Research, Investigations and Technical Developments National Mapping Program 1982

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U.S. Department of the Interior
Geological Survey
National Mapping Division

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

Enclosed is a copy of the U.S. Geological Survey report, "Research, Investigations and Technical Developments, National Mapping Program 1982." Copies have been mailed by the Division Chief to numerous individuals and organizations who are interested in cartography, geography, remote sensing and the activities of the Division.

I would like to thank the numerous individuals who provided input to the report. The interest and effort in strengthening our research program and publicizing the results is appreciