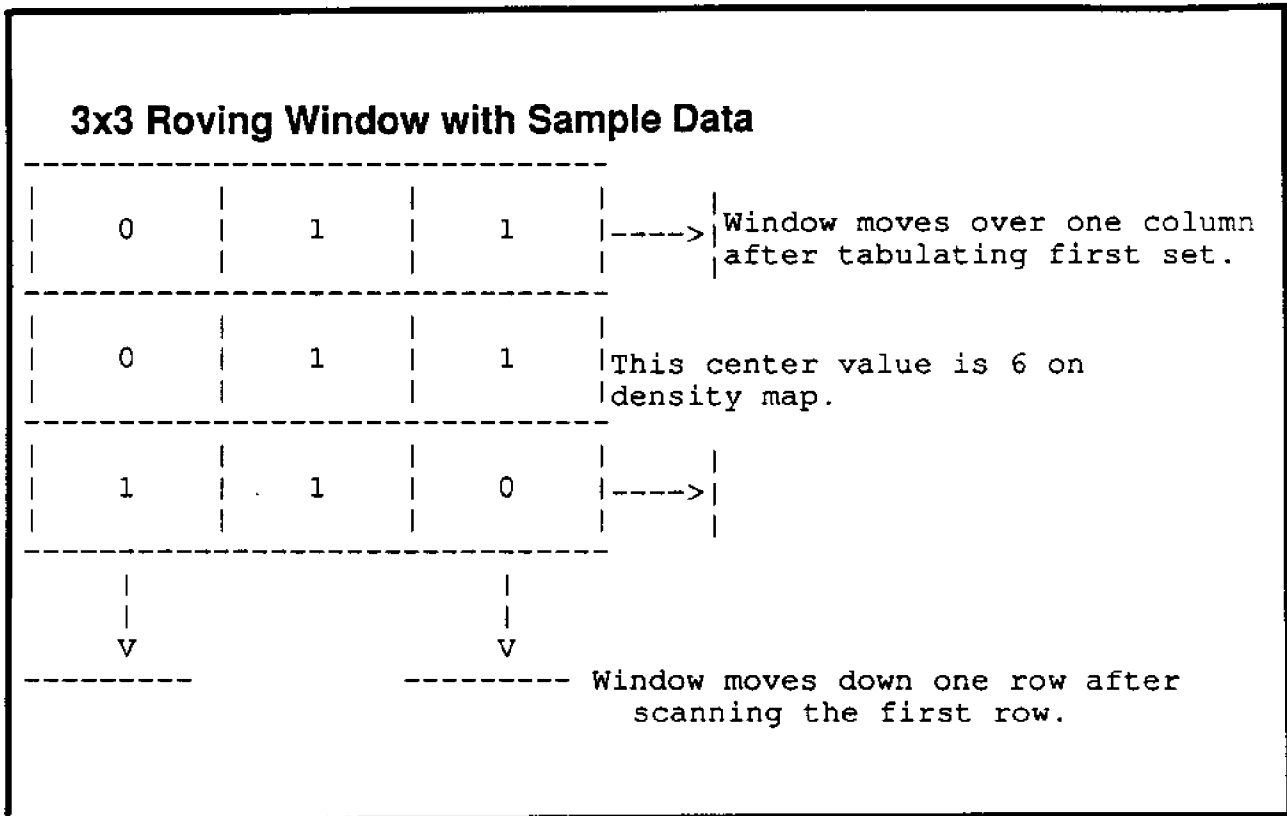

Figure 1. Roving scan window.

from 1 to 9. Table 1 presents the acreages for each value based on a 25x25 meter cell size.

As can be seen from the table, it takes a density value between 6 and 8 before an acre of difference is indicated. For this analysis, any densities below one acre were ignored. The density map was therefore used to create a positive map depicting only areas of change with a density of seven or above. These maps were filtered for concentration and lost their density values, reverting simply to a single

Table 1. Density values and associated acreage.

Value	Acres
1	0.15
2	0.31
3	0.46
4	0.62
5	0.77
6	0.93
8	1.08
9	1.39

value representing an area of high density. Due to the nature of the scan-density analysis, cells of high density will tend to be adjacent to other high density cells, thus forming contiguous areas that are plainly delineated.

Results

In consideration of the difficulties involved, an attempt was made to discover

how effectively we could relate just the water from the two land-cover files. Using three quads as a basis to make the comparison, we found significantly higher water acreages in the habitat data than in the TM data, as we suspected there would be, due to the smaller water bodies and canals identified in the habitat data and due to the broken marsh component in the TM data. The question is, can a uniform adjustment factor be developed to apply to the broken marsh category that would bring the water totals in line for the two sets?

The answer is no; several attempts were made to do this, all of which were unsuccessful for various reasons. To get the water in the TM data to approximate habitat water acreages, an arithmetic factor was applied to the broken marsh so that a percentage of it was added to the water acreage. The factor is calculated as follows:

$$f = (WH-Wt)/Bm,$$

where

f = % acres of broken marsh to add to water;
Wh = total acres of water from the habitat map;
Wt = total acres of water from the TM classified map;
Bm = total acres of broken marsh from the TM classified map.

The goal was to derive a standard factor that could be applied to any TM classified map for 1984 in order to adjust

the water acreages to match the 1983 habitat data. Unfortunately, the factors calculated for the three test maps significantly deviated from each other as shown: LPENC=12%; LOSTL=46%; and PLUMB=83%.

Further attempts to derive a standard adjustment factor also failed. These included excluding the canal and small borrow pits from the habitat water acreage and "burning" the habitat canals and floating vegetation into the TM data. In addition, the intersect-overlay technique was used to develop a cross-tabulation comparison matrix depicting the various possible combinations of classes from the TM and habitat data. The purpose was not to detect change, but to determine consistency between these two differently acquired land-cover data sets. The most important test of consistency in this case was the incidence of land/water intersections in a common area.

To accomplish this, the 1983 Level-1 habitat classes were collapsed into four broad categories: water, land, aquatic vegetation, and unclassified (the unclassified category was required for habitat data due to the fact that there are several undistinguished habitat types that are not assigned to a standard code). The TM data were collapsed to water, broken marsh, land, and unclassified. Since the object of this project was not to identify all discrepancies, but to specifically isolate land-water differences, the data categories were collapsed for

the comparisons. The number of possible change combinations were thus reduced from 196 (14 x 14), to 16 (4 x 4), which made the task of analyzing changes much more manageable. These categories were intersected to determine the coincidence of like classes and the coincidence of land-water intersection for each of the quadrangles used. Most importantly, the 1984 TM land and broken marsh categories were analyzed to establish their cooccurrence with 1983 habitat water, land, and aquatic vegetation categories. This procedure determined which TM non-water areas were actually water or aquatic vegetation in the habitat data.

The intersection of each quad generated a 4x4 matrix of 16 values, each value representing a potentially different combination. As it turned out, there were only seven combinations of interest. Because the unknown category was dominant, combinations with it were meaningless and thus remained unknown. Additionally, two of the combinations did not actually represent a discrepancy. The differences of interest were: land/water; aquatic vegetation/water; water/broken marsh; land/broken marsh; aquatic vegetation/ broken marsh; water/land; and aquatic vegetation/land.

The results indicated several difficulties with the TM data related to aquatic vegetation and contraction of water bodies due to edge pixel effect. In complex environments of intermixed marsh, water, and

aquatic vegetation, the classification process does not adequately separate aquatic vegetation from marsh. Floating vegetation is often classified as marsh, and thus the water acreage is reduced. It is relatively difficult to discriminate the aquatic vegetation, especially with the automated cluster procedure. It is also difficult to routinely detect areas of aquatic vegetation in the satellite imagery.

Future projects will have to rely on positive identification of aquatic vegetation in the imagery prior to classification so that a target signature can be developed for this category. It is very important to correctly identify and assess the extent of floating vegetation in order to accurately classify water classes.

The contraction of water bodies due to the edge pixel effect is another factor contributing to diminished water estimation in TM imagery. This problem results from the boundary overlap of pixels on the edge of water bodies so that the signature is not that of water. The interface pixels cause water bodies to appear smaller than they actually are. When compared to vector data that more accurately traces the boundary of water bodies, the pixel data comes up with smaller area figures that deviate as a function of the perimeter or land/water interface of the associated water body. Additionally, in highly complex marsh-water areas, there are a large number of

interface pixels that produce a broken marsh signature. In contrast, a photo-interpreted image may generalize some of the complex areas to water rather than outline the details, causing an over estimation of water in resulting vector maps.

Several observations can be made from these results:

1. It is not possible to develop a standard factor for broken marsh that will allow comparisons of TM data to habitat data that will be consistent from one quad to another.

2. Aquatic vegetation will have to be more accurately identified and targeted in future studies because it is not stationary and has a wide seasonal variability.

3. To develop more accurate calculations of water acreage, the imagery should be pre-processed to reduce edge pixel effect. This could be accomplished with edge enhancement or other filtering techniques to improve water classification at boundaries. (Disk-to-disk filtering was not available on ERDAS at the beginning of this project). Test results of this technique on a well-defined lake show some interesting results. The following acreages were calculated for Little Pecan Lake from habitat and TM data:

1956 Habitat
Vector Map .... = 410

The 1984 TM Edge Enhance Imagery value is consistent with expansion of the lake and presumably more accurate, even though the 1984 TM Imagery value matches the 1978 calculation.

4. Currently, we are not able to develop a stepwise, generic procedure to compare habitat data with TM data for the entire coastal zone. Each area must be done on an individual basis, taking into account the special problems of each.

5. There is sufficient cause to explore the most appropriate combinations of techniques to use for comparing the TM and habitat data sets. There are many options available to test their compatibility, but there are too many possible combinations of techniques to guess about which would probably work best together. The various approaches should be tested to determine if the data can be made comparable, and if so, which methodology works best. There are many new analytical and enhancement capabilities that may bring the possibility of comparing these data sets closer to reality.

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PARCEL GENERATION TECHNIQUES FOR
OIL AND GAS FIELD STATUS MAPPING

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ABSTRACT

At the New Mexico State Office, Bureau of Land Management (BLM), the Automated Digitizing System (ADS) has proven to be an effective tool for automation of the BLM oil and gas field status maps. The Panel Map Series, or Pen Maps as they are sometimes called, are critical to the BLM for tracking oil field activities such as leasing, well status, and special administrative designations and agreements. By utilizing new computer technology, this manual mapping activity can now be easily automated and become a major component of the BLM New Mexico's Land Information System. Two new computer programs, Parcel Generator and Generate Geographic Well Location (GGWL), have been utilized to allow data development and ADS map generation 5 to 50 times faster than traditional trace digitizing methods.

INTRODUCTION

The BLM, New Mexico State Office, has been selected as the primary location for Land Information System prototyping and user testing. The thrust of this effort is the integration of alpha-numeric land record information, the automated cadastral survey overlay, and natural resource information. Experimentation and new program development over the past three years have proven this is a feasible approach to establishing a comprehensive Bureau Land Information System which utilizes GIS technology. The Roswell Panel Map Project is the first broad-scale use of this technology and its application in a field-user environment.

The purpose of this paper is to briefly describe the Roswell Panel Map Project and the software which made it possible. This paper will also describe the problems encountered and any conclusions reached during the project.

PROJECT SYNOPSIS

The BLM, Roswell District, is responsible for all Federal oil and gas activities in southeastern New Mexico and parts of west Texas. In August 1986, the Roswell Panel Map project

was established in an effort to automate all oil and gas field status information replacing the manually drafted product. Once this information was developed, it was believed, further analysis could then be performed on the data, such as drainage detection, depth contouring, and diligence work. Furthermore, the oil and gas data had to be automated in such a way as to replace the existing oil field status plats and allow for easy update and display.

The Panel Map Project area encompasses about 300 townships in southeastern New Mexico, covering portions of Lea, Chaves, and Eddy Counties. For each township the following themes were developed: public land survey lines; survey lots; well site and map collar information; and patent, active lease, and known geologic structure (KGS) boundaries; Unitization and Communitization Agreement boundaries; and Participating Area, Federal and non-Federal mineral estate, spacing order, and surface ownership boundaries.

This project was considered feasible because all or most of the above data sets were already automated in textural or digital coordinate format. The ADS satisfied all user requirements of update and display. The essential project problem then, was to convert many data sets from a variety of sources to an ADS digitized map format. Once the data were resident in the ADS system, they could then be utilized by any part of the GIS for analysis or display.

The project plan called for acquisition of existing land record data sets from a variety of sources. Once loaded on the computer, a variety of sort, merge, and reformatting programs had to be used to make them conform to the formats required by Parcel Generator and GGWL. This process proved to be very tricky and time consuming but was eventually successful. Once formatted, each data set was run through Parcel Generator to create the desired overlay. That overlay in turn was edited using ADS edit capabilities and then final plots were produced.

Overall, this procedure proved to be successful. After six weeks of data acquisition and reformatting procedures data generation started. After four weeks of data generation, all required data for over 100 townships had been generated. These were then sent to the editing process and final plots were produced.

SOFTWARE DESCRIPTION

Parcel Generator

The Parcel Generator is a module of the Automated Digitizing System. Its specific function is to convert textural aliquot legal descriptions automatically to ADS coordinate maps. In laypersons' terms, the Parcel Generator automatically digitizes maps from legal descriptions in land records.

Using the Parcel Generator program requires certain conditions to be met. The text

file must be in a certain format and use standard legal description references. It also requires a single township format ADS township section polygon map to be present. If these conditions are met, Parcel Generator is capable of converting legal descriptions to maps for hundreds of parcels in seconds.

The current version of Parcel Generator in ADS has some limitations of which the user should be aware. First, Parcel Generator software was designed to operate effectively on normally lotted townships. This means that any unusual or abnormal lottings provided in the text file used by Parcel Generator will be flagged and not generated. Second, we have found that certain abnormal section shapes or section coordinate conditions will cause Parcel Generator to generate incorrectly. These anomalies occur most often along adjustment parallels and along State or meridian boundaries, and when they occur, the user must use ADS edit capabilities to correct the problem data.

The user documentation for Parcel Generator is available from the BLM office in Santa Fe, NM.

Generate Geographic Well Location

Generate Geographic Well Location (GGWL) is a special-purpose program module of the ADS for the generating of oil and gas well locations. Like Parcel Generator, it will convert a legal description for a given well site, and, based on the footage calls provided, create an ADS point file. Again, in laypersons' terms, GGWL automatically digitizes well sites from legal descriptions of them.

GGWL also requires certain fixed format ASCII files upon which to operate. But unlike Parcel Generator, it will operate on either a single township file or a 7.5-minute digital section map. GGWL is less friendly and has no documentation to speak of, but if the user will follow the prompts, hundreds of oil and gas well locations can be generated in minutes.

One known problem now appearing in the Prime version of the program will cause the user some concern. There seems to be a tendency to erratically generate data for certain sections on the extremities of a township map. For example, well locations in Section 34 of township 22 north range 6 west would not generate, yet the same section in another township did!

There is no detailed documentation of GGWL available.

PGFORMAT

Another special-purpose module of ADS is the PGFORMAT program, which allows the user to build a file of legal descriptions compatible with Parcel Generator. This program has proven to be fast, effective, and has no known problems. Its documentation is

also available from BLM's Santa Fe office.

ENTGGWL

A less popular and little known module of ADS is ENTGGWL. This program allows the user to enter and build an ASCII file of legal descriptions for well locations compatible with GGWL. Although there is no documentation available, the prompting is easy enough for most users to follow.

Township Extract

Township Extract is a special purpose program in ADS which will convert township section polygons digitized in 7.5-minute quadrangle format to a single township map format. This program was written to provide users a method of transforming previously digitized data in quad format to township format for use with the Parcel Generator.

Township Extract has a number of limitations and problems. First, it was designed and written to extract normally distributed townships. If township section lines or boundaries vary from this norm too far, a fatal program error occurs and hand massaging of the data must occur. Secondly, there are occasional discrepancies between coordinate values used in map registration of the township map and the same coordinate on the quad-based map. Hand editing of the ADS.MAPNAME file is used to correct this problem.

Overall, however, the Township Extract process is productive. A single township may be produced in about three minutes on the Prime system. There is little or no user documentation provided for this program.

CONCLUSIONS

Parcel Generator with its associated software has proven itself to be a reliable tool in producing spatial graphics from textural legal descriptions. Using this technology, the task is performed quickly and easily, making the ADS system one of the most cost effective data entry systems available.

Overall the Roswell Panel Map is viewed in New Mexico as a success and plans are being made to implement parcel generation techniques across New Mexico, Oklahoma, and Kansas.

More software development dollars should be invested by the BLM to enhance these programs and their documentation in order that parcel generation techniques be made more successful and usable by the public and private sector geographic information technology users.

QUESTIONS AND ANSWERS

Comment: Parcel generation works about 80% of the time.

Q. Estimate how long it takes to digitize by hand.
A. It takes about 4 hours and

about 4 minutes using parcel generator.

Q. Where are the plats of files to use in the program?

A. BLM is in the process of collecting data, but Parcel Generator comes with its own data collection.

THE NAVAL DIGITAL MAPPING, CHARTING AND GEODESY ANALYSIS PROGRAM "NAVY'S COORDINATION EFFORTS FOR THE USE OF DIGITAL MC&G DATA"

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ABSTRACT

The Naval Digital Mapping, Charting and Geodesy Analysis Program (DMAP) at the Naval Ocean Research and Development Activity (NORDA) is coordinating the Navy's use and development of digital mapping, charting, and geodesy (MC&G) data (Breckenridge et al. 1987). The Navy must rely upon the Defense Mapping Agency (DMA) to meet its requirements for these types of digital spatial data. A primary objective of the DMAP is to improve the Navy's ability to define its digital MG&G data requirements and product specifications to DMA, therefore ensuring that the Navy's long-term digital MC&G data requirements are met. This coordination effort concentrates upon identifying the data requirements of prototype Navy systems during the early stages of their development. The DMAP serves the Navy by providing four major areas of support: new product evaluation, technical coordination, ongoing requirements analysis, and hardware/software development. To accomplish these tasks, the DMAP will rely heavily upon the current technology available within the field of Geographic Information Systems (GIS). Since much of this technology exists within the public domain, NORDA is focusing DMAP's GIS efforts upon incorporating this available technology into its ongoing role of Navy MC&G coordination. The MOSS/MAPS Map Overlay Statistical System/May Analysis Support System software will serve a vital role in these coordination efforts.

INTRODUCTION

The Naval Digital Mapping, Charting and Geodesy (MC&G) Analysis Program (DMAP) serves as the focal point for coordinating the Navy's use and development of digital MC&G data. Chief of Naval Operations, OP-096, the Oceanographer of the Navy, has tasked NORDA to develop and maintain this program to support the identification and specification of naval needs and requirements for digital MC&G data (Chief of Naval Operations, OP-096 1986). The requirements for this program

are stated in Commander, Naval Oceanography Command (CNOC) Ltr Ser 952/3U349699 of 27 May 1983:

"Many Navy systems rely heavily on digital cartographic data....The Navy must be a player in the evaluation of Defense Mapping Agency (DMA) prototype digital data bases. The alternative is to accept data and software formats of the other services which may not support Navy requirements."

The DMAP will support these coordination efforts by serving as an information exchange facility between system developers, digital MC&G data users, and the developers of digital MC&G data products. The DMAP is being developed and maintained by NORDA through four major operational phases: New Product Evaluation, Technical Coordination, Ongoing Requirements Analysis, and Hardware and Software Development (Breckenridge et al. 1987). These combined efforts will allow NORDA to provide ongoing support to the Oceanographer of the Navy in accurately identifying the Navy's critical needs and requirements for digital MC&G data. The DMAP will also provide a means of informing Navy system developers of the various types and formats of data available to them, and will inform them of related efforts within Navy and other services. The DMAP's role as a focal point for conducting evaluations of the Navy's current and future digital MC&G data needs will help to ensure that the standard digital data products supplied by DMA more

adequately reflect the needs of the Navy.

The Naval DMAP serves to help minimize overlapping development efforts by maintaining data bases of existing and prototype systems and the various data models used by these systems. The DMAP consists of scientific, engineering, cartographic, and geographic data analysis capabilities and relies heavily upon the capabilities of the current level of GIS technology. It is supported by a broad spectrum of computer hardware and software systems that help to provide system developers the opportunity to identify the digital data needs of their system during the early stages of the development cycle. This interaction of the DMAP in the development, review, and evaluation of MC&G issues for prototype systems will allow for an increased involvement in the development of software and algorithms for MC&G data processing and transformations. The DMAP's ability to intensively test and evaluate the effectiveness of these spatial data models at meeting system needs depends heavily upon its various GIS type capabilities and functions. The MOSS/MAPS software will play an integral role in conducting these evaluations of prototype digital data products.

This paper offers an examination of NORDA's efforts for developing and acquiring an adequate GIS technology base to support its role in the Navy's coordinated use and development of digital MC&G data. The use

of GIS within the various phases of the DMAP's program management will be discussed. The paper further defines the role of GIS for the evaluation of prototype digital MC&G data products and discusses NORDA's acquisition and use of the MOSS/MAPS GIS to support these coordination efforts.

CURRENT HARDWARE AND SOFTWARE CAPABILITIES

The Naval DMAP is currently supported by the full capabilities of NORDA's Pattern Analysis Laboratory (PAL). The PAL is a comprehensive computer facility designed to support most phases of digital image processing and pattern analysis. Its hardware inventory includes DEC VAX 11/780 and 11/750 mini-computers, Gould DeAnza IP8500 and Granelle Image Processors, Sun 3/160 and Silicon Graphics High Speed Workstations, and a host of color hard- and softcopy peripherals to support cartographic display. Although the PAL was not designed specifically for the DMAP, it offers an excellent state-of-the-art environment for conducting research and development in the areas of GIS and computer-aided cartography.

In addition to the PAL, NORDA's facilities offer several micro-level computer systems. At present, NORDA has acquired MacIntosh II computers with a UNIX operating system to conduct R&D in micro-level GIS. This work primarily supports CERL's Geographical Resource Analysis Support System (GRASS), and includes porting

this system to the Mac II environment and enhancing software to ensure full utilization of the Mac II 68020 microprocessor and floating point coprocessor. The Mac II desktop environment promises to be an effective platform for duplicating much of the minicomputer's GIS support capabilities at the micro level. NORDA is also acquiring PIXAR image-rendering systems which may be used to enhance graphic display within the GIS environment for support of terrain modeling and other 3-D operations.

Although the PAL is equipped with an impressive assortment of image processing software (i.e., ELAS, ERDAS) it has not acquired a comparable level of support for GIS technology. Although DMAP has acquired various GIS packages and is currently using components of these systems, NORDA has not begun supporting the continued operations of such a system. Prior to doing so, NORDA will conduct a full investigation of its needs and requirements for this technology, and will identify a method of continued development and support for its GIS efforts. It is presently envisioned that NORDA's GIS will consist of components from various public domain systems working under the control of a major Data Base Management System (DBMS).

IDENTIFICATION OF GIS REQUIREMENTS

Traditionally, the ocean science community has not supported the growth of GIS,

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primarily due to lack of understanding of how this technology might benefit such a broad science. However, recent years have seen an increased effort in the types of computer-aided analyses available for spatial marine information. Scientists are just beginning to examine the ways in which these various data bases can be compared and interacted using GIS to determine an extensive amount of information. The Navy's use of GIS has also been relatively slow in comparison to many in the resource management fields. The increased need for supplying critical spatial information to support worldwide naval operations makes it imperative that this technology be fully utilized. The Navy's interest in developing an Electronic Navigation Chart is an area that promises to rely heavily upon the GIS technology base (Clawson et al. 1986). Other areas of potential use for GIS include bathymetry, sea-floor modeling, and the prediction of ocean currents.

The current efforts of the Naval DMAP demand a broad base of GIS operations to support its various phases of spatial data handling and manipulation. Included in this base is the need for interactive manipulation of raster and vector data models, data reclassification, overlay, merging, and the direct interface of GIS and image processing operations. Although these capabilities do currently exist within public domain software, no one system currently provides an adequately comprehensive package

to meet all of the Navy's needs. NORDA recognizes the benefits of using public domain software for GIS development, and is at present relying upon the combined resources of three main GIS packages. These systems include: (1) MOSS/MAPS, Department of the Interior's Map Overlay and Statistical System/Map Analysis Processing, (2) GRASS – Army CERL's Geographical Resource Analysis Support System, and (3) TERRABASE which is being developed by West Point Academy. Timeframes for implementation of each of these systems vary; however, program deadlines dictate that minimal functionality be accomplished by June 1988. Although NORDA acquired the ULTRIX version of MOSS/MAPS software in March 1987, this system has not been fully operational due to limitations of NORDA's current system configuration. NORDA is scheduled to receive the VMS version of the MOSS/MAPS software system by June 1988. This system will be transferred within the Army ETL's Air-Land Battlefield Environment (ALBE) system and should become operational by 1 July 1988.

The GRASS software currently resides on NORDA's Sun workstation and is available through the Institute for Technology Development located at John C. Stennis Space Technology Laboratories, MS. The DMAP staff is currently involved in porting this system to the Silicon Graphics IRIS workstation. Although the MAPS package offers sufficient capabilities of raster manipulation, the GRASS was chosen as the primary system for these

operations due to its excellent graphics interface to the Sun and Silicon Graphics workstations. It is expected that some links between the MOSS/MAPS and GRASS systems will be developed soon.

The evaluation of prototype digital MC&G products comprises DMAP's highest need for GIS support. This phase of operation requires that a prototype data set be fully tested and evaluated in reference to its data format and structure, cartographic accuracy, and resolution. These products must be evaluated in reference to their ability to fully meet the Navy's stated data needs and requirements. An example of NORDA's work in product evaluation is its efforts for the World Vector Shoreline (WVS) (Langran et al. 1986). Currently the Navy utilizes the CIA World Data Bank II for digital shoreline data. At a scale of 1:3,000,000, these data do not fully support the needs of the Navy (Langra and Conner 1986). As a result of a study to determine Navy requirements for digital MC&G data, DMA was requested to supply a WVS that could be effectively used with Digital Bathymetric and Terrain Evaluation Data Bases to more accurately represent the land-water interface. NORDA was then tasked to evaluate the DMA prototype WVS and to determine if it would meet Navy needs for this data base. After identifying significant deficiencies in the prototype data structure and format, NORDA proposed a new WVS format, which was approved and implemented into the production

version of this standard data product. The evaluation of this product required that the data be displayed and manipulated within a controlled system environment to ensure that the data had been stored in the most efficient manner. Other phases of evaluation included merging and overlaying of data files to ensure compatibility among data. The GIS serves these types of evaluations by providing the means to readily visualize the data's ability to remain compatible to other data bases, while also offering a simulation of the prototype product's ability to meet the needs of its intended applications.

IMPLEMENTATION OF
GIS TECHNOLOGY

The Naval DMAP will begin utilizing its acquired GIS capabilities with its upcoming evaluation of the Tactical Terrain Data (TTD). The evaluation of this raster oriented, topologically structured data base will require intensive use of GIS functions for cartographic modeling and analytical processing. DMAP's efforts will begin with a review of the data structures and content to determine TTD's efficiency and compatibility to other existing products. The ALBE and GRASS systems will be utilized to determine the data's functionality in providing a set of crucial terrain-based analytical and graphic products. These efforts of cartographic modeling will include overlay, reclassification, distance,

slope, viewshed analysis, and other terrain-oriented operations.

TERRABASE, developed at West Point, currently resides with NORDA in a BETA test format. This terrain-oriented GIS is expected to be released as a public domain system within the near future.

CONCLUSION

The Navy fully recognizes the benefits of utilizing the technology available within the field of GIS. As the Navy's lead laboratory for mapping, charting and geodesy, NORDA acknowledges its responsibility to remain abreast of developments within this field, and to encourage the implementation of this technology into naval operations. The MOSS/MAPS GIS will play a vital role in the Navy's coordination of digital MC&G products. Its use in the evaluation of prototype digital MC&G data products will provide the capability needed to determine these products' ability for meeting the digital MC&G data needs of the Navy.

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QUESTIONS AND ANSWERS

Q. Does this reflect more willingness for the Navy Department to release data to other agencies?

A. Yes, it seems to. There already is some. There is a program in place with USGS.

Q. What is the status of the Albe Project?

A. It is being released in prototype format in July 1988. We will be testing it. The Navy is getting MOSS/MAPS now.

USING SIDE SCAN SONAR DATA IN A GEOGRAPHIC INFORMATION SYSTEM TO LOCATE AND DISPLAY LAKE TROUT SPAWNING HABITAT IN THE GREAT LAKES

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ABSTRACT

The National Fisheries Research Center-Great Lakes of the U.S. Fish and Wildlife Service has extensively used a side scan sonar to survey and pinpoint lake trout spawning grounds in the Great Lakes. The Geographic Information System (GIS) of the National Ecology Research Center produced maps from the side scan sonar data showing the exact location of the spawning grounds; this will enable current stocking programs to be carried out at those locations. These maps show the geographic position (latitude and longitude) of both the color-coded primary substrate types and the secondary substrate types, which are denoted by overstrikes. The maps must be supplemented with a Loran-C navigation grid for field use. The maps are proving useful to fishery managers by locating lake trout stocking areas in Lakes Michigan and Huron, as well as to researchers who investigate habitat quality on lake trout spawning grounds.

INTRODUCTION

More than 135 million juvenile hatchery-reared lake trout have been stocked in the Great Lakes since the 1950's to bolster or supplement native lake trout stocks that were depleted or exterminated by overfishing and predation by the sea lamprey (Eshenroder et al. 1984). Despite the large numbers of stocked lake trout now in the Great Lakes, there is little evidence that these fish have reproduced, except in Lake Superior and a few isolated areas in the other Great Lakes. This failure to reproduce has been attributed largely to the practice of stocking the fish in areas of the Great Lakes that were not used for spawning by native lake trout because of a lack of suitable rock spawning substrate. A side scan sonar was used to survey and pinpoint the location of substrates that are suitable for lake trout spawning in the Great Lakes

(Edsall et al. 1988). A Geographic Information System (GIS) developed by the National Ecology Research Center of the U.S. Fish and Wildlife Service was used to digitize, analyze, document, and graphically display the data obtained with the side scan sonar. Our purpose is to describe how the GIS used the side scan sonar data to produce maps that contain the exact geographic location of lake trout spawning grounds in the Great Lakes. In the future stocking efforts can then be focused on the potentially most suitable habitat.

MATERIALS AND METHODS

Lake bed surveys were conducted with an EG&G image-correcting side scan sonar system that provides data in the form of a continuous strip-chart record that displays in black, white, and gray tones the features on the lake bed 100 m to either side of a towfish. The survey vessel traversed each area in parallel, evenly spaced transects with overlap to obtain complete coverage of the spawning grounds. Positioning of the survey vessels was by Loran-C radio navigation, and way points were recorded at regular intervals (usually 2-3 minutes) during the course of a transect. A more detailed explanation of the equipment and procedures used to survey the lake trout spawning reefs is contained in Edsall et al. (1988).

The GIS used for this project was the Analytical Mapping System (AMS) (also known as the Wetlands Analytical Mapping System), the Map Overlay and Statistical System (MOSS), and the Cartographic Output System (COS). The AMS Version 1.03, operating on a Data General Eclipse C-330 minicomputer, was used for digitizing maps. Digitizing hardware included an Altek ACT 34-3 digitizing tablet with an AC90 controller box and 16-button cursor, ADM-5 alphanumeric terminal, and Tektronix 4010-1 graphics display terminal. A Data General Eclipse C-350 minicomputer was used for all data reformatting, data analysis, and cartographic output. The AMS map files were reformatted with the July 1985 version of the ADDWAMS program to convert them to MOSS import format. The September 1985 version of MOSS (Lee et al. 1985) was used to construct MOSS vector maps. Data base construction, documentation, archival, and related techniques were described by Waltermire (1988). The COS Revision 2 (Frosh and Walsh 1985) was used to construct hard copy color maps. Profiles were generated for a Calcomp 1077 plotter. For the final map products, Zeta high-gloss opaque paper was used to emphasize colors and prevent see-through.

Nylon tip, liquid ballpoint, and pressurized ballpoint pens were used to provide adequate colors and line widths.

MAP PRODUCTION AND DISCUSSION

Side Scan Sonar Data Analysis

The side scan sonar data records from the survey

transects were assembled into a mosaic covering the surveyed area in a way similar to that typically used for mosaic assembly in aerial photography (Sabins 1987). Uncontrolled mosaics were constructed by overlapping outstanding lake-bed features contained on the records from adjacent transects, and this process was repeated for each transect until the mosaic was completed. The finished mosaic was then overlaid with frosted plastic mylar which served as the medium for transmittal of information contained on the mosaic to the GIS. Information recorded on the mylar included labels of the location and scale of the original data, and the geographic coordinates that had been converted from the original Loran-C coordinates to degrees, minutes, seconds, and tenths of seconds of latitude and longitude in order to accommodate the AMS.

The identification and delineation of substrate types were then added to the mylar sheet. The boundaries between different substrate types were circumscribed, and each of the resulting polygons was assigned an 11-character substrate classification code or subject (Table 1). The first, third, and fourth characters in the code described the primary substrate type within a given polygon; the seventh, ninth, and eleventh characters described the secondary substrate type (if any) within the polygon. The sixth character consisted of words or phrases to connect the primary and secondary substrate types. Delimiters--dash, slash, dot, and underscore--which allowed for the unique selection of substrate characters were used for the second, fifth, eighth, and tenth characters. An example of the classification code format is 4-84/19.6_0, which represents jagged bedrock ridges with scattered cobble (Table 1).

Using GIS Technologies

We first selected a mosaic representing a 99-ha area of lake bottom from Richards Reef in Lake Michigan as a demonstration project to show how side scan sonar information could be processed in the GIS. Initially the mylars from the mosaic did not contain a grid or tick marks of known geographic coordinates required for map registration. Therefore, coordinates in degrees, minutes, and seconds were obtained for the southeast corner of the map, and control points were mathematically calculated and drafted at equal intervals around the map perimeter. To determine the degree of accuracy achieved by calculating control points, we created a project data base in the AMS, and divided the map into two separate geounits so that hard-copy plots could be produced at the source scale of 1:1,000. Map registration was acceptable for both map sheets, and the substrate data were successfully digitized, verified, and plotted. Although the AMS hard-copy output did not exactly match the original mylar sheet, it was surprisingly accurate considering that control points were calculated rather than transferred from the side scan sonar records.

Table 1. Substrate classification codes.

First character	Second character	Third character	Fourth character	Fifth character
0=NA[a] or Unknown 1=Round 2=Flat 3=Angular 4=Jagged 5=Pitted 6=Worn 7=Broken 8=Smooth	Dash symbol(-)	0=NA 1=Unknown 2=Clay 3=Sand 4=Gravel 5=Rubble 6=Cobble 7=Boulders 8=Bedrock	0=NA or Unknown 1=Evenly Distributed 2=Layers 3=Piles 4=Ridges 5=Ripples 6=Patches 7=Scattered 8=Mounds	Slash symbol(/)

Sixth character	Seventh character	Eighth character	Ninth character	Tenth character	Eleventh character
0=NA 1=With 2=Covered by 3=On 4=Mixed with	0=NA or unknown 1=Round 2=Flat 3=Angular 4=Jagged 5=Pitted 6=Worn 7=Broken 8=Smooth 9=Scattered	Dot symbol(.)	0=NA 1=Unknown 2=Clay 3=Sand 4=Gravel 5=Rubble 6=Cobble 7=Boulders 8=Bedrock	Underscore symbol(_)	0=NA or unknown 1=Evenly distributed 2=Layers 3=Piles 4=Ridges 5=Ripples 6=Patches 7=Scattered 8=Mounds

[a]Not applicable.

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A unique problem resulted from dividing the small area (99 ha) into two separate geounits in the AMS. Since files in the data base are identified by degrees and minutes, and coordinates for both geounits differed only in seconds, it was not possible to move both maps into an AMS data base without losing one map. Two directories were created, and the AMS map files for each map were moved into separate directories. This problem could have been avoided if the mylar sheet had been digitized as a single geounit; however, due to the physical limitations of the plotting device, the mylar was split into two parts for the sole purpose of producing plots of AMS maps at 1:1,000 for comparison against the original mylar sheet. Because of the time-consuming process of calculating control points and the data base problem in the AMS, we did not digitize a second mylar sheet representing 171 ha of lake bottom for Richards Reef.

One of the main objectives of the demonstration project was to pinpoint the exact location of substrate types on the side scan sonar records. To achieve the high positional accuracy required for future efforts, we established three procedures: (1) each mylar sheet should contain at least 12 control points for registration taken directly from the side scan sonar mosaics; (2) the physical size of each mylar sheet should not exceed the 0.91 x 1.22 m active area of the digitizing tablet; and (3) mylar sheets for each reef area should be digitized as a single geounit

in the AMS to avoid the data base problem encountered during the demonstration project. These procedures, combined with the results and outputs obtained in the demonstration project, were then used as standards for the production of maps depicting larger areas.

After completing the demonstration project, we digitized the entire 342-ha area of Richards Reef contained on four 1:1,000 mylar sheets. Each sheet measured 0.91 x 1.22 m and contained 16 control points spaced at equal intervals both within and around each sheet. Because it was not possible to plot the AMS digital files at the 1:1,000 source scale, seconds were carried to the second decimal to ensure a high degree of positional accuracy in digitizing.

A project data base, measuring 1.2 minutes of latitude by 1.4 minutes of longitude, was created for Richards Reef. Due to the high degree of precision used in the transfer, conversion of control points, and the large number of control points used to describe the 342 ha of reef area, the coordinates registered by the program were virtually identical to the mapped coordinates and resulted in an unusually high degree of accuracy for a map registration. The four mylar sheets were digitized as one geounit, and the digital data were successfully verified, plotted, and stored in a permanent data base. One data layer, lake trout spawning areas, was entered into a MOSS

data base for each of the eight study areas. The Universal Transverse Mercator (UTM) projection was used. Since the study areas were in two UTM zones, different projection parameters were used for each zone (Lee and Walsh 1984). Only vector maps were needed for this study. Standard area tables for each map were generated in MOSS, and the area values were manually converted from acres to hectares.

The final map products constructed in COS had the following components: outer border, title, legend with area table, map, 15-second latitude/ longitude grid, locator map, U.S. Fish and Wildlife Service logo, credit statement, north arrow, bar scale, and date of COS construction. The color for polygon fill in COS was based on the third character of the MOSS subject which described the primary substrate type (Table 2). The third character was modified by the first and fourth characters. If the fourth character, which described the distribution of the primary substrate type was known from the side scan sonar data, the hue of the color was changed. The adjectives in the first character describing the shape of the primary substrate were included in the legend but did not affect the color or hue of the polygons. The secondary substrates were described by the seventh, ninth, and eleventh characters. The secondary substrate types represented by the ninth character were displayed within the polygons by a bold black overstrike with varying angles and solid or dashed lines 1 cm

apart (Table 2). The seventh and eleventh characters, which respectively described the shape and distribution of the secondary substrate types, were included in the legend but could not be displayed legibly within the polygons.

Mylar sheets for eight spawning grounds were processed over a 15-month period: Six Fathom Bank-North, Six Fathom Bank-Central, Yankee Reef, and Port Austin Reef in Lake Huron; Boulder Reef, Richards Reef, and Wilmette Reef in Lake Michigan; and Partridge Island Reef in Lake Superior. The number of mylar sheets for each reef ranged from 2 to 14. Total size of the areas mapped ranged from 155 ha (Six Fathom Bank-Central) to 1,416 ha (Boulder Reef). The scale of the COS maps was 1:4,000 except for Boulder Reef, which was 1:8,000.

There were many advantages to using a GIS to display the side scan sonar data obtained from historical lake trout spawning areas. The COS map products produced by the GIS accurately depicted in an understandable, color-coded fashion the geographic distribution of the various substrate types. In addition, a computer data base was constructed that will be available for future inter- active use and the incorpora- tion of additional information such as water depth contours. Finally, MOSS allowed the data base to be accessed quickly when revisions of attributes or selection of map parts with similar characteristics for COS map production were required.

Table 2. Cartographic output system substrate classification system.

Third character	Color	Ninth character	Bold black line (degrees)	
Clay	Silver	Clay	0	Rotation, solid
Sand	Brown	Sand	0	Rotation, dashed
Gravel	Orange	Gravel	45	Rotation, solid
Rubble	Green	Rubble	90	Rotation, solid
Cobble	Blue	Cobble	135	Rotation, solid
Boulders	Red	Boulders	45	Rotation, dashed
Bedrock	Purple	Bedrock	90	Rotation, dashed

Limitations to the GIS, which posed difficulties in processing the side scan sonar data included the inability of the GIS to accommodate Loran-C coordinates. This limitation introduced a potential for error when Loran-C coordinates were converted to latitude and longitude, and required manual drafting of a separate overlay containing a Loran-C grid for each of the spawning areas. Another limitation was evident when spawning grounds included areas with more than two substrate types within a polygon. These areas occurred infrequently and were denoted by a unique overstrike-shade pattern. These two limitations, however, were relatively minor compared to the many advantages of the GIS already mentioned.

The users of this information include both Federal and State fishery managers involved with the restoration of self-sustaining lake trout populations in the Great Lakes. The information contained on these maps has been used for locating stocking areas in northern Lake Michigan as well as in central Lake Huron. Researchers have used the maps to locate experimental study sites on a historical spawning ground in Lake Huron for assessing the quality of the habitat currently on the reef. Many other requests for the information on these maps are expected when the information is published. In the future, the side scan sonar will be used to map other Great Lakes fish habitats, and the continued use of a GIS for processing this information is expected.

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QUESTIONS AND ANSWERS

Comment: It certainly appears that this GIS has made side scan sonar data useful to fishery managers.

Q. Why use a GIS?
A. Because we can get exact geographic positioning with it. We also plan to build on the maps--overlay them with other information.

Q. Can you estimate your accuracy?
A. Within 30 m or so. The lower limit of Loran-C resolution.

Q. Why did you use only two substrates?
A. Latitude/longitude were usually taken directly from the Loran-C receiver. Occasionally a software program developed by NOAA was used to covert Loran-C latitude/longitude.

Q. When will you know of success?
A. We now know about the location of substrates. Other variables, such as experimental stocking programs and contaminant research, will take longer before the results are final.

THE BUREAU OF RECLAMATION/ARIZONA PROJECTS OFFICE USES MOSS ON HP-9000/UNIX AND VAX/VMS COMPUTERS AND SHARES DATA FROM ARC/INFO AND WITH VARIOUS CAD/CAM SYSTEMS

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ABSTRACT

The Bureau of Reclamation/Arizona Projects Office (APO) has been using Geographic Information Systems (GIS) technology provided by the Map Overlay and Statistical System (MOSS) for several years. It is used to collect, manipulate, and produce data in support of engineering and construction projects associated with the Central Arizona Project (CAP).

Initially, the system was installed on a Hewlett Packard 9000 Series 200 computer running the HP-UX operating system. The data consisted of XY digitizing table data, low-altitude photogrammetrically-derived XYZ data collected on an APPS-IV analytical stereoplotter, and dense contour data collected by a Wild B8-S stereo-plotter. Most recently, a MOSS system was installed on APO's VAX/VMS cluster. In addition, the project has successfully demonstrated the capability of acquiring external data from several sources. Data from ARC/INFO PRIME systems, USGS DEM and DLG-3, AUTOGIS AMS and MOSS data resident on Data General, VAX, HP, AT&T, and PRIME systems, as well as INTERGRAPH data bases are all part of this consideration.

The Bureau has long recognized that a major strength of a GIS is the capability to ingest spatial and attribute data from foreign sources. The public-domain version of MOSS provides an excellent and inexpensive vehicle for this need. This is one mechanism the APO utilizes to satisfy the numerous amounts of requests for digital and hardcopy geographical products.

OVERVIEW OF THE CENTRAL ARIZONA PROJECT

The APO is responsible for building the CAP. The CAP was authorized in 1968 to import Colorado River water to Central Arizona to help reduce the overuse of groundwater in the area, and is the largest single water-conveyance project ever authorized for construction by Congress. When construction of the CAP began in 1973, Colorado River water was being pumped from Lake Havasu at a point about 15 miles north of Parker, AZ. By 1992, water will be pumped to the southern border of the San Xavier Indian Reservation, south of Tucson, and will be used for municipal, industrial, recreational, and agricultural purposes.

A 330-mile long series of open canals, inverted siphons, 14 pumping plants, and tunnels will form the CAP water conveyance system. Along the way, the water will be lifted almost 2,900 feet in elevation. Power to run the pumps will come from the Navajo Generating Station near Page, AZ, and from hydroelectric energy generated at Hoover Dam. In addition to these features, construction of three dams and modification of two others have been authorized for additional conservation, flood control, regulation, sediment control, and other purposes. Two existing dams on the Salt River east of Phoenix will be modified for flood control, dam safety, and additional water conservation. The reservoirs behind these dams, new or existing, have the

potential to greatly expand water-based outdoor recreation in a State where water provides a welcome relief from sun-baked summers.

The APO management recognized a need for a mechanism to better organize and manage geographic data, maps, coordinates, measurements, land classifications, etc., required by APO staff. Management identified two basic needs with respect to geographic information. One is to improve the efficiency and timeliness of data collection and analysis using electronic aids. The other is the need to transfer data quickly and accurately among the groups that require them. Both of these needs have been amplified by the recent acceleration of CAP completion and delivery schedules.

Management wanted a system that would provide efficient data storage and transfer between branches to assist in meeting deadlines and an effective data base for planning, administration, and operation. Delays were encountered because data required by different branches could not be transferred digitally. Often automated data had to be re-entered because of hardware and system incompatibilities. The data, by its nature, is cumulative and requires updating. Current analog recording methods were compounding data management problems. Development of an integrated data base, a GIS, to help solve these problems was proposed.

Characteristics of GIS at CAP

System Requirements. The nature of the projects dictated a system that could produce the high accuracy data needed to support design, construction, and other engineering-related activities. The following requirements were identified:

- The system should be able to interface to the APPS-IV analytical stereoplotter so that redigitizing of maps (from photography) could be eliminated. This would provide the high accuracy data that can be produced from stereo models.

- The system should accommodate both arc-node and polygonal data structures. In this way, multi-source data input could be handled.

- It would have to support table digitizing and single photo resection.

- It must be a topographically-defined system and must include vertical map capability.

- It must meet or exceed standards normally associated with Geographical System Technology.

Initial Hardware. In 1985, hardware consisting of a Hewlett Packard 9920T bundled system with a UNIX operating system, FORTRAN 77 compiler, graphics capability, and multi-user functions was purchased. The computer is a desktop 32-bit machine, and it was purchased with 3.02 megabytes (Mbytes) of memory, expandable to 7 Mbytes. The system also included two 55 Mbyte disk drives, system digitizing station graphic CRT's, and a Calcomp 9100 digitizing table. The equipment was interfaced to existing APO hardware consisting of a Calcomp 965 plotter, an APPS-IV analytical stereoplotter, an HP printer, alpha and graphic terminals, and HP-1000 computer.

Baseline GIS Software. The baseline MOSS-system software installed for the CAP emanated from the U.S. Army Engineering Topographic Laboratories (ETL) in Virginia. In 1984, ETL had contracted to Autometric, Inc. to convert the Data General MOSS system to a HP-9000 series 300 environment. The technical details concerning the conversion are presented in Table 1.

This baseline MOSS-system was then tailored to accommodate specific requirements for the CAP. Table 2 presents the modifications to the software.

Current Hardware/Software. Since the initial procurement, the HP9000 has been upgraded with memory. It currently operates with 7 Mbytes of random access memory, the original two 55 Mbytes of disk storage, and an additional 130 Mbytes of disk storage. Another 571 Mbyte disk drive is currently on order.

In addition to the HP-9000 computer system, the CAP has an HP-1000, a VAX-750, a VAX-8300, a VAX-730, a MicroVAX II, and over 100 PC's on site. All of these machines operate in a clustered environment using ROLM and DECNET communication

Table 1. Primary MOSS conversion for ETL.

	DATA GENERAL BASELINE	HP-9000 REQUIREMENTS
OPERATING SYSTEM:	AOS, AOS/VS	HP-UX (UNIX)
WORD CHARACTERISTICS	16 BIT WORD, 8 BIT BYTE	32 BIT, 8 BIT BYTE
SOURCE CODE LANGUAGE:	FORTRAN IV WITH EXTENSIONS (TRUE 16 BIT CODE) DATA GENERAL ASSEMBLY DATA GENERAL CLI	FORTRAN-77 (ANSI) (TRUE 32 BIT CODE) C
SOFTCOPY GRAPHIC LIBRARIES:	PLOT-10 (MONOCHROME)	PLOT-10, DI-3000, HP-DGL (FULL COLOR)
HARDCOPY GRAPHIC LIBRARIES:	ZETA, HOUSTON INSTRUMENTS, VERSATEC, GERBER, CALCOMP	HEWLETT PACKARD
PROGRAM COMPONENTS:	AMS, MOSS, MAPS, COS	AMS, MOSS, MAPS
SUPPORTED INPUT DEVICES:	FLATBED XY DIGITIZERS APPS-IV	FLATBED XY DIGITIZERS LIGHT TABLE MENSURATION SYSTEM (LTMS)

Table 2. Secondary MOSS conversion (CAP).

	ETL HP-9000	CAP HP-9000
SOFTCOPY GRAPHIC LIBRARIES:	PLOT-10, DI-3000, HP-DGL	PLOT-10, DI-3000, HP-DGL, STARBASE
HARDCOPY GRAPHIC LIBRARIES:	HEWLETT PACKARD	CALCOMP
OPERATING SYSTEM:	HP-UX (UNIX)	HP-UX (UNIX)
PROGRAM COMPONENTS:	AMS, MOSS, MAPS	AMS, MOSS, MAPS PHOTOGRAMMETRIC INTERFACE USING B8-S AND APPS-IV
SUPPORTED INPUT DEVICES:	FLATBED XY DIGITIZERS LTMS	FLATBED XY DIGITIZERS APPS-IV

equipment (the HP-9000 does not). This configuration is depicted in Figure 1. The VAX network also provided interfaces to two CAD systems: a direct interface to the GE/CALMA CAD system and an indirect interface to the AutoCAD system marketed by Autodesk, Inc. There was a strong desire to explore GIS technology in the VAX environment. The benefits identified were:

- The VAX systems could support larger digital data bases;
- The VAX systems were higher performance machines than the HP-9000;
- The graphic output components, AutoCAD and GE/CALMA, were interfaced to the VAX environment via the cluster, and
- More engineers and analysts were accessing the VMS environments.

In 1987, APO contracted to Autometric, Inc., to install a VAX/VMS version of MOSS. Tangential contracts have allowed MOSS-system data to be passed between VAX/VMS, HP-9000, Data General, PRIME and AT&T computer hosts for the AMS, MAPS, and MOSS components of MOSS. The configurations using MOSS or MOSS data are presented in Table 3.

HOW THE GIS TECHNOLOGY
CURRENTLY IS BEING USED

The APO user-audience consists of high- and mid-level managers, engineers, surveyors, and public-relations staff. APO has found it very useful to use the GIS to acquire digital geographic data; ensure the validity of digital data; and provide central-database-node capabilities.

Although intermediate graphical products are generated by MOSS, the AutoCAD and GE/CALMA CAD interfaces are frequently used to produce the high-quality graphics for final reports. Data is commonly imported into the HP-9000 MOSS system from the B8-S, the APPS-IV, external contractor-collected systems, and other MOSS systems, to name a few. The capabilities that each source of data provides are briefly presented below.

Input from Other Sources

MOSS Systems. Data can be transferred into or out of the CAP MOSS system via two import/export formats. The MOSS import/export format accommodates data transfer of lineal, polygonal, or point features between the MOSS subcomponent. Attributed arc/node data can be transferred between the AMS subcomponent via the MOVDMAP program and specified format. The benefit for the latter format is the ability to edit and/or topologically verify the data after the import process.

USGS Supplied Data. The MOSS system currently has the capability to ingest several U.S. Geological Survey Products and clones:

- DLG-3 Option Ascii (Digital Line Graph) produced by the U.S. Geological Survey (USGS), Census Bureau, and INTERGRAPH systems,
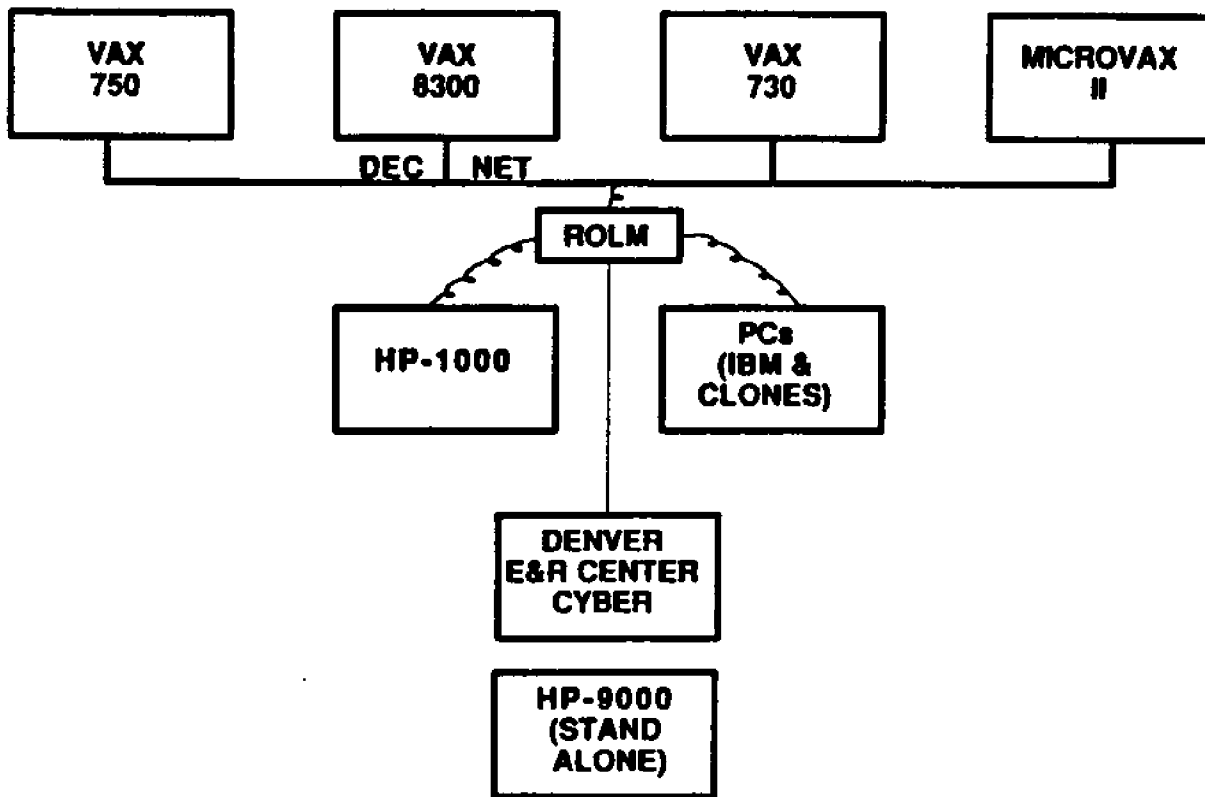
Figure 1. CAP computer hardware environment.

Table 3. CAP system configurations.

TYPE	VAX	HEWLETT PACKARD	PCs
HARDWARE	VAX 750 VAX 8300 MICROVAX II	HP-9000 SERIES 200	IBM & CLONES
	CALCOMP 1077	CALCOMP 965	CALCOMP 1043
OPERATING SYSTEM	VMS	HP-UX (UNIX)	MS-DOS 3.+
SOFTWARE	MOSS SYSTEM GE/CALMA CAD	MOSS SYSTEM	AUTOCAD

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- DLG-3 Ascii (ESRI format) produced by ARC/INFO,

- 30-meter-spaced DEM data produced by the USGS, and

- 3-second-spaced DEM data produced by the USGS.

Mapping Contracts. The APO Photogrammetry Section is responsible for producing cartographic products for use on the project. The maps (analog and digital) are usually generated in-house by a variety of photogrammetric instruments. Large-scale mapping, involving miles of the canal is contracted out. Traditional hardcopy maps and digital files in the MOSS IMPORT format are supplied by subcontractors.

Survey Data. The project frequently requires the survey of centerline stationing, control networks, drill-hole coordinates, geologic strata coordinates, profiles, section lines, etc. for its engineering activities. These data are selectively imported into the GIS using the MOSS IMPORT format.

APO Photogrammetrical Activities

Input from the B8-S. In 1974, a Wild B8-S was purchased to assist in cross-sectioning and to produce highly accurate large scale maps (1"-50' and 1"-100'). To date, over 700 maps have been produced on the B8-S. Larger scale maps (1"-200' and 1"-400') have also been produced and cover the 330 miles of canal and associated dam features. The B8-S has an indirect interface (via the MOSS IMPORT format) to the GIS data base. Data collection, on-line storage, and interactive graphics, along with manipulation and editing activities are performed on the B8-S using a direct interface to a PC running AutoCAD.

Input from the APPS-IV. In 1983, an APPS-IV analytical stereoplotter, loaded with specialized cross-section software, was purchased to automate the cross-sectioning process. The APPS-IV enables the analyst to view images in stereo, thus allowing the operator to accurately identify, locate, and measure features and their dimensions. Interpretation, mensuration, and digitization can be carried out simultaneously, while populating the GIS data base, thereby reducing the number of individual steps and time required to complete a project. This capability accommodates two types of applications: conventional and terrestrial. Feature digitization and gridded collection techniques can be used for both applications.

Topographic Layers

After the data are transferred to the GIS for processing, they are databased for future use and reference. These data are stored by themes or layers, and are tied to the earth by geographic reference. Each topographic layer has an associated dictionary of attribution which may be used in the specification for each associated topographic feature. The data base has been populated

with survey, cadastral, land classification, hydrographical, geological, archaeological, environmental, administrative boundary, land use, and land ownership layers. Most of these layers were derived from 7.5-minute USGS quadrangles.

Final Reports

The systems are expected to help BOR engineers produce better quality designs and improve communication of design intent to contract adminis-trators and contractors. Better representation of design data reduces ambiguities in contract drawings, and decreases bid prices. Carto-graphic products and reports dealing with dam-site selection, corridor selection, construction and contractor monitoring, earth-work calculations, erosion and sedimentation studies, water-shed studies, temporal land-use and topographical changes have all been generated for the project.

Output to Other Systems

As previously stated, the GIS makes an excellent receptacle for geo-referenced data. These data are frequently selectively filtered using theme-layer, area-boundary, or attributed constraints, and exported to (1) CAD/CAM work stations in support of engineering activities; (2) geological modeling packages now available on PC's; and (3) other engi-neering programs that exist on local computers of the Bureau's CDC 6400 Cyber computer located at the Denver Engineering and Research Center.

HOW THE APO WILL USE GIS IN THE FUTURE

The Bureau of Reclamation has recognized that a major strength of a GIS is the capability to ingest spatial and attributed data from a variety of foreign sources. APO frequently acquires these data, performs modeling analysis within the GIS environment, and exports digital products to its CAD environment for final analog product output. Related APO organizations have also been using GIS technology. The GIS technology was not MOSS; however, it has been demon-strated that data from foreign Geographic Information Systems can still be accommodated within the MOSS environment.

How GIS Technology is Currently Being Used Under Contract

The Arizona Projects Office is responsible for determining and mapping eligible agricul-tural lands for Central Arizona Project water service. An Exhibit-B map will be attached to each long-term agricultural water service subcontract, or for each irrigation district, delineating "eligible lands." Eligibility is defined by the combined requirements of Federal law and regulations, and State groundwater law. These requirements mandate that the CAP promote water con-servation and non-expansion of irrigated agriculture in central Arizona. These maps are composed of several layers or themes consisting of (1) Land Classification Coverage (Appendix F of the "CAP

Definite Plan Report"); (2) location of State Grandfathered Water Right Certificates (GFR coverage pursuant to the Groundwater Management Act of 1980); and (3) Irrigation District Boundary coverage.

Due to mutual goals related to administering water law and recognition of the benefits and needs of sharing information, the Arizona Projects Office and the Arizona State Department of Water Resources (DWR) cooperated in using GIS technology. APO supplied the labor to research and digitize data, and the State was contracted to provide equipment, facilities, and GIS management services. This occurred in early 1984, prior to establishment of the in-house GIS program at APO. All of this effort has been accomplished using the ARC/INFO system resident at DWR. Until the advent of APO's GIS, Reclamation could only accept analog products. Quality assurance was difficult and time consuming.

The determination of CAP-eligible agricultural lands is a dynamic process. CAP agricultural distribution systems are still under construction. The data base has and will require updating of land classification, GFR certificates, and district boundaries. Access to analog products only is resulting in the continuance of manual methods on the part of APO. Digital data were available, but transfer and continued use by APO was not possible unless APO had an in-house GIS capability.

Pilot Study to Acquire and Handle Data from Contractor

The APO is initiating a pilot study to reduce its dependency on the State's equipment and facilities. Most importantly, the pilot will investigate means to expand upon the existing digital data base to facilitate administration, operation, and maintenance of the CAP. In particular, uses of GIS to administer multiple aspects of the Reclamation Reform Act of 1982 will be examined. The study will (1) develop procedures to transfer digital data and related attributes from the State's ARC/INFO system to the in-house MOSS system; (2) determine the best way to manipulate and expand the data; (3) determine the best way to create final products; and (4) train personnel in the use of the in-house GIS. The pilot system will be housed on a MicroVAX II networked to the on-site VAX cluster. The MOSS system will be evaluated for its ability to:

- handle large vector data sets,

- join features across digital map-sheet boundaries (not currently accommodated by the ARC/INFO system),

- edit and intensify existing digital data as required,

- handle the available multiple attribution, and

- produce final products in a timely manner.

At the same time, strength and weakness comparisons for data collection and integrity will

be noted between the APO and State systems.

CONCLUSIONS

The Bureau of Reclamation Arizona Projects Office has found digital Geographic Information System technology a valuable tool in its management and dissemination of attributed-spatial data. Both managers and engineers have benefited from the initial MOSS installation on the HP-9000 system. APO recognizes that as the dependency on GIS technology increases, cost factors, limitation factors, and short- and long-term goals must be recognized to ensure that the technology remains viable. APO has a keen interest to ensure that the system will continue to provide a feasible solution for its activities, and that a larger user audience gains access to the solution. This interest requires the following abilities:

- to acquire the enormous quantities of appropriate digital data available within other government agencies, State offices, and private industry. These capabilities will provide large time-and-cost benefits so that more emphasis can be applied towards data modeling activities;

- to share data with other MOSS and non-MOSS GIS and CAD systems;

- to provide system-access mechanisms (either with direct program usage or data flow) that are efficient and enticing;

- to broaden the range of the user audience that can interface directly to the technology; and

- to avoid instances of being limited to specific computer host requirements.

To this end, APO has already installed MOSS on their VAX cluster and MicroVAX II. APO has demonstrated the data exchange capabilities onsite depicted in Figure 2. These demonstrations have also shown that APO can lessen its dependence on digital data and products from the State Department of Water Resources. APO will be studying how this may be achieved in the near future.

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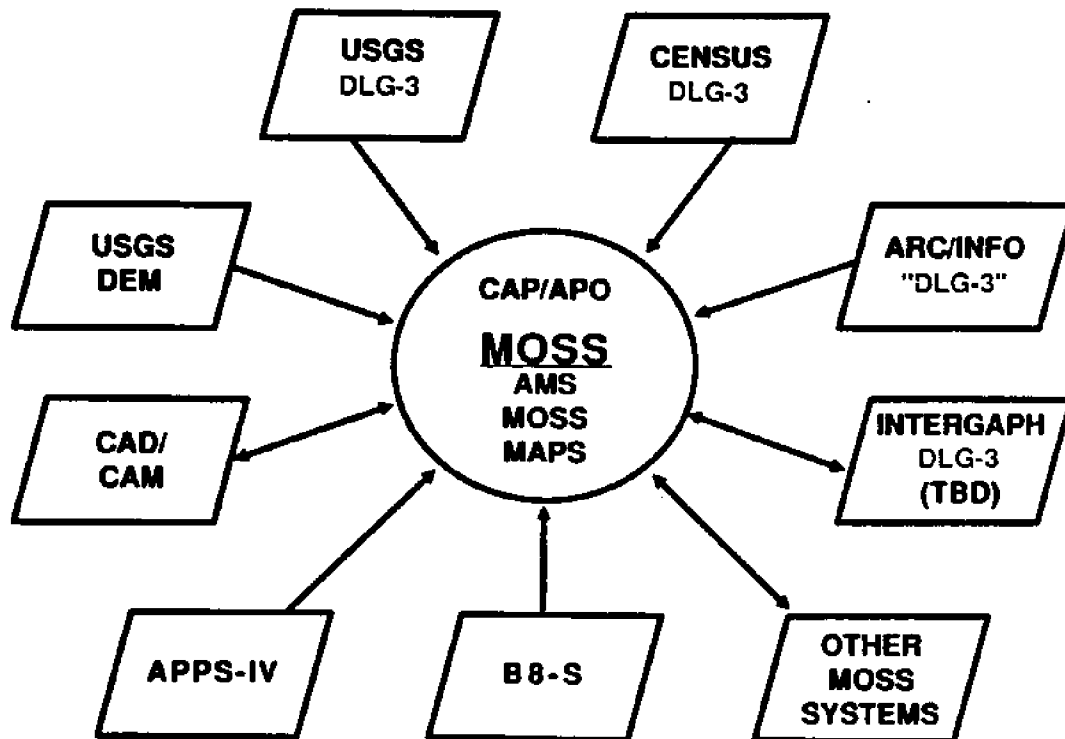   CADD. ENR March 24, 1988.

DATA EXCHANGE CAPABILITIES

Figure 2.

INTEGRATION OF LEGAL LAND RECORDS WITH THE MOSS FAMILY OF GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

The Bureau of Land Management has a valuable resource and a tremendous investment in land, resource, and geographic coordinate data. Because of this, the Bureau must manage this data to ensure efficient access and use for public information purposes as well as for resource allocation decisionmaking.

Currently, the data can be found in many forms and in many locations. To effectively and consistently serve all potential users, the Bureau is in the process of standardizing data collection and making data more readily available. Much of this work requires the use of the MOSS family of software in a Geographic Information System (GIS).

INTRODUCTION

The Bureau of Land Management (BLM) has a valuable resource and a tremendous investment in land, resource, and geographic coordinate data. It is to the benefit of BLM and all other government entities to maintain this data and ensure that all new data collected or acquired from other sources conform to BLM standards for definition and format. All data must be managed to ensure efficient access and use for public information purposes as well as for resource allocation decisionmaking. Many of the resource decisions made will utilize the MOSS family of software in a Geographic Information System (GIS).

Since 1984, the BLM has intensified its land, mineral, and survey data collection efforts in the Western United States. In its endeavor to construct standard data bases, the BLM is creating three data files as base building blocks in each State. These files are legal land description (LLD), status, and geographic coordinates.

Data required for making professional resource allocation decisions exist in many forms in many locations. Some data are stored on paper records, some on "cuff records," and some are automated in a number of incompatible systems. Many data are available for use at a single location only, being

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housed in a desk drawer, on a shelf, or on a personal computer (PC) disk.

To ensure efficient utilization of this data by all personnel, both the BLM and others, there must be a standard format for collection, as well as for storage and retrieval.

LEGAL LAND DESCRIPTION

The Legal Land Description (LLD) or survey data file represents the automation of survey and Master Title Plat land description information, as shown in Attachments A and B. The required information is abstracted to a Bureauwide standard from source documents; coded on a form or keyed into a terminal screen; edited programmatically; corrected as necessary and added to the BLM's Automated Land and Mineral Record System (ALMRS). The data base is stored on State Honeywell Level-6's and the Service Center Honeywell DPS 8/70. The following states have completed their LLD collection phase and have begun editing and updating procedures: Arizona, New Mexico, Utah, Nevada, Idaho, Wyoming, Montana, Oklahoma, California, and Oregon. Colorado, Nebraska, Kansas, North Dakota, and South Dakota should complete the survey data collection within the next year.

No decision has yet been made on collecting LLD for the Eastern States Office. States

involved are those adjoining or east of the Mississippi River. Alaska will begin collecting survey data in the very near future and should be finished within the next 2 or 3 years. LLD data will not be available to other agencies or the general public until all editing processes are completed.

STATUS

The second data file consists of land and mineral ownership data identified as Status. Status is defined as ownership of any land, and/or rights therein, that have been transferred to or from the United States. This file represents the automation of land and mineral ownership information as portrayed on the Master Title Plat, Attachment B. The data in the status file are variable depending on the type of transfer, such as mineral patent or a homestead patent. Due to the variation in the types of data, the span of years over which the data are collected (over 100 years), and the complexities that vary in each State, the collection standards are being developed continually. There is a set of standards which addresses examples of most records. As anomalies in the records are discovered, a team of knowledgeable BLM personnel establishes additional standards as necessary.

Arizona, New Mexico, and Montana have completed their Status collection phase and have begun editing and updating procedures. The following

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states should complete Status collection as noted:

Nevada	Late 1988
Utah	Late 1988
North Dakota	Late 1989
South Dakota	Late 1989
Colorado	Mid 1990
Wyoming	Early 1990
Idaho	Late 1991
California	Late 1991
Oregon	Late 1991

Status collection for Eastern States may be funded as a Special Act of Congress or from Project Funds. Methodology of collection will be similar to that done for the rest of the Bureau; a starting date has not been established.

Alaska has an existing automated system, known as Alaska Automated Land and Mineral Record System (AALMRS), consisting of land and mineral ownership and use data, as well as mining claim recordation information.

GEOGRAPHIC COORDINATES

The geographic coordinate data base (GCDB) is used to produce graphics products similar to those with which the users are familiar (master title plats, special use plats, etc.). It is a critical element in registering records accurately to points on the ground. The GCDB provides the mechanism for linking land records information to resource information.

The Rectangular Land Net is the base level of survey for the United States: all ownership and use are recorded using this basic network. These data are important because two centuries of data have been recorded using this basic network. The BLM has determined the required standards and procedures for data collection. The BLM has the capability to quickly prepare the necessary software for Rectangular Land Net data collections.

An empirical methodology will be used to develop efficient methods for Special Surveys and rights-of-way data collection. The accuracy of metes-and-bounds coordinates will be determined by mapping needs for managers of both surface and subsurface lands.

The Service Center is responsible for GCDB developmental activities. The New Mexico State Office has begun to test and evaluate the procedures of collection of the statewide Rectangular Land Net and special surveys and rights-of-way for one BLM District Office. Geographic coordinate data will then be collected in the remaining states by contract, in-house, or a combination of methods, depending on the results of the New Mexico State Office efforts.

For lands of low economic or management value, mapping requirements will be satisfied by digitizing coordinates for the Land Net. Where high economic land values and potential management conflicts exist, precise coordinates from reliable Cadastral surveys, where available, and coordinates calculated using proper adjustments will be required.

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Each BLM State Office is responsible for inventorying and analyzing its requirements based on established standards and BLM requirements.

MATCH AND MERGE

New Mexico and Arizona have begun merging the LLD and Status files, forming one file with validated survey descriptions with survey and ownership data attributes to specific land parcels. The surveyed parcel with a standard legal description becomes an exchangeable or data-sharing commodity that may be exported to other systems with format/read capabilities. In addition, the Bureau will, within the next 6-12 months, merge the LLD and Status files with two other data systems currently in active use Bureauwide: (1) the Case Recordation System that tracks land and mineral use and transfer data, such as rights-of-way, oil and gas leases, and current land sales and exchanges, and (2) the Mining Claim Recordation System that tracks historical and active mining claim activities to the quarter section level (being within a 160-acre quadrant).

DATA EXCHANGE

The availability of current land and mineral use and ownership data can be effective in reducing data storage and retrieval needs in other systems, especially those in the GIS family. Additionally,

the adoption of standardized data will facilitate the data exchange and sharing among other Federal agencies, as well as, non-Federal entities.

Over the next six months, the BLM will be participating with the U.S. Geological Survey (USGS) and other Federal agencies to test the newly developed SDTS (Spatial Data Transfer Specifications) standards. The ALMRS-GIS Project Office in Denver, CO, will be preparing data sets consisting of land and mineral use and ownership data, coordinates, and specific resource themes such as hydrology, wildlife habitat, and/or soils mapping, using the Automated Digitizing System (ADS). The ADS data will then be converted to SDTS and tested. The testing procedures and documentation will be provided at a workshop to be held in Denver the first week of June 1988. The workshop is open to all members of the standards working group of the Interior Digital Cartographic Coordinating Committee (IDCCC). Testing results are to be forwarded through USGS for preparation of the standards document and its submission to the National Bureau of Standards in January 1989.

SUMMARY STATEMENT

We in the BLM have come to appreciate the value of national data standards in the context of a national automated system that serves Federal, other governmental, and public/private users in a consistent and efficient manner. Over the

next few years, this community of users must make every effort to establish common data standards and exchange formats.
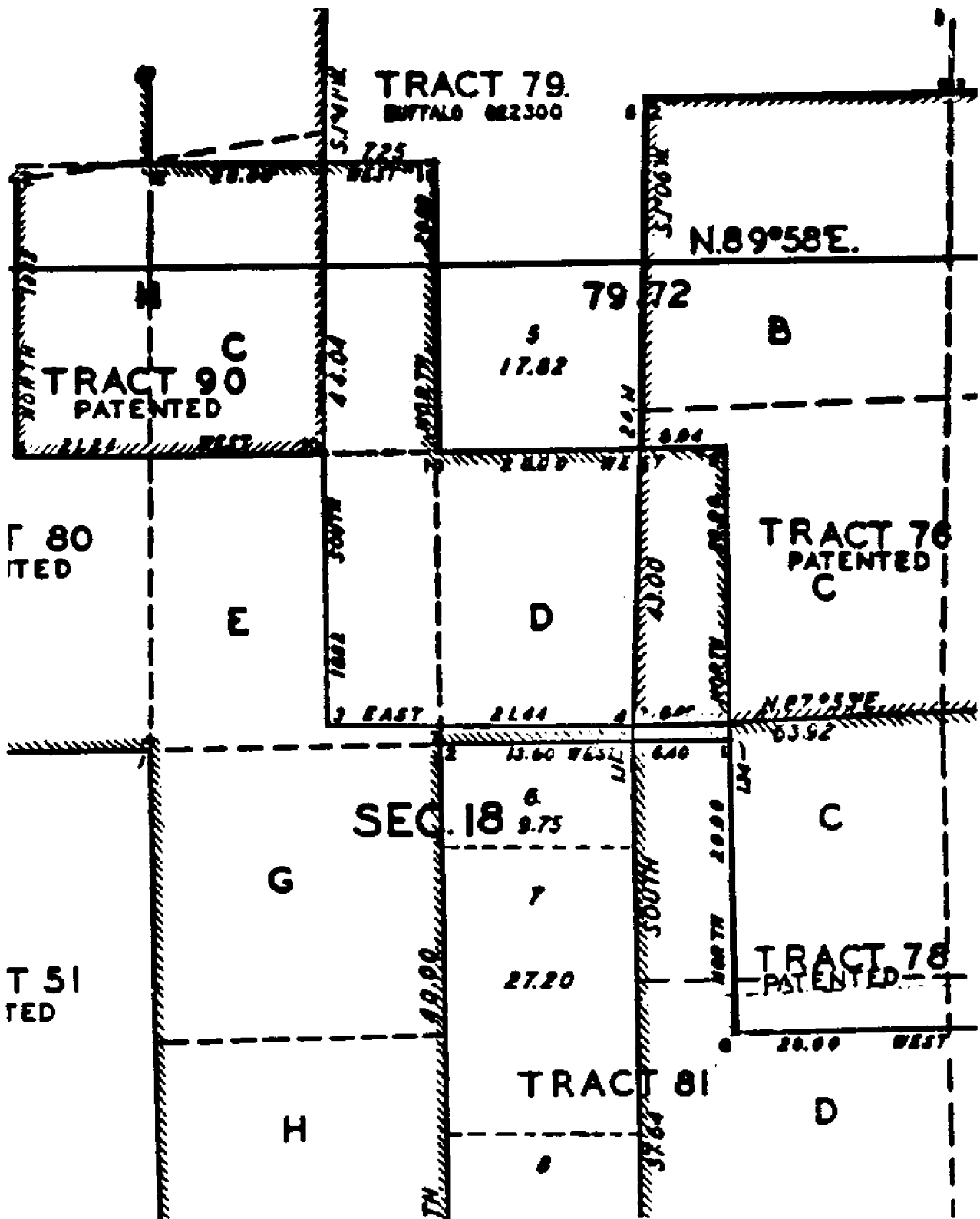
Attachment A. Survey plat.
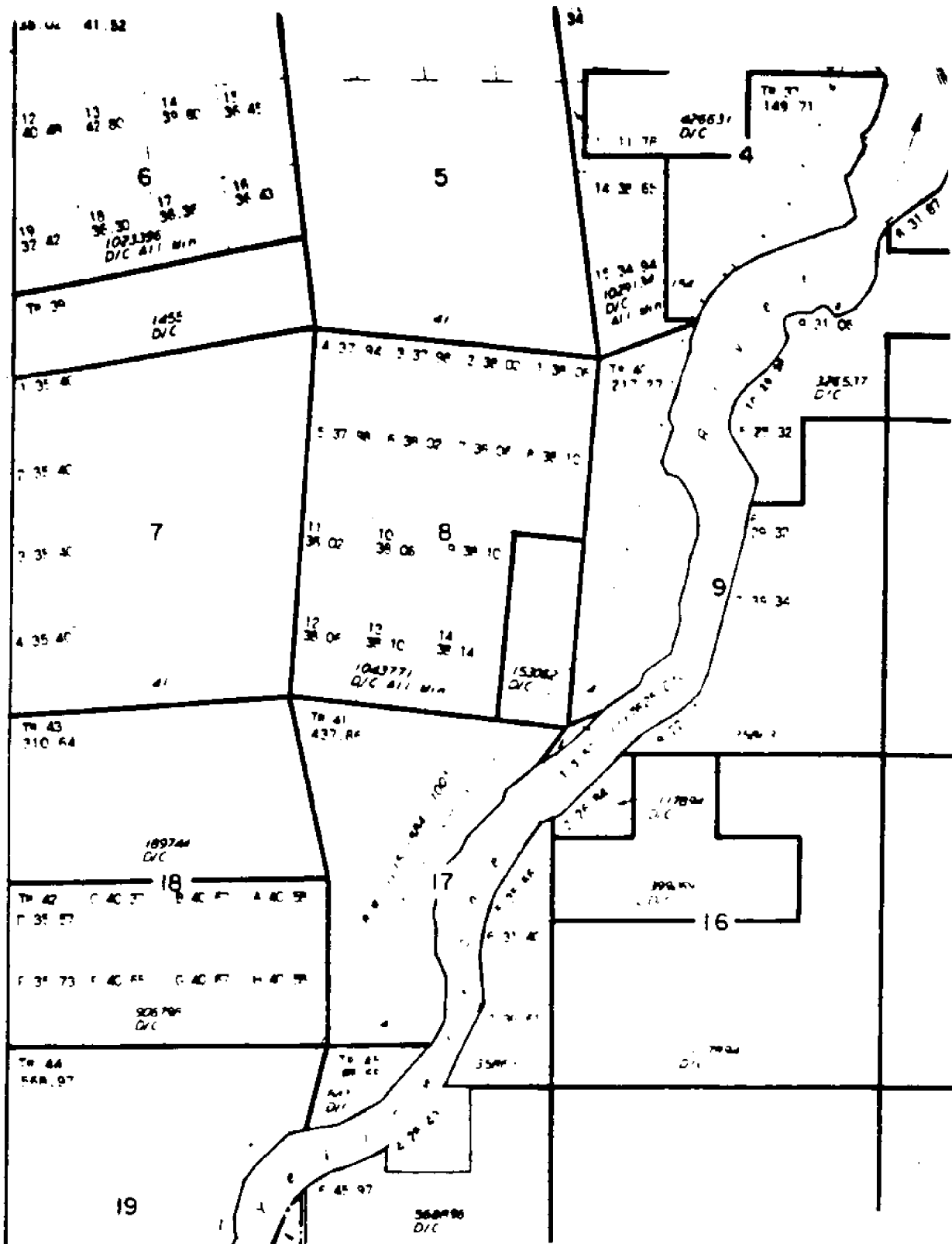
Attachment B. Master title plat.

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Using Geographic Information Systems
to
Determine Coal Volumes

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ABSTRACT

The management of the Nation's coal has become more efficient through the use of an automated Land Information System (LIS). The Bureau of Land Management (BLM) maintains a vast record system of public land survey information, including a data base for coal exploration and developmental drilling. The data base integrates location, stratigraphic, and analytical information; BLM geologists and mining engineers then use MOSS to evaluate coal resources on the Federal lands. Using the automated system has saved much time and expense over the manual methods of data compilation.

INTRODUCTION

The management of the Nation's coal must be compatible with the needs and ambitions of the American public. As the demands of society become more complicated, so do the needs of the managers. Implementing an automated Land Information System (LIS) can increase access to coal data providing a more competent use of natural resources and more responsible and efficient decisionmaking. The Bureau of Land Management (BLM) maintains a vast record system including public land survey information, Federal land and mineral records, and natural resource data which allows BLM to manage, lease, and protect public lands. With the advent of computer technology, BLM has begun automating its data and moving away from paper-and-mylar media.

According to the Department of Energy, Wyoming is the second largest coal producing state in the Nation--trailing only Kentucky. Coal production throughout the United States totaled 888.2 million tons in 1986. Wyoming produced 15.2%, or 135.2 million tons, of this coal while Kentucky produced 18.2%.

In 1987 an estimated 142.6 million tons of coal were taken from Wyoming coal mines. "A modest increase in coal production in the State of Wyoming should continue for a few years. Wyoming will produce 150 million tons by 1989" (Richard Jones; Wyoming Geological Survey; pers. comm.). To determine what coal was economical to mine, an evaluation

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was conducted on the tract or lease areas. Consequently, a data base management system for coal exploration and developmental drilling data gathered by Government agencies and private industry was established. The data base system integrates location, stratigraphic, and analytical information into a relational data base for use by BLM geologists and mining engineers. Using the data base system and Map Overlay and Statistical System (MOSS), ecologists and mining engineers can evaluate coal resources on Federal lands. The use of automation, compared to manual methods, no doubt has saved considerable time.

TECHNOLOGY

The data base for the drill holes can be established by using the Coal Drill Hole Data Base System (COALSYS), version 2.0, developed by Bruce Keating, LIS Coordinator; Vern Rulli, mining engineer; and Gene Rosenlund, contractor from Gallegos Research Group. The drill hole log information is entered into the COALSYS format using a personal computer (PC). In this environment, it can be manipulated and prepared for transfer to a mainframe computer. The mainframe in this instance is a Prime computer system. In the ideal situation, the COALSYS software would already be on the Prime to be used to create the data base; at a later date at the Wyoming State office, this will actually occur. There are several packages available

which allow the transfer of data from PC to mainframe, such as Softerm software, which is used to transfer data from a Compaq microcomputer to the Prime minicomputer system.

Before transferring the data to the Prime, an area must be established on the Prime for the master and work files to reside. The master files contain the base maps showing the area, location of leases, and surface and subsurface ownership. The work files are generated when the master files are manipulated (e.g., merge, overlay, and imported drill holes). While the log files are being prepared, a data base must be established using the Automated Digitizing System (ADS). A project area is established on the Prime under ADSDATA. For example, if the lease area is named Coyote Draw, the ADS project would be Coyote. The path name would then read <DATA1>ADSDATA> COYOTE. The lease area outlined on a USGS 7.5-minute quad would include using a one-mile buffer established around the tract or lease area itself. The buffer area can be greater, but never less, than one mile. The data base should include landnet, ownership, and lease boundaries for the area in question. At this time, any surface restrictions should be established and digitized to build the base. To establish the landnet base, the most current survey plats are reviewed and compared to the USGS quads. The most current survey plats are used to maintain control. If the information is available in a latitude/longitude format

derived from satellite locational technology, this data should be used. The satellite data will give the best absolute control to the earth's surface. The landnet is considered the most important data base because it gives a spatial location to the earth's surface. Once the landnet is digitized under the landnet theme, the lease boundary can be digitized under the lease boundary theme. When a new overlay or boundary is identified, a theme matching that boundary must be entered.

Once an area has been identified and the data base digitized, the information is transferred to the MOSS environment, which creates a project directory coinciding with the ADS project name. The path name in MOSS for the example project, COYOTE, would be <DATA2>MOSSDATA>COYOTE. Using the Softerm software, COALSYS files are transferred to the Prime, and enter the work directory, e.g., <USER1>PATRICK>MOSCOYOTE.

The following steps start a user into MOSS on the Prime computer:

1. login
2. password
3. attach to MOSS work area, e.g., A GRETCHEN MOSCOYOTE
4. (type) MOSS (project name) COYOTE (user name) GRETCHEN
5. ENTER COMMAND ? OPEN (.DT file) COYOTE.DT
6. ENTER COMMAND ? LIST MAPS

Entering the command LIST MAPS results in a complete listing of maps in the master file and the work file area. The next step is to import the data files from COALSYS, using the IMPORT command, so they can be accessed in MOSS. Note that working through the commands requires renaming the files several times; thus, it is wise to keep a log of all names associated with a project and their meanings. Important information should be added to the header when importing information into MOSS. Do not default through the header. Import example:

ENTER COMMAND
?IMPORT DHLCPMO1
WHAT DO YOU WISH TO CALL THE NEW MAP?

IM.DHLCPMO1
ENTER NAME OF MAP TO USE AS TEMPLATE FOR THE NEW MAP HEADER OR ENTER CARRIAGE RETURN TO START MAP HEADER FROM SCRATCH

The user can prompt through the menu and answer the header information. At the prompt, "ENTER NUMBER OF SUBJECTS ( )," enter a number equal or greater than the number in the original file.

When the file is imported, the file itself resides in the work directory. However, if a file listing is asked for, the name is shown under the master file.

The imported file is in State Plane Feet and must be changed to State Plane Meters by running the PROJECTION command. A file must be active before the map projection command can be run; selecting the file will

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make it active. An example of use of PROJECTION is

```
ENTER COMMAND
?PROJECTION (ACTIVE ID)
WHAT DO YOU WISH TO CALL THE
NEW MAP?
---------------
```

The list of menu-driven questions is self-explanatory. (Beware if using the PROJECTION command to transfer into latitude and longitude. The longitude entry must be a negative number for the Western Hemisphere.)

After the file has been transferred and projected to State Plane Meters, it can be selected and plotted to check for location and any data irregularities. After the location of the data has been checked and corrected, other files may be transferred in a batch routine to save time. The following files could make up a coal data base file:

1. drill hole location map
2. drill hole data base sequence (Figure 1)
3. lithofacies file
4. structure contour file, surface (Figure 2)
5. structure contour file
6. coal isopach map file (map can be generated in either COALSYS or MOSS) (Figure 3)
7. isochemical file
   a. BTU/pound (Figure 4)
   b. ash
   c. sulfur

To use the map analysis package MAPS, the imported maps must be rasterized (cell data). Data in raster format allows one structure to be subtracted from the next, which creates an isopach and contour structure maps. The first step to rasterize data is map selection:

```
ENTER COMMAND
?SELECT PRSTCN58 ALL (top of
   the first seam)

ENTER COMMAND
?SELECT PRSTCN59 ALL (bottom
   of the first seam)

ENTER COMMAND
?GRID (active ID) 1
   (newmapname) GRSTCN58

ENTER COMMAND
?GRID (active ID) 2
   (newmapname) GRSTCN59

ENTER ONE OF THE FOLLOWING
GRIDDING OPTIONS
   1=EXIT FROM GRID
   2=FOR A 4-POINT/QUADRANT
     WEIGHTED AVERAGE
   3=FOR AN 8-POINT WEIGHTED
     AVERAGE
   4=FOR SIMPLE OR UNIVERSAL
     KRIGGING
   5=FOR QUINTIC SPLINE
     INTERPOLATION
```

It is important to understand the gridding option selected in reference to the drill hole formation. Experience has shown that option number 5 is best for evaluating numerous holes and option number 2 is best for evaluating a few holes. The user should first test each option to become acquainted with each one:

```
?2
ENTER MASKING FILE NAME
(CR=NONE)
?(CR)
ENTER SCALE VALUE FOR DATA
(CR=1.0)
?(CR)
ENTER DESCRIPTION
```
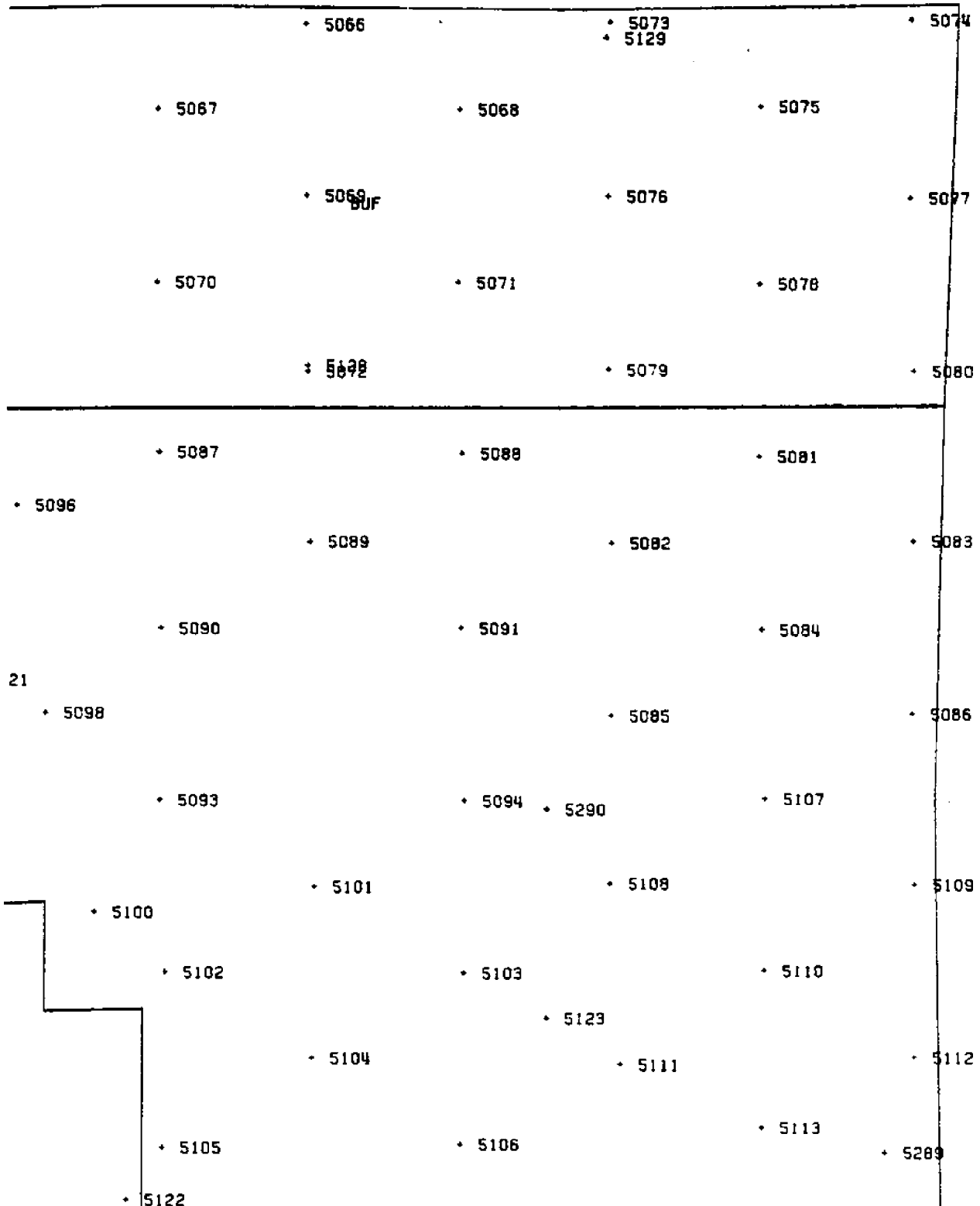
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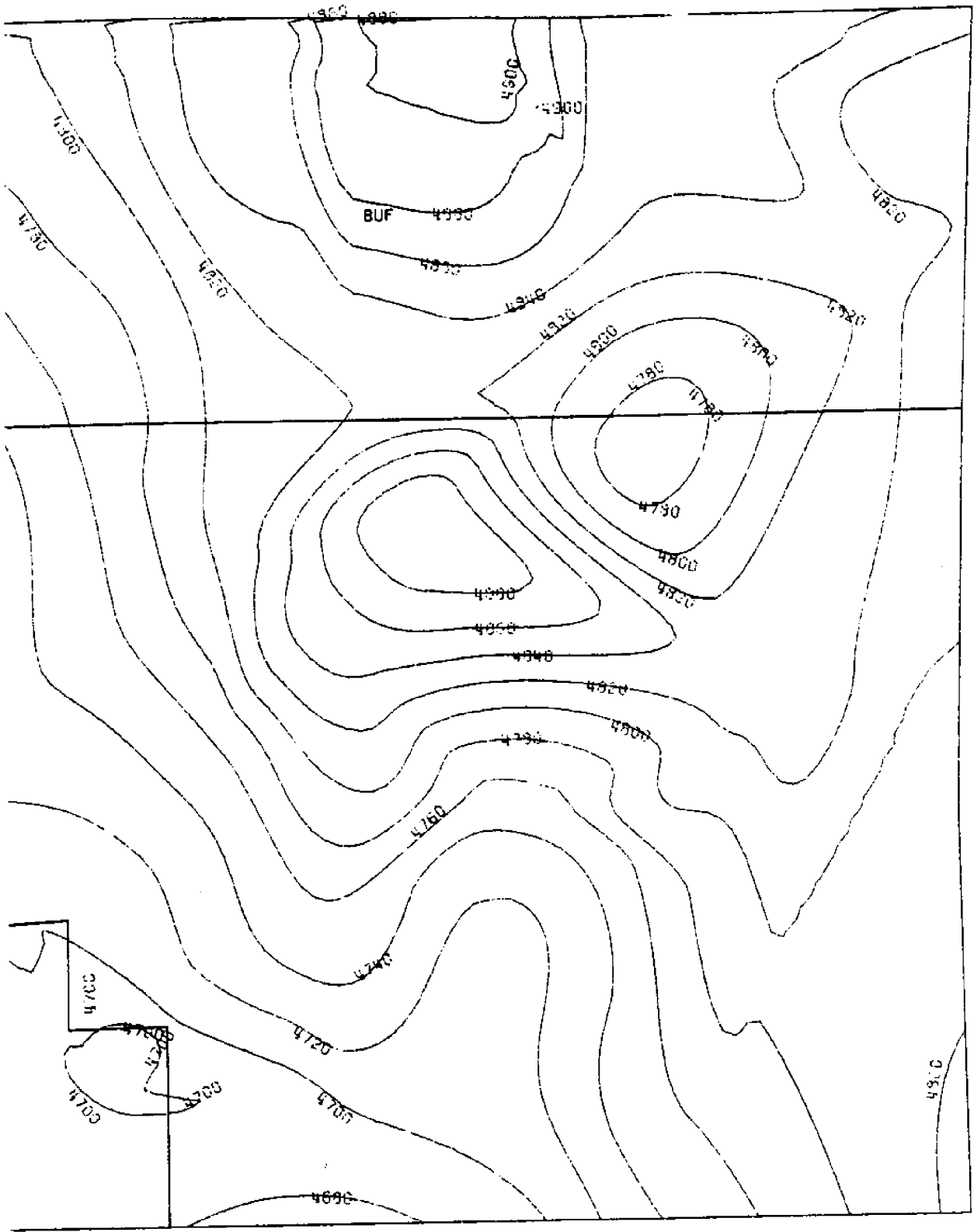Figure 1. Data base sequence number map.

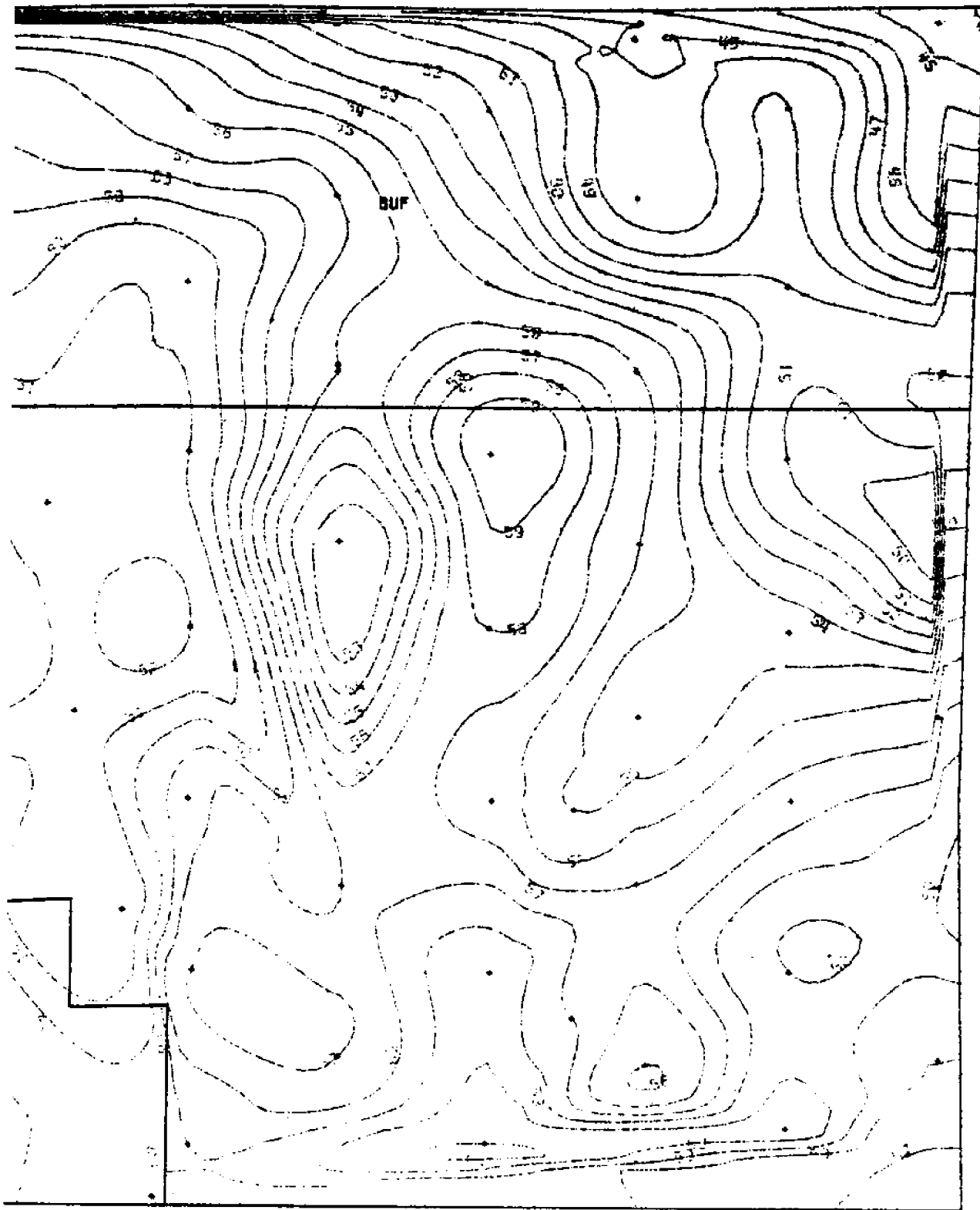Figure 2.   Topographic contour map.   Contour interval = 20 feet.
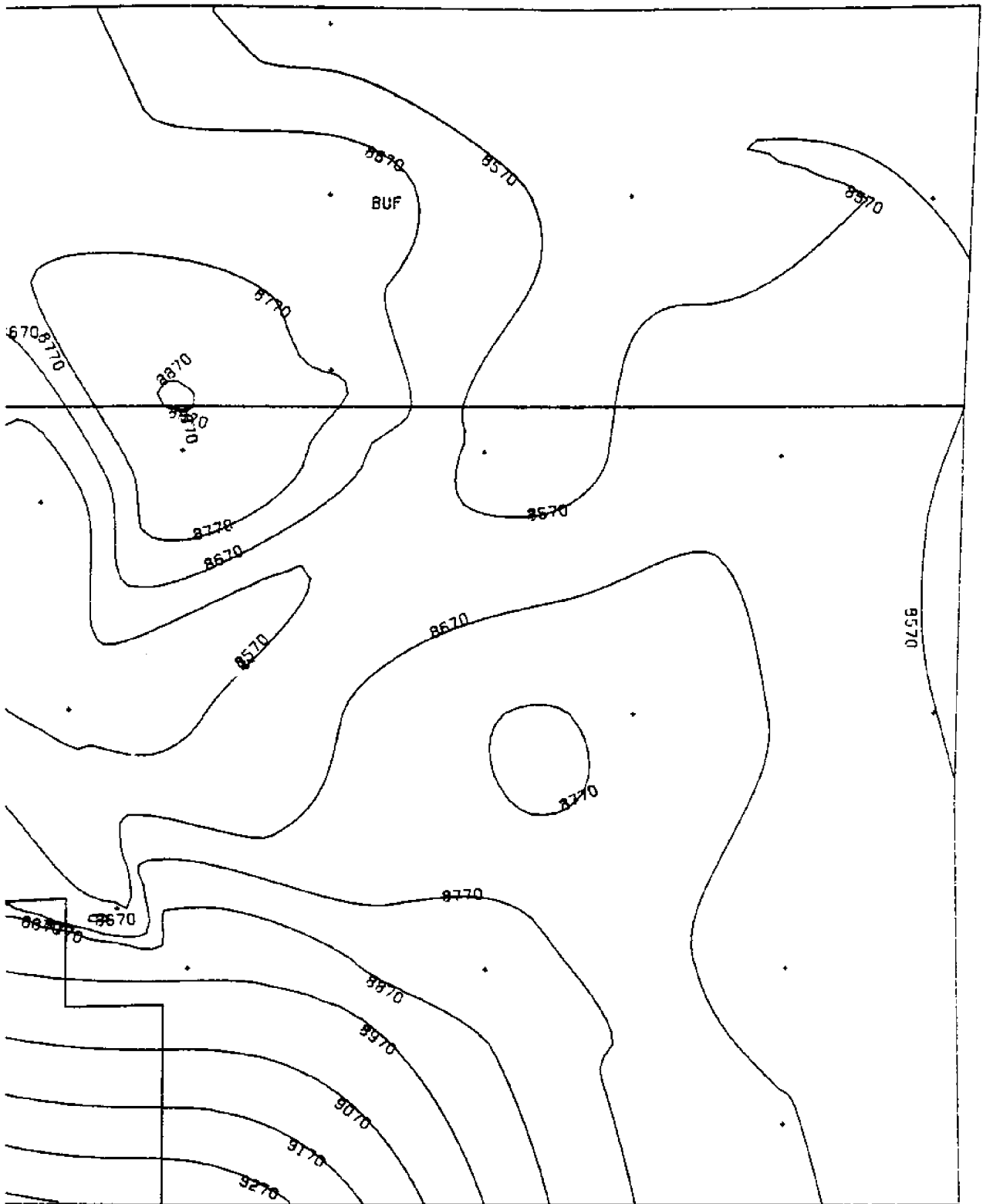
Figure 3.   Isopach map.   Contour interval = 1 foot.

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Figure 4. As received BTU/lb within the combined coal beds.
Contour interval = 100 BTU/lb.

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?SEAM NUMBER ONE TOP
ENTER (A)CRES OR (M)ETERS ON
A SIDE
?M (always enter meters)
ENTER HEIGHT
?80 (Cell size may vary
depending on user preference;
however, 80 has been found to
be the most useful.)
ENTER WIDTH
?80 (must match height)

The maps can be used to
determine overburden, after
being gridded to 80 by 80 if a
Digital Elevation Map (DEM) is
available. The standard DEM
size, 30 by 30 meter cell, has
to be resampled (Resampling
consists of changing all cell
sizes of one value to another
value) by running MAPS. The
DEM is then imported into MAPS
using the import command:

ENTER COMMAND
?MAPS
?IMPORT demname FORMAT DEM
TYPE 8 FOR imdemname
?RESAMPLE imdemname FOR
newmap SIZE 80

A lease area mask should be
prepared using surface data
base maps before any calcula-
tions are done. Other masks
may be built depending on
restrictions.

To build a mask, access MOSS
and select the base maps
containing the lease. Merge
all quads containing the lease
area. The command POLYCELL
will generate a grid map for
the surface mask. An example
is:
?SELECT mapname ALL
?ENTER newmapname
?ENTER cell size in meters 80
?ENTER CELL MAP TYPE OPTION
   1=DICHOTOMOUS (TYPE 6)

   2=DISCRETE (TYPE 7)
   3=CONTINUOUS (TYPE 8)
   select type 7
?ENTER CELL VALUE
ASSIGNMENT OPTION
   1=TERMINATE   POLYCELL
   PROCESS
   2=SUBJECT ASSIGNMENT
   3=ITEM (FEATURE) NUMBER
     ASSIGNMENT
   4=USER   RECODE   SUBJECT
     ASSIGNMENT
   5=MULTIPLE   ATTRIBUTE
     ASSIGNMENT
   select 2
EXECUTING....PLEASE WAIT

Once the data base has been
polycelled, and the different
layers have been gridded, they
are ready to be analyzed in
MAPS. Several options can be
taken at this point; the soft-
ware can either perform all or
the majority of the work. When
using MOSS, the MAPS command
will generate all data in the
raster format. The respective
layers are subtracted from each
other to form the coal
thickness or the overburden/
interburden. To determine
overburden, subtract the top
seam layer from the resampled
DEM (Figure 5).

   Example
   (The enter command prompt
   will not appear; while in
   MAPS only the ? will appear.)
   ?MATH demname - PRSTCN58 FOR
   overburdenname

Other calculations may be
performed in MAPS to determine
coal seam thickness, inter-
burden between coal seams, and
overburden combined with
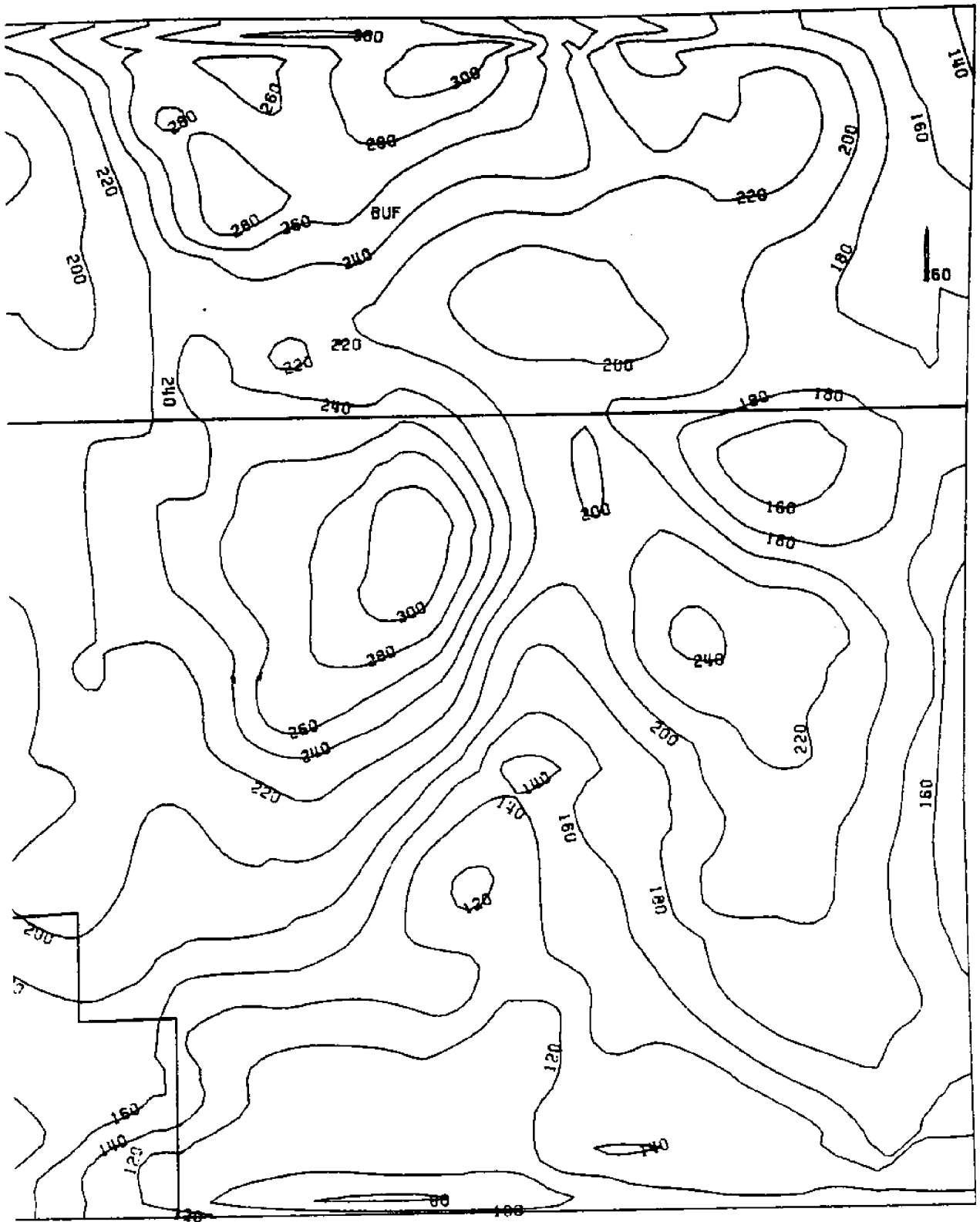interburden.

The command to subtract cell
maps is also in the MATH

Figure 5. Overburden isopach map for the combined coal beds.

command. Note that the rows and columns must be identical when running this command, and cell sizes must be identical or the command will not work. The coal ratio overlay is determined by dividing the overburden/interburden by coal seam thickness (Figure 6). After the layers have been calculated to determine thickness, the contours or isopach overlays can be generated in MOSS. While in MAPS, the command BYE is used to return to MOSS.

The maps developed in MAPS are then selected in MOSS, and the command CONTOUR is run to show contour lines. Depending on need or usage, some of the lines may extend beyond the area of interest. These extended lines can be deleted using the LPOVERLAY command. Different chemical layers and burn areas can be contoured after they have been gridded in MOSS. After the isopachs, isochemical files, and lithoface maps have been contoured, they can be sent to a plotter by running the GENPLOT command at the desired scale. The scale is limited only by the plotter size. After plotting the separate layers, the ecologist can overlay the maps to determine the outer limits of the coal reserve. The geologist can also overlay plots of different coal limitations and construct his own limitations within the seams. The completed information is digitized in ADS and then polycelled in MOSS. This will be the masked or windowed area to be used to calculate coal volume. To calculate the coal volume, the

command TOTAL is used in MAPS (Figure 8):

?TOTAL SEAM4849A FACTOR 1745 BY COALBNDA LABEL TONS FOR LPT
(or to get just thickness),
?TOTAL SEAM4849A BY COALBNDA FOR LPT

When all analyses are completed and the report is compiled (Figures 9, 10, 11), the information can be exported graphically in MOSS or by the Cartographic Output System (COS) (Figures 12 and 13), enabling the user to produce the report with high quality graphic maps.

We have proved that we can save nearly two years in workmonths by using COALSYS and MOSS on a lease area covered with over 1,600 drill holes. Several comparisons have been made using manual techniques and other automation systems. MOSS was either equal to or better than the manual methods in handling large data files. The system does work. The goal now is to get people trained to use the software and thus replace the painstaking process of manual data compilation. A geologist at BLM recently said that a geologist can now be an ecologist instead of a highly paid draftsperson; more time can be spent making decisions on important issues, developing different scenarios, and preparing a more concise report. We plan to improve the system further by moving the coal drill hole data base to the Prime computer in order to handle larger data sets and improve user capabilities. The user will need to research the
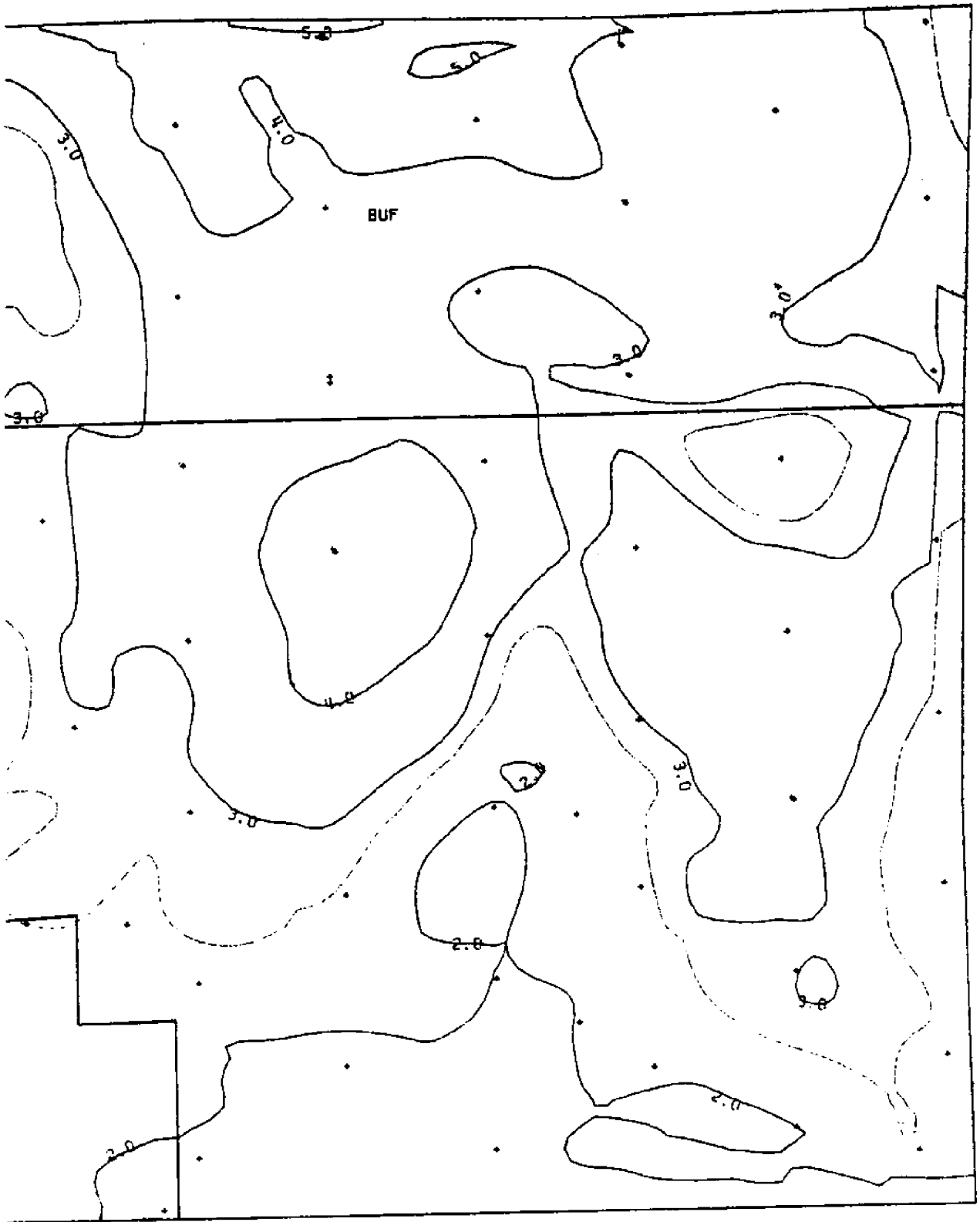
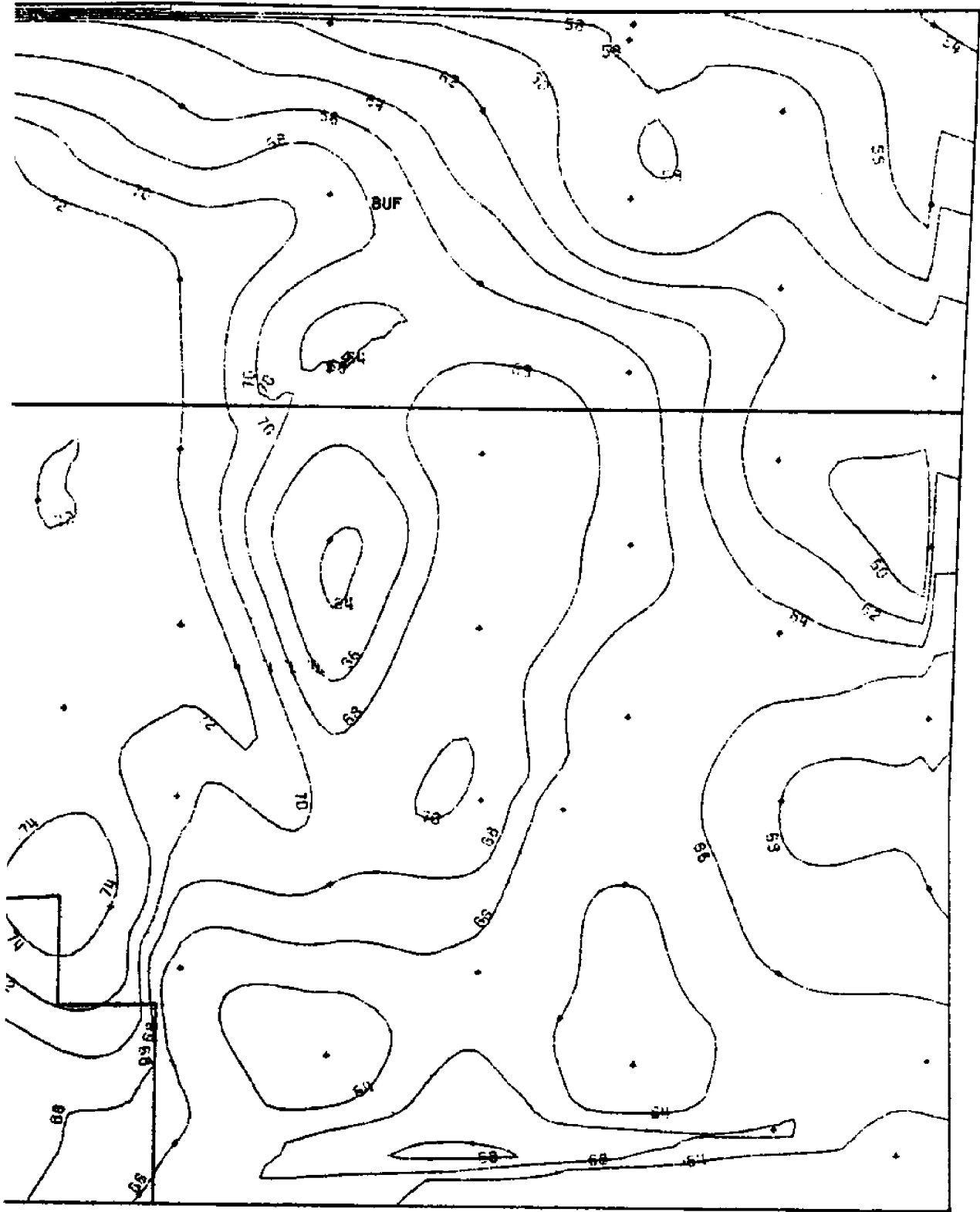Figure 6. Stripping ratio map for the combined coal beds.

Figure 7. Isopach map of the combined coal beds.
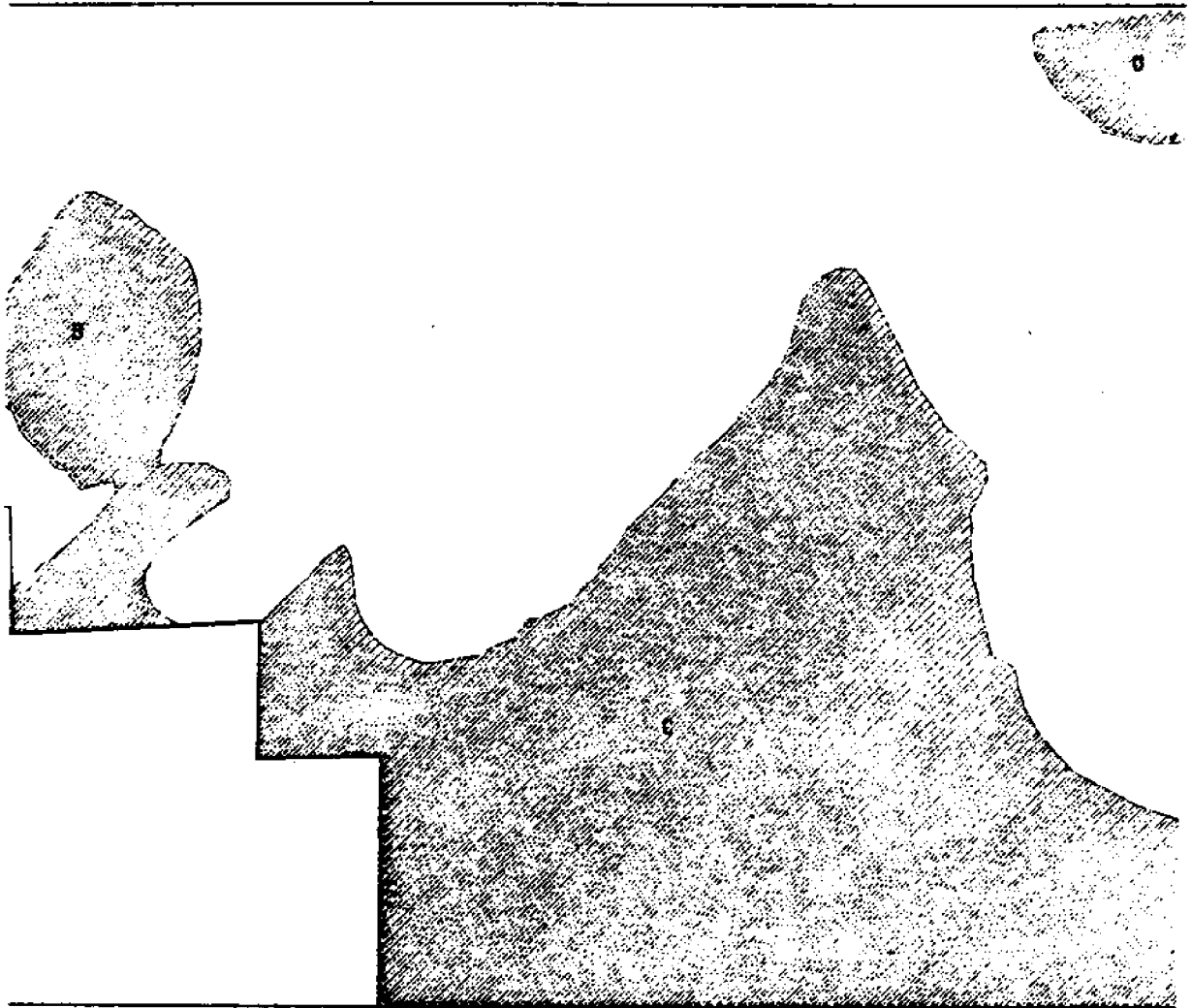Contour interval = 2.0 feet.

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Figure 8.   Areas underlaid by coal reserves.

Coal Tract

Area Summary for Coal Polygons Overlaying Coal Reserves within the Combined Seam 1 and Seam 2 Coal Beds

Vector Calculated Areas

SUBJECTS	AREA (acres)	FREQUENCY
A	167.30	1
B	167.60	1
C	1207.20	1
D	52.00	1

Raster Calculated Areas, Tonnage, and Average Thickness
(50 x 50 meter cell data)

SUBJECTS	TOTAL	FREQUENCY	ACRES	TONS*	AV. THICKNESS
A	19752	267	165	21.292	73.977
B	19802	275	170	21.346	72.006
C	131808	2002	1237	142.088	65.838
D	5123	83	51	5.523	61.725

* Multiply by 1,000,000 for actual tonnage

Manual Tonnage Calculations for Coal Reserves within the Combined Seam 1 and Seam 2 Coal Beds
(Open Pit Methods Assumed)

SUBJECTS	VECTOR AREA (acres)	AV. THICKNESS (feet)	CONV. FACTOR (tons/acre foot)	TONS
A	167.30	73.977	1745	21,596,734
B	167.60	72.006	1745	21,059,017
C	1207.20	65.838	1745	138,691,950
D	52.00	61.725	1745	5,600,927

Figure 9.

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Coyote Coal Tract
Area Summary for Coal Reserves beneath
State and Federal Land
Seam 1 and Seam 2 Coal Beds
(Open Pit Methods Assumed)

Vector Calculated Areas

SUBJECTS	AREA (acres)	FREQUENCY
A SSZZZX	167.35	1
B PPZZZX	11.58	1

Raster Calculated Areas, Tonnage, and Average Thickness
(50 x 50 meter cell data)

SUBJECTS	TOTAL	FREQUENCY	ACRES	TONS*	AV. THICKNESS
A SSZZZX	19830	268	166	21.377	73.992
B PPZZZX	1517	21	13	1.635	72.235

* Multiply by 1,000,000 for actual tonnage

Manual Tonnage Calculations for Coal Reserves beneath
State and Federal Land
Seam 1 and Seam 2 Coal Beds
(Open Pit Methods Assumed)

SUBJECTS	VECTOR AREA (acres)	AV. THICKNESS (feet)	CONV. FACTOR (tons/acre foot)	TONS
A SSZZZX	167.35	73.992	1745	21,607,568
B PPZZZX	11.58	72.235	1745	1,459,660

Figure 10.

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Coal Tract
Area Summary for Coal Reserves beneath
Areas of Adequate Soil Coverage
Seam 1 and Seam 2 Coal Beds
(Open Pit Methods Assumed)

Vector Calculated Areas

SUBJECTS	AREA (acres)	FREQUENCY
SOILA	55.81	1
SOILB	97.51	1
SOILC	891.24	1
SOILD	37.53	1

Raster Calculated Areas, Tonnage, and Average Thickness
(50 x 50 meter cell data)

SUBJECTS	TOTAL	FREQUENCY	ACRES	TONS*	AV. THICKNESS
SOILA	6560	92	57	7.071	71.302
SOILB	11525	160	99	12.423	72.028
SOILC	95376	1482	916	104.970	65.706
SOILD	3673	60	37	3.959	61.222

* Multiply by 1,000,000 for actual tonnage

Manual Tonnage Calculations for Coal Reserves beneath
Areas of Adequate Soil Coverage
Seam 1 and Seam 2 Coal Beds
(Open Pit Methods Assumed)

SUBJECTS	VECTOR AREA (acres)	AV. THICKNESS (feet)	CONV. FACTOR (tons/acre foot)	TONS
SOILA	55.81	71.302	1745	6,945,744
B	97.51	72.028	1745	12,255,920
C	891.24	65.706	1745	102,186,870
D	37.53	61.222	1745	4,009,419

Figure 11.

MOSS manual to develop other GIS/LIS techniques to determine coal seam thickness and coal isopachs using GIS.

Q. What plotter do you use?
A. Comp 1073.

SURFACE/MINERAL MANAGEMENT STATUS
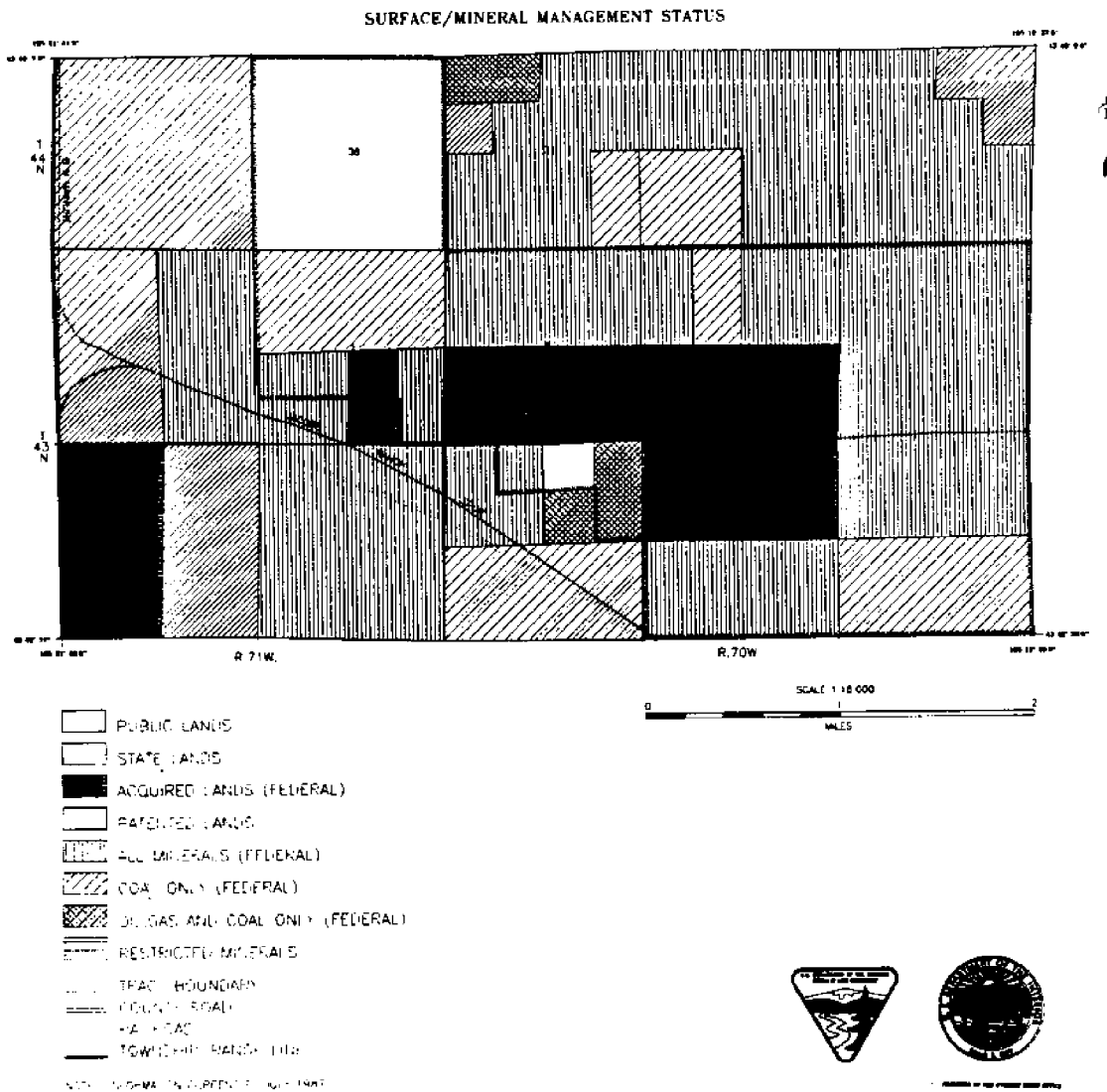

Figure 12.

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CULTURE/SURFACE MANAGEMENT DATA
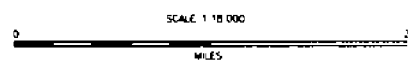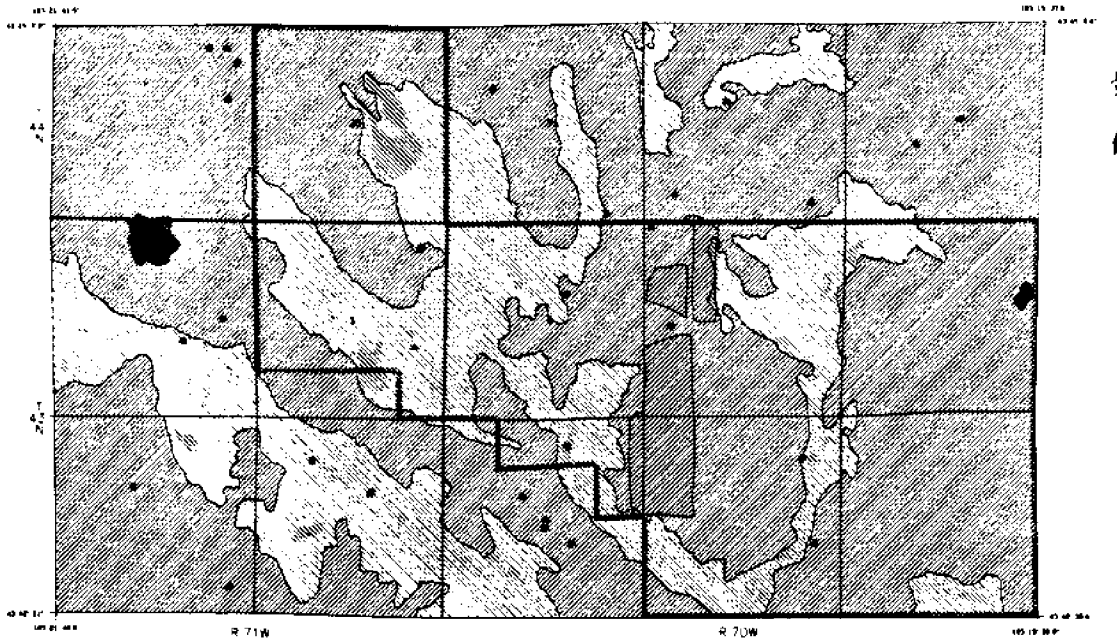
RESERVOIR/DRAINAGE

ADEQUATE QUALITY TOP SOIL (FAIR AND GOOD)

POOR QUALITY TOP SOIL FOR RECLAMATION

CROP (AGRICULTURAL)

LARGE HISTORIC/PREHISTORIC SITE

▲   SMALL HISTORIC/PREHISTORIC SITE
•   WATER WELL
○   KESTREL HAWK
•   FERRUGINOUS HAWK
•   BURROWING OWL
    TRACT BOUNDARY
    TOWNSHIP/RANGE LINE

Figure 13.

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SESSION III

Application of GIS Technologies to Natural Resource Management in the Gulf of Mexico Region

Moderated by: James B. Johnston
U.S. Fish and Wildlife Service

USE OF GIS TECHNOLOGIES IN ADDRESSING RESOURCE MANAGEMENT PROBLEMS IN MOBILE BAY, ALABAMA

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ABSTRACT

Geographic Information Systems (GIS) technologies are being used in three natural resource management studies of Mobile Bay, AL. Each study is briefly discussed. In the first, the GIS was used to analyze wetland habitat changes in the bay over a 25-year period. In the second, cartographic modeling techniques are being used to assess the potential impacts of contaminated sediments on selected resources in the bay. In the third, the GIS is part of a landscape level analysis of cumulative impacts in the bay. GIS applications can provide a spatial dimension to ecological problem-solving and a powerful tool for environmental planning and decisionmaking.

INTRODUCTION

Mobile Bay and its natural resources provide a large portion of the economic base of surrounding Mobile and Baldwin Counties. As such, the Bay is the site of many competing demands from its user groups, including those involved in shipping and commerce, tourism and recreation, fish and shellfishing, oil and gas development, and National defense. Resource managers must balance these conflicting demands and plan and implement policies and programs which maintain the natural values and living resources of the bay without compromising the economic well-being of the surrounding communities. Computer Geographic Information Systems (GIS) provide a powerful tool for spatially characterizing the resources present and planning potential management actions.

In this paper, we report on three applications of GIS technologies to managing the resources of the Bay: (1) an analysis of wetland changes in the bay over about a 25-year period from 1955-79, (2) a cartographically-based risk assessment of the potential impacts of contaminated sediments on selected bay resources, and (3) an analysis of cumulative impacts in the bay and the development of a management plan to address those impacts. We discuss the

strengths and weaknesses in each application, and we present some general ideas about future applications.

APPLICATIONS

Wetland Changes in Mobile Bay

Wetland habitats are critical for the growth and survival of almost all of the commercially and recreationally important fish and shellfish harvested from the bay. The pressures to convert wetlands to other land uses is intense both nationally and in the counties surrounding Mobile Bay. In the continental United States, wetland losses in the 20-year period after 1955 totaled more than 9 million acres (Tiner 1984), or an average of about 458,000 acres per year. A study was undertaken to inventory the wetlands remaining in Mobile Bay, to document wetland loss rates since 1955, and to determine what wetland habitat types and which geographic areas are experiencing the greatest loss.

A complete description of the methods used in this study is contained in Roach et al. (1987). Only a brief summary is presented here. The 1955 wetland habitats were delineated by the Alabama Geological Survey using black-and-white aerial photographs taken between January and July 1955. The 1979 wetland habitats were delineated by the U.S. Fish and Wildlife Service using color infrared photographs taken in November 1979. After photo-interpretation, data from each time period were transferred to 27 1:24,000 U.S. Geological Survey (USGS) stable base topographic quadrangles and digitized into the GIS at the National Wetlands Research Center (Figure 1). Wetland habitat types included on the maps followed Cowardin et al. (1979); dominant upland land-use types followed Anderson et al. (1976). Wetland change was calculated by comparing wetland acreages in 1955 and 1979 by wetland type. Causes of change were determined by examining a review of the maps to see which wetland habitats were converted to other habitat types, and by site visits.

Table 1 presents the habitat and land-use changes occurring over the entire study area from 1955 to 1979. Nonfresh marsh showed the greatest losses (in acreage) but fresh marsh also showed a substantial decline. Upland agricultural and developed areas increased substantially. Photointerpretation problems with the 1955 data led to some misleading results. The large loss of nonfresh water habitat apparent in the table is probably the result of an inability to distinguish mud and sand flats and submerged aquatic vegetation on the black-and-white photographs. If the sum of nonfresh water, mud and sand flats, and submerged aquatic vegetation for 1955 and 1979 are compared, a net gain of 1,509 acres is apparent. This represents the conversion of emergent marsh to open water and is probably a more accurate reflection of what is happening along estuarine shorelines.
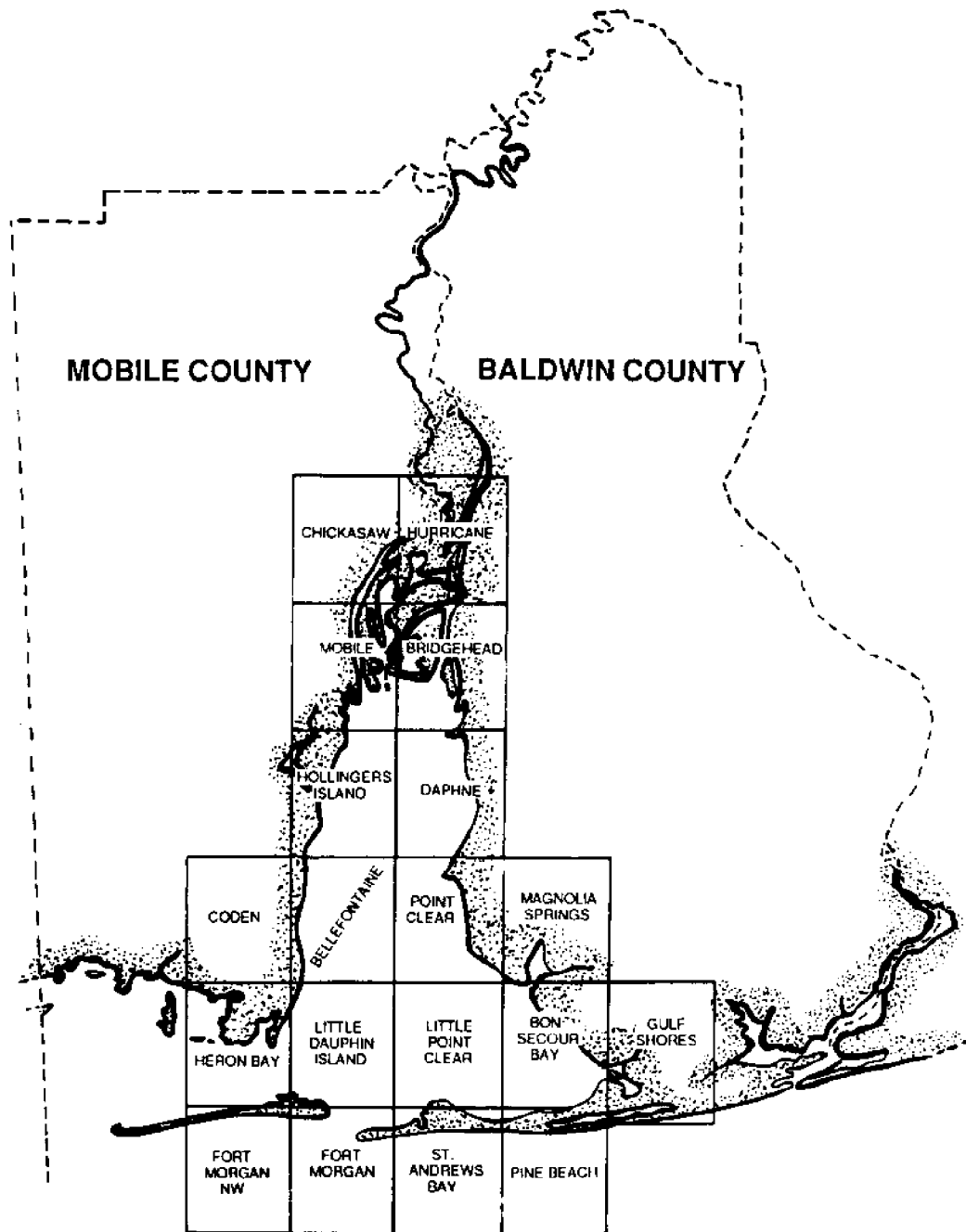
Figure 1. Location of the twenty-seven 7.5-min quadrangles depicting areas surrounding Mobile Bay and including the Alabama coastal zone.

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Table 1. Habitat and land-use changes in coastal Alabama between 1955 and 1979 (27 1:24,000 quadrangles).

Habitat/Land-use type	1955 Acreage	1979 Acreage	Acreage Change	Percent Change
Nonfresh Marsh	41,309	29,282	-12,027	- 29%
Beaches and Bars	919	1,257	+ 338	+ 37%
Mud/Sand Flats	903	6,819	+ 5,916	+655%
Nonfresh Open Water	605,010	595,438	- 9,572	- 2%
Fresh Marsh	9,135	2,867	- 6,268	- 69%
Forested Wetlands	77,417	104,526	+27,109	+ 35%
Scrub-Shrub Wetlands	13,679	19,839	+ 6,160	+ 45%
Floating and Submerged Aquatic Vegetation	226	5,391		
Fresh Open Water	3,185	6,109	+ 2,924	+ 92%
Upland Agriculture	78,692	95,658	+16,966	+ 22%
Upland Barren	5,576	3,735	- 1,841	- 33%
Upland Forest	82,867	81,008	- 1,859	- 2%
Upland Range	80,961	4,513	-76,448	- 94%
Upland Developed	29,779	72,572	+42,793	+144%
Total	1,029,658	1,029,014		

Some very substantial gains are also apparent for forested wetlands and scrub-shrub wetlands. These gains are probably also largely the result of photointerpretation errors in 1955. Wetland soil types were apparently not given enough weight in the 1955 wetland delineations, consequently many wet habitats were classified as upland habitats. When these habitats were correctly identified in the 1979 delineations, it appeared as though a wetland gain had occurred.

In coastal Alabama, a cumulative loss of about 29% of the

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nonfresh marshes and at least 69% of the fresh marshes occurred between 1955 and 1979. In Mobile Bay alone, 35% of the nonfresh marshes were lost, the majority in the southeast portion of the bay. National trends over the same mid-50's to mid-70's time period indicated a loss of 8% of the nonfresh and 5% of the fresh marshes (Frayer et al. 1983). A regional study of the southeastern United States had results similar to Frayer et al.; net losses of nonfresh marshes were 8% and losses of fresh marshes were 18% (Hefner et al. 1983).

In coastal Alabama, 48% of the nonfresh marsh losses could be attributed to human activities and about 47% of the losses were the result of erosion, subsidence, sea-level rise, succession to scrub-shrub communities, or other "natural causes." The implications of this are important because it means that not all wetland losses are under the control of Federal or State agencies via the permitting process. Studies like this one give wetland managers general information that is extremely useful in developing long-range plans for resource management.

Cartographically-based risk assessment for contaminated sediments

Resource managers need to know not only if resources are at risk in an ecosystem, but also exactly where those risks are greatest. By combining traditional contaminant survey approaches with GIS technologies, we are conducting a

cartographically-based risk assessment of the potential impacts of contaminated sediments on selected natural resources in Mobile Bay.

In an ecological sense, the term "risk assessment" is applied generally to the process of identifying, characterizing, and quantifying the potential adverse effects of environmental hazards. Risk assessment goes beyond traditional environmental impact assessment and contaminant surveys in quantifying the probability of an undesired event such as contamination of important natural resources. Our cartographically-based risk assessment tries to tie the probabilities of a contaminant problem to specific locations in our study area.

To accomplish this, we are using the Map Overlay Statistical System (MOSS) to develop spatial data bases on wetland habitats, submerged aquatic vegetation, bathymetry, salinity contours, National Pollution Discharge Elimination System (NPDES) sites, heavy metals concentrations, sediments, shoreline erosion and accretion zones, fish habitats, bird nesting sites, natural gas platforms, the transportation network, and park and refuge boundaries. Heavy metal and sediment data were entered as points and contoured using MOSS/MAPS. Salinity contours were generated from the output of a dynamic model of the bay's hydrography (Raney and Youngblood 1987). Point data such as NPDES sites, bird nesting locations, and natural gas platforms will be buffered

to various distances based on physical characteristics.

Information about the persistence, volatility, and solubility of each chemical entering the bay is also being assembled to determine the likelihood for transport and bioavailability in the bay. Information about a toxicant's partitioning among water, suspended particulates, sediments, and the biota are being evaluated by examining information about the bioaccumulation potentials, structure-activity relationships, and metabolic half-lives of candidate chemicals and chemical groups. While not directly incorporated into the GIS, this assessment will provide guidance about which contaminants should have a higher probability of negatively affecting important natural resources.

Both the simple overlay and the cartographic modeling capabilities of MOSS will be used to highlight areas of low, medium, and high risk of contamination of selected resources by selected contaminants. For example, we have already overlaid NPDES sites with wetland habitats and discovered areas where toxic materials are being discharged into channels near wetlands that are of value to fish and wildlife species. We have also overlaid chromium and nickel concentrations with bay-bottom types to locate accumulation sites. In many areas, Mobile Bay's mineralogy consists of high percentages of silts, clays, and organic carbons. Inorganic and organic contaminants have a longer residence

time in these bottom types (Isphording et al. 1985).

Cartographic modeling will be undertaken in a manner similar to Stayner et al. (1986). First, all data will be converted to cell format and recoded to an appropriate value determined by ranking the categories in each data layer according to contaminant sensitivity (for resources) or toxicity (for chemical sources and accumulation areas). Various combinations of these cell maps will then be arithmetically composited to produce a single output. Contaminant risk index values will be grouped into logical classes to produce a final computer-generated map that depicts low, medium, and high risk areas.

Risk assessments such as this one can provide a more rational basis for making management decisions by quantifying uncertainty. These assessments can be used both to justify more expensive chemical testing programs and to pinpoint where the samples should be taken. Managers can also identify those resources that are at greatest risk and where that risk lies so that risk reduction and restoration efforts can be targeted specifically to those areas. Using risk assessments, resource management decisions can be based more on empirical analysis than subjective judgement.

A cumulative impacts analysis of Mobile Bay

Cumulative impacts, or accumulating effects, are the

result of individually minor but collectively significant disturbances to ecosystems. Cumulative impacts cannot be traced to any one project; they occur over a long period of time, and they are spread over large landscape areas. Indeed cumulative impacts are only seen when resource managers look beyond individual disturbance sites to whole regional landscapes. The GIS is ideally suited to landscape level analysis. We are using the habitat maps discussed earlier to develop an understanding of changes in habitat distribution, patch size distribution, and patch connectedness in the landscape area. Wetland geographic distribution and connectedness in the landscape will have a profound effect on the hydrology, water quality, and biotic diversity of the assessment area. We hope to use this analysis, combined with conceptual models of bay processes, to develop a management plan, which will take the form of environmental goals for the bay.

CONCLUSION

Geographic information systems provide a powerful tool for resource managers. A GIS can be used to store, retrieve, manipulate, analyze, and update both spatial and tabular data with relative ease. Although managers may initially have been drawn to GIS's for their map production capabilities, their analytical capabilities are now receiving equal attention. Data from several themes can be analyzed simultaneously to answer complex questions. Our risk assessment and cumulative impacts analysis are examples of this. Scott et al. (1987) gave another particularly innovative example. They superimposed wildlife distribution data for a number of species on land cover and property ownership maps to design habitat preserves that would maximize the benefits to a diverse assemblage of species. Multispecies approaches like this one probably offer the best long-term hope for preserving biological diversity.

A GIS is also ideal for studies of land-cover changes and their causes over time. Our analysis of wetland change used GIS to depict change from one time period to the next. Walker et al. (1986) also showed how a GIS can be used to analyze cumulative anthropogenic impacts on natural habitats, in this example in Prudhoe Bay, Alaska. In the regulatory arena, a GIS can be used as an "institutional memory" (sensu Gosselink and Lee 1987) of the landscape. When an application for a permit is received by a regulatory agency, the GIS can be used to examine the area in question; if the permit is granted, it can be permanently entered into the data base so its existence and impacts are known when the next permit request is made.

One of the greatest potentials of GIS for environmental scientists and managers may lie in its cartographic modeling capabilities. Once a multivariate data base has been assembled, a large number of

models could be constructed with varying data levels to examine the probabilities of risk to components of the ecosystem from a variety of factors, as we are doing in Mobile Bay. These analyses can provide a spatial dimension to ecological problem-solving and a more rational basis for environmental decisionmaking.

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APPLICATION OF GIS TECHNOLOGY TO MONITOR
BARRIER ISLAND CHANGE: INTEGRATION OF SAGIS AND
MOSS AT GULF ISLANDS NATIONAL SEASHORE

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ABSTRACT

Gulf Islands National Seashore began building a
Geographic Information System (GIS) in 1985 combining
existing MOSS digital data sets, available from the U.S.
Fish and Wildlife Service's National Wetlands Inventory,
with an inexpensive hardware system running SAGIS. This
strategy has provided the park with a versatile system
for managing baseline data, monitoring park resources,
and conducting research on physical and ecological
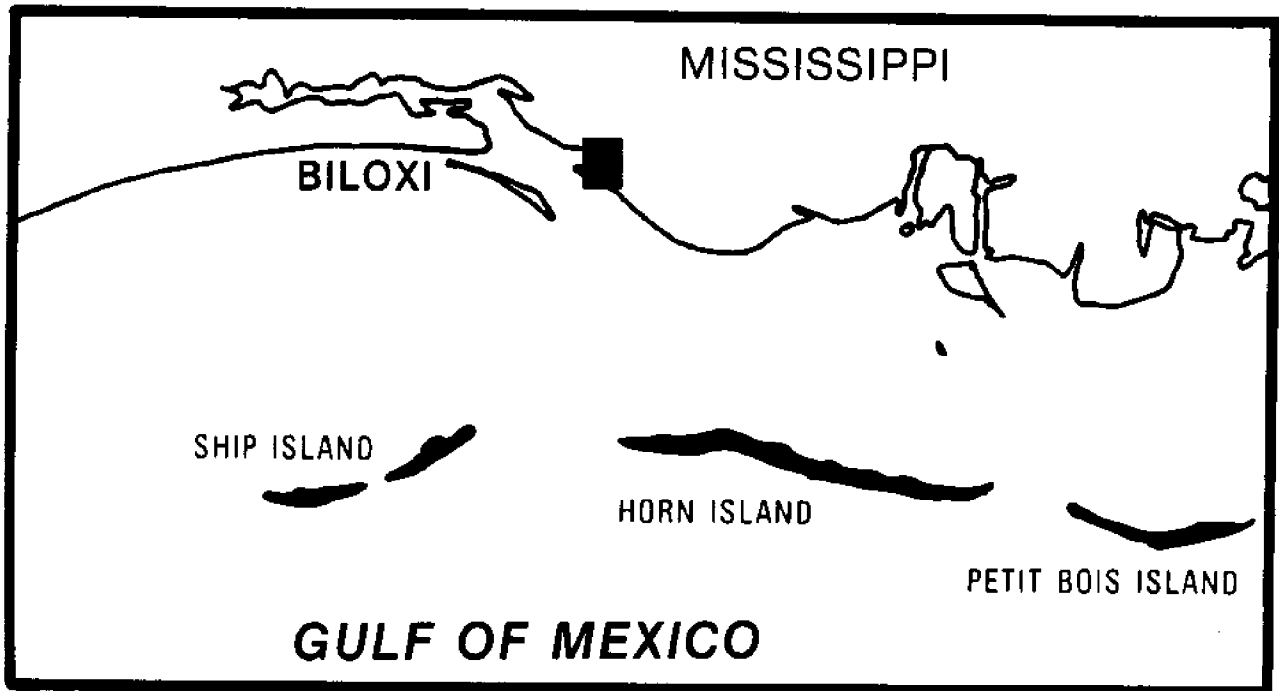processes in the park.

INTRODUCTION

Gulf Islands National Seashore (Figure 1) is comprised of about 57,000 ha of barrier islands and their adjacent waters in northwest Florida and coastal Mississippi. Established in 1971, the Seashore stretches from West Ship Island in Mississippi, 240 km east to the middle of Santa Rosa Island in Florida. The Seashore's resources range from remote wilderness barrier islands with very limited visitation, to readily accessible recreational beaches and historic sites visited by several million people each year. The undeveloped portions of the Seashore represent the best example of an undisturbed barrier island ecosystem remaining in the Gulf of Mexico.

Resource management efforts at the Seashore are aimed at providing park managers with the information and tools required to carry out their difficult and often contradictory responsibilities of preserving park resources for public use. A geographic information system provides a powerful tool for addressing the challenges raised by this mandate. Applications at the Seashore can be divided into four major areas (1) the generation of spatially and temporally referenced baseline data sets on the major components of the park's

MISSISSIPPI

BILOXI

SHIP ISLAND

HORN ISLAND

PETIT BOIS ISLAND

GULF OF MEXICO

■ GULF ISLANDS NATIONAL SEASHORE

PENSACOLA

FLORIDA

SANTA ROSA ISLAND

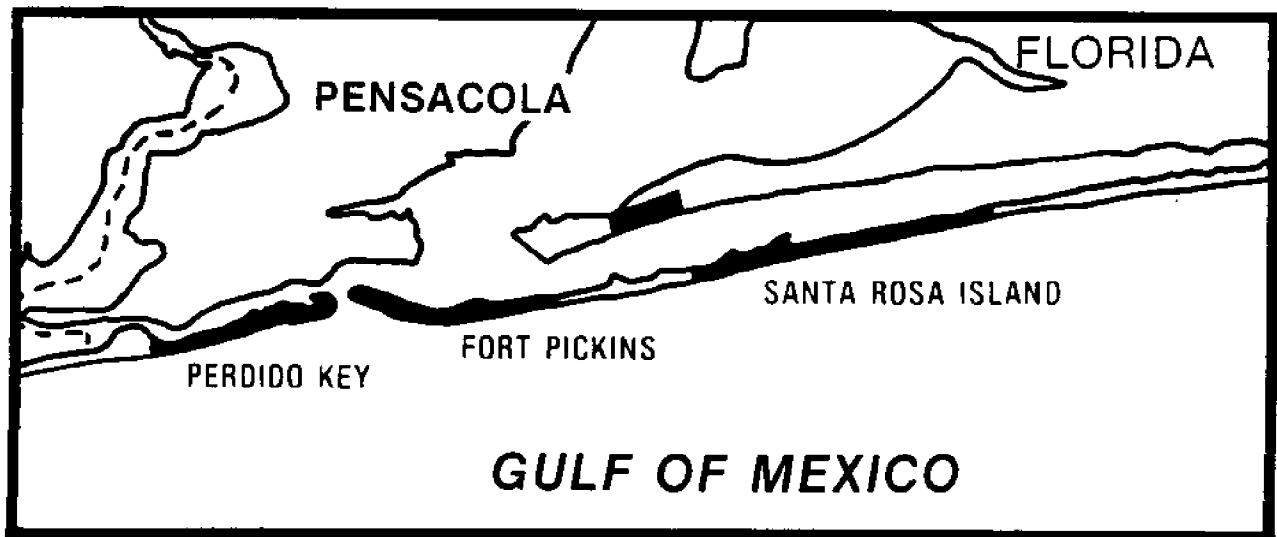FORT PICKINS

PERDIDO KEY

GULF OF MEXICO

Figure 1.   Gulf Islands National Seashore units are located in Mississippi and Florida.

ecosystems; (2) information management and transfer; (3) resource monitoring; and (4) research. The objective of this paper is to provide an overview of how the GIS at Gulf Islands National Seashore has evolved over the past several years, along with examples of current applications in the park.

GIS DEVELOPMENT

Efforts to develop a GIS in the Seashore began in 1985 through a cooperative project between the National Park Service (NPS) and the U.S. Fish and Wildlife Service (FWS). Existing MOSS data from the northern Gulf of Mexico, created by the USFWS as part of their national wetlands inventory, were used to conduct a 1956-78 trend analysis of the Seashore's Mississippi barrier islands and Perdido Key, FL. The approach proved to be a powerful tool for analyzing changes related to vegetational succession, shoreline erosion, and island migration on these highly dynamic barrier islands. Additional color infrared photography was acquired through the National Ocean Survey in 1986 and added to the MOSS data base. At the same time the Seashore began to acquire the hardware necessary to develop GIS applications inhouse, including an IBM-AT and OPUS 32-bit coprocessor board capable of running SAGIS software under ATT UNIX system five. The task of converting the three data sets from MOSS to SAGIS has proved to be fairly painless and has

provided the Seashore with an inexpensive head-start in developing its GIS.

EXISTING DATA BASE CONVERSION

In order to convert the existing habitat data to SAGIS, study areas were generated in MOSS to extract the Seashore data from the parent quadrangles. The study area polygons were overlaid onto the digital habitat maps to produce separate files for each unit of Park property. These files were exported to ASCII import/export format and downloaded to an IBM PC for transfer to SAGIS. Initial attempts to transfer the data over 1,200 baud modem lines from the Data General mini-computer resulted in the loss of numerous records. The files subsequently were transferred by 1.3-megabyte floppy diskettes.

Problems with the MOSS export command caused closure errors in about 10% of the polygons in each map file. The NPS developed a program to identify and close all corrupted polygons. The UNWAMS import program of SAGIS was used to convert the MOSS F11.2 format coordinate data to F11.1 format for data-base construction.

BASELINE DATA

An understanding of the species, communities, and populations that make up the Seashore is essential to making informed resource management decisions. Documenting the

diversity, distribution, and abundance of these essential elements is a key component of several on-going research projects. The park's GIS provides an integrated approach to the management and analysis of information, and it allows the interrelation of spatially and temporally referenced data from a variety of sources. Examples of on-going baseline research projects include; faunal inventories of mammals, reptiles and amphibians, and aquatic invertebrates, and surveys of the park's flora. Parks and other protected areas will prove vital in protecting and fostering biological diversity in the future. The National Park Service is committed to that task and to the documentation of the bio-diversity in parks through the application of GIS technologies.

INFORMATION MANAGEMENT AND TRANSFER

A variety of map products are currently under development through the Seashore's SAGIS-based system that will provide park managers with up-to-date summaries of land use within the Seashore. These include overlays of historic and archaeological sites, rights-of-way, jurisdiction, management zones, and private inholdings. This information is in constant demand in issues related to development and land use adjacent to the park. Another component of the GIS under development is a spatially referenced inventory of endangered, threatened, and

rare species in the park. This data base is being modeled after the Nature Conservancy's Natural Heritage Program and will allow an easy exchange of information within the extensive network of Federal, State, local, and private agencies that manage these species.

RESOURCE MONITORING

The size and relative simplicity of the Seashore's barrier islands lend themselves to analysis with a GIS. For example, although the complexity of our Horn Island data set has increased from seven habitat types and 105 polygons in 1956 to 42 habitat types and 1,637 polygons in 1986, the vegetation mapfile is still manageable on the micro-based system. A trend analysis of vegetation and shoreline data illustrates the dynamic nature of these islands over relatively short periods of time (Figure 2). In general all of the islands are in an erosional state related to several human-induced factors including channel dredging, sea-level rise, and land use practices in developed areas.

RESEARCH

Several research projects underway in the Seashore employ radio telemetry to determine the movement patterns and habitat use of wildlife. These include studies on the dispersal patterns of fledgling osprey, and the ecology of
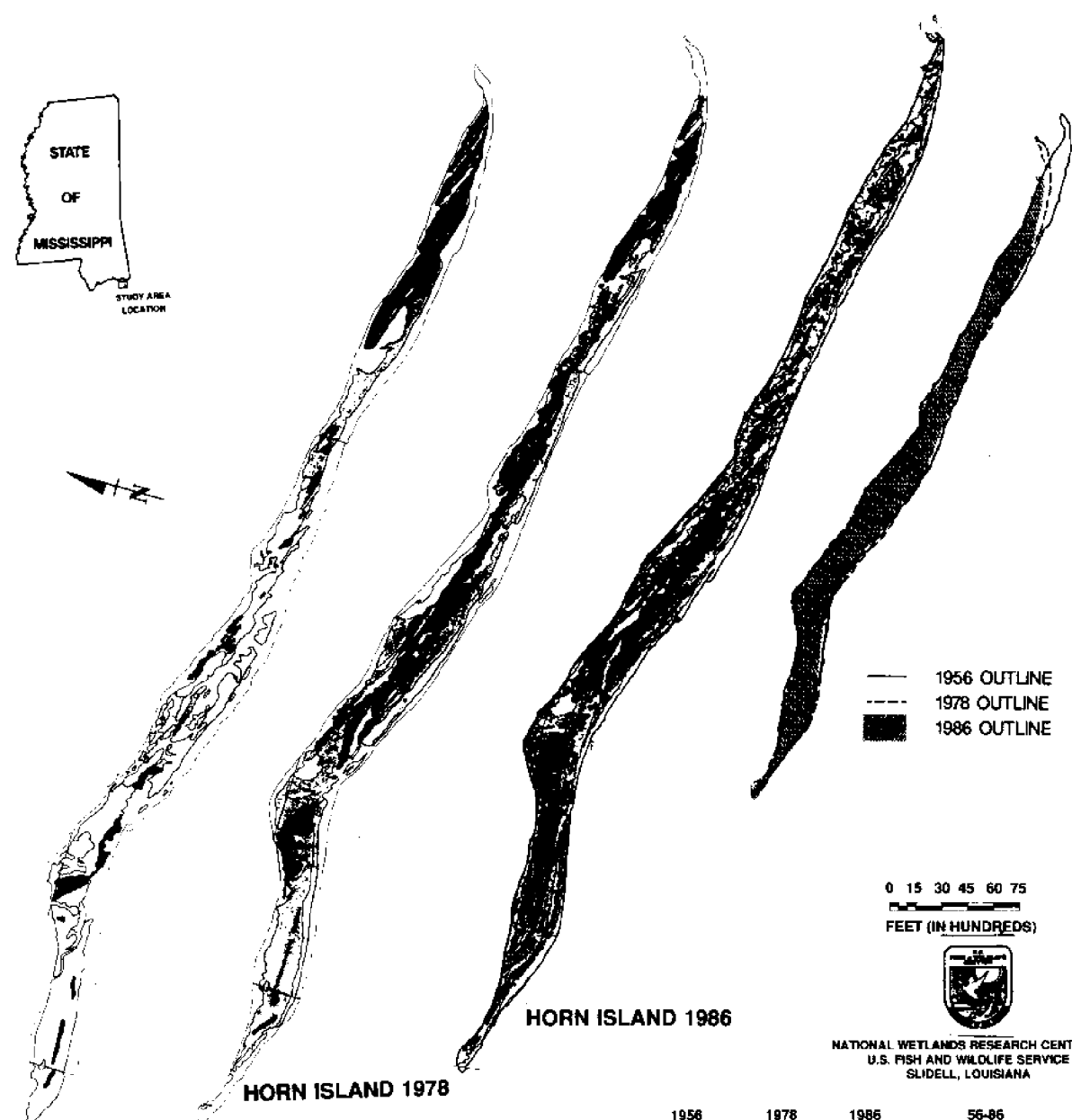
HABITAT TYPE	1956 ACREAGE	1978 ACREAGE	1986 ACREAGE	56-86 CHANGE	% CHANGE
MARSH/GRASSLAND	1,444	1,085	1,155	-289	-20.0%
FORESTS/SCRUB-SHRUB	437	821	346	-91	-20.8%
PONDS & LAGOONS	215	248	180	-35	-16.3%
VEGETATED DUNES	0	338	1,243	+1,243	---
BEACHS & BARS	1,778	1,229	559	-1,219	-68.8%
UPLAND - OTHER	0	0	44	+44	---
TOTAL HABITATS	3,874	3,721	3,527	-347	-9.0%

Figure 2. Wetland changes on Horn Island, Mississippi (1956-1986), Gulf Islands National Seashore.

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raccoons, rabbits, nutria, and red wolves. Locations determined through triangulation from known tracking stations provides geo-referenced locations which can be easily overlaid on vegetation maps. The flexibility of a GIS has proved invaluable in ensuring that the error polygons produced from triangulation do not exceed habitat patch size in evaluating movement patterns.

An experimental project is underway on Perdido Key to determine if beach renourishment is an acceptable solution to a human-induced beach erosion problem. Channel dredging in Pensacola Pass has cut off the sediment supply to Perdido Key and has accelerated beach erosion over the past twenty years. An analysis of habitat change for Perdido Key has provided evidence that over 25% of the upland area and 43% of the beaches was lost to erosion in the period, 1956-79 (Figure 3). In August 1985 two million yards of sand were pumped from Pensacola Pass onto Perdido Key, restoring about 20 ha of new beach to the Seashore. A research project is currently underway to assess the project through an analysis of shoreline change and sediment transport processes on Perdido Key. The incorporation of readily available black-and-white aerial photography from the State of Florida has made analysis of the renourishment project with the GIS simple and inexpensive.

SUMMARY

The employment of a geographic information system at Gulf Islands has proved to be a valuable approach to understanding and managing our natural resources. The transition from MOSS to SAGIS has been a fairly easy process and has allowed us to take advantage of existing digital data and low cost hardware suitable for use at the park level. Our experience clearly underscores the advantages of working towards better communication and cooperation, the standardization of data structures, and data sharing within the GIS community.

QUESTIONS AND ANSWERS

Q. What is the methodology for determining home-range?
A. Public-domain PC programs utilizing the convex polygon method.

Q. How do MAPS and SAGIS compare?
A. Neither system has built-in commands for calculating home range. MAPS provides some procedures for mathematical function development that could be used, but SAGIS is a vector-formatted system that does not have similar capabilities.

NATIONAL WETLANDS RESEARCH CENTER
U.S. FISH AND WILDLIFE SERVICE
SLIDELL, LOUISIANA

PERDIDO KEY 1956

PERDIDO KEY 1979
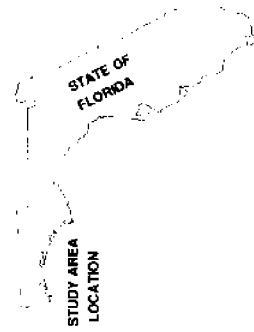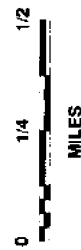
	1956 ACREAGE	1979 ACREAGE	ACREAGE CHANGE	% CHANGE
EMERGENT WETLANDS	74	71	-3	-4.1%
SCRUB-SHRUB WETLANDS	15	17	+2	+13.3%
PONDS & LAGOONS	54	51	-3	-5.6%
BEACHES & FLATS	202	116	-86	-42.6%
UPLANDS	499	372	-127	-25.5%
TOTAL HABITATS	844	627	-217	-25.7%

MILES
0   1/4   1/2

STATE OF FLORIDA

STUDY AREA LOCATION

Figure 3. Wetland changes on the eastern end of Perdido Key, Florida, (1956-1979), Gulf Islands National Seashore.

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SESSION IV

Advanced Geographic Information Systems Applications

Moderated by: Frank D'Erchia
U.S. Fish and Wildlife Service

USING THE MAPS GEOGRAPHIC INFORMATION SYSTEM AS A GEOGRAPHIC EXPERT SYSTEM

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ABSTRACT

An expert system is a computer program that applies rules supplied by an expert. A user answers questions that are used by the program to ask other questions until an answer is found. It is composed of the inference engine, knowledge bases, and a user interface. One such expert system is Prospector, which has been credited with finding an unknown mineral deposit. However, recent enhancements to the Map Analysis and Processing System (MAPS) allow it to copy some of the functions of a map-based Prospector expert system. The Geographic Expert System (GES) was developed for Mineral exploration; however, the methodology can be used for spatial analyses dealing with "uncertain" data.

INTRODUCTION

Nearly all texts on expert systems cite Prospector as a successful expert system, since it is credited with finding an unknown mineral deposit (Campbell et al. 1982). What has not been reported is that the single success occurred using an experimental version of Prospector that used maps as input. This paper will discuss recent enhancements to the Map Analysis and Processing System (MAPS) that allow it to emulate some of the functions of a map-based Prospector expert system.

Geographic Information Systems (GIS) are computer programs that handle spatial data. GIS's fall into two general categories: vector, which stores maps as strings of x-y coordinates; and cell (raster), which breaks up maps into small rectangles. Vector maps are more accurate than cell maps, but they require much more computer time for processing. A cell GIS is better able to process data that contain significant variation within an area, e.g., the outline of a deposit versus the ore grade of the deposit (Figures 1 and 2). A cell GIS can manipulate corresponding cells on different maps (Figure 2A).

An expert system is a computer program that applies rules supplied by an expert. As a user answers questions, the program uses those answers to ask other relevant questions until a final answer is found. An expert system is generally composed of three parts, the inference engine, knowledge bases, and a user interface.

ORIGINAL   VECTOR   COARSE   FINE
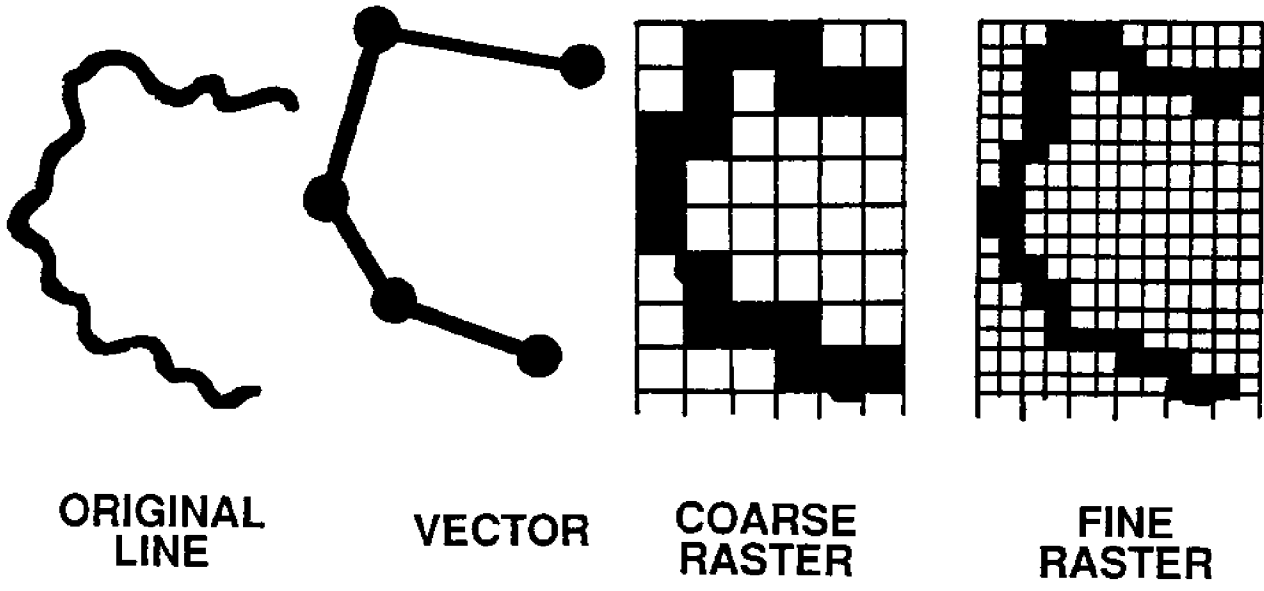LINE   RASTER   RASTER

Figure 1. Digital spatial data may be stored as lines (VECTOR)
or cells (RASTER).

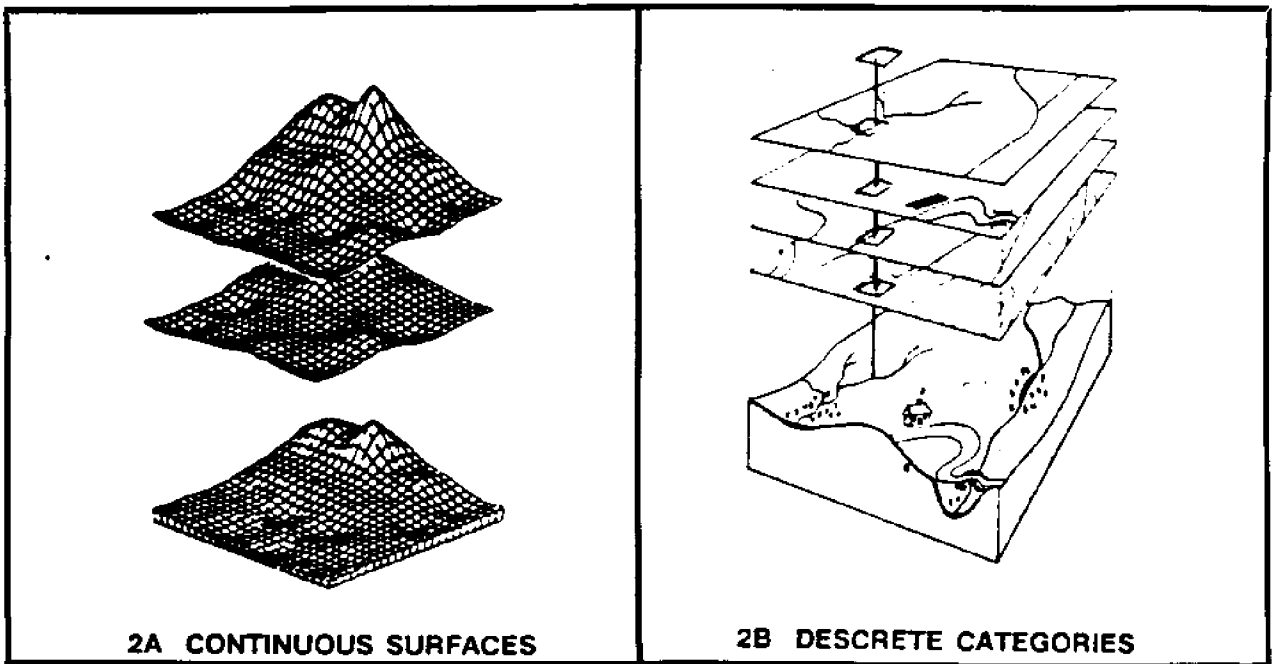2A CONTINUOUS SURFACES   2B DESCRETE CATEGORIES

Figure 2. Processing cell maps.

The inference engine is a computer program for processing rules. A GIS is designed as a toolbox for analyzing maps rather than an inference engine, though recent additions to the MAPS toolbox will now allow it to handle rules in much the same way as Prospector. Knowledge bases can be any number of separate sets of rules compiled by various experts for use by the inference engine. In MAPS the knowledge base is stored as a READ (.RD) file. Duda et al. (1978) and Hart et al. (1978) used rules for locating the best drilling sites for the highest hypogene grade of ore in a porphyry copper deposit. These rules were supplied by Victor F. Hollister, Manager of Canadian Exploration, Duval International Corporation. This paper will use a subset of those rules to demonstrate that MAPS can find the same deposit using the same data. The user interface for this "geographic expert system (GES)" is either a text editor, where the user changes the map names in the READ (.RD) file, or the MAPS RENAME command, which allows the user to change existing map names to the corresponding map name in a READ (.RD) file.

PROSPECTOR'S INFERENCE ENGINE

Prospector's inference engine uses Boolean logic and Bayesian probability to process evidence and hypotheses. This can best be described in terms of an inference network. The three Boolean operators used in Prospector are AND, OR, and NOT. These operators are used to combine separate evidence into a single compound piece of evidence.

With AND logic, all of the evidence statements must be true for the hypothesis to be true. Figure 3A shows how this would be drawn in an inference network. In OR logic, if any of the evidence statements are true, then the hypothesis is true. Figure 3B shows how a logical OR would be drawn in an inference network. Prospector uses a very limited form of the logical NOT operator. If the evidence is not true, then the hypothesis in this case is false, and vice versa, e.g., it is drawn as shown in Figure 3C. If it is not hot, then it is cold. NOT is used to aid in making questions more clear. Rather than asking if gold is absent, Prospector would ask if gold is present and then use NOT.

In the inference network figures, I have used the same conventions as those used in Prospector reports. The boxes are called spaces, and the lines that connect spaces are called arcs. Rules link hypothesis and evidence spaces. In an inference network, the space that is the hypothesis for one rule may be the evidence for another rule, and evidence can be used by more than one rule. Another Prospector convention is putting a short identifier at the upper left of each space and a short description inside each space. An example of the inference network for the quartz-intrusive stockwork model is shown in Figure 4. The inference network is very
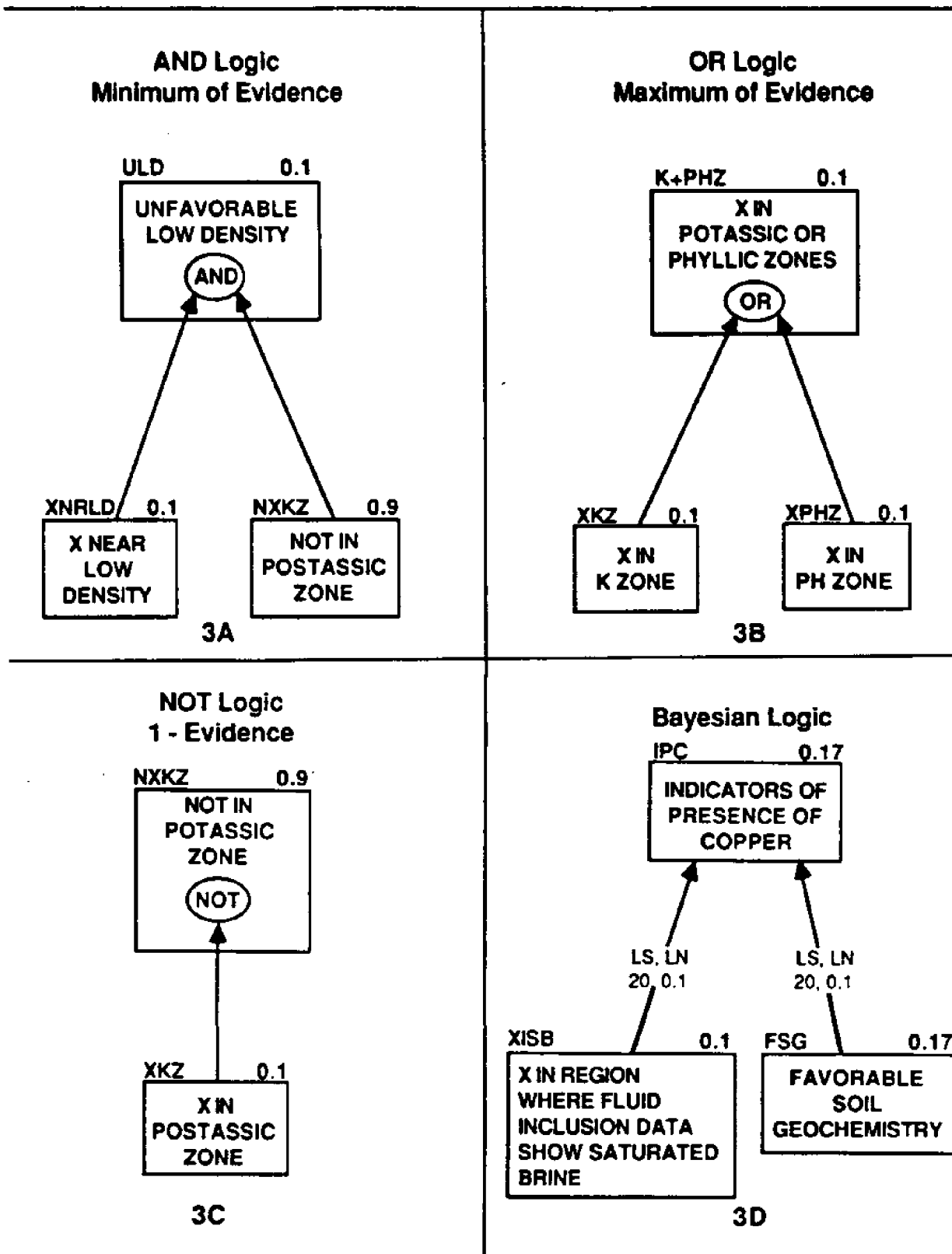
Figure 3. Components of an inference network.

FLD   0.17
FAVORABLE LOCATION
FOR DRILLING

1, 0.0001   3, 0.25   20, 0.1

XLOS   0.1
X WITHIN LIMIT
OF SULFIDE

IPC   0.17
INDICATORS OF
PRESENCE OF
COPPER

OFE   0.23
OTHER
FAVORABLE   (CONTINUED)
EVIDENCE

20, 0.1   20, 0.1

XISB   0.1
X IN REGION
WHERE FLUID
INCLUSION DATA
SHOW SATURATED
BRINE

FSG   0.17
FAVORABLE
SOIL
GEOCHEMISTRY

15, 0.1   3, 1   2, 1

FAMC   0.1
FAVORABLE
Au/Mo AT X
(AND)

XTA   0.1
X IN TRANSITION
AREA BETWEEN
CARBONATES AND
SILICATES

X2-4   0.1
200 TO
400 PPM
Cu AT X

SAMC   0.17
SUGGESTIVE
Au/Mo AT X

20, 1   3, 1

XPMC   0.1
X NEAR
PEAK Mo

XFAC   0.1
X "AWAY
FROM" Au

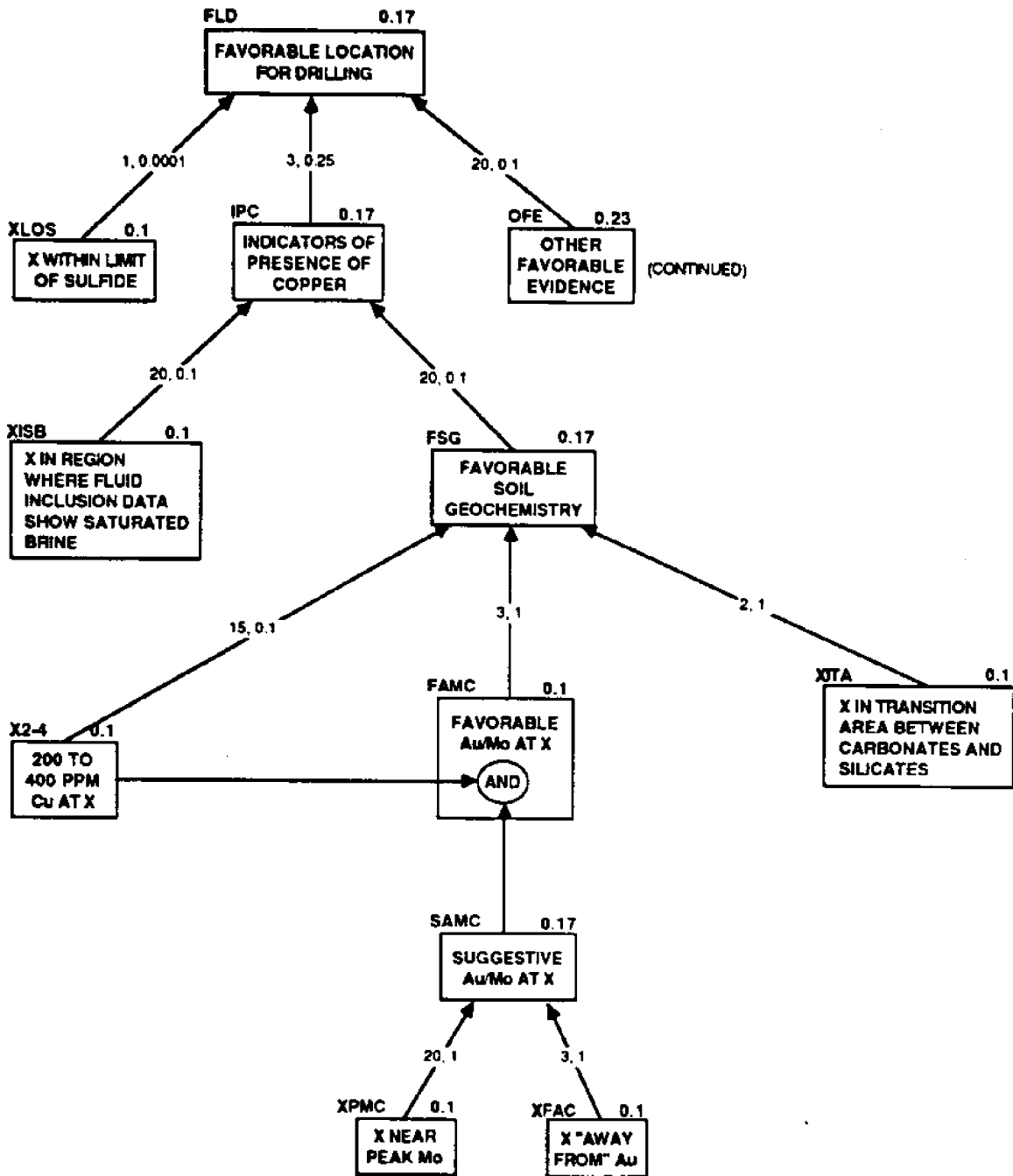Figure 4. Hollister's rules simplified, for stockwork with a
quartz-bearing instrusive. Continued.

OFE   0.23

OTHER FAVORABLE
EVIDENCE   (TO FAVORABLE LOCATION FOR DRILLING - FLD)

3.5, 1

2, 1

8, 0.125

8, 0.143

XNCIR   0.1
X NEAR CONTACT
OF INTRUSIVE AND
INTRUDED ROCK

XAMHL   0.1
X NEAR A
MAGNETIC
HIGH OR LOW

FSM1   0.1
FAVORABLE
STRUCTURES
FOR MODEL1

FLA   0.1
FAVORABLE
LITHOLOGY AND
ALTERATION   (CONTINUED)

7, 1

2, 1

90, 0.02

0.01, 1

FFM1   0.1
FAVORABLE
FAULTS
OR

XNFI1   0.1
X NEAR FAULT
INTERSECTION
REGION

XQOSOVV   0.1
X IN A REGION OF
QUARTZ-ONLY
OR SULFIDE-ONLY
STOCKWORK

FPM1   0.1
FAVORABLE
PROXIMITY TO
M1 FAULTS

FPO1   0.1
FAVORABLE
PROXIMITY
TO "OTHER"
FAULTS

FPD1   0.1
FAVORABLE
PATTERN
AND DENSITY

10000, 1

10000, 1

3.5, 1

3.5, 1

15, 1

15, 1

0.02, 1

0.2, 1

XNCM1   0.1
X NEAR
CONJUGATE
M1 FAULTS*

XNIM1   0.1
X NEAR
INTER-
SECTING
M1
FAULTS*

XNCO1   0.1
X NEAR
CONJUGATE
OTHER FAULTS

XNIO1   0.1
X NEAR
INTER-
SECTING
OTHER
FAULTS

XNCCP   0.1
X NEAR
CENTER

XNRHD   0.1
X NEAR
HIGH
DENSITY

ULD   0.1
UNFAVORABLE
LOW DENSITY
AND

XNBP   0.1
X IS NEAR
BRECCIA
PIPES

XNRLD   0.1
X NEAR
LOW
DENSITY

NXKZ   0.9
NOT IN
POTASSIC
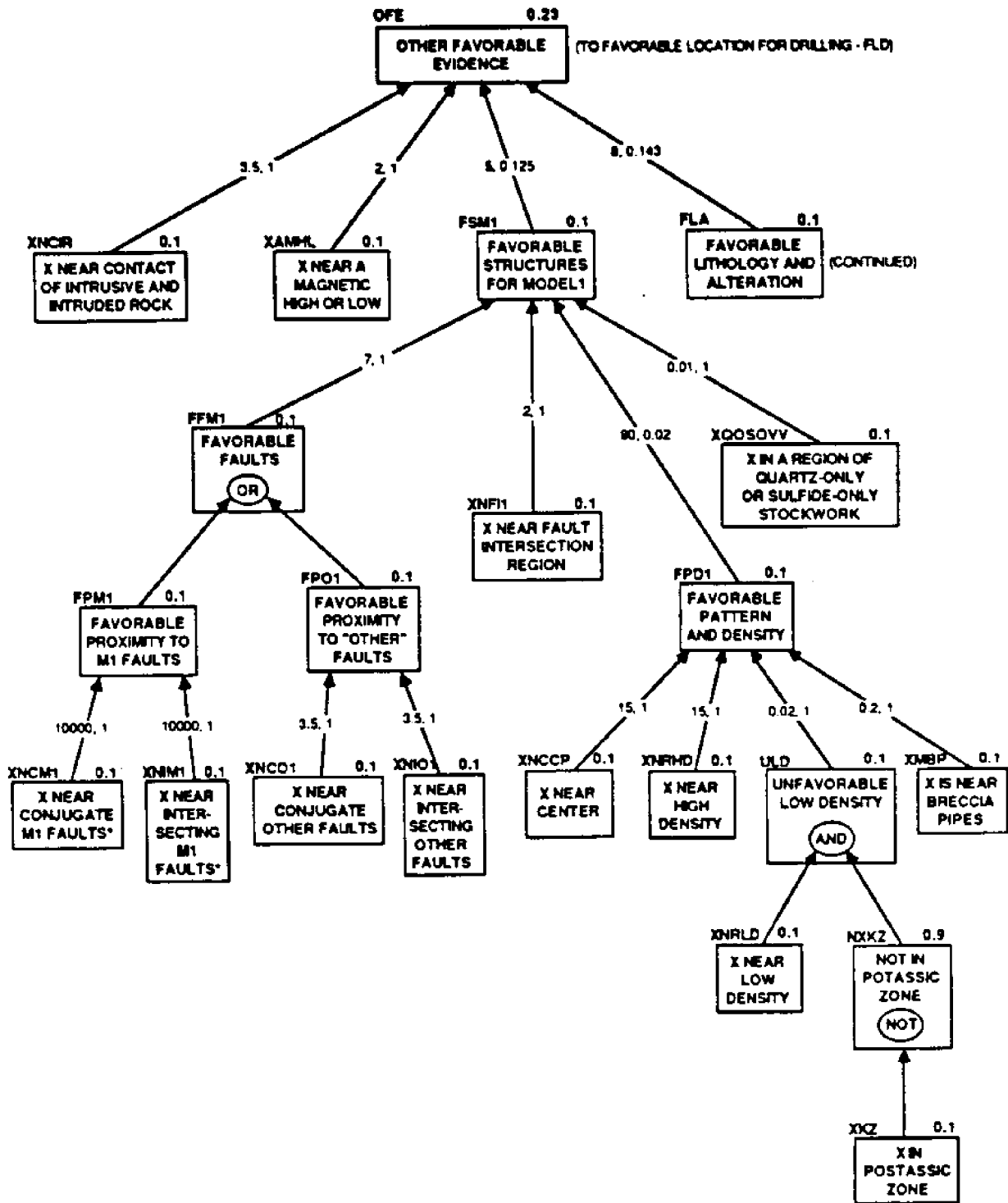ZONE
NOT

XKZ   0.1
X IN
POSTASSIC
ZONE

Figure 4. (Continued.)
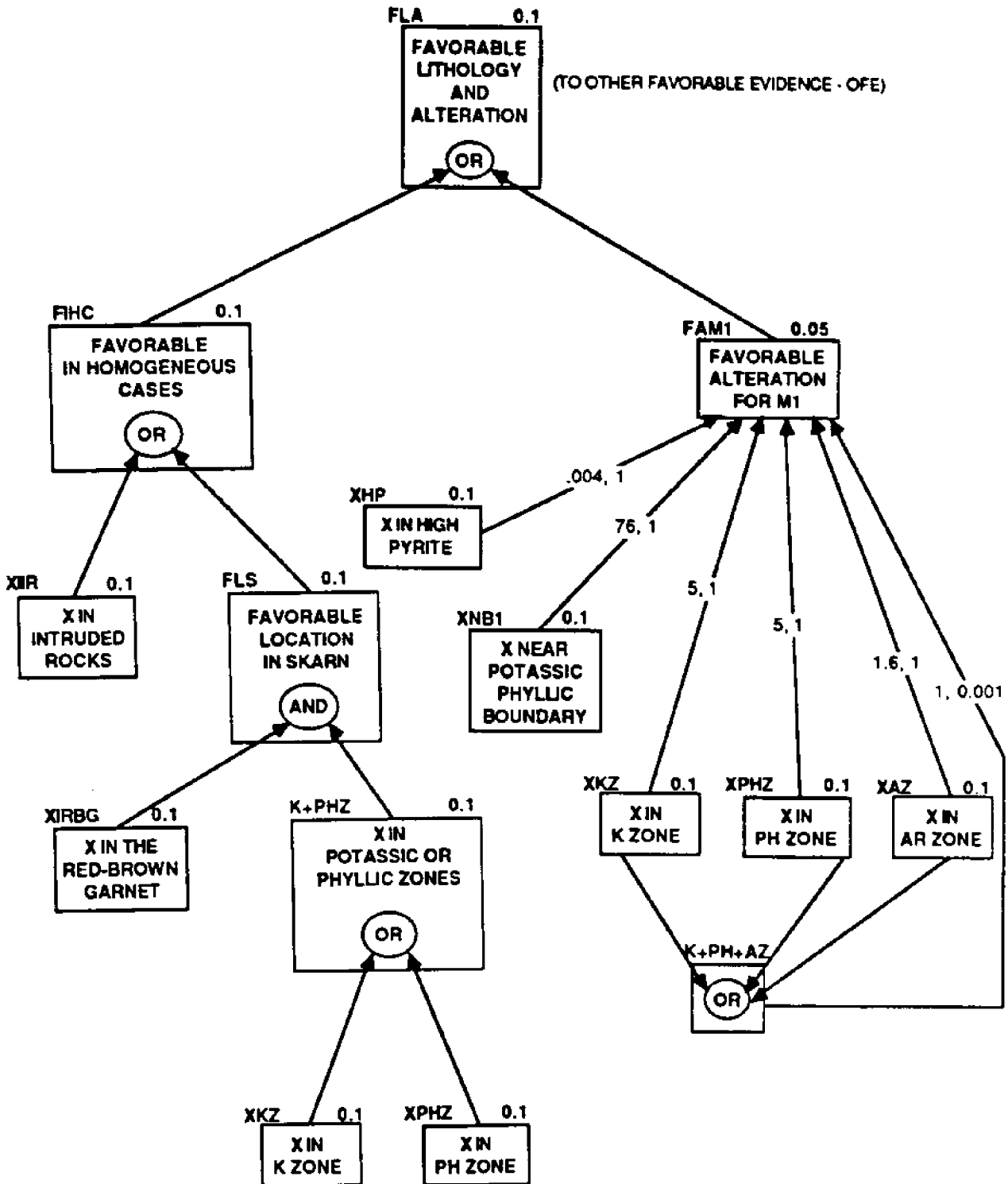
4C - FAVORABLE LITHOLOGY AND ALTERATION

Figure 4. (Concluded.)

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much like the cartographic modeling that is used with GIS's.

Although Prospector asks the user for input in terms of certainty (where -5 means definitely not, +5 means definitely yes, and 0 means I don't know), it immediately converts the certainty to probability (where -5 is 0.0, +5 is 1.0, and 0 certainty is the prior probability assigned to that space by the expert who wrote the rules. Figure 5). To simplify the effort to use maps with Prospector, Duda et al. (1978) used maps of probability; I did the same.

Each space in a Prospector inference network is assigned a prior probability by the expert who makes the rules, or is calculated from spaces lower in the inference network. These values, indicated in the formulas as P(E), prior probability of the evidence, are the expert's opinion of the odds of that space being true, given no other information (odds and probability can easily be converted by the following formulas: ODD = PROB/(1-PROB) and PROB = ODDS/ (1+ODDS). It is as if someone asked you to give odds that a hidden rock is quartz. This P(E) value is placed above the upper right corner of each space. If the user says, "I don't know," e.g., a map does not exist, Prospector uses this prior probability of the evidence for its logical and Bayesian operations.
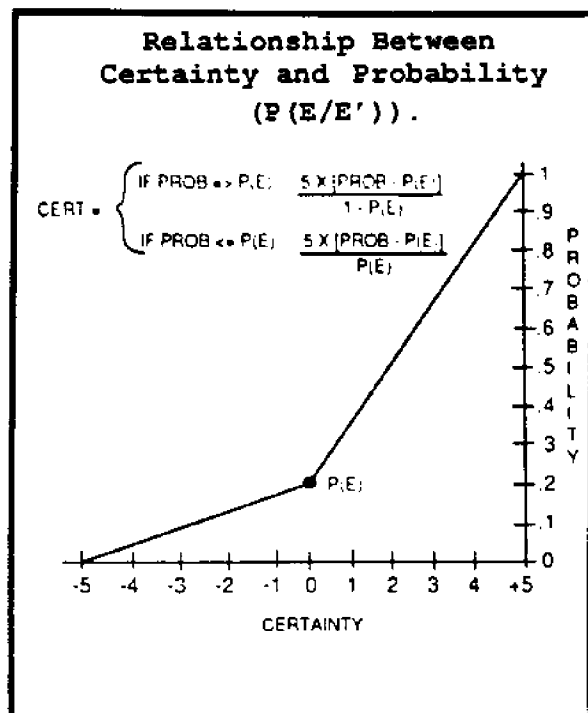
In simple examples of Boolean logic there are only two possible values for each piece of evidence: true, corresponding to a probability of one; and false, corresponding to a probability of zero. In real life, the probability of evidence can range anywhere between these two extremes. Prospector uses fuzzy set logic (Zadeh 1978) to deal with this situation. Logical AND is the minimum probability of any of the evidence; logical OR is the maximum probability of any of the evidence; and logical NOT is one minus the probability of the evidence (see Duda et al. 1977 for a justification of this procedure). To help clarify the logical NOT operation, the following example is given. Prospector might want

Figure 5.

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to know where gold is absent. It could ask, "Indicate how certain you are that gold is present." It would then convert the certainty to probability (ranging from 0 to 1) and, using the NOT operator, subtract the probability from 1 for a new probability indicating the absence of gold.

Bayesian decision theory is the second way Prospector updates probability in an inference network. Figure 3D describes the elements of a Bayesian update. The major difference between Bayesian theory and logical operations is the assignment of LS and LN values to each arc by the expert. LS is a likelihood ratio that indicates the sufficiency of the evidence for proving the hypothesis, and LN is the likelihood ratio that indicates how necessary the evidence is for the hypothesis. An LS value greater than one means the evidence is sufficient for proving the hypothesis. An LN value of less than one indicates that the evidence is necessary to prove the hypothesis. Without going into the details, the following must apply to LS and LN values:

1. Both can't be equal to one.
2. Both can't be greater than one.
3. Both can't be less than one.
4. Neither can be less than zero.

Picking the right values for P(E), LS, and LN is a difficult undertaking. Reboh (1981) discusses the relationship between the Knowledge Engineer (KE),

who is building the knowledge base, and the Domain Expert (DE), who, in Prospector's case, is an expert geologist. He said:

The task of figuring out large quantities of numerical parameters is naturally the most tedious. The DE sometimes feels uneasy and does not really believe that these numbers are useful because he thinks of all the situations and exceptions in his experience where these numbers are actually wrong, and cannot visualize the overall effect on the model. The KE does not believe either that the numbers are correct, but has to get each one of them. He skillfully pushes the DE into the smallest corner possible, and painfully but systematically extracts numbers to fill all his empty slots. Because of the size and complexity of the interaction in parts of the model, the numbers often contain inconsistencies that are detected only when the entire model is analyzed (Reboh 1981).

BAYESIAN UPDATING OF PROBABILITY

When several pieces of evidence affect a hypothesis, the hypothesis is updated using Bayesian probability. This is done by multiplying the O(H) (ODDS for the hypothesis) by the effective likelihood ratio (LE) of each piece of evidence. A Bayesian rule is shown as arcs with LN and LS values connecting evidence spaces to a hypothesis space. The

mechanics of using a Bayesian rule to calculate LE are described in Katz (1987).

MAPS AS AN INFERENCE ENGINE

Although Prospector allows the user to volunteer information, and then is prompted by a series of questions, the MAPS inference engine requires the user to prepare a series of maps, each corresponding to a leaf, e.g., "askable" space, in the inference network. In Prospector, a certainty of 0 is converted to the expert supplied P(E). If a user does not have a required map, the new commands will use the previously assigned P(E) value that is a required option. Although all of the literature about Prospector states each space must have a prior probability, neither of the reports dealing with Hollister's rules report a P(E) for the majority of spaces. I assigned a P(E) of 0.1 to most of the unassigned spaces. Figure 4 shows the prior probability of the evidence, P(E) for each required map in the drilling location rule base, as well as all other spaces. All spaces that represent maps start with "X". Maps must be "leaves" in the inference network. If an interpolated map exists, but its range of values is not presented in terms of probability, it can be converted using the MATH command, e.g., MATH (MAP1 - MINVALUE)/MAXVALUE FOR PROB.MAP), or by using the RENUMBER or EXTRACT commands.

Duda et al. (1978) presented a method of extrapolating known data (probability of 1.0) to a

probability of 0 and called it a favorability function. For each required map, the expert assigns two distance factors referenced as A and B. The known data, e.g., faults, high copper values, are always assigned a probability of 1.0. The A factor is the number of meters to extend the 1.0 probability from the original feature. The B factor indicates the distance for extrapolation, from 1.0 to 0. Any area beyond the B distance is always 0. Figure 6 shows the
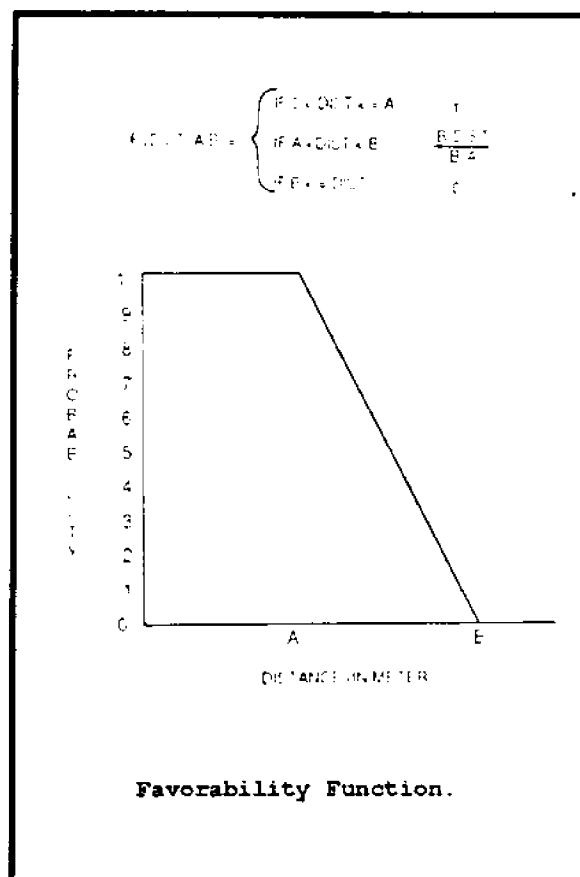

Favorability Function.

Figure 6.

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concept as mathematical formulas. Table 1 shows the A and B factors as well as a short description for the maps used in the upcoming example. MAPS requires two different procedures to apply these rules: one set of commands will apply if the A factor is zero; the other, if the A factor is greater than zero. The set of MAPS commands to calculate favorability is shown in Figure 7. Figure 8 is an example of a probability map.

MAPS is a tool box of programs that is used to process cell maps. MAPS has about 70 commands that do a variety of functions. In an earlier paper (Katz 1987), I discussed emulating Prospector using existing MAPS commands. In order to make this GES viable, five new commands were added to the Prime version of MAPS (Table 2). They allow a MAPS user to build a read (.Rn) file that directly follows the logic in the inference network.

Table 1.   Input maps for simplified quartz-bearing intrusive stockwork model (after Duda et al. 1978).

Space Name	Space Description	Favorability Parameters:	A (m)	B (m)
XAMHL	in a magnetic anomaly region		0	100
XAZ	in an argillic zone		0	0
XFAC	"favorable" with respect to Au concentration		0	100
XHP	in a region of high pyrite		0	0
XIIR	in intruded rocks		0	0
XIRBG	in red-brown garnet		0	0
XISB	fluid inclusion data show saturated brine		0	0
XITA	in transition area, carbonates to silicates		0	100
XKZ	in a potassic zone		0	0
XLOS	within limit of sulfide		0	0
XNBP	in a breccia-pipe region		0	50
XNB1	near potassic/phyllic boundary		0	0
XNCCP	near center of circular stockwork pattern		300	1000
XNCIR	near intrusive contact		20	100
XNCM1	near conjugate strike-slip faults		100	500
XNCO1	near conjugate non-strike-slip faults		100	500
XNFI1	in intersection region of strike-slip faults		0	0
XNIM1	near intersecting strike-slip faults		100	500
XNIO1	near intersecting non-strike-slip faults		100	500
XNRHD	in a region of high stockwork density		0	0
XNRLD	in a region of low stockwork density		0	0
XPHZ	in a phyllic zone		0	0
XPMC	in a region of peak Mo concentration		0	100
XPRZ	in a propylitic zone		0	0
XQOSOVV	in quartz-only or sulfide-only veins or veinlets		0	0
X2-4	in 200 to 400 ppm Cu concentration		0	100

```
┌─────────────────────────────────────────────────────────┐
│         CASE 1:   "A" DISTANCE IS GREATER THAN ZERO       │
│                                                           │
│   1.  Zone IN.MAP into 1 to A_Distance for FAVZONEA       │
│   2.  Zone FAVZONEA into 9 to B-A_Distance for FAVZONEB   │
│   3.  Math FAVZONEB + 0 for FAVMATH                       │
│   4.  Renumber FAVMATH ASSIGN 11 to 0 for FAVRENUM        │
│   5.  Math ( FAVRENUM - 11 ) * -.1 for OUT.MAP            │
│                                                           │
│           CASE 2:   "A" DISTANCE IS EQUAL TO ZERO         │
│                                                           │
│   1.  Zone IN.MAP into 9 to B_Distance for FAVZONEB       │
│   2.  Math FAVZONEB + 0 for FAVMATH                       │
│   3.  Renumber FAVMATH ASSIGN 11 to 0 for FAVRENUM        │
│   4.  Math ( FAVRENUM - 11 ) * -.1 for OUT.MAP            │
└─────────────────────────────────────────────────────────┘
```

Figure 7. MAPS implementation for the favorability function.

The new commands will work even if a map (or many maps) doesn't exist. This is significantly different from other MAPS commands and happens because the Commands require an expert-supplied PE value which is used if a map doesn't exist. Other new arguments can include LS, LN, and PH values. Table 3 shows the READ (.RD) file using the new commands to match the inference network shown in Figure 4 A,B, and C. The ZONE and MATH commands are necessary for creating the original "leaf" maps (Figure 7).

In order to test the validity of this approach, I attempted to duplicate as much as possible the work reported by Duda et al. (1978) using the data for the Island Copper deposit in British Columbia. Their model had 112 spaces and 53 rules. I simplified the model to deal only with a quartz-bearing intrusive stockwork model resulting in 44 spaces and 41 rules. Figures 9, 10, and 11 show the input data used; Figures 12, 13, and 14 show the intermediate results, and Figure 15 shows the final result of running the model and shows the outline of the ore body. All the figures show the limit of sulfide as a reference. All of these figures have been converted to certainty for direct comparison with Duda et al.'s results. Although Duda et al.'s maps are not reproduced here, visual Fures inspection indicated better than 80% agreement. Duda et al. (1978) made the following observation:

It is interesting to see how the inference network combined these data to form the final results. For example, the data in Figure . . . [9] were combined to produce a favorability map based on structural infor- mation alone (corresponding to Space FSM1 in Figure . . . [4b]. This 128-by-128 array of certainty values is shown as an image in Figure . . . [12]. In these favor- ability images . . . [larger squares] correspond to a

certainty of -5, . . . [smaller squares] to a certainty of +5--with intermediate . . . [sized squares] corresponding to certainties . . . [from large is low, to small is high]. Thus, based on structural information alone, the most favorable sites are seen to be near the fault intersections, the least favorable sites, in the breccia pipes or in the region of sulfide-only stockwork.

Figure . . . [13] shows how the data on lithology and alteration were combined with the IP data (corresponding to Space FLA in Figure. . .[4c]. Based on these data alone, the most favorable sites are near the boundary of the potassic and the phyllic zones, the least favorable in the regions of high pyrite.

These results on structures and alteration are combined with the data on magnetic anomalies and the intrusive contact to produce the results portrayed in Figure . . . [14] (see Space OFE in Figure . . . . . [4B]. The addition of data from geochemical soil sampling produces the final favorability map, shown in Figure . . . (15). In addition to indicating the most favorable drilling sites, this map gives some idea of the expected size of the ore body. Figure . . . (14 also] shows the outline of the ore body superimposed on the final map. Clearly, the size of the ore body has been underestimated, but the most favorable drilling sites are

in high-grade ore prospects Duda et al. 1978.

The foregoing methodology is only the start for developing a true GES. Others have tried to apply Prospector's rules, including Duda et al. (1978); Campbell et al. (1982); and S. Doesher and R. McCammon (pers. comm.) (1987). Davis and Nanninga (1985) discussed GEOMYCIN, an expert system tied to a vector GIS. Texas Instruments (1987) reported some success developing a vector-based GES. Morse (1987) described using an expert system and passing the conclusions to a vector GIS for selection of the appropriate features from a target map. Chandra and Goren (1986) developed an experimental knowledge-based geographic data analysis program called Geodex, and Robinson et al. (1986) reviewed and discussed expert systems and GIS's. Usery et al. (1988) published a report on interfacing in expert system with the ERDAS image processing system.

POSSIBLE FUTURE ENHANCEMENTS

A possible enhancement would be a network evaluator similar to RENE, the Resident Network Evaluator (Reboh 1981), written for Prospector, which would assist the expert in creating the knowledge base. It would find and point out logical inconsistencies in P(E) values as well as unconnected spaces. After checking, it would write out the required command stream. Another useful program
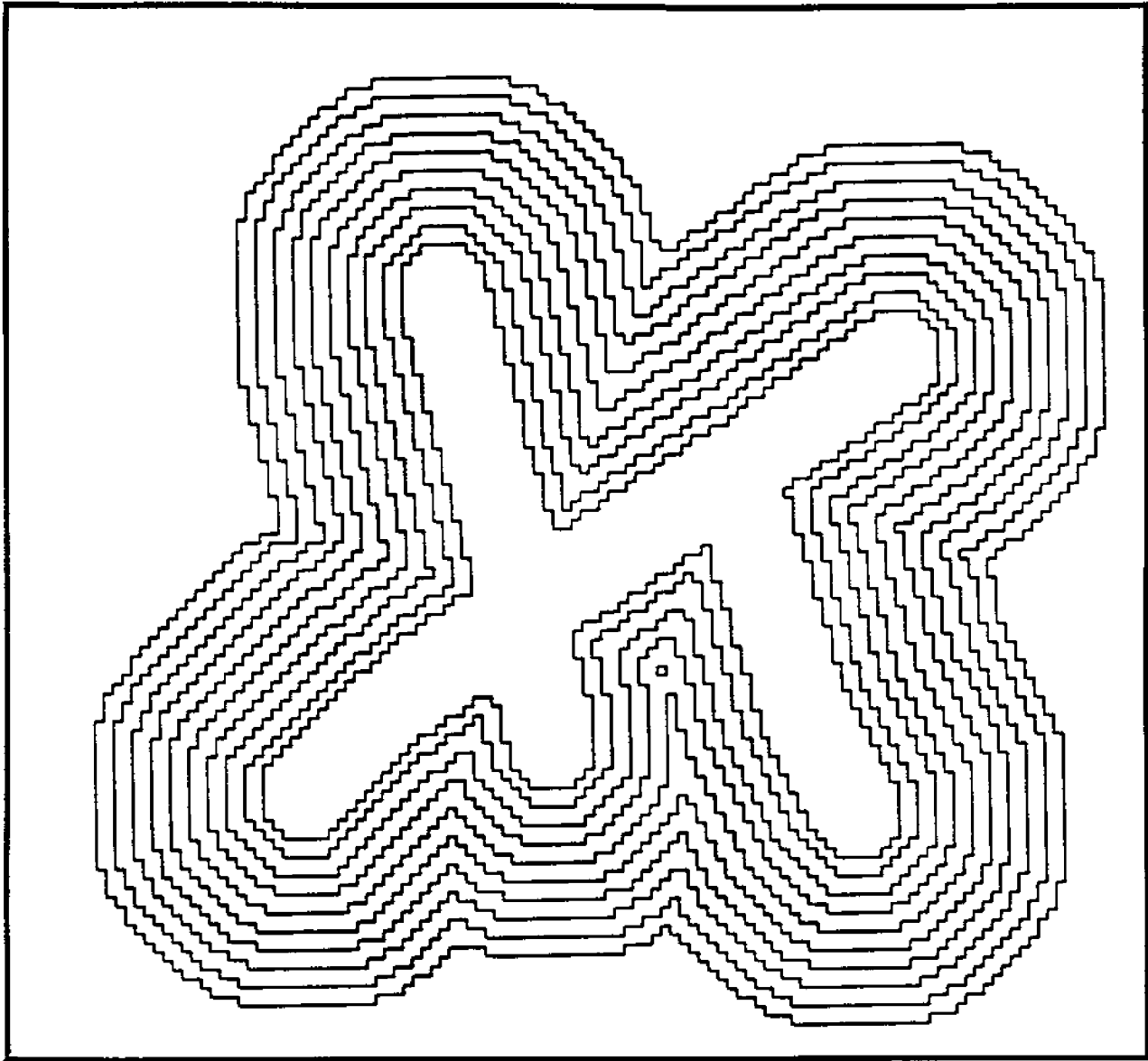
Figure 8. Probability Map XNCM1. A=100, B=500

would be one which prompts the user for map names he/she assigned to a space and would substitute that name for the default values in the read (.RD) file. A simple enhancement would be to add range checking before a map is used to prevent the inadvertent use of maps with values out of the 0 - 1 probability range.

IMPORTANT FEATURES OF PROSPECTOR THAT HAVE NOT BEEN EMULATED

Prospector is a backward chaining expert system: it finds the most reasonable top-level hypothesis and "climbs" down the inference network to find questions that would

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Table 2. Five new MAPS commands.

AND	performs fuzzy AND logic on up to 64 maps.
OR	performs fuzzy OR logic on up to 64 maps.
NOT	performs fuzzy NOT logic on 1 map.
BAYES	performs Bayesian probability on up to 64 maps.
CERTAINTY	converts from probability to certainty on 1 map.

The new AND command finds the minimum value from each space, e.g.:
   AND evidence1 PE .1 WITH evidence2 PE .04 .... FOR hypothesis.

The new OR command finds the maximum value from each space, e.g.:
   OR evidence1 PE .3 WITH evidence2 PE .2 .... FOR hypothesis.

The new NOT command subtracts each cell from 1, e.g.:
   NOT evidence1 PE .25 FOR hypothesis.

The new BAYES command does Bayesian updating of probability e.g.:
   BAYES evidence1 PE .32 LS .04 LN 1 ,
   WITH evidence2 PE .12 LS 1.5 LN .24 ,
   .
   .
   FOR   hypothesis PH .05

The new CERTAINTY command converts probability maps (range 0 to 1)
to certainty maps (range -5 to +5), e.g:
   CERTAINTY probmap PE 1.7 FOR certmap.

---

affect that hypothesis. Since all answers are propagated upward through the entire inference network, a different hypothesis might result. This can lead to a different set of questions being asked.

Prospector communicates with the user using certainty factors (-5 to +5), which it converts to probability for internal calculations. Prospector has extensive error checking, e.g., you answer the question, "How certain are you that biotite is present?" with a value of +3. Later in the session you answer, "How cer-

tain are you that hornblende has been altered to biotite?" with a value of +5. Prospector will catch this inconsistency and force you to correct it. Context rules are used to determine in what order to ask questions, or even if a question should be asked, e.g., if you are certain that biotite is absent, it makes no sense to ask if hornblende has been altered to biotite.

Prospector allows the user to ask for a more detailed rephrasing of a question, as well as giving a detailed explanation on why the question

Table 3. Maps read file for GES model.

```
COMMENT     START OF GES MODEL FOR FAVORABLE DRILLING LOCATION
COMMENT                       -- FIG. 4 --
COMMENT
COMMENT     START OF FAVORABLE LITHOLOGY AND ALTERATION
COMMENT                     -- FLA -- FIG. 4C --
COMMENT     USE THIS READ (.RD) FILE FIRST
COMMENT
OR          XKZ       PE .1 ,
WITH        XNB1      PE .1 ,
WITH        XPHZ      PE .1 ,
WITH        XAZ       PE .1 ,
FOR         K_PH_AZ
COMMENT
BAYES       XHP       PE .1 LS    .004 LN 1 ,
WITH        XKZ       PE .1 LS   5.0   LN 1 ,
WITH        XNB1      PE .1 LS  76.0   LN 1 ,
WITH        XPHZ      PE .1 LS   5.0   LN 1 ,
WITH        XAZ       PE .1 LS   1.6   LN 1 ,
WITH        K_PH_AZ   PE .1 LS   1.0   LN  .001 ,
FOR         FAM1      PH .05
COMMENT
OR          XKZ       PE .1 ,
WITH        XPHZ      PE .1 ,
FOR         K_PHZ
COMMENT
AND         XIRBG     PE .1 ,
WITH        K_PHZ     PE .1 ,
FOR         FLS
COMMENT
OR          FLS       PE .1 ,
WITH        XIIR      PE .1 ,
FOR         FIHC
COMMENT
OR          FIHC      PE .1 ,
WITH        FAM1      PE .1 ,
FOR         FLA
COMMENT     END OF FAVORABLE LITHOLOGY AND ALTERATION
COMMENT                   -- FLA -- FIG. 4C --
COMMENT     CONTINUE WITH OTHER FAVORABLE EVIDENCE
COMMENT                   -- OFE -- FIG. 4B --
COMMENT     START OF OTHER FAVORABLE EVIDENCE
COMMENT                     -- OFE -- FIG. 4B --
COMMENT     USE THIS READ (.RD) FILE SECOND
COMMENT
NOT         XKZ       PE .1 ,
FOR         NXKZ
```

(Continued)

Table 3.   (Continued).

```
COMMENT
AND        XNRLD    PE .1 ,
WITH       NXK2     PE .9 ,
FOR        ULD
COMMENT
BAYES      XNCCP    PE .1 LS 15      LN 1 ,
WITH       XNRHD    PE .1 LS 15      LN 1 ,
WITH       ULD      PE .1 LS    .02 LN 1 ,
WITH       XNBP     PE .1 LS    .2  LN 1 ,
FOR        FPD1     PH .1
COMMENT
BAYES      XNCO1    PE .1 LS  3.5   LN 1 ,
WITH       XNIO1    PE .1 LS  3.5   LN 1 ,
FOR        FPO1     PH .1
COMMENT
BAYES      XNCM1    PE .1 LS 1000   LN 1 ,
WITH       XNIM1    PE .1 LS 1000   LN 1 ,
FOR        FPM1     PH .1
COMMENT
OR         FPM1     PE .1 ,
WITH       FPO1     PE .1 ,
FOR        FFM1
COMMENT
BAYES      FFM1     PE .1 LS  7.0   LN 1   ,
WITH       XNFI1    PE .1 LS  2.0   LN 1   ,
WITH       FPD1     PE .1 LS 90.0   LN .02 ,
WITH       XQOSOVV  PE .1 LS    .01 LN 1   ,
FOR        FSM1     PH .1
COMMENT
BAYES      XNCIR    PE .1 LS  3.5   .LN 1.0    ,
WITH       XAMHL    PE .1 LS  2.0   LN 1.0    ,
WITH       FSM1     PE .1 LS  5.0   LN  .125 ,
WITH       FLA      PE .1 LS  8.0   LN  .143 ,
FOR        OFE      PH .23
COMMENT    END   OF   OTHER FAVORABLE EVIDENCE
COMMENT                  -- OFE   -- FIG. 4B --
COMMENT    CONTINUE WITH FAVORABLE LOCATION TO DRILL
COMMENT                  -- FLD   -- FIG. 4A --
COMMENT    START OF FAVORABLE LOCATION FOR DRILLING
COMMENT                      -- FLD -- FIG.4A --
COMMENT    USE THIS READ (.RD) FILE THIRD
COMMENT
BAYES      XPMC     PE .1  LS 20 LN 1 ,
WITH       XFAC     PE .1  LS  3 LN 1 ,
FOR        SAMC13 PH .17
COMMENT
```

(Continued)

Table 3. (Concluded).

```
AND        X2_4    PE  .1 ,
WITH       SAMC13  PE  .17 ,
FOR        FAMC
COMMENT
BAYES      X2_4    PE  .1   LS  15  LN  0.1 ,
WITH       FAMC    PE  .1   LS   3  LN  1.0 ,
WITH       XITA    PE  .1   LS   2  LN  1.0 ,
FOR        FSG     PH  .17
COMMENT
BAYES      FSG     PE  .17  LS  20  LN  .1 ,
WITH       XISB    PE  .1   LS  20  LN  .1 ,
FOR        IPC     PH  .17
COMMENT
BAYES      XLOS    PE  .1   LS   1  LN  .0001 ,
WITH       IPC     PE  .17  LS   3  LN  .25 ,
WITH       OFE     PE  .23  LS  20  LN  .1 ,
FOR        FLD     PH  .17
COMMENT
COMMENT    END OF FAVORABLE LOCATION FOR DRILLING
COMMENT                  -- FLD -- FIG. 4A --
COMMENT    END OF GES MODEL
COMMENT                  -- FIG. 4 --
COMMENT    MODEL EXECUTION COMPLETED, RETURNING TO INTERACTIVE
           MAPS READ
```

was asked. Prospector allows the user to volunteer information in order to influence the top-level hypothesis. Prospector can give the user a detailed summary, at any time, explaining what factors had what effect on its certainty values.

SUMMARY

As you can see, setting up a GIS as an expert system is not a simple undertaking, but once the knowledge base is completed to some acceptable level, the user needs only create the required input maps. Although this paper discusses using a GES for finding minerals, the methodology can easily be used for spatial analysis of any problem that deals with "uncertain" data.

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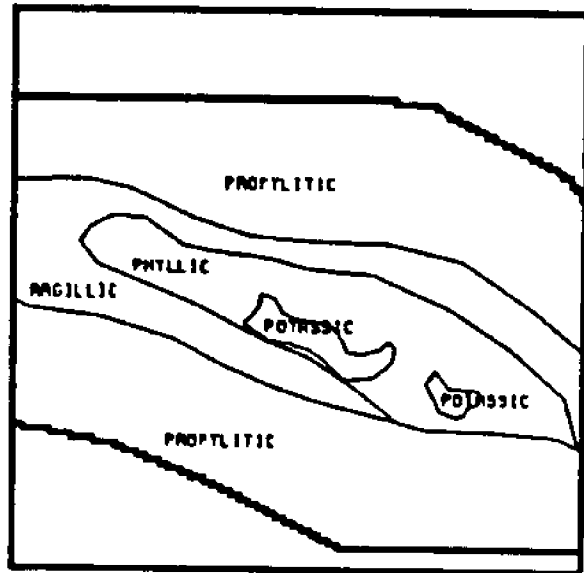
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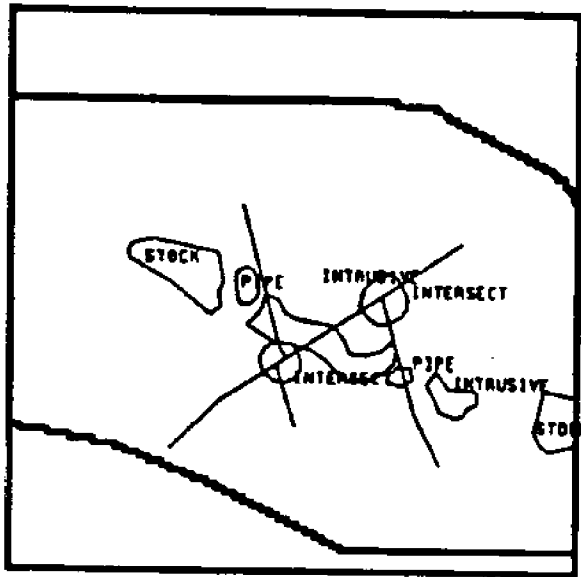
Figure 9.   Structures.
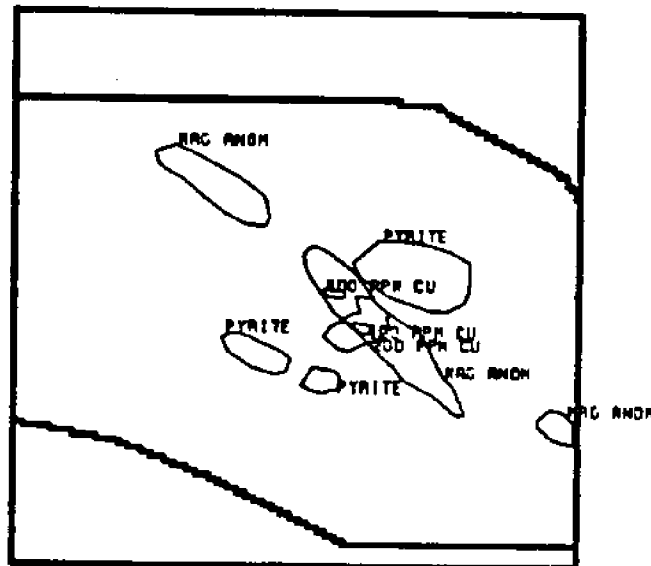

Figure 10.   Alteration.

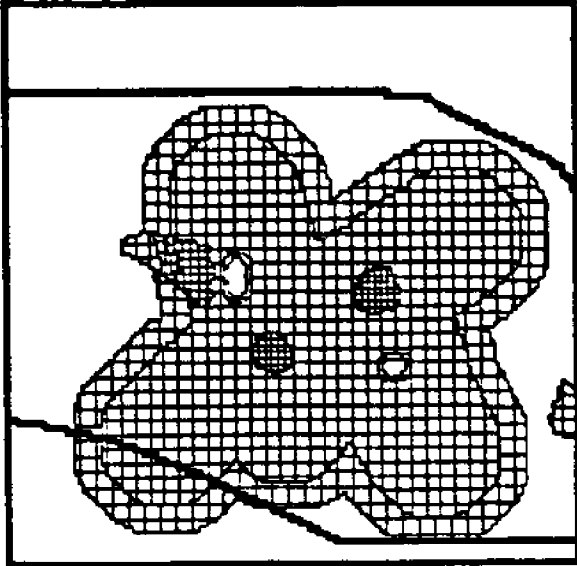
Figure 11.   Geochemistry and geophysics.

Figure 12.   Favorable
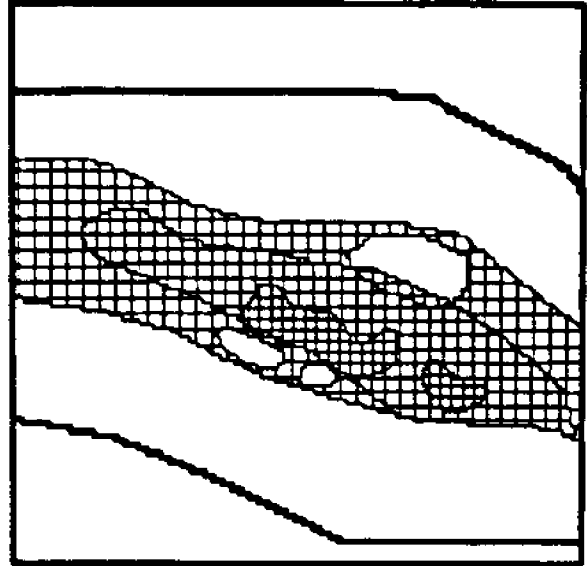structures.

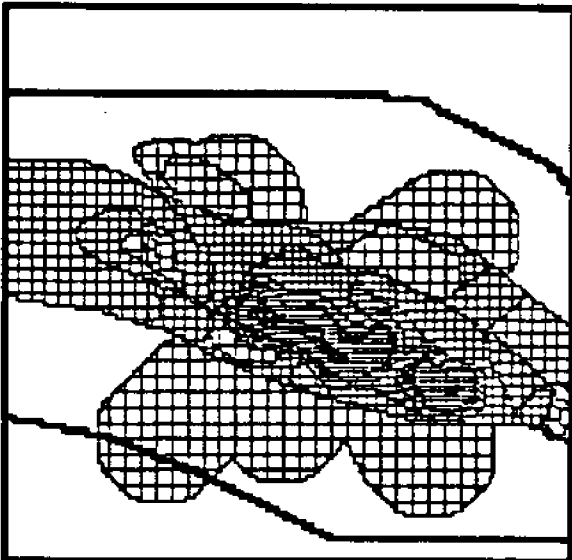Figure 13. Favorable lithology
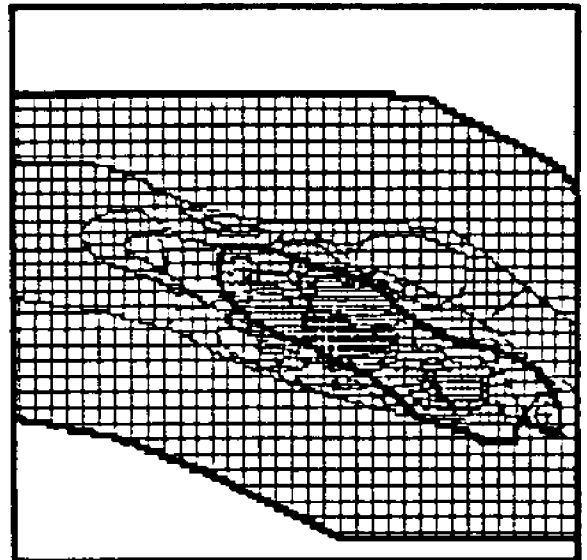and alteration.

Figure 14.   Other favorable
evidence.

Figure 15.   Final favorability
map.

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GEOLOGICAL MAPPING IN THE BLANDING
BASIN OF SOUTHEAST UTAH USING MOSS

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ABSTRACT

A full suite of complex subsurface geological maps of the Upper Ismay Formation in southeast Utah were prepared using GIS. The result was the Greater Blanding Basin Known Geological Structure (KGS), which added 98,000 new acres of Federal land and consolidated eight smaller KGS's. The primary benefit was the competitive sale of prime Federal oil and gas leases. The technology consisted of producing an Upper Ismay, presumably productive, area map by overlaying porosity, thickness, and structure contour maps of the Upper Ismay formation using GIS. In addition, current well status base maps were produced and updated regularly in order to pin-point changes in the oil field activity.

PROJECT DESCRIPTION

The Branch of Fluid Minerals in the Moab District office of the Bureau of Land Management (BLM) prepared a full suite of complex subsurface geological maps of the Upper Ismay Formation in southeast Utah using the Geographic Information System (GIS) computer program. This study demonstrated that an area covering 131,000 acres was highly prospective for the discovery of new oil fields. Consequently, the Greater Blanding Basin Known Geological Structure (KGS) was established to designate Federal land in this area as "presumably productive." Previously, eight small "administrative" KGS's, covering about 33,000 acres, had been formed in the study area. Therefore, the net result of the study was to add 98,000 "new" acres and to consolidate the existing KGS's. The study area focused on sixteen townships, about 576 square miles, located in the Blanding Basin; one of the most active oil plays in the Rocky Mountain region. The study commenced in February 1986 when all non-competitive leasing in the study area was suspended and ended fifteen months later in May 1987.

BENEFITS

The Federal Government benefited from this study because 16,659 acres of oil and gas leases were sold via competitive auction rather than through the simultaneous lottery. At the competitive

sale in April 1988, this acreage was sold for total bonus bids of $2,109,500 plus filing fees. If the KGS study had not been undertaken, this same acreage would have been sold via the lottery drawing for $1.00 per acre or total bonus bids of $16,659 plus filing fees. The net economic benefit to the Government, from bonus bids alone, is therefore greater than $2 million. Even though the recent Federal leasing bill has abolished KGS's, this project paid off handsomely. In addition, the GIS and component program MOSS (Mapping Overlay and Statistical System) were proven to be valuable tools for geological mapping and base map preparation.

BASE MAP PREPARATION

The first step in any geological investigation is preparation of a base map which displays oil production from the target formation (Figure 1). Land net over 32 townships was digitized from topographic maps using ADS (Automated Digitizing System). Section lines were identified separately from township boundaries so that each could be plotted with a different line type. The land-net data were then merged using the DISSOLVE command to remove lat/long "merge" lines, which are not attractive. A mapping window that extended a few sections beyond the study area in all directions was formed using the GENERATE rectangle command. Next, well locations were digitized from topographic

maps after being carefully spotted using footage coordinates from the well files. The subject assigned to each well location was an API number, a unique identifier. Resultant well locations were plotted and double checked to ensure accuracy of about 100 feet.

WELL STATUS, ISMAY FORMATION

The study area initially contained 240 wells completed in five different productive formations. Continuous drilling added 41 wells, which revealed four significant new oil fields during the course of the study. Since we were only concerned with the characteristics of Ismay formation in this study, the productivity of other formations was not considered. Therefore, well status shown in Figure 1 is based upon hydrocarbon shows and production test results from just the Ismay Formation in each well. This base clearly shows a linear alignment of the productive Ismay oil wells in rows trending northwest to southeast through the study area. We recognized that this trend was caused by some physical phenomena which could probably be mapped and quantified.

ISMAY STRUCTURE CONTOUR MAP

The next step was to map the structure on top of the Ismay to see if production is related to highs or lows or faulting. This map is similar to a topographic map but it describes

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GREATER BLANDING BASIN
KNOWN GEOLOGICAL STRUCTURE
STRUCTURE – UPPER ISMAY

T36S

T37S

T38S

T39S

R23E   R24E   R25E   R26E
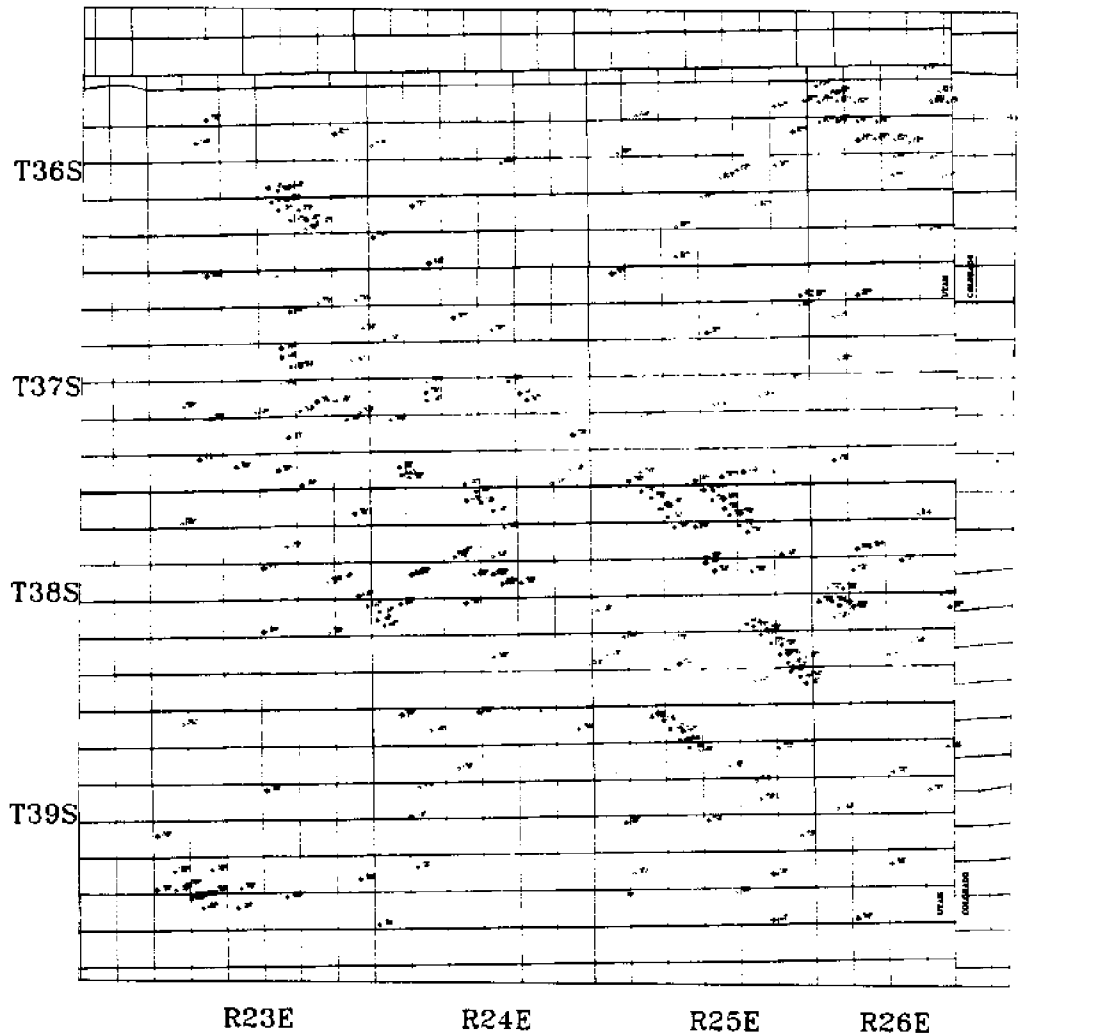
Geological Analysis: A. Lynn Jackson
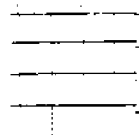Computer Mapping: Steven Jones
Technical Review:

Map Overlay Statistical System (MOSS)
GEOGRAPHIC INFORMATION SYSTEM

U.S. Department of the Interior
Bureau of Land Management
Moab District Office
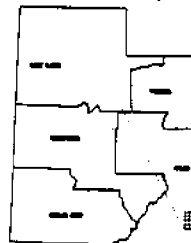San Juan Resource Area
San Juan County, Utah

Effective

N

Location Map

State of Utah

BASE MAP
WELL STATUS AT COMPLETION
UPPER ISMAY FORMATION ONLY

• PRODUCTIVE OIL WELL

• PRODUCTIVE GAS WELL

• P&A, WITH SHOW OF OIL OR GAS

• P&A, NO TEST DATA AVAILABLE

• P&A, TESTED BUT NO OIL OR GAS

— ATTRIBUTE DISPLAY —
(TOP) WELL API NUMBER
(BOTTOM) STRUCTURE, SUBSEA

Figure 1.

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the upper surface of the Ismay, 6,000 feet below ground level. The elevation of the top of the Ismay for each well was determined by detailed analysis of subsurface well logs. The elevation data were gridded and contoured (mechanics of mapping discussed later) to produce Figure 2. Notice that many of the productive oil wells in the Ismay occur on an "intermediate structural platform" trending northwest to southeast through the study area.

DEFINING THE INTERMEDIATE STRUCTURAL PLATFORM

The boundaries of this platform were defined using three MOSS commands. The PROFILE command generated cross sections, which are vertical slices through the formation. We were then able to view structure in the y-z or thickness dimension. By repeating the PROFILE command, we dissected the study area in all directions and readily identified all major structural features, including the intermediate platform. The SLOPE command was then used to identify those areas where the rate of change of the slope (dip) was greater than 10%. The target platform was well defined because the average slope was less than 5%. The only other "flat" features in the study area are two "benches" (one in the northeast and one in the southwest corners of the study area) and the bottom of the syncline in the southwest. The SLOPE command generated a grid map which could be shaded on screen but could not be plotted at
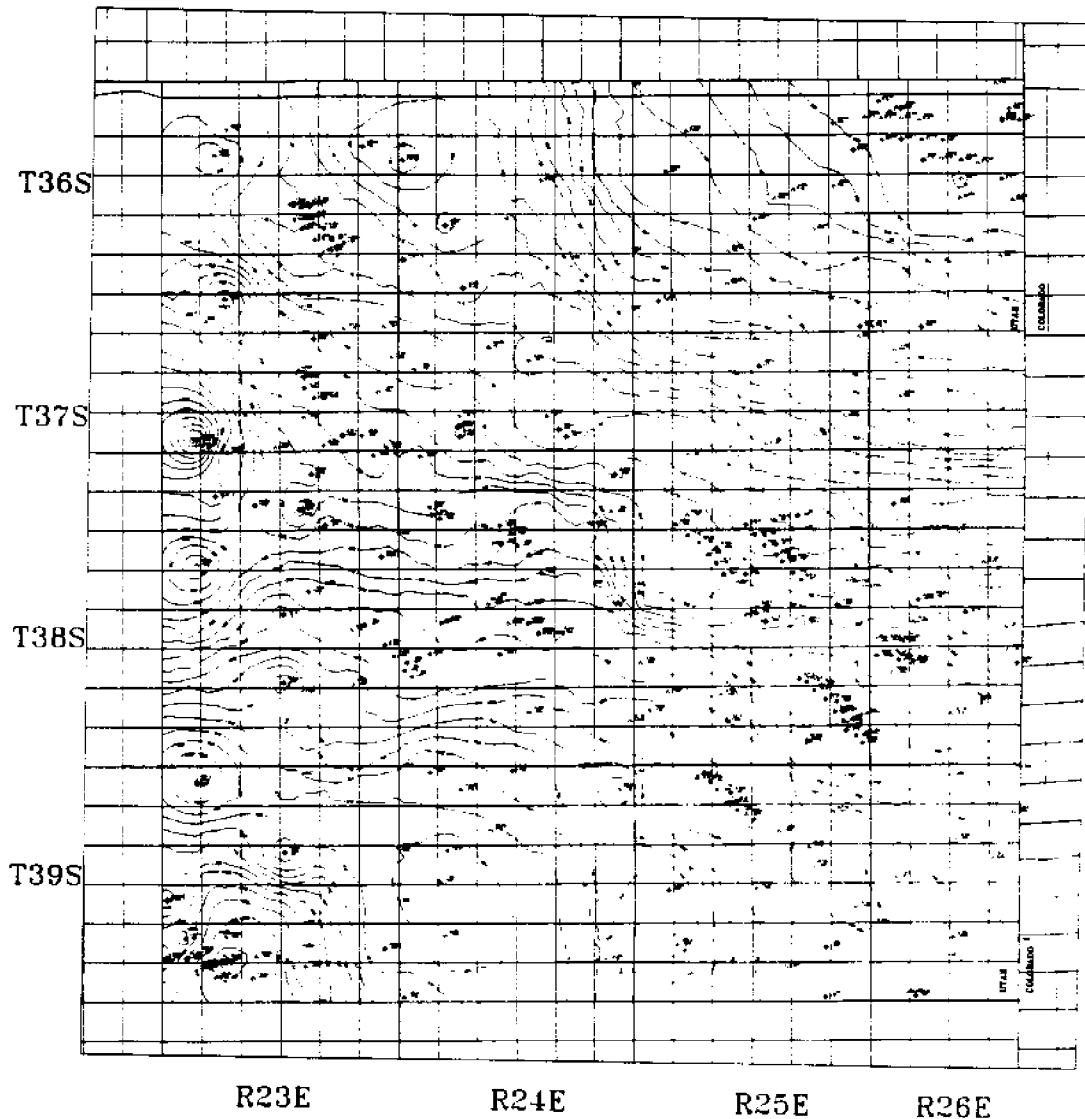
this time. Last, the THREED command was used to depict the Ismay topographic map in three dimensions. This command yields a qualitative image which cannot be plotted. However, rotating 576 square miles of land through dozens of orientations confirmed the nature of the regional dip and our interpretation of the structure.

ISMAY THICKNESS CONTOUR MAP

The oil reservoirs in the Ismay Formation in this area are carbonate mounds which are similar to modern "algal" reefs. Therefore, we wondered if the Upper Ismay Formation would thicken in those areas where the mounds had developed. The thickness of the Upper Ismay was calculated by subtracting the elevation of the top from the elevation of the base, using the MATH command (for each well for which a well log was available). This attribute, thickness, was then gridded and contoured to yield a "gross isopach" map (Figure 3). This map shows that overall thickness does indeed increase significantly in the area previously identified as the intermediate structural platform. Thickness increased to over 130 feet around the productive region and thinned rapidly to the north and east. The 130-foot isopach contour line was isolated using the SELECT ITEM command and overlaid on the structure map for detailed comparison.

In the southwest part of the study area, however, the thickness continues to increase to

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GREATER BLANDING BASIN
KNOWN GEOLOGICAL STRUCTURE
STRUCTURE – UPPER ISMAY

T36S

T37S

T38S

T39S

R23E   R24E   R25E   R26E

Geological Analysis: A. Lynn Jackson
Computer Mapping: Steven Jones
Technical Review: Utah State Office

Map Overlay Statistical System (MOSS)
GEOGRAPHIC INFORMATION SYSTEM

U.S. Department of the Interior
Bureau of Land Management
Moab District Office
San Juan Resource Area
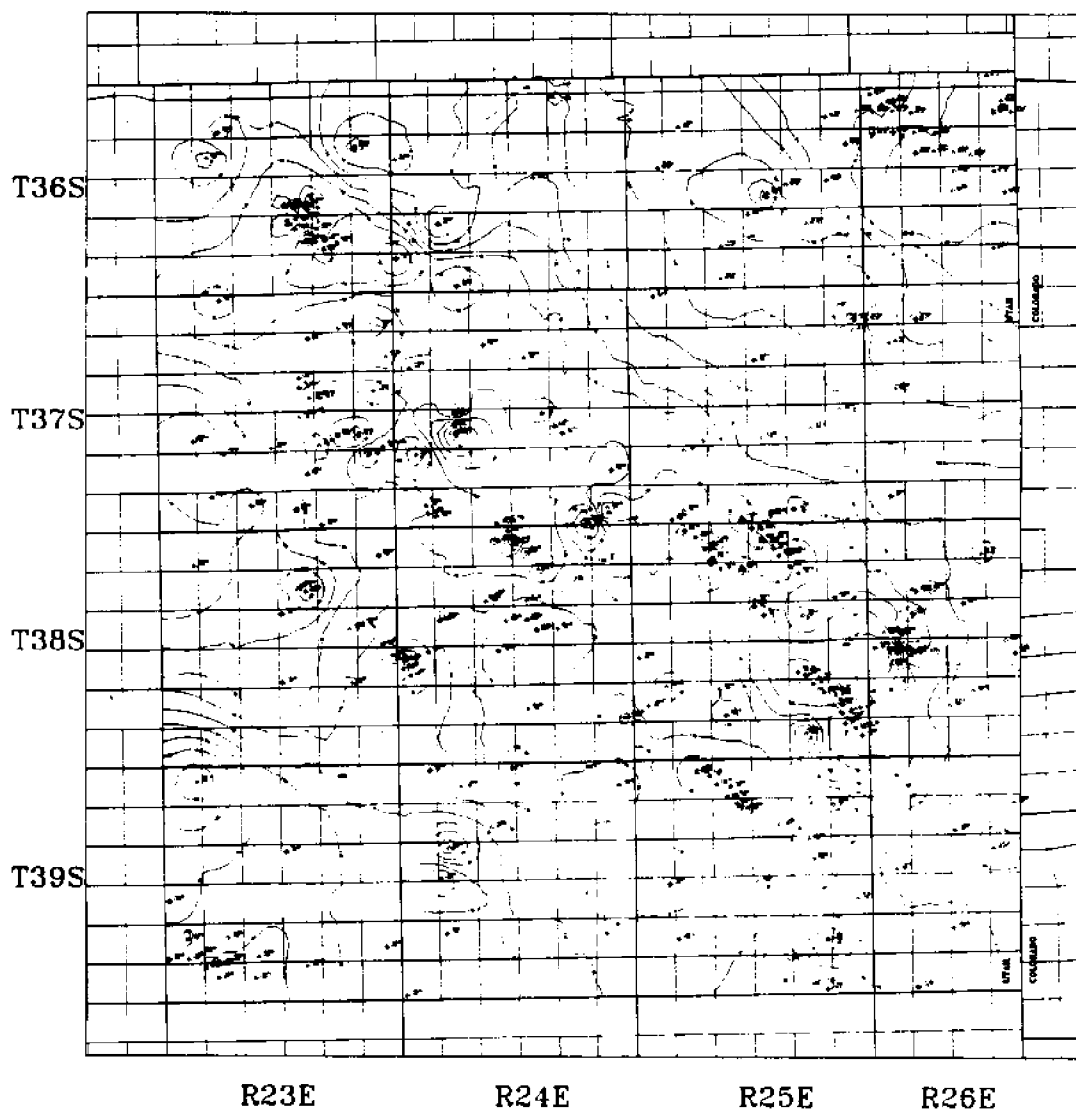San Juan County, Utah

Effective May 1, 1987

BASE MAP
WELL STATUS AT COMPLETION
UPPER ISMAY FORMATION ONLY

* PRODUCTIVE OIL WELL
* PRODUCTIVE GAS WELL
* P&A. WITH SHOW OF OIL OR GAS
* P&A. NO TEST DATA AVAILABLE
* P&A. TESTED BUT NO OIL OR GAS

** ATTRIBUTE DISPLAY **
(TOP) WELL API NUMBER
(BOTTOM) AVERAGE POROSITY

Figure 2.

GREATER BLANDING BASIN
KNOWN GEOLOGICAL STRUCTURE
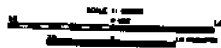# THICKNESS – UPPER ISMAY

Geological Analysis: A. Lynn Jackson
Computer Mapping: Steven Jones
Technical Review: Utah State Office

Map Overlay Statistical System (MOSS)
GEOGRAPHIC INFORMATION SYSTEM

U.S. Department of the Interior
Bureau of Land Management
Moab District Office
San Juan Resource Area
San Juan County, Utah

Effective May 1, 1987

BASE MAP
WELL STATUS AT COMPLETION
UPPER ISMAY FORMATION ONLY

• PRODUCTIVE OIL WELL
• PRODUCTIVE GAS WELL
• P&A, WITH SHOW OF OIL OR GAS
• P&A, NO TEST DATA AVAILABLE
• P&A, TESTED BUT NO OIL OR GAS

** ATTRIBUTE DISPLAY **
(TOP) WELL API NUMBER
(BOTTOM) AVERAGE POROSITY

Figure 3.

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over 170 feet. The well logs revealed that this thickening is due to the Upper and Lower Ismay Formations combining to form one geological unit. In fact, the shale which separates the two formations in the area around the intermediate platform disappears in the southwest. Therefore, where this shale is absent, our basic premise was not valid. To further complicate the analysis, the regional dip appeared to be distorting the "true structural and stratigraphic relationships." Nature is not usually simple to explain and a team of KGS experts decided that additional investigation was required.

ISMAY POROSITY CONTOUR MAP

To better define the productive trend, several months were spent working with well logs to determine the "weighted average porosity" (void space in the rock) in the Upper Ismay in each well. The logs indicated that geological "facies" or rock type varied across the study area. In the southwest, the Upper and Lower Ismay Formations combined into one limestone unit with little porosity. This and other work led us to conclude that this part of the Ismay was originally deposited in a "shallow, nearshore" environment. In a similar manner, it was postulated that in the northeast, the Upper Ismay was deposited in a "deep water marine" type environment, which also reduced porosity development. Across the center

of the study area, the average porosity increased to over 4% in the "build up" or "shelf" facies, which may have been deposited in intermediate water depths.

Average porosity for each well was gridded and contoured (Figure 4). This map shows significant development of porosity around the productive oil fields. The porosity, thickness, and structure maps were overlaid and areas of intersection examined using grid-map shading. All productive Ismay oil fields were present within the area where porosity increases to over 4% and where the Ismay generally thickens to over 130 feet-- along the intermediate structural platform or on adjacent structural features. One theory to explain this observation is that when the Ismay Formation developed, the combination of water depth, temperature, and light conditions along the platform was just right for the growth of the porous reefs. Combining porosity, thickness, and structure parameters was convincing and after geological editing, the Greater Blanding Basin KGS was defined using the 4% porosity contour.

PROBLEMS WITH
COMPUTER CONTOURING

The geologists were pleased with the information conveyed by the maps and the ways that MOSS was able to reduce drudgery and repetition. However, at this stage of the process, it was important that the

GREATER BLANDING BASIN
KNOWN GEOLOGICAL STRUCTURE
POROSITY IN UPPER ISMAY
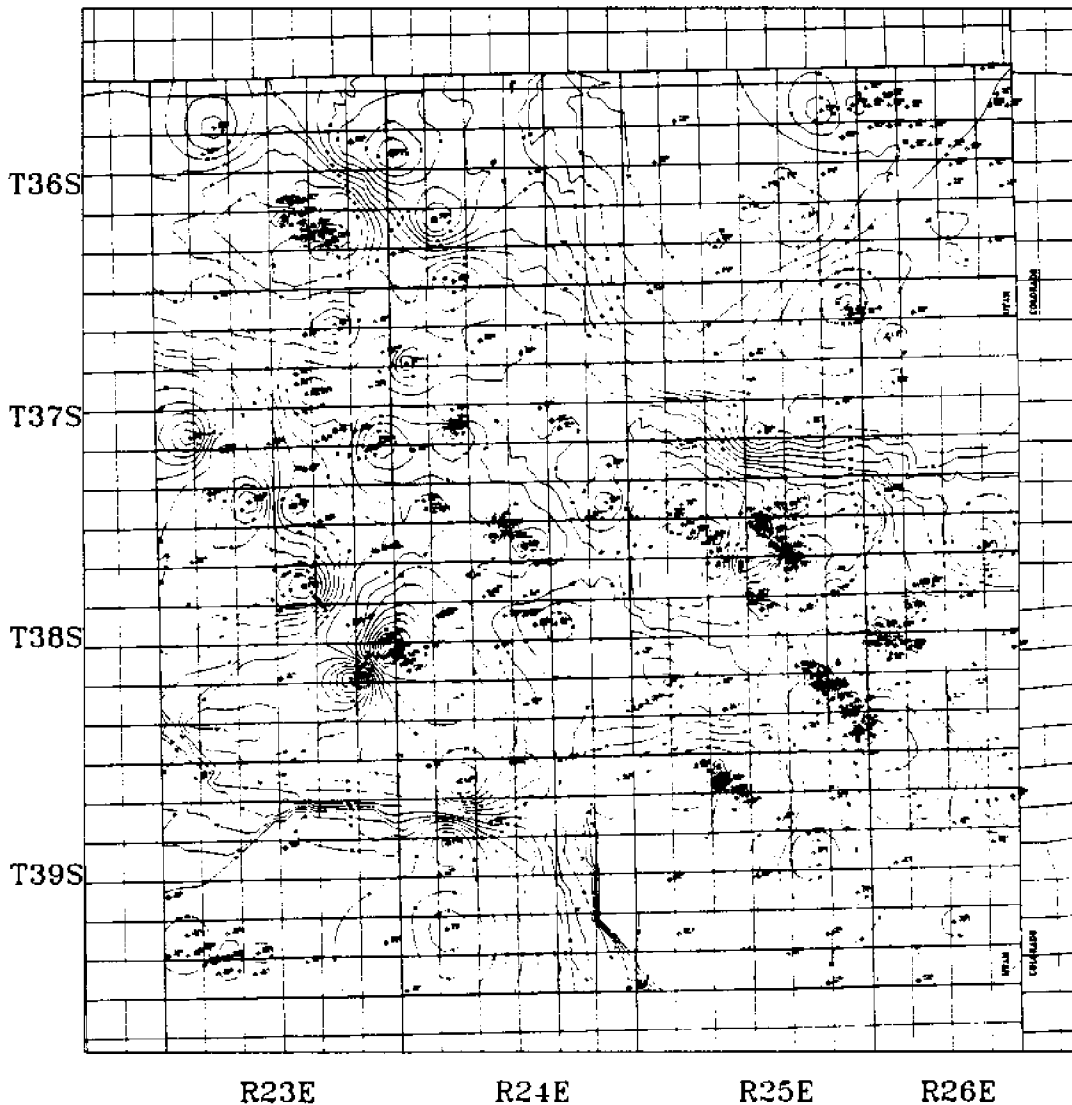
BASE MAP
WELL STATUS AT COMPLETION
UPPER ISMAY FORMATION ONLY

· PRODUCTIVE OIL WELL
* PRODUCTIVE GAS WELL
+ P&A, WITH SHOW OF OIL OR GAS
· P&A, NO TEST DATA AVAILABLE
* P&A, TESTED BUT NO OIL OR GAS

** ATTRIBUTE DISPLAY **
(TOP) WELL API NUMBER
(BOTTOM) AVERAGE POROSITY

Figure 4.

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geologists input their own knowledge and experience to make the maps more realistic and useful. The gridding process tends to distort and extrapolate data in areas where data density is low. For example, on the average porosity map, the contours in the southwest part of the study area are extended several miles beyond actual well control. This expands the area of porosity development without a firm basis. Therefore, these contours were manually edited as shown in Figure 5. Another problem area for the gridding process is in the productive oilfields where data density is high. We used 40-acre grid cells, which obviously eliminates high resolution in the oilfields where well density is 40 acres or less. This result led to the conclusion that the computer maps were actually describing geology on a "regional basis." To compensate, the oilfields were manually mapped to resemble "elongated bulls eyes" as seen in reef buildups exposed in nearby outcrop (Figure 5).

Other changes to the computer maps consisted of closing contours and smoothing to form a more continuous surface, which more accurately reflects nature. The SMOOTH command was not useful because the amount of smoothing was barely discernible. Figure 6 is a hand-smoothed version of the Ismay structure map (Figure 2) for comparison. A major improvement to MOSS would be an attachment of a computer-aided drafting package such as AUTOCAD for contour and cartographic editing.

GRIDDING

The gridding process is the technique used to extrapolate known data--multiple attributes from each well--into areas of no-well control. This procedure strongly affects the quality and usefulness of the contour map derived from the resultant grid cell map. We divided the entire study area, 576 square miles (plus some buffer zone), into 10,000 forty-acre grid cells. A numerical value of the multiple attribute was assigned to each grid cell. Three gridding algorithms were available at this time: krigging, quintic spline, and the 8-point weighted average. Krigging is based on advanced geostatistical theory using variograms and is the preferred technique in many oil companies. We defaulted through the menus and produced the porosity contour map shown in Figure 7. This krigged contour map is aesthetically appealing, but the contours do not rigorously honor the basic data points. This may be statistically reasonable, but it violates the laws of contouring and is unacceptable for KGS maps. The quintic spline gridding algorithm yields beautiful smooth, curvy contour lines on a macroscopic scale. However, the geologists felt that the contours were excessively rounded and circular and not representative. Instead, we preferred the 8-point weighted average gridding algorithm which is simple to use and rigorously honors the basic data points. The resultant contour lines are

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GREATER BLANDING BASIN KGS
POROSITY IN UPPER ISMAY
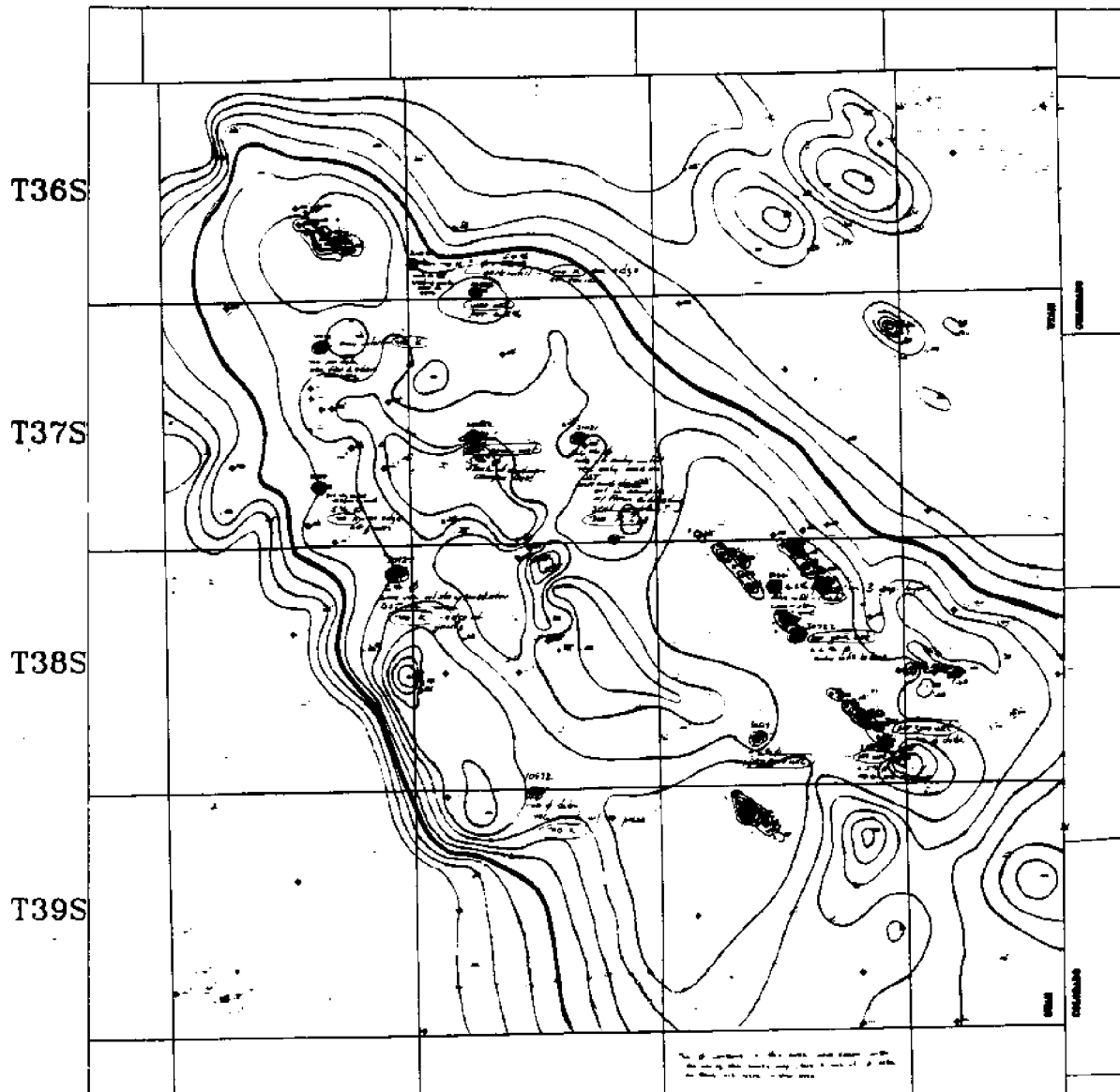
T36S

T37S

T38S

T39S

R23E   R24E   R25E   R26E

WELL STATUS
INITIAL COMPLETION, UPPER ISMAY

- Productive Oil Well
● Productive Gas Well
◆ Well with Show of Oil or Gas, P&A
Plugged and Abandoned

Figure 5.

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GREATER BLANDING BASIN KGS
STRUCTURE TOP UPPER ISMAY, SS
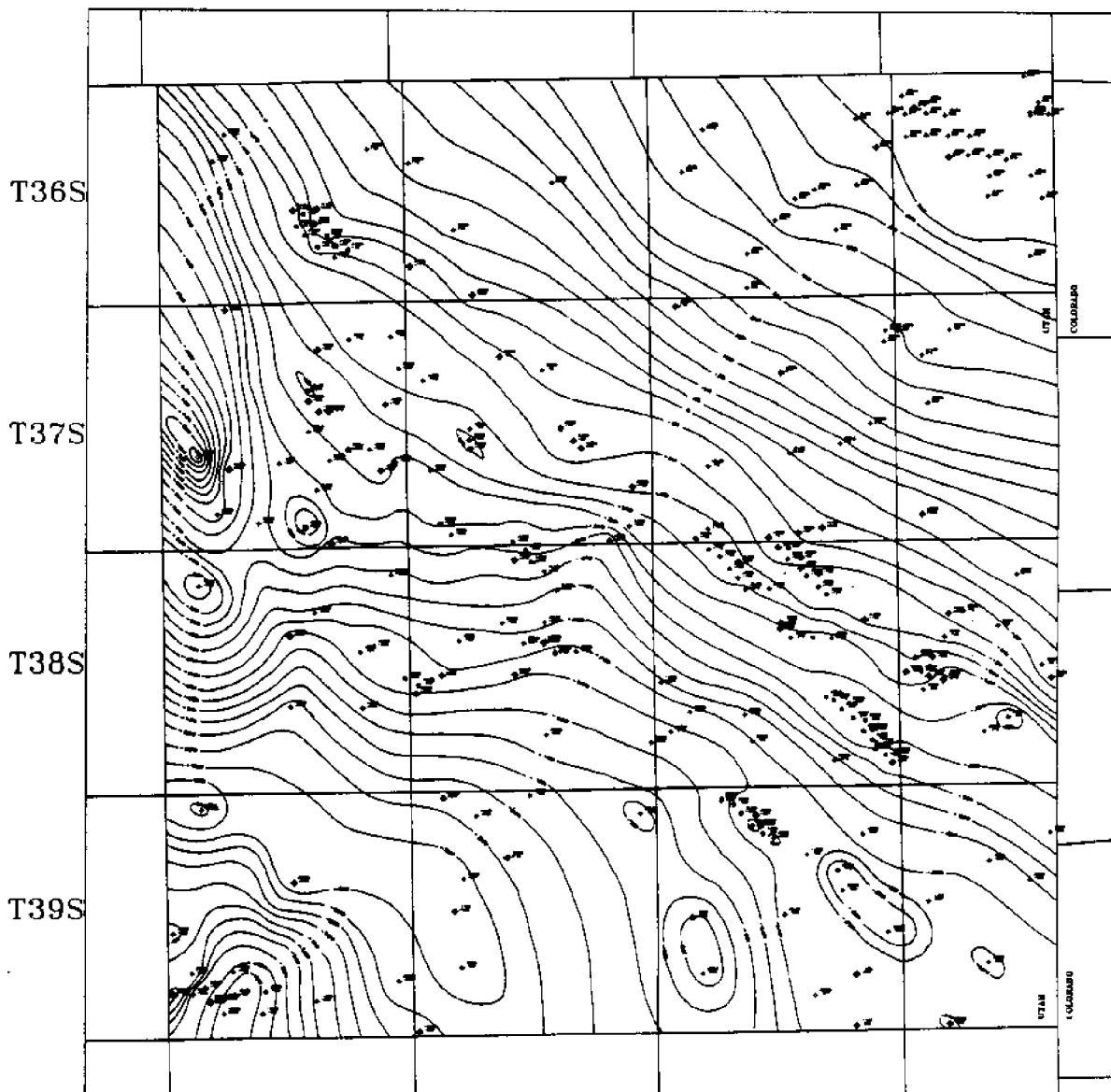
WELL STATUS
INITIAL COMPLETION, UPPER ISMAY

- Productive Oil Well
- Productive Gas Well
- Well with Show of Oil or Gas, P&A
- Plugged and Abandoned

Figure 6.

GREATER BLANDING BASIN KGS
AVERAGE POROSITY IN UPPER ISMAY

T36S

T37S

T38S

T39S

R23E   R24E   R25E   R26E

WELL STATUS
INITIAL COMPLETION, UPPER ISMAY

- Productive Oil Well
- Productive Gas Well
- Well with Show of Oil or Gas, P&A
- Dry Well with No Show, P&A
- Well with No Data, P&A

SCALE 1:62500

MILES

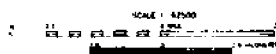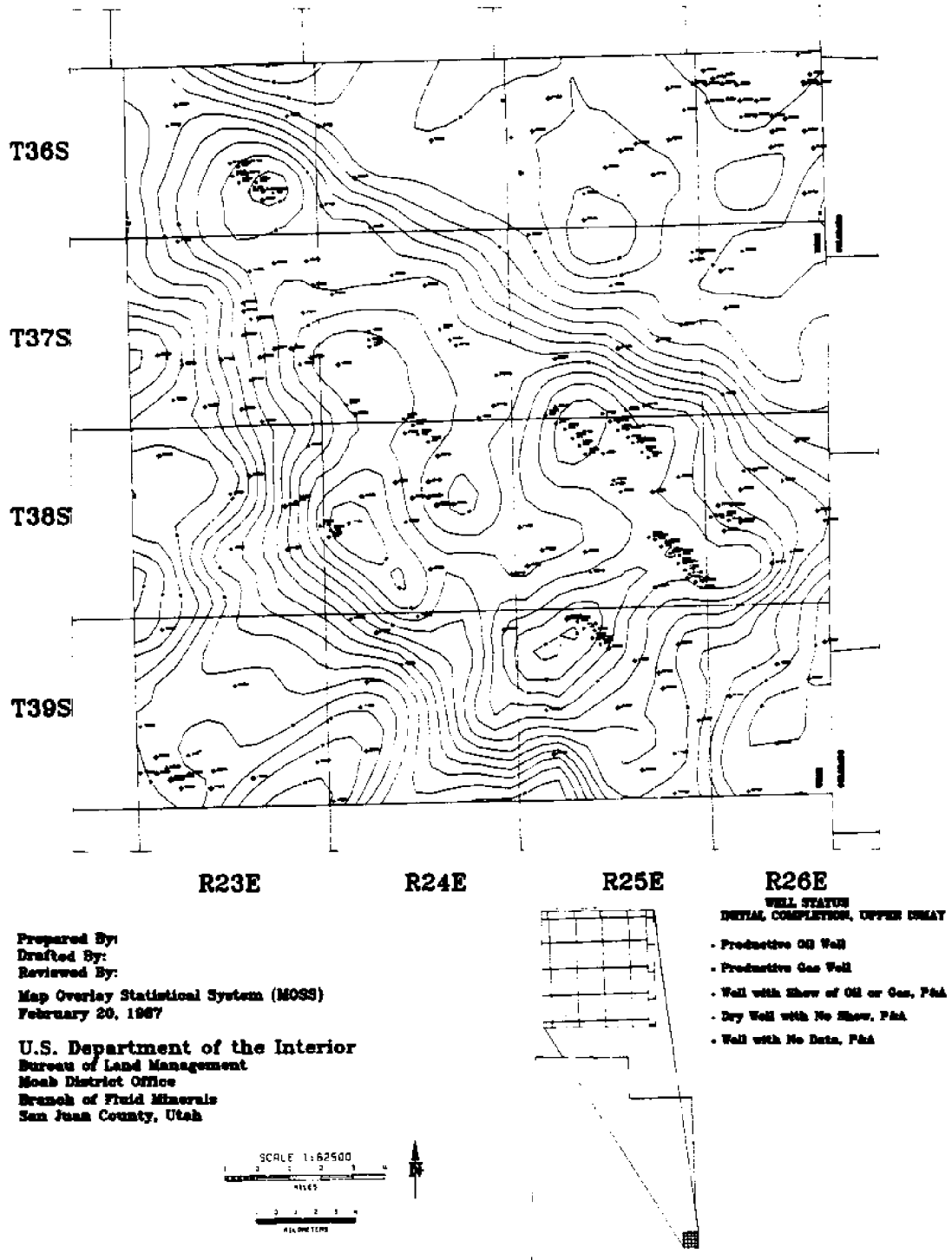KILOMETERS

Figure 7.

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jagged and much less aesthetically appealing but they are mathematically valid and were considered the most representative. Other algorithms are now available which may be even better.

MECHANICS

The mapping process required knowledge of several personal-computer-based programs, the Data General's AOS operating system, and GIS components ADS, MOSS, and COS (cartographic output system). Basic geological and engineering information was generated and stored using personal computer programs. A well log analysis program was used to calculate formation tops and porosity, which was then stored in Geographix's WELLBASE geological data base. Textual data such as formation core descriptions, drill stem test data, well status, and personal notes were managed with a "text" data-base manager. Oil production data were stored and analyzed using Garrett's LINDA software. Select reports were prepared from the PC data bases and then telecommunicated and uploaded into the Data General computer in Denver using the AOS CREATE command.

The uploaded files were edited and spaces removed using the SED editor and various macros. In MOSS, the PC reports were resequenced and then combined with the digitized well locations using UTILITY commands. API number is the key field used to link the records containing the multiple attri-

butes to the points. Specific attributes were selected using BSEARCH and then contour maps and base maps were generated using the PENPLOT command. Impressive cartographic enhancements were added to the final plots by overlaying COS plots on those from PENPLOT. Most GIS work was performed on an IBM-AT personal computer using PCPLOT for graphics emulation and SOFTERM for AOS and text editing.

CURRENT WELL STATUS BASE MAP

When the geological maps were complete, it became evident that a different kind of base map would also be useful. Therefore, well symbols were changed to display current class and status regardless of which formation might be producing. Well class is the function for which the well is being used, such as producing oil well, water injection well, or water supply well. Well status is whether the well is currently active, temporarily shut-in, or plugged and abandoned. The concept is to provide a snapshot of what is happening in the field right now. We soon discovered that current well status changes regularly, unlike well status at completion. In fact, changes were happening so rapidly that a new suite of base maps were made and distributed almost monthly. New wells were being drilled continuously. Existing wells were changing status as old wells were depleted. New waterfloods were started and pipelines were constructed to shut-in gas wells. Much of the

value of the current-status base maps is the capability to quickly convey significant new developments to those who need to know.

MINERAL OWNERSHIP AND RASTERIZATION

The rasterization capability available in the GIS was useful in determining exactly how Federal lands were impacted by the Blanding Basin KGS. Figure 8 is the current well status base map with two important themes overlaid: KGS's, both old and new, and Federal mineral ownership. We rasterized the KGS theme and then the Federal mineral ownership theme to produce two cell maps. These two cell maps were then CROSSed to form a third cell map. The resultant cell map pinpointed the unleased Federal lands which were inside the new KGS but outside the old KGS's. These valuable lands were the primary target of the study and competitive leasing was recommended. All lands outside the Blanding Basin KGS that were being held in suspense were immediately released for sale via the simultaneous lottery. The CROSS command produced a detailed list of all possible combinations of the two themes which allowed us to distinguish Federal from non-Federal lands and leased from unleased lands, both inside and outside all KGS's.

FEDERAL UNITS AND PARTICIPATING AREAS

In order to make the current-status base map even more use-
ful, we digitized and overlaid two other themes important in fluid minerals applications: Federal units and participating areas (Figure 9). These "jurisdictional themes" are important to identify because ownership and regulatory requirements are significantly impacted by such designations. Unit boundaries change as old units contract and new units are established. Participating areas are formed and expanded; thus, updates are needed every few months. Oil companies were keeping the study area blanketed by units, which told us that we were on the right track. As a result of the geological phase of this study, we recognized that the Ismay oil fields are small in areal extent, typically two or three miles long and half-a-mile wide. Therefore, we pressed operators to request smaller units and to submit more realistic unit geological maps. The Units Section in the Utah State office could then start requiring one obligatory unit well for each· 5,000 acres, approximately, in each proposed unit. Previously, the Bradford Canyon unit, which included 22,000 acres of prime land, had been formed by the drilling of just one well. Therefore, as a result of this study, additional Federal wells were drilled, some of which were completed as producers.

ADDITIONAL BENEFITS

The geological and especially the current well status base maps were found to be useful tools for day-to-day operations. The number of

GREATER BLANDING BASIN
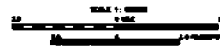# KNOWN GEOLOGICAL STRUCTURES
CURRENT WELL STATUS
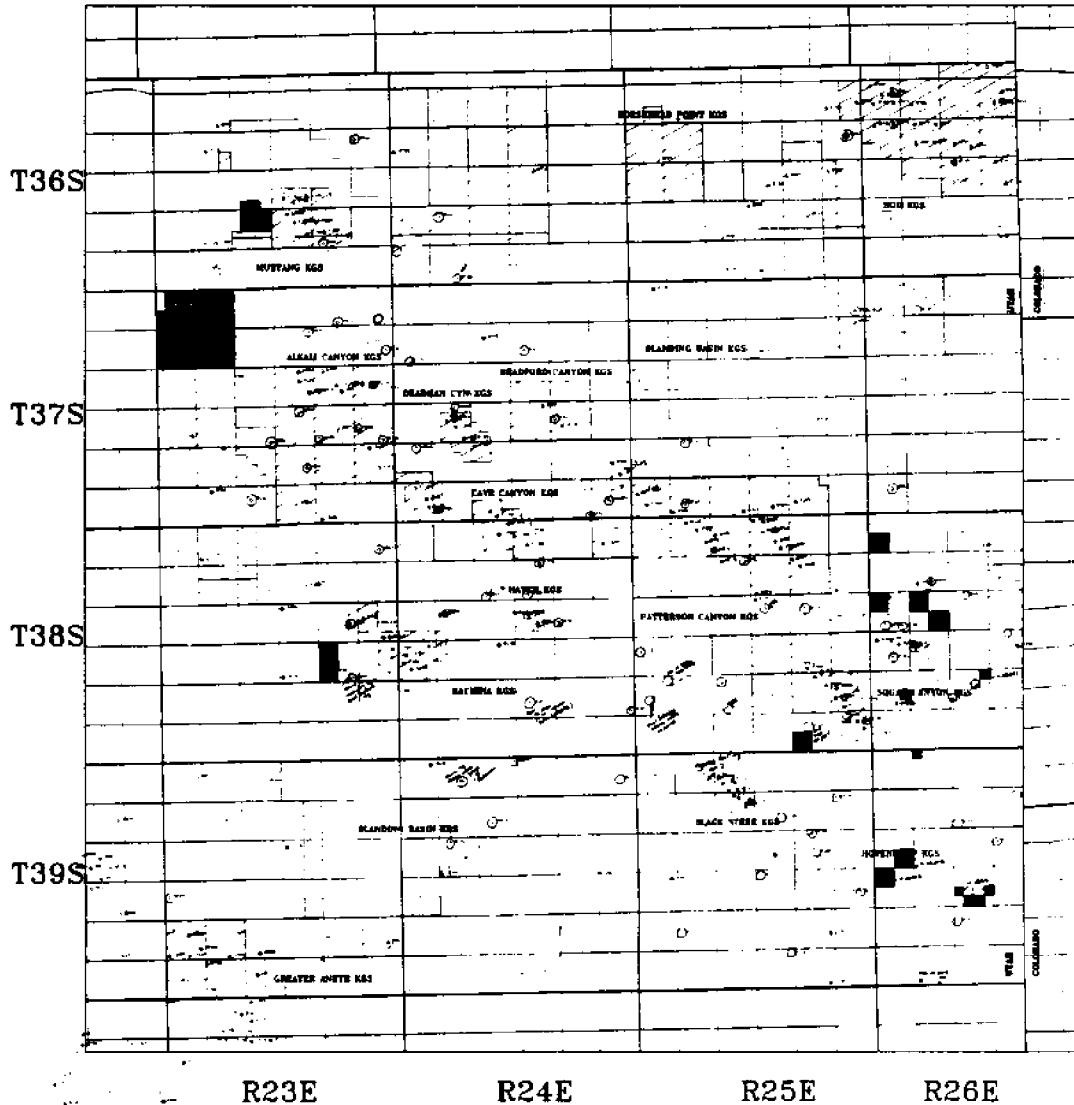
Figure 8.

Map Overlay Statistical System (MOSS)
GEOGRAPHIC INFORMATION SYSTEM

U.S. Department of the Interior
Bureau of Land Management
Moab District Office
San Juan Resource Area
San Juan County, Utah

Effective October 1, 1987

WELL SYMBOLS

GREATER BLANDING BASIN
UNITS & PARTICIPATING AREAS
CURRENT WELL STATUS
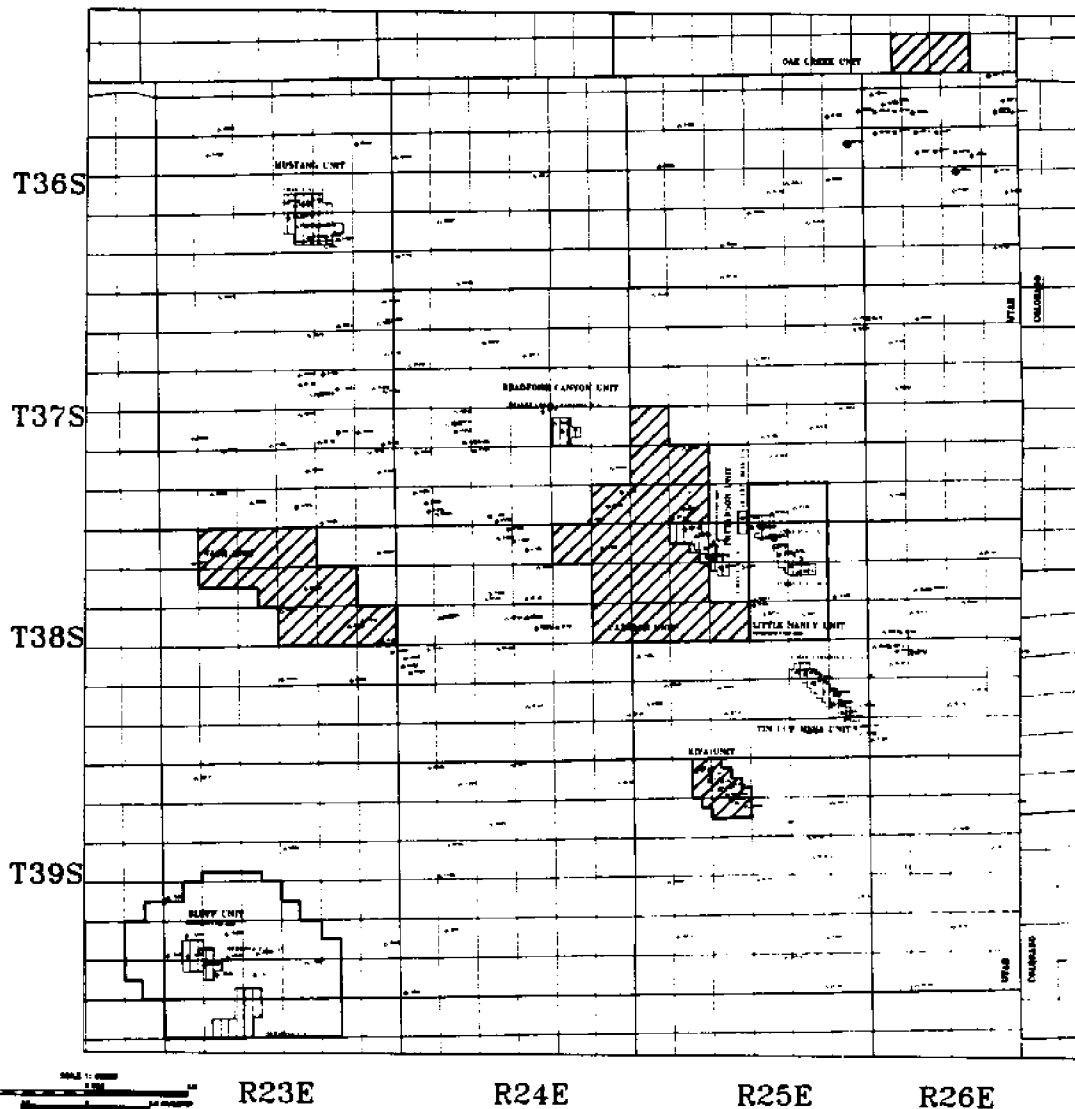
Figure 9.

unforeseen benefits which materialized was surprising. The Fluid Minerals staff in the District and Resource Area began using the maps to help keep track of activity both in the office and out in the field. The maps became a focal point during discussions with operators who frequently requested copies because they conveyed a great deal of relevant information. The District Manager used the maps during meetings with the National Park Service, who were proposing to expand the boundaries of the Hovenweep National Park into the area that we defined as the Greater Blanding Basin KGS. The maps were used during negotiations with the State of Utah regarding Federal/State land exchanges and consolidations. They were also used to identify areas of significant oilfield activity which had been designated as critical deer winter habitat. Such a designation restricted use of these lands from November 1 through March 1, the wintering period for deer. The maps enabled us to identify which wells and operators were going to be impacted by this restriction. The maps were also used in presentations to the Utah State Office on Fluid Minerals program progress and other management presentations. Other viable applications for these kinds of maps may develop in environmental or planning studies.

ACKNOWLEDGMENTS

DUCK NUMBERS ESTIMATED FROM GROUND COUNTS, MOSS MAP DATA, AND AERIAL VIDEO

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H. Ross Pywell, U.S. Fish and Wildlife Service, St. Petersburg, FL 33702

Lee D. Miller, MicroImages, Inc., Lincoln, NE 68528

ABSTRACT

We describe the use of remotely sensed data on pond abundance and availability of upland habitats, in conjunction with ground counts of breeding ducks, to estimate pond conditions, breeding populations, and recruitment. Sample areas were mapped from aerial photographs and MOSS files were prepared. Aerial video data were obtained for the same areas and entered into a microcomputer by custom software. Models were developed to estimate breeding populations and recruitment for five species of ducks. The estimates compared favorably with published estimates. A combination of detailed MOSS base maps, aerial video data, and ground census data holds promise as the basis for an efficient operational system for waterfowl managers.

INTRODUCTION

Inventory of habitat and estimation of population size are prerequisite to wildlife management (Davis and Winstead 1980). Waterfowl (Anatidae) present particularly difficult problems in inventorying because of their mobility and extensive ranges (Cowardin and Blohm 1987). Nearly all census methods involve sampling and most methods are indirect. The best known and most comprehensive surveys in North America are the cooperative breeding ground surveys con- ducted by the U.S. Fish and Wildlife Service and the Canadian Wildlife Service (Martin et al. 1979). These surveys are conducted from low-flying aircraft along sample transects. The number of ducks counted from the aircraft are corrected for birds not seen by conducting concurrent ground counts on some of the same areas and applying an air-ground correction.

We took a different approach for four reasons. First, ground counts are time con-suming and costly and can cover only a minute fraction of the

vast breeding ground. Second, aircraft time is expensive and the need for an air-ground correction introduces variation and possibly bias into the estimates. Third, the amount of water is correlated with the spring breeding population, at least in the southern portion of the prairie pothole region of North America. Fourth, the amount of wetland habitat is relatively easy to estimate by remote sensing and the technology is improving at a rapid pace. Our method used the amount of wetland measured from remote sensing to predict the breeding population of ducks.

Waterfowl managers also require estimates of the number of young recruited to the fall population. This estimate is even more difficult to derive than that of the breeding population. The recruitment rate, like the breeding population, is, in part, a function of the amount and type of wetland and upland habitat available. We again used remote sensing to estimate habitat availability, which in turn served as a predictor of recruitment rate.

We summarize the technology that we used, describe its reliance on digitized remote-sensing data, and link these data to data derived from ground counts and aerial video. Finally we present examples of the results obtained from the method. After the base maps and aerial video were acquired, all data processing was done on microcomputers of the type that are available to most biologists.

METHODS

Base Maps

Detailed base maps were essential to development of our method. We applied the method in two studies. The first study estimated breeding population and recruitment for five species of dabbling ducks, mallard (_Anas platyrhynchos_), gadwall (_A. strepera_), blue-winged teal (_A. discors_), northern shoveler (_A. clypeata_), and northern pintail (_A. acuta_), on 320 10.4-km^2 plots from selected wetland management districts. Digitized habitat maps of these plots had been prepared during a previous study (Cowardin et al. 1988). The second study estimated mallard breeding population on nine 51.8-km^2 study areas in eastern North Dakota and western Minnesota. These study areas are being used by a team of researchers, and the maps serve their needs as well as ours.

All plots and study areas were mapped from high-altitude National Aeronautics and Space Administration, 1:65,000, color infrared photographs and National High Altitude Program, 1:58,000, color infrared photographs. Photointerpreted data from the 10.4-km^2 plots were transferred to overlays of United States Geological Survey (USGS) 1:24,000 topographic maps and then digitized on a digitizing tablet by means of the Wetland Analytical Mapping System (WAMS) software. Data for the 51.8-km^2 study areas were interpreted and digitized simultaneously by using an APPS-IV analytical stereo-

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plotter with graphics super-position and the WAMS software. The digitized data were converted to Map Overlay and Statistical System (MOSS) files and used to create various map products as well as ASCII text files. Each record in the text file gave the class, size, and perimeter of each polygon, a mapping unit representing a single habitat class. Classes of wetland were those described by Cowardin et al. (1979) and classes of uplands followed Cowardin et al. (1988). The maps and data files served to describe duck habitat at the time of photography, four to six years before the date for which breeding population and recruitment estimates were needed.

Data on three land ownership classes--Fish and Wildlife Service (FWS) easement, FWS owned in fee, and private land--were compiled on 1:250,000 USGS quadrangle maps and were digitized. MOSS files derived from these maps will be used in the future for re-stratification of the sample of $10.4-km^2$ plots.

Duck Counts

Early (1-15 May) and late (20 May-5 June) counts of breeding ducks were made on sample wetland basins on all plots and study areas. Ducks were tallied according to social groups described by Dzubin (1969) and interpreted as indicated breeding pairs by the method described by Hammond (1969).

The count was recorded separately for each wetland

basin. Wetland basins were assigned a unique number based on polygon numbers from the MOSS files. Those basins that contained a single polygon were given a basin number identical to the polygon number. When basins contained more than one polygon, the basin was assigned the number of the single polygon with greatest size within the deepest water regime.

Aerial Video

We obtained aerial color video of $10.4-km^2$ plots and $51.8-km^2$ study areas during May 1987. A JVC GY S700U camera equipped with a 6.5-mm wide-angle lens was mounted in each of several available aircraft including Cessna 172 and 185 and Partenavia surveyor. Data were recorded on a JVC BR 6200U tape recorder and images were viewed on a 12.8-cm JVC TM 22U color monitor in the aircraft. We obtained a swath sufficient to cover the $3.2-km^2$ wide plots and allow for navigational error by flying at an altitude of approximately 3,658 m above ground level. The $51.8-km^2$ study areas were flown in $1.6-km^2$ wide transects at an altitude of approximately 2,438 m above ground level.

ANALYSIS TECHNIQUES

Predictive Equations

Baseline regression equations relating the number of indicated breeding pairs to area and square root of area of each pond (that portion of a wetland basin containing water) were derived by means of SAS

(SAS Institute 1987) procedures during a prior study (Cowardin et al. 1988). We assumed that the curvilinear form of the equations would not change from year to year and place to place but that the density of ducks on a pond of a given size would. The duck counts conducted during the current study on a sample of individual ponds were used to adjust the regression equations up or down relative to the baseline equations and thereby obtain predictive equations specific to a given year and area. In this study we did not use separate regressions for different classes of wetland basins as in previous studies (Cowardin et al. 1983) because it was not possible to accurately classify wetland basins from our aerial video.

Wetland Classification

The purpose of the aerial video was to obtain estimates of the number and size of ponds. During a pilot study we were able to visually interpret the wet portion of a basin from video obtained during spring, but because of various problems, such as the presence of vegetation over the water, variation in turbidity, and sun glint, a completely automated classification did not appear possible. First attempts to obtain the data by a process involving visual classification of the wet basins on a video monitor and hand coding of the data proved to be impractical for applications requiring large samples of plots.

We used a custom micro-computer program designed by MicroImages, Inc., of Lincoln, NE, to overcome the problem described above. Our software FEATUREMAP was incorporated into the Map and Image Processing System (MIPS) marketed by that company. The software requires an IBM AT-compatible microcomputer equipped with an AT&T targa 16-image grabber board, a two-button mouse, monochrome monitor, and medium-resolution RGB color monitor.

We first viewed the taped image of the plot passing across the monitor and grabbed the image when it was about centered on the screen, as three digital rasters that were stored on various devices compatible with microcomputers. The software then allowed us to select a 10.4-km^2 plot or legal section (2.6 km^2) from the scene on the monitor and calibrate the data to the proper map scale. We next entered land ownership categories by copying the ownership boundaries from hard-copy maps to the screen with a mouse.

Ponds were classified by a combination of direct photo-interpretation of the image on the monitor and by automated techniques that allowed us to select a training set of pixels that were known to represent water from our ground-truth data. We knew that some areas, such as water under dense vegetation or water that showed sun glint, were wet but we could not classify them by automated techniques. The software allowed us to draw around these areas on the monitor by means of the mouse, and designate them as wet. All

areas classified as wet were color coded on the monitor. The software then produced three files: the original scene, the classified scene, and an ASCII text file with one record for each pond that gave its ownership, area, and perimeter. This file was used as input to the regression equations used for predicting breeding pairs.

The size of the image files (about 0.5 megabytes) and the number of scenes captured and classified during the two studies soon caused a problem with data storage and retrieval. The problem was solved by storing the image data on optical disks (about 115 megabytes per side). In addition, Micro-Images, Inc., developed indexing and retrieval software (HYPER) that allowed us to easily retrieve the scenes by pointing at the area to be retrieved on images of maps. These maps represented a series that increased in detail.

Data Summary and Reports

Several custom programs in PC-SAS were developed for processing the raw data and for producing the final report. Our intention is that these programs will become part of a system available to refuge managers with minimal training in statistics or computer programming. Field data were recorded on specially designed forms, entered into ASCII files, and subjected to error-checking routines. Errors were corrected. Data from the two counts were then combined into a single record giving the estimated breeding pairs of

each species for each pond. The program selected the early or late count for early- and late-nesting species. Mid-nesting species were assigned to the count nearest to the mid-date of the breeding season. Another program used the pond data and the adjusted regression equations to estimate numbers of breeding pairs for each species on each study area or wetland management district.

Recruitment rates by species for each sample plot or study area were calculated from the availability of nesting habitat taken from MOSS files and nest survival data reported by Klett et al. (1988). The program that calculated these rates was a simplified deterministic version of the stochastic model described by Johnson et al. (1987). Finally, another program estimated the number of young recruited to the fall population as the product of breeding population and recruitment rate and produced summary statistics (Tables 1 and 2).

RESULTS

MOSS Maps and Data Files

Three products were produced by means of MOSS and the Cartographic Output System (COS). Habitat maps at a scale of 1:5,000 for the 10.4-km^2 plots and 1:12,000 (Figure 1) for the 51.8-km^2 study areas were produced and used for various purposes such as planning simulated treatments (Cowardin et al. 1988) and
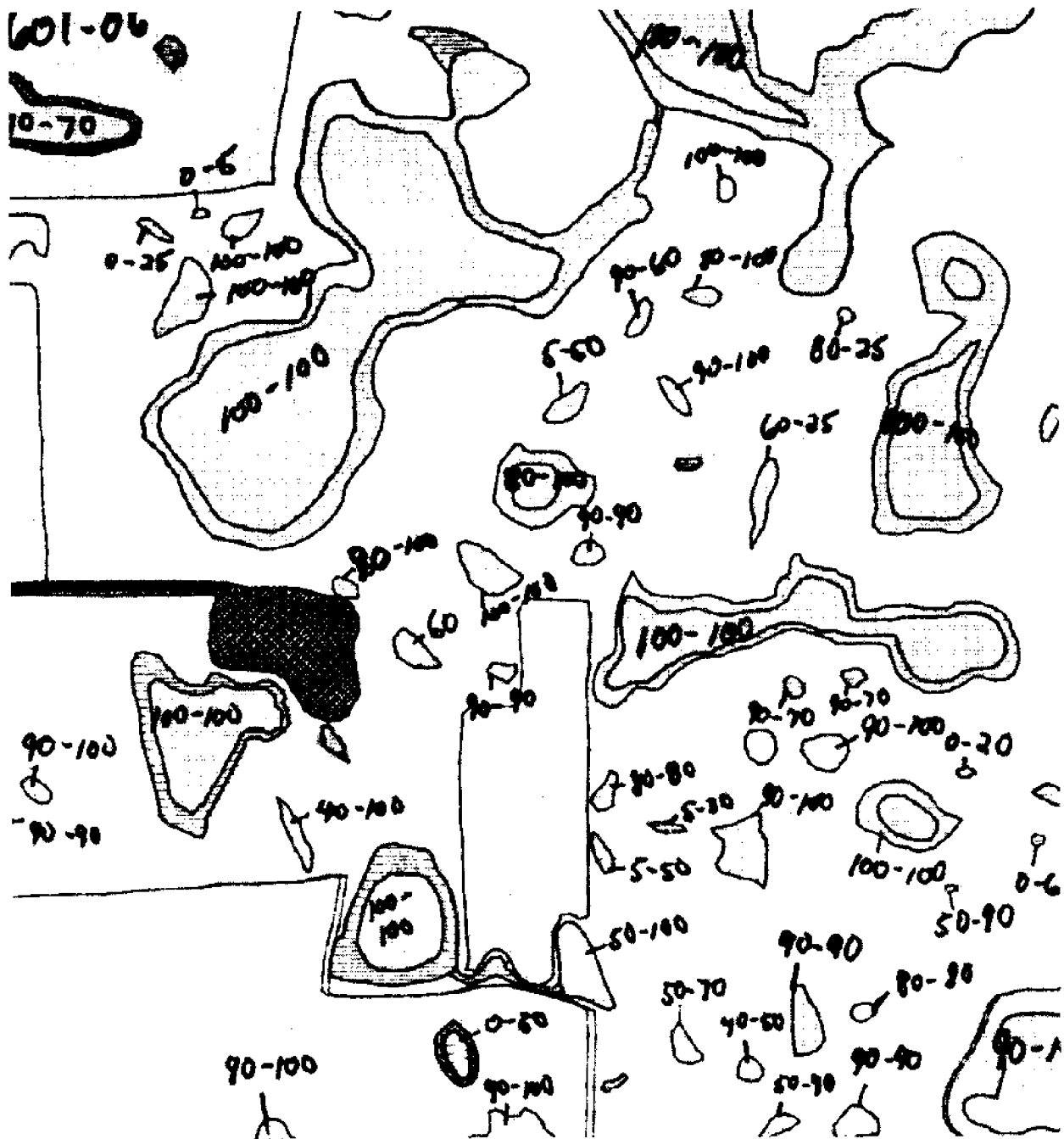
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Figure 1. Legal section (2.6 km^2) from a study area map showing upland and wetland habitats. Handwritten numbers represent annotation by ground crews of the percent of wetland basins that were full. These data aided photointerpretation of aerial video data.

selection of sample areas for ground studies (U.S. Fish and Wildlife Service, Small Unit Management, Jamestown, ND, unpublished progress report). The MOSS data were also used in combination with enlargements of the original photographs to produce many field maps at a scale of 1:12,000 (Figure 2). These maps were constructed by plotting the MOSS maps on mylar and photographically compositing them with enlargements of the original photographs and then preparing a master for production of inexpensive diazo copies. These maps were used by the ground crews for locating the wetlands where breeding pairs were counted as well as by others working on other projects on the same study areas. The MOSS data were also used to produce a file with an individual record for each polygon by means of the MOSS Audit command. This file was essential for selection of sample ponds and was required by the programs used to estimate breeding duck populations.

Aerial Video

We obtained aerial video (Meisner 1985) of 320 10.4-km^2 plots in May 1987 and 900 scenes of legal sections (2.6 km^2) covering nine study areas during the first week of April, May, June, and July 1987. The quality of the aerial video data was satisfactory for detecting ponds. We experienced some difficulties in detecting the pond boundary when ponds were in plowed fields or under shrub vegetation. The same problems are also encountered when

interpreting color aerial photographs. Our video methods were similar to those described by Maggio and Baker (1987) who also found that video furnished an inexpensive alternative to aerial photography and had the added benefit of furnishing immediately available data. Our experience suggests that one of the biggest advantages of video is the ability to monitor the images as they are acquired, thus assuring complete coverage of the target areas. The video images also have the advantage of being accessible to microcomputer via an image grabber board without using a scanner to capture the image.

The biggest problems with the video were the altitude (2,438 to 3,658 m above ground) and short focal length lens required to obtain complete coverage of our targets in a single pass. At those altitudes the images had poor color separation and were dominated by blue, especially on days with haze or dust in the air. This problem was compounded by our inability to maintain proper white balance when light conditions varied. Images obtained with the short focal length lens also had considerable spherical distortion.

Microcomputer Software

The software developed for this study made the job of interpretation and data summary possible. Previous attempts involved overlaying an image from a video monitor on a map with a Bausch and Lomb Zoom Transfer Scope (Meisner and

Figure 2. Portion of field map produced by overlaying MOSS map data on an enlargement of an aerial photograph. Polygon numbers were used to identify ponds.

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Lindstrom 1985) and then hand coding the attributes of the ponds. This method was abandoned because it took two people as much as four hours to process a scene. The semi-automated procedure reported here required about 15 to 60 minutes for one operator to process a scene. In addition, there were no transcription errors because the computer produced the data file. We also found that there was much value in having a record (classified image file) of the interpreted image.

The original (Figure 3) and classified images (Figure 4), which are easily retrievable from optical disk by means of the indexing software, furnish an updated record of habitat conditions that can be used in conjunction with base maps produced by MOSS. These images have been essential to other investigators working on the same study areas.

Wetland Habitat

Biological interpretation of the data derived by the methods described here is beyond the scope of this paper. However, we shall present two examples of the type of estimates that were derived.

Table 1 summarizes the wetland statistics for four land ownership classes based on May 1987 video for wetland management districts east of the Missouri River in North Dakota. Note that there are more ponds per square kilometer on easement land than on other ownership categories. The data show that 7.6% of the

surface of this region was covered by ponds. Cowardin et al. (1981) estimated that 10% of the land surface on a large study area in central North Dakota was occupied by wetland. That figure includes both ponds and dry wetlands. On Federal refuges and waterfowl production areas, 41% of the surface is wetland but these wetlands are much larger than for the other ownership classes (66.7 ha). Wetlands taken under easement are similar in size to private wetlands but there are more of them per square kilometer than on private land. The data suggest that the FWS accomplished its intent of protecting small wetlands used by pairs through wetland easement and purchase of larger more permanent wetlands as brood areas.

Duck Populations

Table 2 shows estimated breeding populations and recruitment estimates for five species of dabbling ducks. These estimates are similar to estimates presented by Stewart and Kantrud (1974) for the years 1967, 1968, and 1969, derived from census of 0.65-km^2 random sample plots in about the same area covered by our survey. They presented breeding pair densities of 2.8, 1.9, 5.4, 1.5, and 2.8 pairs/km^2 for the same species listed in Table 2. We would not expect an exact correspondence because annual duck populations vary greatly depending on pond conditions and other environmental factors, but their estimates are of the same magnitude as ours. There is no
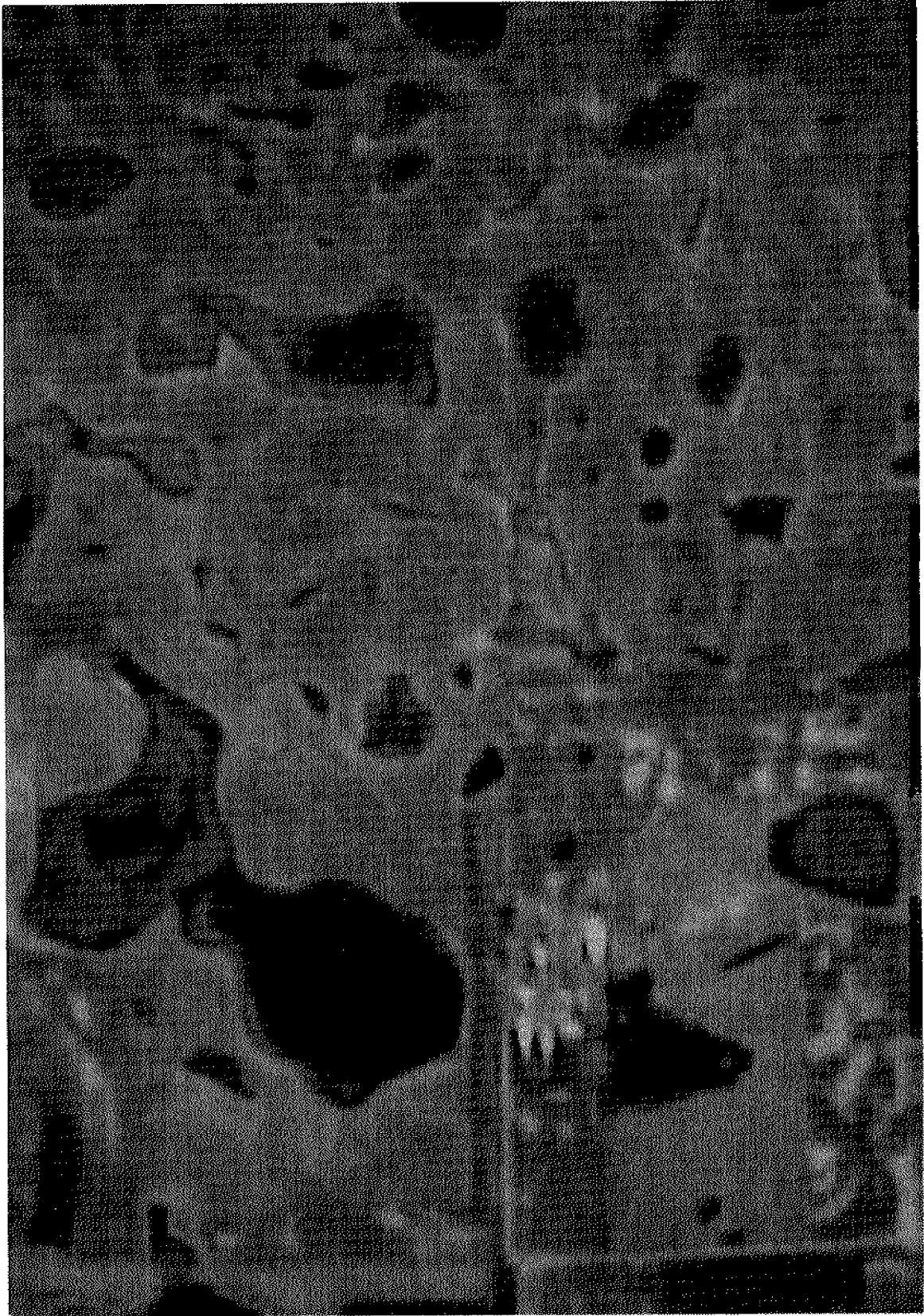
Figure 3. Photograph of monitor showing aerial video image of one legal section (2.6 km^2) from a study area.
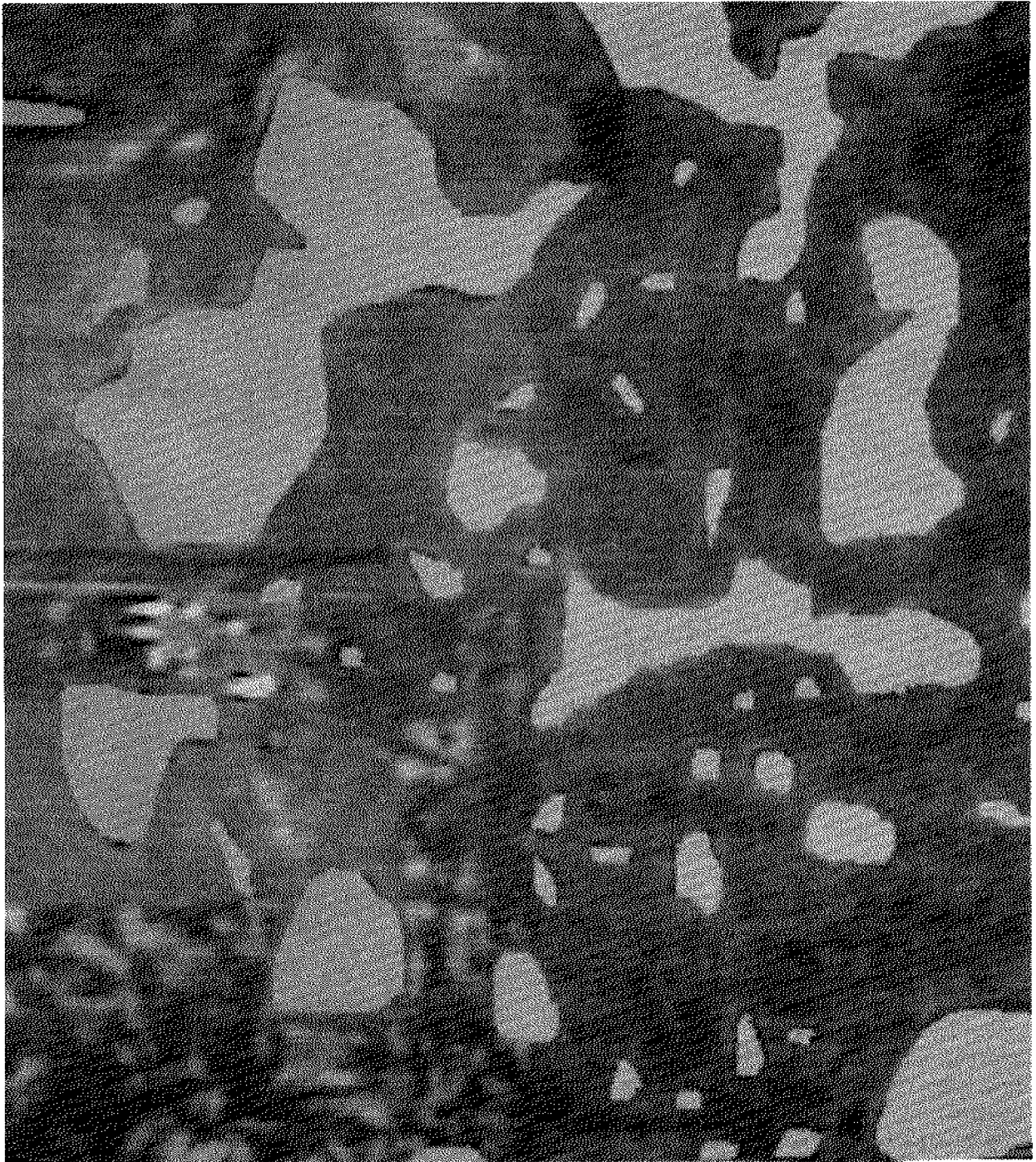
Figure 4. Photograph of monitor showing aerial video image of one legal section (2.6 km^2) from a study area. Light areas have been classified as wet by means of a microcomputer.

Table 1. Area and density of ponds by ownership class east of the Missouri River in North Dakota estimated from sample aerial video obtained in May 1987.

Ownership Class	Surface Area (km^2)	Pond Area (km^2)	Number Ponds	Ponds/ km^2	Average Size (ha)
FWS Easement	18,964	2,028	152,655	8.0	8.2
FWS Ownership	1,408	579	5,296	3.8	66.7
Private Land	109,241	7,265	526,171	4.8	8.4
All Land	129,613	9,872	684,122	5.3	8.9

Table 2. Breeding populations and production of five species of Dabbling Ducks East of the Missouri River in North Dakota estimated from ground counts, MOSS map data, and aerial video.

Species	Breeding Pairs	Pairs/ km^2	Recruits	Recruits/ km^2
Mallard	445,297	3.4	302,365	2.3
Gadwall	318,119	2.5	465,967	3.6
Blue-winged Teal	864,510	6.7	1,189,376	9.2
Northern Shoveler	195,292	1.5	247,093	1.9
Northern Pintail	220,002	1.7	182,081	1.4

way to verify our estimates short of conducting complete inventories on large tracts of land. Cowardin et al. (1988) reported a verification for a single wetland management district. The method, involving regression of breeding pair numbers on pond size, was essentially the same as that reported here but did not use the automated procedures described here nor cover as large an area.

DISCUSSION AND FUTURE DEVELOPMENTS

The system we described has been used in two projects and shows sufficient promise to be developed into an operational method. Modifications and further refinement of the system are planned. The sample of 10.4-km^2 plots was originally drawn for a different purpose in a two-stage sampling

procedure where the ownership in the primary sampling units but not the individual 10.4-km^2 plots was known. The sample allocation favored the stratum with the highest FWS ownership. In the current application we treated the sample as though it were a simple random sample, which probably causes a positive bias in the results. We plan to restratify the existing sample based on the amount of FWS ownership in each cell in the sample universe. This will be accomplished by overlaying a digitized grid with all possible sample plots on the digitized data for land ownership by means of MOSS. Each cell in the sample universe will then be assigned to the appropriate stratum and the strata sizes computed in order to derive estimates for a stratified rather than simple random sample.

Although the current video data were usable, we suspect that improvements can be made by using better-quality lenses, automatic white balance, and perhaps filters that will enhance the presence of water. We are also planning test combinations of altitudes and focal lengths to improve color and resolution and reduce spherical distortion.

Finally, MicroImages, Inc., is developing software that will allow us to import the vector data from the MOSS maps into MIPS. These data will be floated over the video images and by pointing at the same pond in the video and MOSS data we will be able to cross reference the two files and add wetland attributes from the MOSS data to the ASCII file produced by FEATUREMAP. Prototype software is functional and will be used operationally for processing data to be obtained in 1988 and future years.

In summary, we believe that remote sensing data used to supplement ground census have great potential for improving the precision of estimates of duck breeding populations and production. The task at hand is to place this rapidly developing technology in the hands of the waterfowl biologist.

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video images. Special credit is due P. Marshall-Prigge, who with the assistance of K. Grosz and M. Johnson, accomplished the arduous task of classifying video images and preparing the appropriate data files.

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QUESTIONS AND ANSWERS

Q. What is the availability of the software?
A. Microimages is still in prototype and is unavailable commercially. AMS and the software to overlay MOSS to video is available.

THE ROLE OF MOSS IN ARCHEOLOGICAL PREDICTIVE MODELING

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ABSTRACT

Geographic information systems such as MOSS can prove to be an invaluable tool for archeological predictive modeling. These systems provide the capability to correlate multiple variables and predict quantitatively and spatially the distribution of site locations. The design of a GIS for modeling is a time-consuming process and many considerations must be made prior to implementation. These decisions will dictate the success or failure of the system.

INTRODUCTION

Predictive modeling of archeological site locations has become increasingly important for cultural resource management and for complex hypothesis testing. Its importance is due partly to the environmental impact legislation that requires an evaluation of proposed construction impacts to potential archeological resources as well as to known sites. Consequently, questions addressing the potential for site location demand equal attention as those concerning the significance of previously recorded sites. Similarly, archeological research has advanced beyond single site interpretation to incorporate regional model building and hypothesis testing (Kohler and Parker 1986; Judge and Martin 1988).

Within the past decade, it has been demonstrated repeatedly that archeological predictive modeling is best accomplished with geographic information systems such as the Map Overlay and Statistical System (MOSS) (Parker 1986; Limp 1988; Kvamme, n.d.). These systems not only provide the capability to overlay multiple variables, but also to statistically correlate these variables and predict quantitatively and cartographically the distribution of site locations.

Development of a system for predictive modeling is not a simple process. It requires a series of decisions involving functional requirements, data elements, map scale and data

resolution, software, hardware, and personnel. Incorrect choices at any stage of the developmental process may render the system non-functional during implementation. Application of the system to a pilot project in the design phase may alleviate any potential problems during final implementation. Problems detected in the pilot study will allow for changes in the final system design (Calkins and Tomlinson 1977). This paper will discuss several of the critical elements involved with the design of a geographic-based archeological information system and assess the utility of the MOSS system for predictive modeling applications.

FUNCTIONAL REQUIREMENTS

The number of potential archeological applications of a geographic information system are as varied as the number of users. As a result, it is often difficult to determine which functions are essential to the system. Generally, a comprehensive GIS will include spatial and quantitative analyses, data base management and report summary, and cartographic output capabilities. For predictive modeling, spatial and quantitative analysis functions are especially critical.

Among the necessary components are commands which calculate the intersection of multivariate data layers, determine distance and characteristic of surrounding zones, interpolate point and sample data, statistically correlate data, and facilitate development of predictive distributions based on interpretive and cyclical data processing results.

The MOSS/MAPS software subsystems contain numerous commands, in both vector and raster format, to accomplish these tasks. The overlay commands (OVERLAY in MOSS and INTERSECT in MAPS) provide procedures to calculate the cooccurence/overlap between data layers. Using the BSEARCH and other spatial retrieval functions, data categories may be subset for subsequent analysis and hypothesis testing. The PROXIMITY and CONTIGUITY commands provide distance measures to determine the spatial relationships between variables. Similarly, the EDGE command extracts segment data, such as boundaries between specific ecological zones or soil types, from the parent polygonal data.

Most of the recent archeological modeling has employed cell-based or raster geographic information systems (Limp 1988; Parker 1986). These systems have two major advantages over most vector-based GIS. First, the attribute values are replaced by integers which can be recoded and/or weighted according to their degree of significance in the model. Subsequent mathematical operations are performed on individual cell values, resulting in a cumulative score for each cell. Secondly, since cell size is consistent between data layers, no topological restructuring is required. Consequently, processing speed is

enhanced. In addition to enhanced performance, raster systems can incorporate SPOT and LANDSAT-TM digital data into the data base. The Map Analysis Package (MAPS) subsystem of MOSS provides numerous mathematical and Boolean operation commands for raster data. In order to use vector data in predictive modeling, MOSS provides a POLYCELL command for conversion of vector data, such as soils, to a raster format for use with MAPS.

Despite the name Map Overlay and Statistical System, MOSS contains no quantitative analysis capabilities beyond basic descriptive statistical summaries. The SPSS command does provide, however, a mechanism to export raster data files into an ASCII format for analysis with a statistical package such as SAS or SPSS. Currently, there is no capability for the quantitative analysis of vector data, without substantial data conversion, editing, and transfer to a statistical analysis software package.

One key element to the successful implementation of an archeological information system is the ability to store, access, and organize the large volumes of attribute data which accompany each site. These data are essential for Boolean retrieval and analysis, cultural resource management, and report summary preparation. Storage and manipulation of attribute data are accomplished most effectively with a system in which attribute data are linked to a related spatial data file of site locations. MOSS provides a multiple attribute file capability which allows the association of 200 variables with each point, line, or polygon in a map file. However, this is a sequenced, flat file and the sequence of input values must follow the exact input sequence of spatial data items. Although the multiple attribute file is not as flexible as a true relational data-base system, it does provide rudimentary calculations, retrieval, and variable redefinition. Unfortunately, many of the MOSS commands that create data subsets, such as OVERLAY, do not carry the multiple attribute associations to the new data file.

The final functional component of an archeological information system is cartographic output capabilities. These functions are necessary to discern and illustrate the spatial relationships inherent in site distributions. MOSS and its related subsystem, COS, provide the capabilities for large format hardcopy output with various line symbology, fonts, and text styles. It also provides interfaces to numerous vector and raster plot devices.

DATA ELEMENTS

Although the required data elements for a geographic-based archeological information system vary according to region and user needs, there are several data types which are common to predictive modeling applications.

Archeological Site Location

An archaeological site can be defined as any place, large or small, where there is found to be evidence of ancient (or past) human activity and/or occupation (Hole and Heizer 1973). Most sites are recorded through random discovery although the cultural resource surveys of the past two decades have resulted in systematic coverage of areas with rapid economic development. Recorded with each site location are numerous physical, cultural affiliation, material culture, and cultural resource management attributes.

Soil Types and Drainage Characteristics

Soil types and their associated drainage characteristics may be critical elements affecting site location because of their influence on the regional floral and faunal resource distributions. From these data, additional information such as patch size, ecotonal interfaces, distance to contiguous or ecotonal areas may be derived and incorporated as individual data themes.

Hydrology

Both surface and groundwater hydrology may be useful items. The researcher should be aware, however, that the current hydrologic conditions may not reflect the past adequately. Hydrology is essential for catchment, distance to water, and other model building calculations.

Vegetation

As with hydrology, caution should be exercised with mapping vegetation. In some regions, both climatic and human-induced change has altered the native vegetative regimes. However, unaltered vegetation data could be useful for determining resource distributions and availability. Existing vegetative data also could be used to design appropriate survey methods.

Elevation

These data may be digitized in two formats, as sample elevation points or contours. Sample elevation data are recommended for archeological applications because they can be used to calculate other essential variables including slope, aspect, and view shed. These variables potentially provide data pertaining to seasonality, occupation duration, hunting behavior, and warfare/security.

Digital elevation data are available from the U.S. Geological Survey for parts of the United States, at large (1:24,000) and small (1:250,000) scales. Regional coverage of the large scale data base is limited; however, the Survey will generally cost-share digitization of any desired quadrangles.

Digital Line Graphs (DLG)

Digital line graph data, including transportation, political boundaries, and hypsography, also are available from

USGS. While these data are of limited use for modeling, they are useful for map cosmetics, survey design, and resource management.

MAP SCALE AND DATA RESOLUTION

Map scale and data resolution are related characteristics that indicate the level of detail represented in a data layer. Generally, larger map scales, such as 1:24,000, provide greater data definition since a smaller geographic area is represented within the specified base map. Data resolution is the minimum unit of area which can be represented within the base map scale. Minimum mapping units have been standardized for specific map scales, but can vary according to project design, time and cost allotted for photointerpretation, and the variable being mapped. For most archeological predictive modeling, map scales of 1:15,000 to 1:24,000 and minimum mapping units of one-half to one-acre are preferred. The MOSS/MAPS software has no limits to the level of detail represented in a data base. However, there are coordinate (vector) and row/column (raster) limits that can not be exceeded without restructuring or modifying the data base. Because of the time and costs involved with photointerpretation and digitization, careful consideration of the scale and resolution required for an archeological information system must be addressed prior to data-base construction. Inadequate data definition is a common, and

most critical, reason for the failure of many land information systems (Guinn and Kennedy 1975).

SOFTWARE AND HARDWARE

Much recent debate has revolved around which system is best for complex geographic analysis--polygonal, arc/node, or raster. The appropriate question is whether the specific software and/or hardware can adequately perform the necessary functions outlined by the users as critical to their mission. A detailed user requirements survey should be conducted and specific software and hardware systems benchmarked prior to the procurement of any system. Each system should be evaluated for functionality, service record and dependability, vendor support, and initial purchase and annual operating costs.

Consideration also must be given to peripheral and support devices such as printers, plotters, digitizing tablets, and graphics terminals. The MOSS and COS subsystems support a wide variety of plotters and graphics terminals with both color and monochrome output. Selection of the hardcopy plot option generates a generic METAFILE which is used with specific plotter drivers (interfaces) to convert the METAFILE code to the appropriate plotter language. Consequently, new plot device drivers may be developed without alteration of the basic MOSS and COS graphics systems.

PERSONNEL

Development, maintenance, and operation of a geographic information system requires the availability of qualified technical and support staff. Burrough (1986) summarizes the support necessary to maintain a GIS at various levels of implementation. Ideally, archeological staff can be trained to design applications specific to their research or modeling projects. Several GIS software systems provide macro language and menu design capabilities to "tailor" redundant applications. This reduces the number of trained GIS specialists required for site support since macros can be developed which guide researchers through the project. The MOSS/MAPS software, while prompted and user-friendly, does not provide an internal macro language or menu design. Consequently, substantial training would be required before most archeological staff could adequately use the system.

ASSESSING MOSS FOR ARCHEOLOGICAL PREDICTIVE MODELING

In order to evaluate MOSS for archeological predictive modeling, cultural and ecological data from the interior lower coastal plain of South Carolina were analyzed. A 2,300 acre site adjacent to the Cooper River in Berkeley County was surveyed during an environmental impact assessment of proposed industrial development (Brooks and Scurry 1978). The area was stratified by soil drainage characteristics and sampled with a series of one-half meter test excavations uniformly distributed within 200 square meter sample grids randomly selected for each soil type. A total of 11.6% of the survey area was tested. Twenty sites were discovered during the survey and five previously recorded sites were relocated and tested. Various physical and cultural attributes, including site density and diversity, size, and cultural affiliation were recorded for each site.

Subsistence-settlement models developed for the interriverine zone of the lower coastal plain hypothesized correlation between moderate to well-drained soils and low density ceramic and lithic scatters of the Woodland period (1000 B.C.-A.D. 1000). These models were based on the assumption that prehistoric occupation of this environmental zone during the late-fall through early-winter was oriented toward exploitation of the oak-hickory forest for gathering nuts and hunting the deer that fed on the acorn mast (Brooks and Scurry 1978; Brooks 1980). Manual analysis of the data supported the hypothesis and indicated a high association of sites with moderate to well-drained soils. This was particularly significant since 79% of the sites were associated with these soils, and they comprised less than 40% of the survey area (Brooks and Scurry 1978). Although sparse, the data indicated a possible correlation between elevation and sites when site density, diversity,

and number of components were considered. Four sites exhibited an unusually high artifact density. Three were multicomponent sites and all four were located at higher elevations on well-drained soils. It was hypothesized that the fluctuating sea levels, which had been documented for the area during this period, altered the oak-hickory forest at the lower elevations (Brooks et al. 1979; Colquhoun et al. 1981). The soil drainage, and thus vegetation, at the higher elevations remained relatively stable and, therefore, provided the most consistent nut and deer resources (Brooks and Scurry 1978).

With statistical support for the hypothesis, the MOSS GIS was used to extend the model into those areas not included in the original sampling design. In this study, the spatial retrieval and analysis capabilities of MOSS were used to test other ecological variables (Scurry, n.d.). Four data themes were digitized with the Analytical Mapping System (AMS) and exported to MOSS. These included soils, hydrology, archeological site locations, and elevations. Overlay of the sites and soils substantiated the spatial association between sites and moderate to well-drained soils. It also indicated that these sites were located near (30 to 40 meters) the interfaces between the moderate to well-drained, and poorly drained soils. These ecotonal areas would have provided the most species diversity for exploitation by prehistoric populations (Pianka 1978). The EDGE command was

used to extract the interfaces between these soil types and 30-meter buffers were generated around each segment.

As expected with temporary hunting and gathering sites, there was no apparent association between site location and distance to water. Statistical analysis of proximity and distance calculations for site location and hydrology indicated no relationship. This was expected since permanent water tended to be class-1 to class-3 streams located in poorly drained areas and away from the better drained soils.

Elevation sample points were digitized for the study area and gridded into one-tenth acre cells. Soils, buffered edges, and archeological sites were converted from vector to raster format, also at one-tenth acre, for use with MAPS. Slope and aspect were calculated from the gridded elevation files and overlain with site location. Spatial analysis of these data indicated no apparent relationship between slope or aspect and site location. Although expected for slope, it was hypothesized that southeast-south-southwest facing slopes (aspects) may contain most sites since these areas would receive the warmth of the sun and provide protection from northerly winds during this time of year. The absence of an association between aspect and sites would tend to support the temporary nature of prehistoric use of these inter-riverine uplands.

Export of the raster data, through the SPSS command, to a

statistical analysis package allowed for measures of association between these variables. Significant relationships were indicated between site location and soils and distance to soil interfaces. Elevation seemed to be important only during high sea-level stands, but the data was too sparse for confirmation. As a result, the values of the soil types and buffered interfaces were recoded, weighted, and processed mathematically in MAPS. The result was a predictive surface map indicating areas of potential site location at 1,500 BP near the end of the Woodland Period (Figure 1). A second map was processed using elevation to emulate sea level change and its impact on soil drainage characteristics. This map illustrates the increased site potential near the beginning of the Woodland Period with a sea level of 2 meters below the present stage (Figure 2).

CONCLUSIONS

Predictive modeling of archeological site locations with a geographic information system requires the employment of a wide range of spatial, statistical, cartographic, and data-base management capabilities. Successful implementation of a system depends on the satisfactory completion of several steps related to function, data requirements and scales, equipment, and personnel. One such system is the Map Overlay and Statistical System (MOSS) of the U.S. Department of the Interior. MOSS was used to correlate prehistoric site location and various ecological data and to predict the potential distribution of sites to similar environmental zones. MOSS adequately performed the spatial analysis functions although the analyses had to be completed in the raster-based MAPS subsystem. This introduced an extra step to processing by converting the vector data to the required MAPS format.

Two areas which could be detrimental to predictive modeling with MOSS are the statistical interfaces and lack of a data-base management system. There is no effective method to interface vector attribute information to a statistical system without extensive report generation, export, and conversion to ASCII format. Development of efficient, straightforward interfaces to SAS or SPSS, for both vector and raster data, would enhance the modeling capabilities of the system. Similarly, the multiple attribute file does not provide the level of data retrieval, redefinition, or mathematical calculations of true relational data-base management systems. In addition, the loss of multiple attributes through OVERLAY and similar commands requires reconstruction of the files after spatial data processing. This is an unnecessary and unacceptable product of the MOSS multiple attribute handling capabilities. Incorporation of ORACLE or a similar RDBMS and modification of the OVERLAY command would alleviate many of these problems and would provide capabilities

PREDICTED ARCHEOLOGICAL SITE LOCATIONS IN THE AMOCO PROJECT AREA, SOUTH CAROLINA

1:24,000

0   .25   .50

MILES

SYMBOL	PROBABILITY	ACREAGE	% OF TOTAL
■	HIGH	332	14.4%
▨	MODERATE	989	42.9%
☐	LOW	984	42.7%
	TOTAL	2305	100%

LEGEND

Figure 1.

PREDICTED ARCHEOLOGICAL SITE LOCATIONS IN THE AMOCO PROJECT AREA, SOUTH CAROLINA

1:24,000

MILES
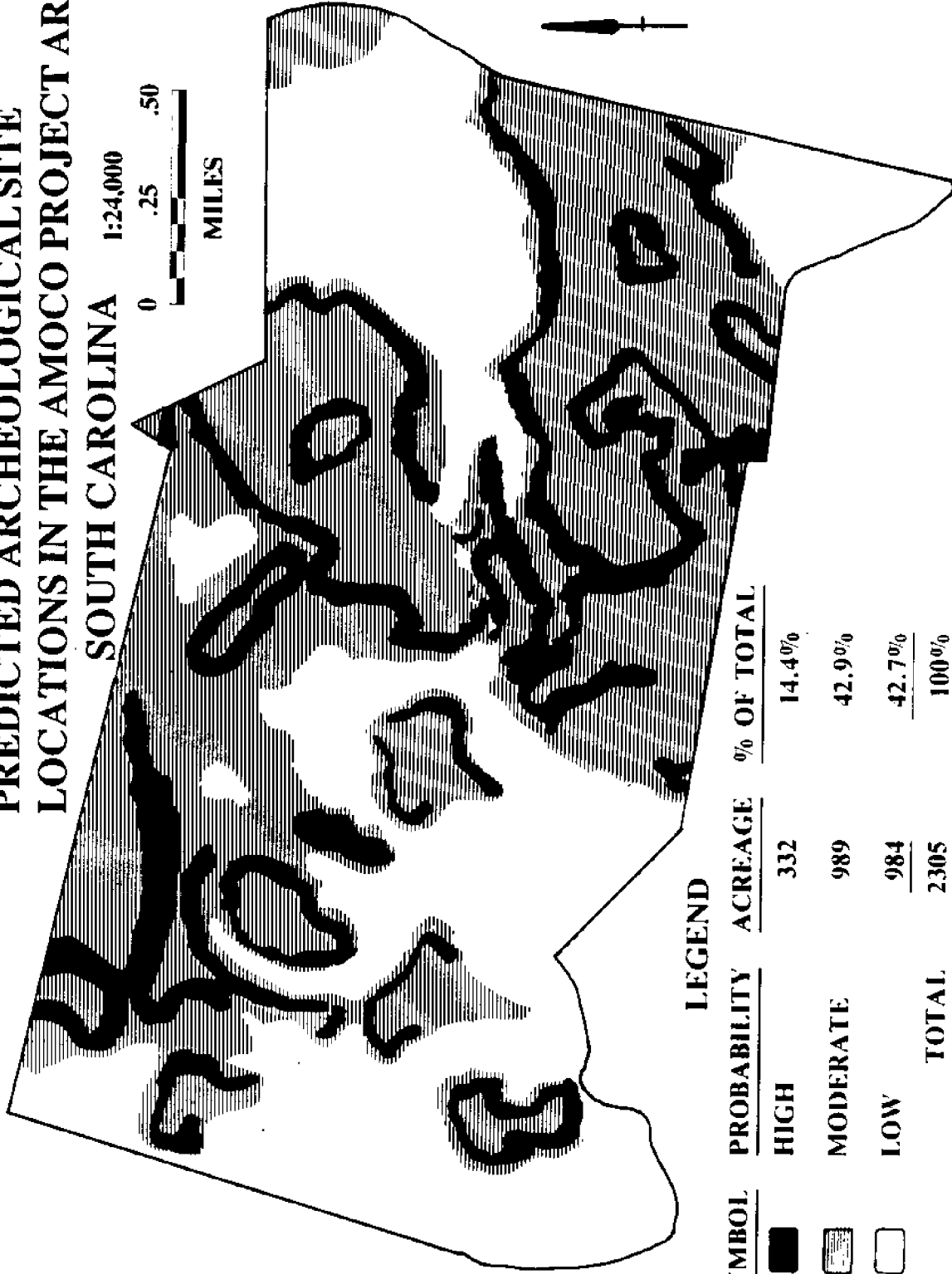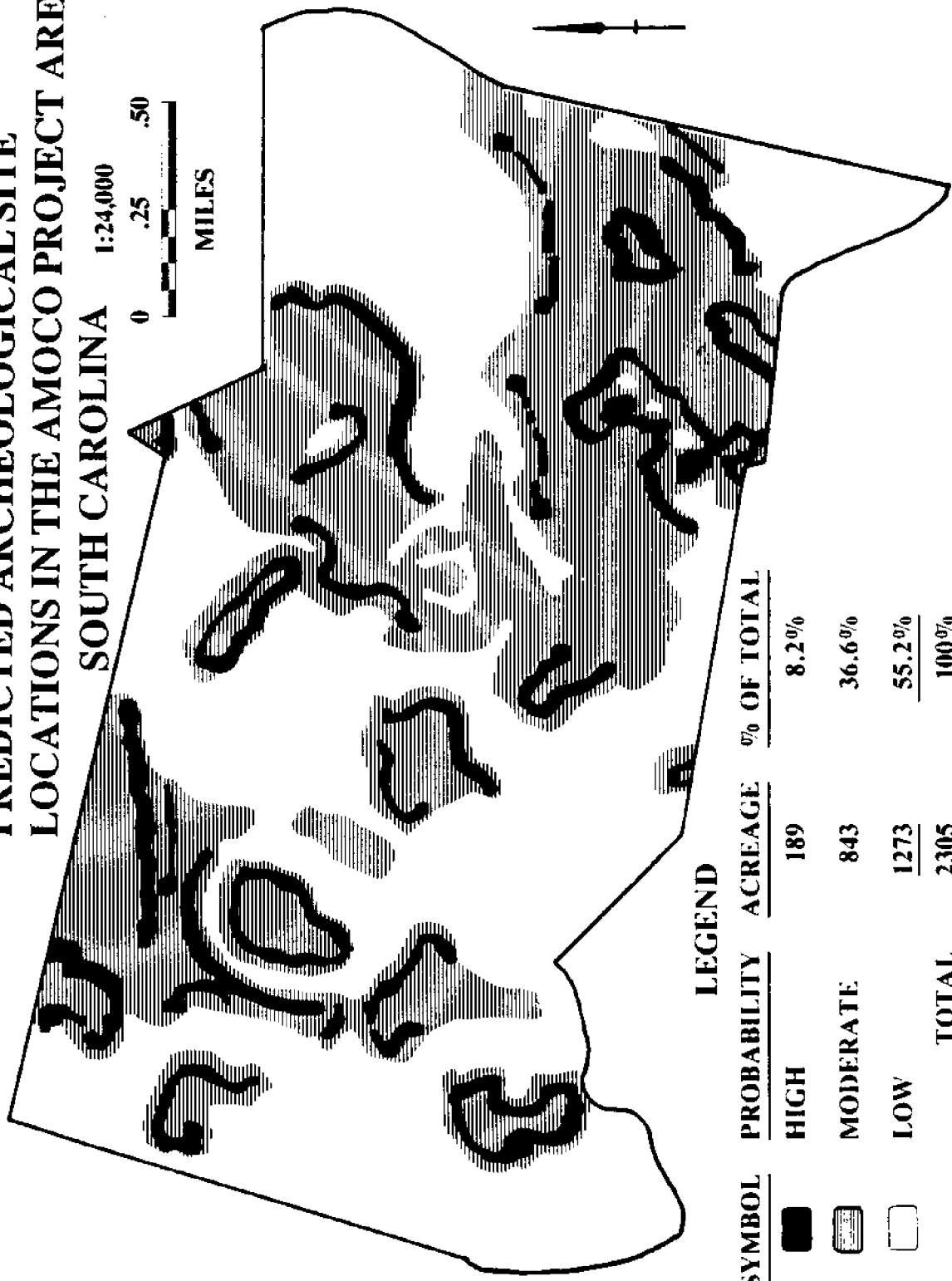
LEGEND

SYMBOL	PROBABILITY	ACREAGE	% OF TOTAL
■	HIGH	189	8.2%
▨	MODERATE	843	36.6%
▢	LOW	1273	55.2%
	TOTAL	2305	100%

Figure 2.

essential to archeological predictive modeling.

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INTERFACING SOIL LOSS PREDICTION WITH A GEOGRAPHIC INFORMATION SYSTEM (GIS): REPORT ON WORK IN PROGRESS

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ABSTRACT

The purpose of this project is to develop a means of interfacing the linear Revised Universal Soil Loss Equation (RVUSLE) with the Geographic Information System (GIS) in the Bureau of Land Management. The final product, due in the spring of 1989, is to be an easy-to-use procedure that uses the Map Overlay and Statistical System (MOSS) and Maps Analysis and Processing System (MAPS) capabilities to calculate soil erosion potential for 7.5-minute-quadrangle-size areas, producing output in the form of type-8 continuous soil loss potential maps. At the heart of the RVUSLE/GIS procedure is the overlaying and multiplication of maps that hold spatially distributed values for various factors of the RVUSLE, such as rainfall (R), soil erodibility (K), terrain, which combines slope and slope length (L*S), and the combined cover and management and support practice factors (C*P).

Analysis of watershed soil erosion potential is necessary for evaluating soil management practices and is critical for identification of areas at risk in resource management planning. The Revised Universal Soil Loss Equation (RVUSLE) is a site-specific soil-loss model. It is an automated procedure that relies on easily obtainable information and permits a user to be flexible in manipulation of data and evaluation of management alternatives.

INTRODUCTION

The purpose of this project is to develop means of interfacing the linear Revised Universal Soil Loss Equation (RVUSLE) with the Geographic Information System (GIS) in the Bureau of Land Management (BLM) (Figure 1). It requires understanding the operational capabilities of the GIS, which includes the Automated Digitizing System (ADS), the Map Overlay and Statistical System (MOSS), the Map Analysis and Processing System (MAPS)

THE RVUSLE/GIS PROCEDURE

	K	L,S	C,P	R
MAP INPUT	SOILS MAP	DEM	LAND USE/ LAND COVER	
USER INPUT/ GIS ROUTINE	ENTER OR CALCULATE K RENUMBER	SLOPE LENGTH & GRADIENT PROCEDURE	ENTER OR CALCULATE C ENTER P RENUMBER	ENTER OR CALCULATE FROM LAT. & LONG.

* * * * VALUE

GIS MAIN PROCEDURE

OUTPUT — CONTINUOUS SOIL EROSION POTENTIAL MAP

POSSIBLE OUTPUT PRODUCTS

- SOIL EROSION SCORED OVER SOIL UNITS
- SOIL EROSION SCORED OVER VEG. TYPES
- 3-D OF SOIL EROSION
- EXTRACTED LEVELS OF EROSION
- CONTOUR MAP OF EROSION

Figure 1.

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and the PRIMOS operating system as well as developing a field-level familiarity with the RVUSLE. The final product is to be a user-friendly software module capable of calculating soil erosion potential using the RVUSLE for up to 7.5-minute-quadrangle-size areas. The output product would take the form of soil erosion maps, which then could be used for further resource analysis and management.

Analysis of watershed soil-loss conditions and erosion susceptibility is necessary to "evaluate current watershed conditions in relation to potential or desired conditions, to assess the susceptibility of watershed conditions to impairment, and to evaluate the feasibility or desirability for altering watershed conditions through management activities" (Jackson and Foster 1986). Dennis Phillippi (1978) lists several applications of soil erosion information in his USLE for Rangeland:

1. Predicting average annual erosion rates under various land-use and management conditions.

2. Providing landowners with conservation alternatives in reducing sheet and rill erosion rates.

3. Predicting how much soil loss can be reduced by changes in management systems and cultural practices.

4. Providing local erosion-rate data for discussing

erosion control alternatives with ranchers, farmers, and industry.

5. Predicting average annual erosion rates from sheet and rill erosion within particular watersheds.

Calculating soil erosion using the Universal Soil Loss Equation (USLE) can be very work-intensive, requiring large amounts of field data, and painstaking analytical procedures for determining various factors from maps and remote sensing data. Consequently, an automated procedure that would permit user flexibility in terms of manipulation of data relied on readily available information, and resulted in a digital soil erosion map that could be used in various ways for further analysis would be very desirable. In deciding what approach to take in developing RVUSLE/GIS, these requirements, BLM's GIS hardware and software capabilities, and present day developments in the area of watershed analysis from digital data were taken into account.

GENERAL PROCEDURE

At the heart of the RVUSLE/GIS procedure is the overlaying and multiplication of cell maps that hold spatially distributed values for various factors of the USLE. The factors include the rainfall factor (R); the soil erodibility factor (K); the terrain factor, which combines slope gradient and slope length (L*S); and the combined cover

and management and support practice factors (C*P). With the exception of terrain, the factors will be determined per soils unit, or per land use-land cover unit using a RVUSLE subroutine. The terrain factor (L*S) will be determined from a digital elevation model (DEM) for the area. In this way, the procedure will reflect the structure of the USLE:

$$A = R * K * L * S * C * P$$

Where

A   is the computed soil loss per unit area, usually in tons per acre per year;

R   is the rainfall and runoff factor and is the number of rainfall erosion index units;

K   is the soil erodibility factor, or the soil loss rate per erosion index unit for a specified soil, as measured on a unit plot (a 72.6-ft length of uniform 9% slope continuously in clean tilled fallow);

L   is the slope-length factor or the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions;

S   is the slope-steepness factor or the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical conditions;

C   is the cover and management factor or the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow; and

P   is the support practice factor or the ratio of soil loss with a support practice, like contouring, strip-cropping, or terracing, to that with straight-row farming up and down the slope (Wischmeier and Smith 1978).

Each of the maps will be RASTERIZEd and then RENUMBERed with appropriate values by the user, either through direct input of a value if available, or through calculation by a routine developed to obtain that value. The exception to this is the L*S factor map, which will be calculated by an algorithm that will not involve user input of values, although an alternative could be included where the users will be able to create their own L*S factor map, bypassing this algorithm. The computer method for obtaining the L*S factor map will probably have to be brought into MOSS/MAPS as a separate command.

The RASTERIZE command in MAPS is a data manipulation command that transforms a point, line, or polygon vector map to create a new dichotomous, discrete, or continuous cell map. The value for either the acres per cell, or the ratio of cell height to width, or the values for cell

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height and width, must be specified to establish cell size. All of the cell maps which are to be overlaid have to be the same cell size, otherwise the overlay commands in MAPS will not work.

The RENUMBER command in MAPS is a data reclassification command which creates a new map by assigning new cell values to the cell values of an existing discrete or continuous map. Therefore, the RENUMBER command can assign K values to values assigned to soil type areas during rasterization.

The maps and the R-value will be multiplied on a cell-by-cell basis. While this might take more Central Processing Unit (CPU) time than some other methods, it is both necessary and desirable. Each of the maps will have different spatial distribution of values, and the product of the multiplication will be a continuous map of soil erosion potential. Such a map can be, for example, represented in 3-D in MOSS/MAPS. In the 3-D representation, the resource analyst should be able to clearly see contributions from various factors, which can provide useful feedback to the resource analyst. A continuous map can be combined with other maps in a variety of useful ways. Possible output products are discussed later in this paper.

THE INDIVIDUAL FACTORS

The K-factor Map

The basis for the K-factor map is a digitized soil polygon map which is then RASTERIZEd and RENUMBERed with K values replacing the subject value for each polygon which was automatically assigned during rasterization.

The K values are entered directly or calculated by a subroutine taken from the RVUSLE, which requires user input of percentage in the soil of silt and very fine sand, clay, and organic matter, soil structure, and permeability codes.

The routine for creating this map involves reading the subject and value information for a soils map into a table. Then, sequentially, a K value is assigned for each subject-soil type. As long as there are no more than 64 different types of soils (limitation of the RENUMBER command), which is highly unlikely, the values for each subject would then be renumbered with K values.

L*S (Terrain) Factor

The L*S factor consists of two components: slope length (L) and slope gradient (S) related through an empirically derived equation. The slope length and slope gradient can be obtained through geometric analysis of topographic contour maps of the area or through field measurement. Very often slope length data per soil unit is available in soil surveys, although this information can often be incomplete and may measure the width of the soil unit rather than actual slope length (Morris-Jones 1985). Because obtaining L and S information in this fashion is

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very work-intensive, computer algorithms for determining these values and other information about watersheds were developed from digital topographic data in the form of Digitial Elevation Models (DEM's) and Digital Terrain Models (DTM's).

The definition of the L factor is the length of slope from the origination of overland flow to the area where deposition begins or flow enters a well-defined channel (gully). The L*S value obtained from a table, a graph, or calculated from the equation always uses this full slope length. If extensive changes in gradient occur along a slope length, the average gradient generally used will not be adequate. A slope can be divided into equal segments (usually not more than three) for which percentage of erosion can be calculated according to the soil loss fraction equation given by Wischmeier and Smith (1978). The total L*S factor is obtained by using the overall slope length as one of the elements and the particular gradient as the other, multiplying the result by the percentage of erosion expected from a particular segment. Because of the necessity to use the entire slope length, the L factor information given per soils unit is usually not adequate and will tend to underestimate erosion. (A soil unit usually covers only part of the slope rather than its entire length.)

One of the best ways to determine slope length was documented by Dennis Phillippi (1978) in his USLE For Rangeland technical note in which he describes partitioning a watershed into minibasins and determining L from measurements within a minibasin from the top of the divide to the channel. Algorithms for determining minibasins from a DEM were developed by Susan Jenson (1985) of the U.S. Geological Survey (USGS) and Marj Larson and Dale White (1988) from Construction Engineering Research Laboratory. At the present time, however, it would be difficult to apply these algorithms immediately to our needs (personal communication from algorithm developers). They should, however, be considered for future development of the RVUSLE/GIS method, as well as other applications which require partitioning of an area into watersheds and minibasins.

The most promising algorithm for determining slope length found to date was developed by Michael Spanner (1983), TGS, Inc., Ames Research Laboratories. The method begins with the first cell (first row, first column) of a DEM. The program begins searching upwards of the cell, i.e, it looks within a 3x3 matrix for a cell with the biggest positive elevation difference from the center cell. Then it calculates the Pythagorean distance between the two cells, and continues its search for the cell with the next highest aspect. The program will not look at cells with an aspect greater than 45 degrees of the previous cell. It continues to calculate the Pythagorean

distance as it continues upslope until it reaches a point where there are no cells at higher elevations. At that point the search has reached the top of the ridge. The sum of these distances is added to the value of the beginning cell. Then the algorithm proceeds to the next cell (first row, second column), and repeats the search. In this way, the steepest pathways to each cell are found, and the length of the path leading to each cell is assigned to that cell. The decreasing distance assigned to each cell along a particular path could be said to reflect decreasing erosion for that segment of the path closest to the source. Spanner states that "length of slope and slope gradient values obtained from a DEM were tested against 7.5-minute topographic map derived length of slope and slope values, yielding Pearson product moment correlation coefficients, R, of .81 and .93 respectively" (Spanner 1983). Further work is being done on comparing the L*S factor values obtained with the Wischmeier and Smith method to the values obtained with the Spanner method.

There are several other considerations in using DEM data. Most of the DEM's are Level I, which means that they contain raw, unsmoothed data which might contain pits reflective of the digitizing process. Most of the watershed analysis algorithms include smoothing routines which remove the pits before further processing. The presence of microrelief, which causes deposition, will not show on a

DEM. In one study (Morris-Jones 1985), which also used one of Spanner's earlier versions of the slope length algorithm, the number of moves uphill was limited to three, after consultation with an expert on the area of study. The need for improvement in these areas will partially depend on the accuracy of other data that goes into the RVUSLE.

The S factor can be easily calculated from the already existing slope algorithm in MOSS/MAPS. Since the RVUSLE applies to slopes between 0% and 50%, the slope map will have to be renumbered assigning 0 values to cells with higher percentage slope. The 0 value will produce 0 erosion in final multiplication. The L*S factor can be obtained as a value per cell using the appropriate equation. The calculation is performed using the MATH command, which creates a new continuous map by performing mathematical operations on existing discrete or continuous cell maps. The mathematical expressions may contain map names, numerical values, mathematical operations, and mathematical functions and parentheses, which can be put together to form an equation.

R-Factor

The R factor (rainfall factor) may be entered or calculated with respect to the latitude and longitude of the area under study. It is a single value by which all the cells in each map are multiplied.

C and P Factors

The RVUSLE in its present form has a relatively thorough method for calculating the C factor for rangelands. For areas under cultivation, a table is used to establish the P factor.

If the C factor is not known, the RVUSLE asks for the following input: percentage of canopy cover, average canopy height, surface percentage of rock, gravel, litter, and vegetation, root mass in the top four inches of soil, and roughness values associated with field conditions. RVUSLE then calculates the C value from this input.

The base map for the C and P values is a digitized land use-land cover map, or a vegetation map. This map is rasterized and its subjects read into a table with their associated values. Repetition of the RVUSLE code concerning C and P values associates a C*P product with each of the subjects, but is limited to no more than 64 different subjects. Then the map is renumbered with a C*P product replacing the original values.

INPUT CONSIDERATIONS

In review, there are two types of input: user input and digitized data in the form of maps which include a DEM, a Soil Units Map, and a Land Use-Land Cover or Vegetation Map. The user input, with the exception of the L*S factor calculations, controls the types of numbers associated with each of the factors. The RVUSLE code controls the values, while the digitized maps control the spatial distribution of these values. The GIS provides the necessary capabilities for the processing of both.

A very important consideration with digitized maps is that they must have the same cell size, the same projection, and the same number of rows and columns, or they cannot be overlaid. MOSS/ MAPS is capable of reprojecting vector maps; the maps can be trimmed to the necessary number of rows and columns. When rasterizing, the user can specify desired cell size.

The sources of the map data are the U.S. Geological Survey and BLM field offices.

POSSIBLE OUTPUT PRODUCTS

As mentioned before, this method will produce a continuous map of soil erosion potential which can then be processed further in a variety of ways. A continuous map can be SCOREd or TOTALed with a soils map, vegetation map, or map of other relevant units to produce information on soil erosion potential for those units. The SCORE command creates a new discrete map by comparing the cell values from one existing discrete map with those of another existing discrete and continuous map. For each category of the first map, it then summarizes the values of the second map that

occur over the same geographic area to determine the values that will be assigned to the new map. The TOTAL command works similarly except that it produces output in tabular form. A continuous map of erosion potential can be EXTRACTed for levels of potential; it can be CONTOURed and represented in 3-D. A continuous map of soil erosion potential can be used for a variety of analyses possible on the MOSS/MAPS GIS, and can become a useful component of resource analysis and resource management decisionmaking. Additionally, by changing the input values of various factors of the RVUSLE, several models of soil erosion can be prepared to approximate the actual erosion for the area. This provides immediate feedback with respect to the accuracy of the RVUSLE as well as furnishing a method whereby a good approximation of actual soil erosion can be easily prepared for a large area.

VALIDATION

While the various components of the program will have been tested for accuracy, software errors may occur, such as user friendliness, etc. However, it is not within the scope of this project to test the RVUSLE itself. While this method provides a relatively fast way of testing the RVUSLE for large areas, interfacing the equation with the Geographic Information Systems makes it a more powerful tool. In this study, the author is not responsible for proving that the erosion

data thus obtained are accurate, but that this method of interfacing with the GIS does not change the RVUSLE structurally in any way.

THE USERS MANUAL

A comprehensive users manual will be prepared on all aspects of the procedure, including uses, limitations, and assumptions. Input of field offices will be essential in editing the manual, so that clarity and ease of application of the RVUSLE/GIS method are assured.

APPLICATIONS OF THE RVUSLE/GIS PROCEDURE

GIS capability for application of the RVUSLE provides several important benefits for resource planning and management with respect to soils.

1. The USLE is a site-specific hill-slope model, while areas considered in planning are often large. The RVUSLE/GIS procedure will permit broad geographic application of the RVUSLE to large planning areas.

2. The easy manipulation of data will permit comparison of existing erosion conditions to natural potential, to planned management induced conditions, or to other assumed situations. Therefore, the procedure is applicable to resource condition analysis in preparation of Resource Management Plans and other similar applications through manipulation of C and P factors.

3. In preparation for erosion hazard analysis for an Environmental Impact Statement, data can be manipulated to show what would happen if vegetation and/or soil were completely removed from a certain area due to development, such as construction of a pipeline or strip mining. This could be accomplished by manipulation of the K and C factors, and possibly by estimating changes in terrain and altering the DEM used for calculation of the L*S factor according to these assumptions.

4. The RVUSLE/GIS procedure could be used as a rangeland monitoring tool, i.e., in combination with vegetation monitoring in the grazing program, and through manipulating the C factor input, calculation, and interpretation of the erosion status.

5. The procedure could be used in project design development, i.e., modeling of erosion conditions that could occur with the building of a reservoir.

6. The procedure could provide valuable feedback on the accuracy of the RVUSLE when applied in large areas, leading to further developments in the RVUSLE methodology itself.

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THE WODDB "TOOLBOX"

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ABSTRACT

The Western Oregon Digital Data Base (WODDB) project is an effort to develop a data base to support Resource Management plans scheduled for completion in 1990 on lands administered by the Bureau of Land Management (BLM) in Western Oregon. Mapping of over 7 million acres is involved, with 41 base and thematic layers. To accomplish this task, a "TOOLBOX" was developed of hardware, software, and personnel, mixing minicomputers, microcomputers, video processing, software, etc. The paper discusses the planning and implementation of the various elements of the Project.

INTRODUCTION

The Western Oregon Digital Data Base (WODDB) project is a Bureau of Land Management (BLM) effort to develop a digital data base to support Resource Management Plans (RMP's) scheduled for completion in 1990 on BLM-administered lands in western Oregon. The project involves digital mapping of over 7 million acres at a scale of 1:4,800 with 41 base and thematic layers, and the development of a GIS spatial data base linked to resource information in relational data bases (RDBM's) for analysis.

TOOLBOX

The accomplishment of WODDB in a very short time required the development of a "TOOLBOX" of hardware, software, and personnel consisting of existing items, as well as substantial innovation. The unique mix of minicomputers, microcomputers, "smart terminals," video processing, off-the-shelf and in-house software, color electrostatic plotting, project management software, local area network, and a support services contractor has made the project achievable. The cost effective combination will provide a very powerful base for the management of lands under BLM jurisdiction in western Oregon.

The largest single item in the "TOOLBOX" was the installation of a PRIME 9955-II, with six gigabytes of hard disc, three tri-density tape drives, a cartridge drive, and a 1,000 line-per-minute printer. This installation at the State office in Portland, OR, will serve as the host computer for the State, and will be synchronously linked to

District Office Primes. Plans are to have level-B Primes installed in the five westside districts, level-C Primes in the five eastside districts, and level D's in the resource areas.

The GIS Smart Terminal is a triple-use work station configured around a 386 micro-computer with AutoCAD software for digitizing and editing, Grafpoint's TGRAF-07 Tektronix emulation, and the capability to run micro-based relational data base software. The units serve as the basic data entry work stations at both the State and District Office levels with high resolution 19-inch monitors. They can instead be configured with medium resolution 14-inch monitors if expensive high resolution is not required. They also serve as a very powerful analysis work station by being able to access the Prime to run MOSS, and have the ability to access and process the relational data bases used by resource managers by transferring data between the two systems using DB-LINK software developed by the support services contractor.

The Intelligent Cursor (tm) is a video line follower used to digitize resource themes from a variety of source products. The processor follows lines on video image of a source map or photo very rapidly, creating a vector file that is transferred to AutoCAD for processing into MOSS. The software is being modified to allow for cost effective scanning of contours and other complex data themes. The system is also capable of density slicing digitizing which will allow effective updating of existing digital maps.

Initial tests of plotter requirements using 25 IPS color-pen plotters showed that plot times of six to eight hours per map was normal. The plotters also used three $2.00 pens and created a very nervous operator waiting for the pens to run out of ink in the middle of a plot. With 30,000 maps to plot, and a required 42-inch width, a 44-inch color electrostatic plotter was installed. The plotter has the high speed option, 400 DPI resolution, on-board raster-izer, and parallel interface to the PRIME. However, consider-able problems have been experienced with firmware, mechanical defects, and locating suitable media for stable plots.

Initial project requirements testing showed that the existing ADS/MOSS/COS system would not provide the digitiz-ing and output capabilities required by the project time lines. ADS and COS were replaced with AutoCAD, and MOSS was retained for analysis work. AutoCAD has proven to be a very effective digitizing and editing package.

Project time frames began to become condensed in 1987 due to late contractor deliveries of base data, placing more emphasis on streamlining and developing more efficient pro-cesses. A Software Analyst was brought on board to examine all activities and to design soft-ware to enhance appropriate processes. This led to

development of DXFADS to take AutoCAD data to ADS and into MOSS; DB-LINK to link resource RDBMS's to MOSS; REVIEW to automatically document the MOSS files; ENDCHK and ENDFIX to do automatic line editing on AutoCAD files; SELECT to allow selection of line segments from multiple layers in AutoCAD to create new data layers without creating slivers or redigitizing lines; and PRODMGMT to track internal contractor production performance. A full-time position has been assigned to maintain the software and support a standard micro configuration.

Managing a project of the complexity of WODDB rapidly reached the impossible level without automated help in the form of project scheduling software called PROMIS. This software allows the tracking of the various contractors, processes, personnel, branches, activities, equipment, and the flow of data to a very detailed level. The nine mapping blocks, comprising 1,750 mapping manuscripts, which combine into 371 townships, and then into five districts are all tracked by the 6-18 individual steps at each level. The approximate 42,000 individual items tracked have taxed a 386 micro to the limits for

processing, but the return to management has been well worth the effort.

The rapid buildup and high level of support required to meet WODDB time frames led to the development of an on-site support services contractor. Infotec Data Products, Inc., was selected to provide computer operations, training and user support, equipment specification and procurement, software development and maintenance, digitizing services, and data base development.

The use of a contractor has allowed rapid reaction to project requirements at a very reasonable cost. BLM specialists have also been able to concentrate on managing the project and on directing the development of the technology rather than trying to find and fill BLM positions. The contractor has been able to rapidly staff to twenty-hour days, and seven-day weeks in order to meet project demands.

Time-frames have been compressed and workload has been increased due to unanticipated delays in data delivery and production. However, by development of the technology described, the project is still achievable.

WORKLOAD MODELING AND CAPACITY PLANNING FOR RESOURCE APPLICATIONS OF GIS TECHNOLOGY

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ABSTRACT

The Bureau of Land Management (BLM), as a land management agency of federally regulated lands, uses GIS technology extensively as a management tool for resource applications. In 1986 an internal BLM study, titled "Automated Resource Requirements Study" (ARRS), identified the potentially automatable resource management functions performed by BLM (ARRS 1986). A subsequent workload analysis was conducted in 1987 to determine the type and quantity of computer outputs necessary to perform the resource management functions identified in the ARRS study. The quantified workload requirements were, in turn, used to estimate the computer hardware capacity requirements. These estimates are targeted for 1996, the year projected by the ARRS for the complete implementation of all potentially automatable resource management functions. Workload analysis models were developed for four major activities performed regularly in the course of BLM resource management applications. These activities are the simple query, the environmental assessment, the activity plan, and the resource management plan. The workload analysis was performed using the concept of a fully automated full-time equivalent (FTE). This hypothetical FTE is assumed to be a full-time employee whose work activities are fully dedicated to performing automatable resource activities. This study uses the FTE estimates for potentially automatable tasks identified in the ARRS to estimate the computer hardware requirements for each of the BLM's co-located offices. As a verification of the workload analysis approach, a second methodology was employed. This methodology used the number of employees in resource related activities as identified in the ARRS to determine the type and amount of computer hardware and peripherals necessary to support their resource activities. In conclusion, a comparison of these two approaches is provided.

INTRODUCTION

The BLM uses GIS technology extensively as a management tool for resource applications on federally regulated lands. Planning adequate computer capacity to support these GIS applications in the future requires estimating workload to drive system sizing and configuration models. A workload analysis was performed in 1987 to determine the computer capacity and peripheral hardware requirements necessary to satisfy the automated resource requirements of the BLM. This study relied on the results of the ARRS conducted previously. The ARRS examined the resource management functions performed by BLM and identified the potential benefits to be accrued to each office by automating appropriate functions. Through a series of interviews with resource specialists in BLM offices, the ARRS estimated the time spent performing resource management functions in 1985 and projected these estimates through 1996. The automatable portions of each resource management function were also identified.

This paper details the subsequent workload modeling and analysis study conducted to determine the type and quantity of computer outputs necessary to perform the potentially automatable resource functions identified in the ARRS study. The workload analysis used the ARRS estimates of potentially automated workload and the number of employees performing resource-related activities. As part of the workload analysis, four resource activity models were developed.

This paper also describes the methodology for relating the quantified workload requirements to computer peripheral requirements. The resource activity models and the peripheral hardware requirements were provided to the hardware configuration study conducted by American Management Systems (AMS) while under contract to BLM. Computer resource requirements and acceptable and optimal response or elapsed times for each of the four models served as input for the AMS computer capacity sizing model, Capsiz. The AMS model was then used to estimate required system size and configuration.

WORKLOAD ANALYSIS MODELS

To facilitate the estimation of the workload, the study elected to examine typical categories of potentially automatable resource tasks. The study selected four classes of activities varying from highly repetitive activities performed in a short time with a low demand for computer resources to infrequent activities with longer times and a high demand for computer resources. Within these broad classes a single representative task was selected for detailed examination.

The four classes of activities selected to represent

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potentially automatable resource tasks were:

A. Query - a simple query activity having relatively low computer resource requirements.

B. EA/APD - an environmental assessment (EA) activity with the specific task being an application for permit to drill (APD) with medium computer resource requirements.

C. AP/HMP - an activity planning (AP) activity with the specific task being a habitat management plan (HMP). This activity would have relatively high computer resource requirements.

D. EIS/RMP - an environmental impact statement (EIS) activity with the specific task being resource management planning (RMP). This activity would have very high computer resource requirements.

A model for each of these representative tasks was developed assuming the use of the Bureau's Geographic Information System (GIS) capabilities indigenous to the MOSS family of software. The models examined computer response time and real elapsed time to perform each task. With the ten year RMP cycle followed in the BLM, models A, B, and C assume that an RMP has already been completed. The models assumed that a fully automated resource data base will be in place in the year 1996. As a result, the

automated processing fell primarily into the three ARRS automated capability categories: data manipulation (DM), data analysis (DA), and data output (DO). Data entry (DE) was treated as a separate task. The models are based on neither a best case nor a worst case example of each task. Rather they focus on estimating computer resource requirements for a case representing above-average complexity for each task.

MODEL OUTPUTS

For each model the number of different types of outputs were estimated. The type and frequency of MOSS command usage were used to estimate the number of GIS outputs. These were broken into terminal alphanumeric, terminal graphic, hardcopy alphanumeric, hardcopy graphic, and plotter outputs. The unit of measure was deemed to be a "page" rather than a specific number of bytes. One page was defined to be either a printed page or terminal screen of alphanumeric or graphic output. Estimates were also provided for the number of pages of terminal and hardcopy alphanumeric information produced by accessing the non-GIS resource data bases. These two sources were totaled to provide the number of outputs required for each of the four tasks modeled. The figures are presented in Table 1.

The next step is to determine the number of outputs that could be generated by one FTE in the year 1996. The fully

Table 1. Alphanumeric and graphic outputs

Model	Terminal A/N	Terminal Graphics	Hardcopy A/N	Hardcopy Graphics	Plotter Outputs
A. Query					
GIS	8	4	3	2	0
Database	6	0	6	0	0
Total	14	4	9	2	0
B. EA/APD					
GIS	75	43	24	33	1
Database	20	0	10	0	0
Total	95	43	34	33	1
C. AP/HMP					
GIS	184	96	84	96	12
Database	364	0	168	0	0
Total	548	96	252	96	12
D. EIS/RMP					
GIS	20,000	3,000	3,900	990	540
Database	42,000	0	15,000	0	0
Total	62,000	3,000	18,900	990	540

automated FTE is defined to be a work year devoted to performing only automated tasks. Since no actual employee would perform automated tasks 100% of the time, this fully automated FTE represents the work performed by a number of system users.

A model for fully automated users in the year 1996 was developed for an "average" office. In the average office, which would be representative of a Bureau Resource Area Office, there would typically be a ratio of eight resource specialists to four program leaders to one technical specialist. Each resource specialist would spend approximately 1.5 hours performing automated tasks, the program leaders would spend four hours per day performing automated tasks, and the technical specialist would be full time. The percentage of system use can be calculated to be 33%, 44%, and 23% respectively for the three categories of workers. These calculations are provided in Table 2.

In addition, the workers in each of the categories spend varying amounts of time

Table 2. Average office use of automation

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8 Resource Specialists (RS) x 1.5 hrs/day = 1.5 days (33%)
4 Program Leaders (PL)   x 4 hrs/day   = 2.0 days (44%)
1 Technical Specialist (TS) x 8 hrs/day   = 1.0 days (23%)

Total 4.5 days

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performing each of the tasks in the four activity areas modeled. The resource specialist would be most concerned with simple queries and environmental assessments, while the program leader and technical specialists would be concerned more with projects such as activity plans and resource management plans, which require more time and a higher usage of computer resources. By comparing the times spent by each specialist on each of the four activities with the percentage of computer use as discussed in the previous paragraph, the relative proportions of time spent performing each of the four activities can be calculated. As a result 21% of the FTE time-performing automated tasks in the average office is dedicated to performing simple queries. In addition, 16%, 26%, and 37% of the FTE automated time is spent on models B, C, and D, respectively. These results are summarized in Table 3.

Knowing the percentage of time spent by a fully automated FTE on each of the four areas modeled and the number of outputs required to perform a single repetition of each task, the outputs produced by one

fully automated FTE in one work year can be fully calculated. The elapsed time necessary to complete each of the four tasks is assumed to be acceptable time, defined previously. Since an RMP would typically be completed over a three-year period, one-third is assumed to be completed in one year. A fully automated work year is assumed to contain 250 work days or 2,000 work hours. For example, if an APD could be done in the automated mode in four hours, 500 could be done in a year. From the average office model, actually only 16% of the automated time is spent performing EA/APD activities. Thus, only 80 APD's would be completed by one fully automated FTE in one work year. Multiplying 80 times the number of each type of output required to produce one APD gives the expected outputs in one work year.

These calculations are provided in Table 4. Summing across the four models provides the total outputs and dividing by 250 work days provides the outputs per day. The final entry gives the total alphanumeric and graphic outputs per day. Since the four models assumed little or no data entry to be necessary, it is

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Table 3. Automated FTE allocation

MODEL	Resource Specialist	Program Leader	Technical Specialist	% of FTE
A. Query	45%	10%	10%	21
B. EA/APD	35%	5%	10%	16
C. AP/HMP	10%	45%	15%	26
D. EIS/RMP	10%	40%	65%	37
TOTAL	100%	100%	100%	100

Table 4. Fully automated FTE production per year

Model	% of FTE	Time Per Job	Jobs Per Yr.	Terminal A/N Output	Terminal Graphic Output	Hardcopy A/N Output	Hardcopy Graphic Output	Plotter Graphic Output
A. Query	21	1 hr	2,000	5,880	1,680	3,780	840	0
B. EA/APD	16	4 hrs	500	7,600	3,440	2,720	2,640	80
C. AP/HMP	26	6 days	40	5,480	960	2,520	960	120
D. EIS/RMP	37	3 yrs	1/3	7,770	370	2,331	122	67
		Outputs/yr		26,730	6,450	11,351	4,562	267
		Outputs/day		107	26	45	18	1

emphasized that the numbers in this table should be increased if substantial data base building were required.

Using the daily output requirements given above, the throughput rates for each device type can be calculated.

Alphanumeric and graphic outputs are summed to produce the number of terminal screens and hardcopy outputs. In addition, the capacities for each device type should be estimated. It is assumed that a user will produce a terminal screen of output for each 4

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minutes of elapsed time and a hardcopy for each 8 minutes of elapsed time. A hardcopy plot on a plotting device is assumed to take one hour to produce, including set-up time. The magnitude of these numbers provides some insight to the number of devices required. These throughput rates and device capacities are summarized in Table 5.

The final portion of the analysis focuses on building a bridge between the potentially automated workload identified in the ARRS and the throughput requirements defined above to estimate computer hardware requirements. The ARRS identified 5,603 FTE's involved in performing resource-related tasks, of which 1,664 FTE's, or 30%, were identified as being potentially automatable. These 1,664 FTE's were further separated into five automated capability categories: DE, DM, DA, DO, and import and export (DX). The ARRS estimated the FTE's within each automated capability category for each field-office. The following discussion describes the link from these field-office FTE estimates to field-office computer hardware requirements.

WORLAND DISTRICT
OFFICE EXAMPLE

To demonstrate this link and keep the numbers simple, the Worland District Office (WDO) in Wyoming is presented by example. Since the data entry function is markedly different from the data analysis functions, data entry is handled

separately. The four data analysis functions (DM, DA, DO, and DX), are similar in two respects and are combined for subsequent analysis: these functions are handled by the same class of users, and the ARRS estimated similar potential savings for each of these four functions. For the WDO, the ARRS estimated the following potentially automatable FTE by automated capability category: DE, 1.12; DM, 5.10; DA, 2.75; DO, 2.43; AND DX, 0.87 for a total FTE of 12.27.

Since these are 1985 potentially automatable FTE's, a growth factor must be applied to reach the 1996 FTE. The ARRS assumed a 3% per year growth factor which, compounded over 10 years to 1996, provides a growth factor of 1.41. The potentially automatable FTE also must be adjusted to reflect the changes caused by automating a task. In the ARRS, a benefit of 70%-90% work savings was estimated for the DM and DA categories, a benefit of 70%-80% for DO and a benefit of 60%-70% for DX. On average a conservative benefit of 70% is assumed for these four categories. The factor representing the amount of work remaining after full automation can be assumed to be the remaining 30%. Therefore, the potentially automated FTE's in 1985 are multiplied by 1.41 to give 1996 FTE's and then multiplied by 30% to give the 1996 automated FTE or work years remaining for the data processing tasks of DM, DA, DO, and DX. On the other hand, the ARRS estimated a negative benefit or increased cost of 10%-25% for the DE automated

Table 5. Device throughput and capacity

A/N or Graphic Terminal:

Throughput: 107 A/N screens/day + 26 graphic screens/day = 1 3 3
                   screens/day
Capacity: 120 screens/day = 1 terminal at 4 min. per screen

Hard Copy Device:

Throughput: 45 A/N outputs/day + 18 graphic outputs/day = 63
hardcopies/day
Capacity: 60 hardcopies/day = 1 hardcopy device at 8 min. per
                   hardcopy

Plotter:

Throughput: 1 plot/day
Capacity: 8 plots/day = 1 plotter at 60 min. per plot

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capability category. Using the more conservative figure, the 1996 FTE's for DE are multiplied by 125% to reflect the negative benefit or additional cost for data entry. These calculations are summarized in Table 6.

The next step requires building a bridge between the automated FTE, i.e., full-time years of automated data processing and the number of actual users. Intuitively, it is anticipated that this workload would be performed by a mix of different resource specialists and in varying quantities depending on the organizational position. Using our "average" office, which was discussed earlier, we calculate that 13 resource specialists will perform 4.5 days of automated processing in one work day. This ratio of 13 workers

to 4.5 days gives an idea of the ratio between users and workload.

At this point the discussion takes us into the realm of mathematics and statistics called queuing theory. We need to determine how many computer work stations or data processing terminals are needed to perform 4.5 days of work assuming we have 13 users. In this situation, if we had hypothetically 4.5 terminals, we could get 4.5 days of automated processing completed during each work day. The terminal would be busy 8 hours a day. We would also have to have perfect scheduling to use every hour the terminals are available. Since workers cannot schedule their data processing requirements that closely, more than the minimum number of terminals is necessary. This

Table 6. FY 1996 automated FTE for Worland District Office.

Automated Capability	1985 Potentially Automatable FTE	1996 Potentially Automatable FTE	1996 Remaining Automatable FTE	1996 Estimated Concurrent Users
Data Entry (DE)	1.12	1.58	1.97	3.95
Data Processing (DM, DA, DO, DX)	11.15	15.72	4.72	11.80

is analogous to the situation at a supermarket where grocery shoppers arrive at unscheduled times at the checkout stand. We want enough checkers so that the shoppers do not have to stand in line too long, but neither do we want the checkers standing idle.

Besides having access to available equipment, there are other arguments for having more terminals than the minimum, such as avoiding the expense of traveling to a location where a terminal is available, scheduling problems related to the other duties employees must perform as part of their job descriptions, and overhead for training and retraining. For example, the four models described previously contain no allowance for training of new employees and little allowance for the process of employee familiarization with the automated mode of performing these tasks.

In the "average" office, if we assume that a typical computer session at the terminal is 1.5 hours, then there will have to be an average of 24

sessions to complete the 4.5 days of automated processing in one work day. In order to have 24 sessions in an eight-hour day, a user will be arriving at the terminal on average every 20 minutes. In queuing theory, this 20 minutes is the inter-arrival time and the 1.5 hours is the service time. If we had 11 terminals, queuing theory tells us that we would have to wait about 1.16 hours for a terminal to come free for our use. Eleven terminals would argue for an average of 11 concurrent users on the system. Eleven users on the system divided by 4.5 days of work gives a Q-factor of 2.5.

With a Q-factor of 2.5 for the DM, DA, DO, and DX and the 4.72 FY 1996 automated FTE calculated previously for the WDO, we get 11.80 data processing users. A lower Q-factor is argued for the DE category. A similar Q-factor would apply to alphanumeric DE of resource data but the Q-factor for digitizing would probably be significantly lower. This results from the fact that most DE users involved in digitizing often

spend 80% of their time at the terminal performing this specialized form of data entry. In other words, the ratio between the actual number of users and the automated FTE is less. For these reasons, this study assumed a Q-factor of 2.0 for DE. With the 1.97 FY 1996 automated FTE engaged in DE for the WDO and a Q-factor of 2.0, we estimate 3.95 DE users.

Using the throughput rates generated from the four activities modeled and the capacities of the various computer peripheral devices, we can then calculate the number of peripheral devices required. A separate set of calculations is made for the DE category as the throughput rates are different for this task.

The number of digitizers is unique to the DE category. For the WDO a separate analysis was made to characterize the throughput requirements for digitizing resource data. The Wyoming GIS implementation plan provides estimates used in the calculations for the WDO. There are about 86 resource themes per 7.5-minute quad. In the WDO, there are about 125 quads for a total of 10,750 themes. Since we are assuming full automation will take 10 years, 1,075 themes will be digitized per year. Using 250 work days per year, the WDO needs to digitize 4.3 maps per day. Assuming that on average it takes one work day for a DE user to digitize or update a 7.5-minute quad theme and enter associated alphanumeric data into a data base, we need 4 DE users to meet the WDO workload,

at a throughput rate of 1-map-per-day for the digitizing process (Table 7).

The capacity for digitizers was determined to be approximately 2 maps per day. The 86 resource themes include 23 point maps, 15 line maps and 48 polygon maps. Point, line and polygon maps require respectively 1, 2, and 8 hours of automated time to perform the data capture checking and editing, or about 5 hours per theme. A slightly more optimistic 4 hours per map or 2 maps per day was used for the previous calculations.

As a verification of this workload analysis modeling approach, a second methodology was employed. This approach used the number of employees involved in resource-related functions identified in the ARRS to estimate the type and amount of computer hardware and peripherals necessary to support their activities. Again, the Worland District Office was used as an example. WDO currently has 47 employees in resource-related positions. A group of GIS managers familiar with operational GIS activities performed by field offices within the BLM were queried to intuitively derive the number of users, the number of peak users, and the number of concurrent users as a percentage of the total number of resource employees. Forty-two people or 90% were estimated to be users. The peak number of users was estimated to be 25 people or 54% of the resource employees and the number of concurrent users was estimated to be 13 people or 27%. The

Table 7. Calculated number of peripheral devices.

Users	Output Per User/Day		Total Outputs		Device Capacity	Number of Devices	
Data Entry (DE)							
3.95 x	1	map	=	3.9 maps		2/day= 2.0	
digitizers							
3.95 x	2	plots	=	7.9 plots		8/day= 1.0	plotters
3.95 x	133	screens	=	525 screens		130/day= 4.0	terminals
3.95 x	8	hardcopies	=	32 hardcopies		60/day= 0.5	
hardcopier							
Data Processing (DM, DA, DO, DX)							
11.79 x	1	plot	=	11.8 plots		8/day= 1.5	plotters
11.79 x	133	screens	=	1,568 screens		120/day=13.1	terminals
11.79 x	63	hardcopies	=	743 hardcopies		60/day=12.4	
hardcopiers							

number of concurrent users compares in a favorable fashion with the 11.80 FTE data processing users derived previously. The 17.1 terminals estimated for data entry and data processing in Table 7 corresponds to 70% of the peak number (25) of users. A like methodology was employed to derive verification estimates for the required number of digitizers, plotters, graphics terminals, and graphics hardcopy devices.

CONCLUSIONS

The workload analysis served as a bridge between the ARRS study and the AMS hardware configuration study. A workload analysis was performed for four models of resource related activities corresponding to four common classes of resource activities performed by the BLM. Using the number of potentially automatable FTE's from the ARRS study, a methodology was derived to estimate the peripheral hardware requirements for each co-located BLM office. The validity of these estimates was verified using an intuitive approach based on the collective expertise of a group of experienced GIS managers familiar with operational GIS activities with the BLM. The number of employees performing resource related functions as derived in the ARRS study provided the input to the verification process. Additionally the four resource activity models served as input into the AMS hardware configuration study. The central processing unit resources and the required response time or elapsed time for each model was

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estimated and served as input into a proprietary hardware-sizing model named Capsiz developed by AMS. With this information AMS was able to provide a view of the hardware configuration required to meet the resource-related hardware and processing requirements for the year 1996 for the BLM.

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QUESTIONS AND ANSWERS

Q. How much does the model take downtime, etc., into account?

A. The LAPS time considers downtime. The assumption is made that there will be user downtime.

Q. How comfortable are you with your numbers?

A. We know they correspond with the first target numbers, but we are not comfortable with allocating against organizations, etc. These are constraints in a way, forced by economics.

BLM LAND INFORMATION SYSTEM FIELD TEST SITES:
A MANAGEMENT TOOL FOR ADP MODERNIZATION

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ABSTRACT

This paper describes the ongoing implementation effort of the Bureau of Land Management's (the Bureau) Land Information System (LIS) at various Field Test Sites from a management perspective. The purpose of Field Test Sites, considerations, field office impact, as well as problems identified to date, are specifically addressed.

Field Test Sites (FTS's) have been established for the purpose of developing an LIS configuration management strategy as well as the LIS application technology itself. They are the "showplaces" of new BLM technology. Problems that have been identified to date from two Bureau FTS's generally fall into five areas: (1) the FTS selection and approval process, (2) FTS funding requirements and commitments, (3) discrete FTS projects to be initiated and managed, (4) dedicated Service Center support for FTS workloads, and (5) field office impacts.

However, Management has already initiated efforts to resolve most of these five problem areas. The paper briefly touches on each of these problem areas and makes recommendations concerning any corrective actions necessary.

INTRODUCTION

The Bureau's LIS is the integration of available natural resource, geographic coordinate (GCDB), and land record (ALMRS) data using existing hardware, software, and data-base management system capabilities. This system will be maintained and enhanced in such a manner that will serve the Bureau's requirements for the next five years (to 1993) or until the Bureau's proposed target system is developed and implemented.

In this transition period, the Bureau will prepare itself for target system implementation by making necessary organizational adjustments, developing and maintaining standard digital data bases, and actively involving all end users in the definition, development, and implementation of LIS.

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The LIS concept will take the Bureau from its existing fragmented manual and automated procedures to a more efficient, comprehensive, and coordinated system of resource, coordinate, and land-record data that can be effectively stored, manipulated, analyzed, transported, and graphically displayed. Elements of the LIS will be integrated into the Bureau's target system.

PURPOSE OF THE FIELD TEST SITES

The Bureau's LIS Committee has approved a concept in which various field offices of the Bureau will be established as FTS's for the purpose of (1) developing a system management strategy that will eventually be utilized by the Bureau as an infrastructure to implement the target system and, more importantly, (2) examining LIS user acceptance criteria in an operational (field) environment. An FTS consists of Bureau offices in a selected State, responsible for the operational testing of the Bureau's LIS. This testing will help the Bureau to prepare for modernization, while providing time for training and developing standardized data themes and resource application technology which can be transported to whatever hardware and software that becomes available.

The ongoing establishment of FTS's has focused on the definition, development, and implementation of LIS for specific Bureau programs. Furthermore,

applications developed at the FTS's can probably be used anywhere in the Bureau.

The FTS's are designed to develop an integrated, interactive, flexible, and unique system characteristic of what is needed for the Bureau's target system. Establishing Service Center support for the sites to be located in strategic Bureau offices will allow better technical support for developing field uses under field conditions. This "hands on" technical approach will facilitate better LIS support and target system delineation.

Specific benefits derived from the establishment of Bureau FTS's are outlined as follows:

1. **Data** - Benefits relating to all aspects of building and maintaining data-bases specific to energy minerals.

   A. Standards
   B. Formats
   C. Exchange standards
   D. Level of effort
   E. Data-base administration
   F. Data-base security

2. **Software** - The primary benefits relating to how the software is accepted by users, which includes support, technical, and managerial staffs.

   A. User requirements
   B. User interface
   C. User capabilities
   D. Configuration

3. **Hardware** - Benefits of using an FTS for evaluating

hardware, i.e., what is needed for the job in which office.

A. Sizing
B. Placement
C. Configuration

4. Communications - Benefits of testing communications for the FTS, i.e., how to maintain the best quality communications in remote areas.

A. Networking
B. Means of communications
C. Costs

5. Infrastructure - Benefits to the organization and response to management needs from analyses of the following as they relate to the target system and the LIS concept.

A. Staffing needs
B. Skills needs
C. Training needs
D. Space needs
E. Costs
F. Management

6. Feedback - Benefits from information gathered from evaluations that can be used to correct or guide proper program management.

A. Evaluation
B. Individual experience
C. Documentation

Bureau communication of the applications being defined, developed, and implemented for use Bureauwide from FTS's is of critical importance to all Bureau management specialists because of the immediate and long-term impacts to their respective programs. The designation of FTS's signals resource management specialists Bureauwide that management is committed to a coordinated and field-oriented technical approach to automation in support of their programs.

HISTORY AND CURRENT STATUS OF EXISTING FIELD TEST SITES

The Farmington Demonstration Project was initiated by the Bureau in March 1986. The purpose of this project was to test, in a field-office environment, the integration of records, resources, and coordinate data for improved land-based decisionmaking. The first phase of the project, the Redline, assisted the Bureau in defining functional and system requirements for the interim LIS using existing Bureau hardware and software. An additional effort called the Blueline helped clarify functional and system requirements for the interim and target LIS with increased capability possible with developmental hardware and software. The Application for Permit to Drill (APD) was selected as the vehicle for the test because its requirements for processing data are similar to a number of other case processing functions in the Bureau.

The Farmington Demonstration Project has now moved from the completed Redline and Blueline benchmark testing programs into the realm of software design and development in support of LIS. The applications supported by the Farmington

Demonstration Project deal with resource area-level responsibilities in energy mineral resources (currently oil and gas).

The Bureau's Casper District Office was designated as a Demonstration Project in October 1987 to examine LIS support to be applied to energy mineral activities (coal, oil and gas). Application work will be designed for the District-level and, in some cases, the State Office-level responsibility. The Casper District Office has been selected because it has the highest energy mineral program workloads in the Bureau (49% oil and gas, and 80% coal), of availability of extensive digital data sets, both Bureau and non-Bureau, specific to mineral resources, ongoing Statewide GCDB capture effort prioritized to areas with high Federal energy mineral activity and, finally, Wyoming has an ongoing program of data entry of ALMRS status and legal land description.

The Farmington and Casper offices are in the process of organizing necessary Bureau-wide, Statewide, and site management and staffing infrastructures to support the FTS. In particular, both FTS's are procuring necessary ADP equipment, managing site preparation, performing data-base design and inventory efforts, all to move the LIS Field Test Sites into the next phase of LIS application development and testing.

Strategically between the Farmington and Casper Projects,

more than 70% of the Bureau's energy mineral program will be supported by ongoing developments.

MANAGEMENT CONSIDERATIONS

FTS Selection and Approval Criteria

The Bureau's LIS Committee is establishing a formal policy on the FTS selection and approval process, which is of critical importance to the LIS. However, since the Bureau has limited financial resource to support such sites, it is extremely important that all potential sites be screened by using a cost/benefit scenario for the Bureau's LIS effort.

At this time, the developing policy on FTS selection and approval has delineated the following parameters that may be used to determine whether or not a specific office should be considered as an FTS:

1. Size of the Office's programmatic workload compared with that of other offices across the Bureau. LIS applications developed at the site should be able to fit the "worst case scenarios" found in other Bureau locales. All too often an application is developed that is not technically capable of supporting other offices where the work is much greater, of a finer detail, or more complex, etc.

2. Availability and condition of resource data bases. In

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some cases, Bureau offices may already have substantial digital data bases, whether in-house or other, that can substantially affect demonstration project progress. The extreme situation is that in which the integrity of existing manual data bases and inventories are suspect. Choosing one of these sites could result in considerable expense if the office is not at the point where automation can be easily implemented to ensure timely project success for the cost.

3. The FTS must be in an area where GCBD, ALMRS legal land description (LLD), and status recordation are being compiled or soon will be compiled. These baseline data are the backbone of LIS. If the potential site develops the system without these LIS standards, the necessary effort of integrating into the Bureauwide LIS may be difficult.

4. The proposed site must have a substantial logistical value to the program to be supported by the FTS project. As an example, an FTS designated for range management should have a high percentage of the site's workload and staff supporting range management activities. In addition, the site should be located near other BLM offices that share the same program emphasis because any developments made at the field test site will be of criti-

cal importance to the management experts in those offices. This will aid the Bureau in the implementation of this technology as it is applied to a specific program. Most importantly, this logistical consideration increases the chances of developing what the field really needs, satisfying more end users.

Field Test Site Funding

Funding for the Bureau's two existing FTS's is being allocated using cooperative funding from the Washington Office, ALMRS-GIS Project Office, field offices, and the BLM State organizations in which the sites are located. The Service Center has assisted with initial "seed" money commitments with funds matched by benefiting programs of the site and the respective State. It is only through this type of shared funding that the existing FTS's have been established; any single respective budget cannot support the cost of an FTS alone. Eventually the cost of the operation of the site will be the responsibility of the appropriate State/site office.

Table 1 shows estimated funding that has been allocated to the Farmington and Casper Field Test Sites (Greg Graff, Chief, Branch of a GIS Project Office Support (D-151), BLM, Denver, CO, 1988, pers. comm.; Sam Montgomery, Project Manager, Framington FTS, 1988, pers. comm.). It is important to note that the figures shown should be considered estimates

Table 1. Estimated Field Test Site funding appropriations to date.

FTS	Fiscal year	WO & SC FTE	State FTE	DO/RAO FTE
Farmington	1986	$ 475,000 (3)*	- (1)*	-
Farmington	1987	350,000 (3)*	-	$ 15,000 (3)
Farmington	1988	206,000 (3)*	$	$ 15,000 (3)
Casper FTS	1988	80,000 (1)	$30,000 (0)	52,000 (2)
Subtotal		$1,111,000 (10)	$30,000 (1)	$ 82,000 (8)
Estimated Total funding for Bureau FTS's				$1,223,000 (19)

*Denotes estimated total Full Time Equivalent (FTE) for personnel. WO = Washington Office; SC = Service Center; DO = District Office; RAO = Resource Area Office.

only; exact figures were not readily available.

As illustrated by this table, an estimated total of $1,223,000 has been allocated by the Bureau in support of the two existing FTS's (not including an estimated 19 FTE's and Service Center programmed cost for FTS software development support). Early Redline and Blueline testing programs account for an estimated $825,000, while the later costs associated with the LIS Field Test Sites total $398,000.

The total funding that has been allocated to the Bureau's two field test sites (including Redline and Blueline Testing) represents just over 5% of the total ALMRS-GIS Project Office Budget for the three years shown. The funding sources for the FTS's include the Washington Office, the Service Center, and participating state and site offices. Overall, a very small percentage of the Bureau's ADP budget has been expended on the two existing Field Test Sites compared with the substantial benefit that has and should be derived by the use of these two prototyping environments.

FTS Developmental Project Workloads

At this time another Bureau effort is being initiated to establish the appropriate management architecture to facilitate the nomination, selection, and prioritization of potential ADP applications that will be developed by the FTS's. This management architecture will allow for the delineation and recommendations for appropriation of application funding, technical review of applications to meet LIS standards, as well as provide any necessary support for formal approval and Bureauwide implementation of FTS developments.

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Figure 1 is a potential application management architecture that is currently being analyzed by the FTS, Service Center, and the Washington Office staffs. A final architecture must be implemented as soon as possible to allow appropriate management control of potential FTS applications, provide the Bureau the mechanism for nomination of applications, as well as facilitate Bureauwide LIS communication on application development (Bureau of Land Management 1988a).

The New Mexico BLM has recently approved an application plan for the Farmington FTS as part of a larger LIS Pilot State Plan. The Farmington application plan formally identifies necessary funding, staffing, workloads, and data management criteria fundamental for FTS operational control. This plan is designed to provide a yearly measure of anticipated requirements and will subsequently be revised every year during the life of the Farmington site (Bureau of Land Management 1988b).

The Wyoming BLM has formally reviewed a draft project document and operational plan for the Casper Field Test Site similar to the New Mexico plans. Currently these plans are being finalized by the Service Center for formal approval in late May.

Both the Farmington and Casper operational plans are intended to integrate with the previously discussed Bureauwide management architecture for nominating, selecting, and

prioritizing projects for FTS ADP project support.

To aid the Bureau in selection of the most needed applications for development at the FTS's, the following examples of selection criteria can be used to measure cost/benefit:

1. Projects or workloads that require substantial Bureau budget. These specific projects are areas where LIS technology may provide relief due to more efficient workload processing. Examples of these include the Energy Mineral Resource workloads, Renewable Resources, and the Bureau's Lands programs.

2. Applications having considerable importance to the public and private sectors. These include the Bureau's leasing programs supported by ALMRS.

3. Programs that critically rely on the Bureau for support have been devastated due to other Bureau priorities. Hazardous waste management or the cultural resource management programs for certain Bureau offices are examples of programs that have been negatively impacted by Bureau priority or funding limitations.

4. Programs that are the dual responsibility of the Bureau and other agencies that may at times require considerable Bureau workloads. An example of these includes Bureau support to the Minerals Management Service (MMS) needs.
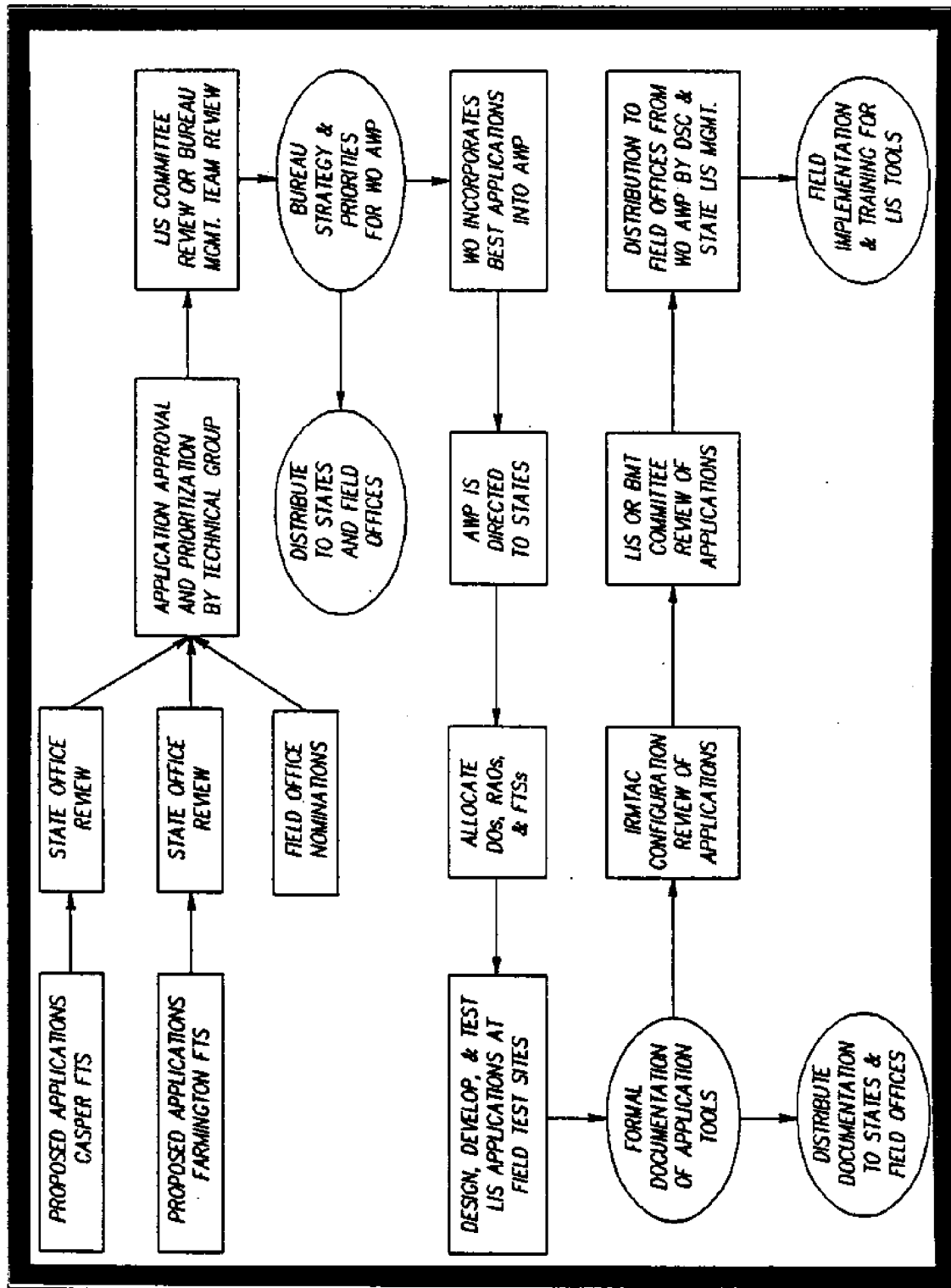
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Figure 1. FTS application management.

Evaluation and Communication of FTS Efforts

Bureau communication of the applications being defined, developed, and implemented for use Bureauwide from the FTS's is of critical importance to all Bureau personnel because of the immediate and long-term impacts to their respective programs. Therefore, good communication is one of the most critical requirements of the Field Test Sites. This feedback, in the form of evaluations and documentation primarily, is necessary to provide information for corrective guidance and for proper program management. This will be done on a recurring basis or as deemed necessary as a Bureau priority.

The evolving Bureau policy on Field Test Sites being developed for the LIS Committee includes their evaluation and communication parameters. It is apparent that these evaluation and communication procedures will include the LIS Committee itself, specific administrative staffs from the Washington Office, the Bureau's Information Resources Management Advisory Council (IRMAC), and the Service Center, as well as expert resource management specialists from a variety of offices across the Bureau.

Of particular importance is the fact that there will be areas of benefit that Demonstration Projects may provide that are not immediately apparent at this time and will have to be evaluated and communicated accordingly. These benefits include use by the public and industry of LIS technology.

Currently Identified Successes and Problems

Problems that have been identified to date from the two Bureau FTS's generally fall into five areas: (1) the FTS selection and approval process, (2) FTS funding requirements and commitments, (3) discrete FTS projects to be initiated and managed, (4) dedicated Service Center support for FTS workloads, and (5) Field Office impacts.

Management has already initiated efforts to resolve most of these five FTS problem areas.

The Field Test Site Selection and Approval Process. Site Managers at Farmington and Casper are concerned about the potential number, the locale, and areas of application responsibility of any additional FTS's.

Field Test Sites have been established for the purpose of developing an LIS configuration management strategy as well as the LIS application technology itself. However, if too many FTS's are initiated, effective management control will not be easy. As an example, ongoing software development is difficult to support at a number of sites in an integrated, non-duplicative, cost-effective, and code-efficient manner when there are many ongoing efforts at different stages of activity.

The Bureau's FTS's are considered by management to be

"show places of new BLM technology." This prototyping environment must be protected and allowed to become productive, with the "real world" applications that prototypes are engineered to provide. From a systems engineering perspective, having numerous prototypes while minimizing the risk of failure is a tremendous expense in view of the Bureau's limited resources.

It is the opinion of this author and the Farmington Project Manager that the Bureau financially, logistically, and managerially can only afford two additional FTS's. Suggested locales and programmatic emphasis could possibly include Oregon with Renewable Resources and Alaska with Lands and Cadastral Survey.

Extreme care is recommended in the selection of any additional Field Test Sites. As previously mentioned, the Bureau LIS Committee has initiated an effort to develop policy on FTS's which includes selection and approval criteria. Until such policy is implemented, any additional requested approvals for Field Test Sites should be suspended.

FTS Funding Requirements and Commitments. As was illustrated earlier in this paper, the Bureau has invested $398,000 in the two existing LIS Field Test Sites. This investment is indicative of the initial start-up capital needed for such prototyping environments.

To protect the FTS's for the purposes intended, dedicated operational funding must be established to ensure success. With additional FTS's proposed and other ongoing LIS efforts, an obvious competition for funding is prevalent. Very likely, FTS funding will be affected to some degree, but unfortunately it is probably unavoidable. An investment has been made in the existing FTS's and from an effective management perspective; these sites should be maintained by appropriate funding. The Bureau's LIS hinges on functional Field Test Sites.

A recommendation is to allocate dedicated funding for the FTS's from the Washington Office, Service Center, State Office, District, and Resource Area Office funding sources. Each specific office at which the Field Test Site is located is responsible for staffing, maintenance, and training costs, while the Service Center is responsible for ADP system development support. Each FTS State has funded, from already tight budgets, the above-mentioned elements. Any additional funding must come from the Washington Office through the Service Center. Through Annual Work Plans and the project management architecture, a more rigid planning and allocation process for FTS funding requirements must be initiated to alleviate any "gray area" funding problems and, in particular, to allow for the funding accommodations for necessary technical changes that result from the prototyping environment of the Field Test Sites. Good planning and communication between Washington Office, Service Center, and

FTS States are vital to the resolution of this problem.

Many other agencies and industries are currently being faced with the same funding situation as the BLM. Joint applications of this technology are an effective way to minimize the individual risk associated with unique development by each agency, as well as provide a substantial monetary cost savings to each organization. This area must not be taken lightly, and work must be initiated to address joint applications among agencies from the onset of FTS designation. This will ensure that these dual needs are identified from the beginning of project work. From a political perspective, this would be an excellent area for the Washington Office and Service Center to begin developing.

Discrete FTS Project Workloads. It is extremely important that the BLM receive technological support that can, in fact, be used for daily work requirements from the ongoing LIS development effort. Recent history illustrates specific examples of ADP applications that were chosen by management, developed, tested, and implemented to the field, but were not used there because the logistical and technical problems associated with "field conditions" were overlooked. Extremely powerful application may not be used because field staffs more urgently need "simpler" and more "fundamental" tools--the classic "overkill" of ADP systems design.

Going one step further, the Bureau must identify real and practical applications for development at the FTS's. The Bureau must avoid wasting valuable resources on applications arbitrarily chosen by a single individual when that application has little utility. In addition, the Field Test Sites must have discrete projects identified to minimize any duplication of effort between sites, and allow the integration of developing technology through time.

The FTS application management architecture (Figure 1) will provide a great deal of support in identifying applications that will most benefit the Bureau with the least development cost, as well as provide necessary technical review, management and funding allocation control. This management tool should be initiated as soon as possible to facilitate the parameters already identified and minimize any wasted effort and limited resources.

Dedicated DSC support for Field Test Site Workloads. Concern is raised by FTS personnel pertaining to the availability of Service Center technical specialists necessary for supporting FTS LIS application technological design, development, and testing. This concern becomes particularly evident in light of ongoing Service Center activity that may eventually conflict with necessary prototyping support at the FTS's. At this time, no conflicts have yet resulted, and hopefully through proper

annual work planning and good communication between Service Center and FTS management, any potential conflicts or short-falls can be easily avoided.

Field Office Impacts. In general, much of the office field staff at the test sites, including managerial, technical, and support staffs, are eager to use the developing LIS technology and are very willing to do anything necessary to facilitate its arrival. Other office staff are impatient and, in some cases, skeptical, after having had previous bad experiences with Bureau ADP systems.

All field staffs are extremely pleased and feel quite fortunate to have been selected as an FTS and accordingly are extremely grateful for the Service Center's emphasis of allowing them, the end users, to become involved in the design of LIS.

The impact of a Bureau office having been selected as a Bureau LIS field test site is considerable when it comes to logistical and managerial requirements. If those requirements necessary to support the Prime Level-B Systems currently being installed at the FTS's are any indication of what can be expected with the arrival of the proposed Bureau target system, the requirements may be extremely difficult for many Bureau offices to overcome. To more fully delineate the cost and impacts of this type of technology implemented at the field level may be premature. The Field Test Sites will need to be analyzed over a longer span of time.

Specific areas of impact include the following:

1. Potential additional staff requirements. In order to implement highly applied ADP technology to the FTS, the field office must be aware of the potential need for staff such as computer system managers, system operators, data-base administrators, etc. The Service Center will support the application development of software, while the field office will be responsible for systems staffing requirements.

2. Logistical considerations for computer systems. The field office is responsible for much of the site preparation for any computer system support and ultimately major portions of system equipment cost, maintenance cost, and peripheral equipment cost. The cost impact can be estimated to be a minimum of $250,000 per site, from systems installed at the FTS's.

3. Management impacts to existing field office staffs. These impacts include the need for wider training requirements for personnel who will be affected, as well as other management requirements, such as skills and training needs. As an example, lower and middle management training on the management of this type of technology will be required.

Once the Farmington and Casper Field Test Sites become operational, a greater tangible measure of the logistical and managerial costs will be more readily available and will be used as appropriate for necessary management feedback and baseline documentation.

CONCLUSION

From this discussion, it should be apparent that the Bureau's Field Test Sites are a relatively new tool, fundamental to the design and implementation of a Land Information System. Currently, the two existing FTS's are being prepared with operational status scheduled for late 1988. Simultaneously, an appropriate management architecture is being configured to facilitate nomination, selection, prioritization, and funding of LIS applications to be developed at the FTS's. Bureau policy is being developed to address management criteria, in greater detail, such as the FTS selection and approval process.

Currently, FTS problems that have been identified generally fall into five areas: (1) the selection and approval process, (2) funding requirements and commitments, (3) discrete Projects to be initiated, (4) dedicated Service Center support for workloads, and (5) Field Office impacts. Bureau management has initiated efforts that will ultimately resolve these problems.

The cost of using FTS's to prototype LIS technology is an extremely small percentage of the existing LIS funding. These Field Test Sites will, in return, minimize developmental LIS risk, aid in the delineation of beneficial parameters concerning data, software, hardware, communication, Bureau infrastructure, and produce timely management feedback necessary to effectively design, implement, and manage the Bureau's Land Information System.

ACKNOWLEDGMENTS

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A REPORT: BLM PLANNING IN
WESTERN OREGON FOR THE 1990's
A VIDEO

Shown by Don Pearson, WODDB Project, Oregon State Office,
BLM, Portland, OR 97208

ABSTRACT

The video "Planning in Western Oregon for the 1990's" is 15
minutes long and discusses the need for accurate data and how they
will be used to develop Resource Management Plans (RMP's) for the
five BLM districts in western Oregon.   The decision was made by
management to use GIS technology in developing the RMP's.   The
video shows the technologies and processes that have been developed
by BLM Oregon to capture and analyze digital data for resource
management purpose.

QUESTIONS AND ANSWERS

Q. What kind of camera did you
use?

A. We used a V-con Orthocon
for uncontrolled aerial
photography.

Q. How did you introduce
control to input?

A. The zoom lens takes care of
distortion.

CONFIGURATION MANAGEMENT FOR GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

The U.S. Department of the Interior, Bureau of Land Management, (BLM) has begun the implementation of Configuration Management for the Geographic Information Systems (GIS). Configuration Management is defined as "the creation and enforcement of procedures and standards to establish a compatible, Bureauwide computer environment. This encompasses the installation and maintenance of operating systems, hardware, software and data communications" (BLM 1988a). The implementation of Configuration Management encompasses the creation of an environment for ease of system, software, and user interface maintenance and implementation, a disciplined approach to defining directory structures, operating system releases and installation, software testing, documentation, release schedules, change management (enhancement and error reporting procedures), and coordination with other agencies utilizing the MOSS family of software. (BLM 1988b).

INTRODUCTION

Configuration Management has been used and implemented throughout industry for a number of years. The MOSS family of software had been adhering to a mode of configuration management; however, the need to build a more structured environment with established goals and guidelines has now been created. In the context of this discussion, Configuration Management is defined as "the creation and enforcement of procedures and standards to establish a compatible, Bureauwide computer environment. This encompasses the installation and maintenance of operating systems, hardware, software and data communications" (BLM 1988a).

In the past, the BLM had been maintaining the MOSS family of software on six Data General computer systems (Parker 1985). However, with the current Prime procurement, BLM now has 46 computer systems with the potential for 242 systems. With this expansion the BLM has recognized the need to standardize and create a

minimum system configuration to maintain a fully implemented and integrated computer system.

STANDARDIZATION AND MINIMUM SYSTEM CONFIGURATION

To establish an environment for ease of system, software, and user interface maintenance and implementation, a disciplined approach to defining directory structures, operating system releases and installation, software testing, documentation, release schedules, change management (enhancement and error reporting procedures), and coordination with other agencies utilizing the MOSS family of software has been initiated (BLM 1988b).

DIRECTORY STRUCTURE

Since each computer facility will vary from a standardized directory structure, the Configuration Management guidance will maintain a compatible environment by establishing a minimum national directory structure. Tracking the data and software directories for each computer location is to be a major task of the BLM field offices. If each level of the computer network is maintained in a minimum standard directory structure, then the requirement to use the PATHBLOCK feature (BLM 1988c), currently in the MOSS software package, will be alleviated.

To network the PRIME hardware into a local area network or wide area network, a strict adherence to standardized

Master File Directory (MFD) naming conventions will be required. Each MFD and partitions must be labeled uniformly throughout the organization to provide the basis for an integrated network. The proposed directory structure will permit the BLM to use existing standardized codes for current manual file procedures to extend into an electronic file system that is tied to each level of the organization, discipline, and location (BLM 1988c).

OPERATING SYSTEM RELEASES AND INSTALLATION

Periodically, systems vendors will make changes to operating systems, which affect the functionality of application software. To remain responsive to field operations, the BLM Service Center has the responsibility to notify the field offices when the application software has been fully tested and modified to the latest operating system. The test and changing of application software to operating systems is known as adaptive maintenance (Pressman 1982). Prior to the release of the application software (MOSS), the Service Center will provide ample lead time so that the field sites can order and install the latest operating system. Currently, the BLM Service Center is testing the next software release against the latest PRIMOS operating system.

If problems with the application software and the latest version of the operating

system are not severe, then patches to the application software will be provided. The patches will eliminate the long wait for the next application software release to upgrade operating systems. Remember, this will depend on the severity of the application software malfunction.

APPLICATION SOFTWARE TESTING

In the past, software testing or corrective maintenance (Pressman 1982) has varied in intensity. To correct maintenance variability, the BLM Service Center has established a Quality Assurance and Testing Team to fully investigate and test the application software prior to each release. This team will use data supplied by field offices to test the software in a simulated field operational environment so that data may be passed from one command or subsystem to another. In this manner, compatibility of commands and subsystems can be fully analyzed for anomalies and errors.

On occasion, a field office will either volunteer or be asked to participate in a Beta Test of the software prior to release. The Beta Test will be valuable to assist the Quality Assurance and Testing Team on non-simulated field application tests of the software. All Beta Test software will be released under strict guidelines and only for specific purposes mutually agreed upon by the Beta Test site and the BLM Service Center (BLM 1988b).

DOCUMENTATION

The software releases and patches will have documentation provided to assist the field offices in the loading of the software; it will be sent with the tapes. The documentation will include: (1) proper methodology to load the files provided on the release tape; (2) instructions regarding the directories into which the individual subsystems are loaded; (3) the commands that are to be executed; (4) instructions on data refor-matting and macro execution to implement the reformatting, and (5) an explanation of changes made to the software since the last release. The user manuals will not be the responsibility of Configuration Management except that the scheduling of releases, the software changes to be reflected in the manuals, etc., will be coordinated with the Field Operations Team, which has the responsibility of providing user manuals to the field offices.

RELEASE SCHEDULING

The scheduling of releases will be the responsibility of the Configuration Manager. To ascertain the critical point that a release is necessary or when a software patch is needed will be determined by such parameters as the following:

• Is a major data conversion required for the enhancements proposed?

• Does the next upgrade of the operating system have a

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significant impact on the software?

- Are there numerous or major enhancements?

- Is there a significant impact on the internal structure of the software that warrants a change to the computer operating environment (i.e., directory structures)?

CHANGE MANAGEMENT (ERROR REPORTING AND ENHANCEMENTS)

The BLM has begun to structure the means to accept and report changes to the software, whether errors or new enhancements. Coordinating software support is known as perfective maintenance (Pressman 1982).

Error Reporting

Errors discovered in the latest release will be reported through the Prime COMO file procedure, and will include all input and output activity during software execution. This file, in printed (spooled) form, will be sent to the software systems managers to review and to determine problem(s). The tracking and recording of a software problem is difficult without the hardcopy for reference.

If the error is in the software, then repairs are rated into the following three levels:

Level 1 - At this level, the error is so severe that the system will not function (a software patch is required immediately).

Level 2 - This level error affects a module but does not affect the full operational functionality of the GIS system (a patch will be provided as time will permit).

Level 3 - At this level, the error repair may be delayed until the next release and phone support will be provided to alleviate the problem (BLM 1988b).

If the reported error is caused by a faulty operating procedure, then the Field Operations Team will contact the individual that reported the error and assist in making the necessary changes to operating procedures.

Enhancements

All enhancements (except for software fixes) should follow the Life-Cycle review process. Essentially, the days when the "wish list" was developed and "someone" established a priority for software development are gone. Any enhancements specifically required by a user will have to be submitted with a design document software specification package for subsequent review by the software systems manager at the BLM Service Center. The cost for incorporating the enhancement may be levied upon the requesting organization.

COORDINATION WITH OTHER AGENCIES

The MOSS family of software is extending its utility to

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include the interface of spatial data with land records, alphanumeric data, and coordinate data. To create a system-operational environment, BLM will maintain a minimum directory structure on Prime computers to facilitate the implementation of software modules as they are developed. This change in direction will create some operational problems for agencies outside the BLM. The MOSS family of software will remain as intact as possible but BLM will isolate those functions that will link the software to the Land Information System functionality without affecting the agencies that do not have the same requirements. As these requirements begin to unfold, changes will be coordinated with the agencies using the software.

The BLM has recognized the need to create a more structured environment for software development, change management, and subsequent software releases. With the Land Information System initiative underway, MOSS family users are encouraged to participate in the Configuration Management process.

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Work Group Sessions

User Group Sessions

Moderated by: James D. Scurry
U.S. Fish and Wildlife Service

System Group Sessions

Moderated by: Wendy Tetley and John Foster
Bureau of Land Management

Management Group Sessions

Moderated by: Claude J. Christensen
U.S. Fish and Wildflife Service, and
Duane Sonnenburg
Bureau of Land Management

SUMMARY OF USER GROUP SESSION

James D. Scurry, Session Moderator

INTRODUCTION

The User Group held its planning and advisement session on Wednesday and Thursday, May 4-5, 1988. About 45 attendees participated in the session. Primary among the topics discussed was the status of the MOSS enhancement proposal prepared by the User and Systems Groups of the MOSS Management Configuration Team (MCMT) since the last Workshop in Denver. The agenda included the following items:

1. Presentation of the MOSS enhancement proposal;
2. Changes to priorities and additions to the enhancement proposal;
3. Skills development within the User Community;
4. Concern over the absence of several key agencies at this year's Workshop;
5. Impact of the common data structure, especially to non-BLM agencies;
6. Communications among Users as well as the Systems and Management personnel;
7. BLM Hotline support; and
8. User Group leadership for FY89.

PRESENTATION OF THE MOSS ENHANCEMENT PROPOSAL

During the 1987 MOSS Workshop in Denver, the Management Group of the MCMT tasked the Systems and User Groups with the design of an enhancement proposal for short- (1 year) and long-term (3 year) development of MOSS. The proposal was to include all necessary fixes, enhancements, and modifications of the software to bring MOSS in-line with state-of-the-art geographic information systems technologies. This proposal was to include the necessary equipment, personnel, and schedules for completion. Subsequent meetings in Denver with William J. Bonner and Claude J. Christensen (telephone), chairpersons of the MCMT Management Group, established the criteria for development of the proposal. Directions from the Management Group were to assume "ground-up" structuring of a software support group and to consider only those enhancements and fixes scheduled for the Spring 1988 release as part of the current software configuration. Post-spring enhancements, whether initiated or planned, were to be considered in the design document. User and Systems Working Group members met in Denver the week of October 5, 1987, and outlined the necessary guidelines for the enhancement of MOSS.

Enhancements to the MOSS software were proposed as short-term (those of immediate need which could be completed in one year or less) and long-term (those which would require

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more than one year to complete regardless of need). Each proposed enhancement or fix was prioritized according to the concensus need. The short-term and long-term recommendations are summarized in Tables 1 and 2. Included are the assigned priority, the status of current work, and the projected completion date. Several proposed enhancements have been completed and are scheduled for July 1988, the next software release date.

The personnel, hardware/software, and miscellaneous funding requirements to implement this program were estimated for each of the three years of the program. Hardware and other start-up costs were included in the first year. Although these costs decreased dramatically for the second and third years, the increased demand for programmer support to facilitate the long-term objectives negated any substantial cost savings. A breakdown of the projected cost not including space, utilities, and other facilities support are listed in Table 3.

The proposal currently is being evaluated by the Management Group of the MCMT. In accordance with the 1987 MOSS Action Plan, funding initiatives will be established for implementation of the enhancement program (USDOI/BIA 1987: Section 1). This will involve the transfer of participating agency funds and/or personnel to the designated lead agency and establishment of the MCMT as an oversight committee to monitor the progress of the implementation of the program.

CHANGES TO PRIORITIES AND ADDITIONS TO THE ENHANCEMENT PROPOSAL

Seven additional enhancements/fixes were proposed for incorporation into the MOSS enhancement document. These new additions included several capabilities which had been identified since the last meeting of the MCMT User Group. Each item was categorized as a short-term modification (requiring less than one year) and considered essential to the completion of existing agency projects. The proposed enhancements were:

1. Multiple attribute editing (highest priority);
2. Multivariate analysis capabilities;
3. TIN volumetrics and contouring;
4. Fence diagrams;
5. CTOG directly incorporated in MOSS;
6. CAD/COGO integrated into EDMAP; and
7. Reincorporate DIGITIZER option into GENERATE and enhance GENERATE to include topology and error checking.

Concerns were expressed that the more extensive prototyping initiatives are receiving immediate attention over the user-specified enhancements and fixes. The users request the establishment of a mechanism by which they can be informed of system progress and, therefore, assured that their needs are being adequately addressed.

Similarly, questions were raised concerning the rationale

Table 1. Proposed short term enhancements and fixes to the MOSS software.

Task	Priority	Status	Completion
Establish standardized and current release of MOSS on the Prime	1	In Progress	July 1988
Provide OVERLAY and BUFFER commands that function correctly	2	Not Funded	------
Improve data accuracy and coordinate storage	3	Prototype completed	July 1988
Improve documentation	4	In progress	------
Enhance cartographic symbology and annotation capabilities	5	In progress#	------
Implement raster-to-vector conversion in MAPS	6	Study initiated	------
Combine similar commands	7	In progress	------
Enhance SELECT command	8	Completed	July 1988
Enhance data summary and browse	8	Not funded	------
Enhance SUBEDIT option of UTILITY	8	Completed	July 1988
User-defined translate/rotate options	8	Not funded	------
Standardize multiple attribute capabilities throughout the software	8	Not funded	------
Provide access to multiple projects	8	Completed	July 1988
Standardize all default parameters	8	Completed	July 1988
Implement "CENTROID" command	8	Not Funded	------
Implement SPLINE function in GENERATE	8	In Progress#	------

(continued)

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Table 1. Concluded.

Task	Priority	Status	Completion
Integrate MOSS .41 into Prime software	8	In Progress*	July 1988

\# The Los Alamos National Laboratory has funded developmental support for these commands.

* The Bureau of Land Management has implemented rudimentary color capabilities into the Prime software for vector maps. A task has been funded to permit with raster maps. This is vector assignment, however, not flood routines.

A completion date of July 1988 has been assigned to those tasks currently completed, which will be in the next release scheduled for July.

Table 2. Proposed long term enhancements and fixes to the MOSS software .

Task	Priority	Status	Completion
Implement relational data base management system for attributes	1	Phototype completed	-----
Hardware independence for all software subsystems	2	Completed (MOSS)* In progress (AMS)	Summer 1988
Combine existing cartographic output systems	3	Partial completion; prototype initiated for LGS at BLM	----
Investigate alternative data structures	4	In progress	Summer 1988
Incorporate AMS 2.0 into Prime AMS	5	In progress	Fall 1988
Investigate adoption of single data entry system	6	Not funded	------

(continued)

Table 2. Concluded.

Task	Priority	Status	Completion
Implement trend surface and nearest-neighbor analyses	7	Not funded	------
Enhance IMPORT and EXPORT commands to include additional formats	7	Not funded	------
Enhance QUAD and GRID options in MOSS and COS to use other projections	7	Not funded	------
Enhance SIZE or SAVE option to drop or weed-sized item coordinates	7	Not funded	------
Increase MAPS file size to 8,192 by 8,192 matrix	7	Completed	July 1988
Provide automated command processor into MOSS/MAPS	7	Completed	July 1988
Implement new USGS projection package	7	Completed	July 1988
Develop direct interface from AMS to MOSS	7	Not funded	------
Incorporate projection modification capabilities into MAPS	7	Completed	July 1988
Improve color graphics capability in MOSS/MAPS	7	Not funded	------
Convert latest (Prime) version of MOSS/MAPS to Data General	7	Completed	July 1988

* Includes MOSS, MAPS, ADS, and COS subsystems.

A completion date of July 1988 has been assigned to those tasks currently completed which will be included in the next release scheduled for July.

Table 3. Funding requirements

	Personnel*	Hardware	Total
Year 1	$ 958,333	$425,000	$1,383,333
Year 2	$ 954,167	$ 50,000	$1,004,167
Year 3	$1,050,000	$ 50,000	$1,100,000
Total	$2,962,500	$525,000	$3,487,500

* Assumes $50,000 in salary and benefits for each staff member including contractors.

for recommending any changes to the software since the MOSS system is to be replaced by BLM's LIS in 1992-93. Many of the modifications proposed in the enhancement document and at this session are not scheduled for completion until 1991.

SKILLS DEVELOPMENT WITHIN THE USER COMMUNITY

With the possible exception of the Denver Service Center, there generally is a lack of technical training and GIS skills development opportunity to the User community. The manuals illustrate one particular implementation alternative, but provide little more than listings of possible responses to the command options and virtually nothing of the rationale to which they should be used. Other systems, such as ARC/INFO, Intergraph, and ERDAS, routinely provide training sessions and seminars ranging from software basics to technical systems and appli-

cations management. This Workshop should be expanded to include training sessions and lectures that address relevant GIS issues and provide hands-on experience with the various components of the MOSS subsystems. These seminars also would inform users of recent software modifications. In addition, similar regional seminars and classes should be organized on an annual or semiannual basis for those unable to attend the National Workshop.

CONCERN OVER THE ABSENCE OF KEY AGENCIES AT THIS YEAR'S WORKSHOP

During the 1987 Workshop in Denver, about 80 attendees participated in the User meetings, compared to 45 at this meeting. The reason for this decrease is not known; however, there is growing concern over the apparent fragmentation and lack of coordination among agencies

using GIS. Similarly, several past key participants, such as the Bureau of Indian Affairs (BIA), have chosen other systems for their GIS. It was agreed that there is a tremendous need to keep an active MOSS user community as well as maintain a viable working relationship with other agencies not using MOSS.

There was no general concensus on how this could be accomplished. Some felt that the MOSS conference should maintain its autonomy, while others expressed interest in a merger with other conferences such as GRASS. The MOSS Configuration Management Team (MCMT) should investigate possible Workshop alternatives. Symposia concerned with MOSS could be organized as individual sessions within the larger context of a joint geographic information systems workshop. This hopefully would allow independent exchange of ideas that would benefit all users.

IMPACT OF THE COMMON DATA STRUCTURE

The impact of implementing a common data structure throughout all subsystems of MOSS was of extreme concern. There generally was a lack of understanding of what data-base management and conversion considerations would result from its implementation. There was special concern by non-BLM agencies that they had been closed out of the evaluation process. Draft versions of the common data structure document had been distributed for comment among the BLM, but not to other users. It was agreed that coordination should be improved, and a sign-up list was circulated for those wishing to receive the document. A short overview was presented by staff of the BLM on the status of the common data structure document and current implementation initiatives. Following the presentation, it was suggested that a workshop be held addressing the potential impacts created by conversion to a common data structure.

COMMUNICATIONS AMONG USERS, SYSTEMS MANAGEMENT PERSONNEL

Whether real or imagined, there is a perceived problem with coordination among agencies using MOSS. Many of these problems can be directly attributed to the absence of any formal communications network through which to disseminate information related to MOSS and GIS activities in the Federal Government. An overwhelming recommendation of the User Group is to establish a quarterly newsletter explaining proposed changes to the software, the rationale for the change, their impact to existing systems and data bases, and implementation progress. This newsletter also would provide a forum for input into system directions as well as provide a mechanism for sharing macros, project results, and "bug" reports. Funds should be appropriated from all participating agencies

and personnel designated to support the newsletter. This should receive immediate attention from each of the three MOSS support groups.

BLM HOTLINE SUPPORT

There was obvious frustration over the support provided by the BLM through the GIS Hotline. Complaints ranged from busy phones or no answer to failure of Hotline personnel to respond to identified problems. Suggested improvements to Hotline service include development of a system to track incoming questions, record known problems, and determine the status of inquiries/responses. This system would be an online bulletin board-type informational service that would provide descriptions of known problems and potential fixes or alternatives. Hotline staff would continue to serve users with problems not listed on the service or which can not be answered appropriately. A tracking system would provide some reassurance that problems were receiving adequate attention.

The BLM acknowledged that staff shortages were taxing the limits of the Hotline service and offered several suggestions to facilitate the process.

1. All users were invited to bring any data, problem or otherwise, to Denver and help test or prepare documentation. Help is desperately needed.

2. If a problem is encountered, rerun the commands to duplicate the problem. If it reoccurs, send a tape of the data and a COMI file recreating the exact command sequence for processing at the Denver Service Center.

USER GROUP LEADERSHIP FOR FY89

Robin L. Gebhard, National Wetlands Inventory, U.S. Fish and Wildlife Service, was unanimously selected as chairperson for the MOSS Configuration Management Team (MCMT) User Group for FY89.

SUMMARY OF USER GROUP RECOMMENDATIONS

The following items are submitted for incorporation into the FY89 MOSS Action Plan to be implemented by the MCMT.

1. Incorporate the following enhancements and fixes into the software implementation plan:

   -Multiple attribute editing,
   -Multivariate analysis capabilities,
   -TIN volumetrics and contouring,
   -Fence diagrams,
   -Incorporate CTOG directly into MOSS,
   -CAD/COGO integrated into EDMAP, and
   -Reincorporate DIGITIZER option into GENERATE and enhance GENERATE to include topology and error checking.

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2. Incorporate hands-on training sessions at future MOSS Workshops.

3. Develop national or regional training sessions on a regular basis.

4. Investigate merger of MOSS Workshop with other public domain software conferences.

5. Develop workshop on the impact of implementation of a common data structure throughout the MOSS subsystems.

6. Establish newsletter to improve information dissemination and coordination among MOSS users.

7. Improve GIS Hotline support with additional staff, online system status summary, and inquiry tracking system.

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SUMMARY OF SYSTEM GROUP SESSION

Wendy Tetley and John Foster, Session Moderators

INTRODUCTION

The System Group held its coordination session on Wednesday and Thursday, May 4–5, 1988. Approximately 15 attendees participated in the session. The primary topic of discussion was system configuration and standardization: how to provide the appropriate resources to implement an agency-wide system management strategy. Since software-specific modifications are either in progress or addressed in the MOSS enhancement proposal, this aspect of system configuration is the next logical step to providing a comprehensive software/system management plan. The systems group agenda included five major elements.

1. Establishment of regional/ State system administrative groups;
2. Incorporation and support of commercial software into the system;
3. Standardization of software release procedures;
4. Recommended changes in User support, and
5. Technical evaluation of specific software components/enhancements.

ESTABLISHMENT OF REGIONAL/STATE SYSTEM ADMINISTRATIVE GROUPS

System configuration implies a holistic approach to software development, testing, management, dissemination, documentation, and support. Support includes both data-base development and technical assistance to the users. Successful integration of these diverse elements requires an infrastructure designed to efficiently assemble information, evaluate user needs, and recommend the appropriate actions. Within the BLM, State offices have Information Resources Management (IRM) officials that advise the Denver Service Center on systems issues. The current administrative structure has not always provided effective dialog between the DSC and the IRM. This has resulted primarily from the absence of a formal organizational structure designed to direct information flow between the Service Center and the State offices. Establishment of state Prime system administrators to advise the IRM would provide more effective coordination and facilitate GIS support within the Bureau. Other agencies also should establish similar administrators at their various regional software installations to provide a single focus for system configuration support.

INCORPORATION AND SUPPORT OF COMMERCIAL SOFTWARE

With the implementation of ORACLE as a relational data-

base management system and GKS as a graphics standard, commercial "off-the-shelf" software packages will become integral components of the geographic information system. This requires the development of specific software and user support both from the commercial software vendor and within the Government. In order to incorporate these systems, the following items must be made available:

1. Readily available support from the software vendors, including toll free (1-800) telephone numbers for user and technical support.
2. A pool of expertise within the Government to provide user assistance with the software and with technical knowledge of the system configuration, i.e., how the software fits into the overall system.

STANDARDIZATION OF SOFTWARE RELEASE PROCEDURES

One of the most critical aspects of system maintenance is the installation of software updates. The level of expertise at the numerous GIS facilities varies significantly and the impact of specific software changes to other elements of the system may be poorly understood. Consequently, instructions for installation of software releases, upgrades/patches, and enhancements should be standardized to provide concise and consistent procedures. These instructions should also contain information regarding the specific software modifi-cations, new commands, and their impact to overall system configuration.

RECOMMEND CHANGES TO USER SUPPORT

The recent dissatisfaction with the BLM hotline necessitates changes to the user support procedures. Primary among the complaints has been the absence of a tracking system to determine the status of problem reports and the solutions to those problems. Several steps could be implemented at the DSC to alleviate many of these support problems.

1. Insure that the GIS Hotline is manned throughout normal working hours.
2. Establish electronic bulletin board notices for all Level I and II "bugs".
3. Provide feedback to the field regarding the status, known problems, and solutions to various hardware and software, using the electronic bulletin board and READ ME FIRST files included with each release.
4. Periodic review of technical assistance requests, both at the DSC and in the field, to determine trends or specific problem areas that may be alleviated with training or changes in the user interface.

TECHNICAL EVALUATION OF SPECIFIC SOFTWARE COMPONENTS/ENHANCEMENTS

Two studies are recommended for the MOSS software. The first is to evaluate the

MOSSPLOT graphics system for reliability and simplification while maintaining the METAFILE concept. The second study is to establish a technical committee to evaluate native UNIX on the Prime 50 series computers for incorporation into the system. This report should be completed by mid-1989.

SUMMARY OF SYSTEM RECOMMENDATIONS

Five items are recommended for consideration by the User and Management Groups.

1. Establish a State/facility Prime system administrative group to advise IRM.

2. Develop expertise and support network for commercial software that includes toll free vendor support and governmental expertise for user assistance and system configuration.

3. Standardize release instructions for software releases, enhancements, and patches.

4. Improve user support with electronic bulletin board to post notices of known bugs and to provide a tracking system to monitor the disposition of technical support requests. Also conduct periodic review of technical support requests to identify potential user interface/training problems.

5. Conduct studies of MOSSPLOT to identify potential improvement and simplification, and form a technical group to evaluate native UNIX on the Prime 50 series computers.

Claude J. Christensen and Duane Sonnenberg, Session Moderators

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INTRODUCTION

The Management Group held its annual coordination meeting on Wednesday and Thursday, May 4-5, 1988. Approximately 15 workshop attendees participated in the session. The primary topic of discussion was the "care and feeding" of MOSS for the next 3-5 years; particularly the disposition of the MOSS enhancement proposal prepared by the User and Systems Groups of the MOSS Configuration Management Team (MCMT) since the 1987 Workshop in Denver. Specific agenda topics included the following items:

1. MOSS enhancement proposal deposition,
2. Management Group reorganization, and
3. The 1989 MOSS User Workshop.

MOSS ENHANCEMENT PROPOSAL DISPOSITION

The User and Systems Groups of the MOSS Configuration Management Team (MCMT) assembled an enhancement proposal that outlined the modifications necessary to bring MOSS current with other state-of-the-art geographic information systems software. This document detailed 34 short- and long-term enhancements and prioritized their implementation according to immediate need for existing project completion, as well as, their overall impact to the functionality of the software (Stayner and Scurry 1988). This proposal projected a total of 711 work months, at a cost of 3.5 million dollars over a 3-year period, for completion of the program.

The User and Systems Groups are to be commended for their comprehensive and thorough software evaluation. However, because of the extensive time and costs necessary to develop this program, the establishment of an independent multi-agency support center is not feasible in the short term. The Management Group proposes an alternative strategy in which the BLM, with specific conditions, assumes the lead responsibility for MOSS software support. This approach provides an immediate cost savings since space, hardware, and other start-up expenses are dramatically reduced. The MOSS enhancement document will function as the technical agenda to direct the system development and software enhancements.

The recommendation to establish the BLM as the lead agency for MOSS is based upon the existence of experienced support staff at the Denver Service Center and upon the BLM's commitment to the MOSS family of software leading to

their target system implementation in 1993-94. This recommendation, however, is contingent upon the mutual acceptance of five conditions.

1. BLM will support MOSS on the PRIME hardware and software processing environment. This includes software development, testing, documentation, and user support.

2. BLM will make available to other agencies using Prime computer, all MOSS and related sub-system software, including routine patches, modifications, and enhancements. For those agencies not using Prime, source code will be made available for conversion and maintenance to other systems. All costs associated with the conversion are to be incurred by the requesting agency. Subsequent enhancements and modifications also must be requested and converted by the user agency.

3. BLM will serve as a focal-point agency for enhancements and support for MOSS in accordance with existing agreements. Expansion of support services or involvement of agencies without existing memoranda of understanding (MOU)'s may require new agreements.

4. All modification/enhancement requests are to be submitted on behalf of a consolidated user community and formalized through Agency directorate and assistant secretaries for IRMRC approval. This will provide for concensus approval of all software modifications and decrease the potential of initiating conflicting requests.

5. Interbureau communications and coordination will be improved by the establishment of Agency contacts through which all software releases, questions, and issues will be addressed. A directory of these contacts, as well as other relevant GIS personnel, will be developed and made available through hardcopy or "on-line" services. The BLM LIS bulletin board will serve as the electronic information service for announcements and for dissemination of significant items to all participating GIS users.

MANAGEMENT GROUP REORGANIZATION

The Management Group selected Claude J. Christensen, Fish and Wildlife Service, and Duane Sonnenberg, Bureau of Land Management as co-chairpersons for 1988-89.

THE 1989 MOSS USERS WORKSHOP

The Management Group commends the National Wetlands Research Center, and, in particular, Jim Scurry, for hosting the 1988 Workshop in New Orleans. The following recommendations are suggested for the 1989 MOSS User Workshop.

1. The 1989 Workshop should remain user driven and organized, but should be expanded to include other resource management oriented systems and applications. It should focus on resource management issues which emphasize comprehensive Land Information Systems (LIS) technologies.

2. The Workshop should be developed around a central theme such as evaluating MOSS and other GIS technologies to meet agency resource needs. It should include sessions specific to MOSS, as well as those on data exchange and evaluation and application of other geographic information systems for resource management.

3. The 1989 Workshop should be held in one of the following locations: New Mexico, Wyoming, Portland, OR, or Reno, NV.

SUMMARY OF MANAGEMENT RECOMMENDATIONS

The Management Group submits the following recommendations for the future development and support of the MOSS family of software and for the continuation of user-related support activities:

1. The BLM assumes the lead responsibility for the development and support of MOSS. This lead is contingent upon acceptance of the criteria outlined in this session summary.

2. Claude J. Christensen, FWS, and Duane Sonnenberg, BLM, share leadership responsibility for the 1988-89 Management Group.

3. The 1989 MOSS User Workshop be expanded to include other resource management oriented geographic information systems and be developed around a central theme. It is also recommended that the next workshop be held in one of the following locations-- New Mexico, Wyoming, Portland, OR, or Reno, NV.

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3CI, Inc.
2057 Vermont Drive
Fort Collins, CO 80525-2913

Exhibit Product: Relational data base management system –
INFOCEN
Contact: Kathryn Kurtz
Telephone: (303) 223-2722

Altek Corporation
12210 Plum Orchard Drive
Silver Springs, MD 20904

Exhibit Product: High resolution digitizing tablet
Contact: Diane Mitol
Telephone: (301) 572-2555

Graph-On Corporation
1980 Concourse Drive
San Jose, CA 95131

Exhibit Product: High resolution monochrome graphics terminal
Contact: Mike Buschell
Telephone: (408) 371-8500 or 1-800-472-7466

Pericom, Inc.
2291 205th Street, Suite 103
Torrence, CA 90501

Exhibit Product: Medium resolution color graphics terminals
Contact: Diane Smith
Telephone: (213) 618-9190

Prime Computers, Inc.
1375 Piccard Dr., Suite 300
Rockville, MD 20850

Exhibit product: Minicomputer system
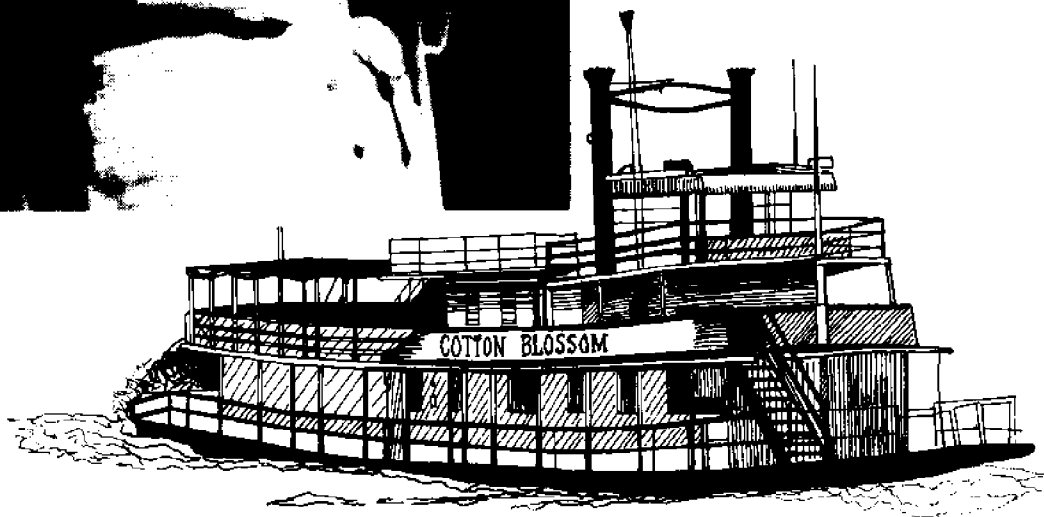Contact: Michael Cleaves
Telephone: (301) 948-7010 ext. 285

Tektronix, Inc.
700 Professional Drive
P.O. Box 6026
Gaithersburg, MD 20877

Exhibit Product: High resolution color graphics workstation
Contact: Kathleen M. Archer
Telephone: (301) 948-7151

LAGNIAPPE

Lagniappe in Cajun French refers to "a tip, a little extra," and is commonly used in South Louisiana. The Fifth Annual MOSS Conference added some "lagniappe"--the banquet Tuesday night at the hotel featuring "An Evening with Mark Twain" starring Phil White, editor of the Slidell (Louisiana) Daily Sentry News, and the evening social on Wednesday, hosted by Autometric, Inc., on the stern-wheeler Cotton Blossom. A Dixieland band furnished music for dancing, singing-along, and a group second-line.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.

4. Title and Subtitle	5. Report Date
Proceedings Fifth National MOSS Users Workshop	February 1989
	6.

7. Author(s)	8. Performing Organization Rept. No.
James D. Scurry, Compiler	

9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
U.S. Fish and Wildlife Service Louisiana Sea College Program	
National Wetlands Research Center Louisiana State University	11. Contract(C) or Grant(G) No.
1010 Gause Boulevard Baton Rouge, LA 70803-7507	(C)
Slidell, LA 70458	(G)

12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
Same As Above	
	14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The Fifth National MOSS Users Workshop was held in New Orleans, LA, May 2-6, 1988. The workshop was designed to incorporate information about MOSS (Map Overlay Statistical Systems), including data integration, software development, and data management issues. Twenty-four papers and one video detailed 1987 accomplishments and changes and future development.

17. Document Analysis a. Descriptors

Geographic Information Systems   MOSS
Computers   Maps

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited distribution	Unclassified	xviii + 308
	20. Security Class (This Page)	22. Price
	Unclassified	

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce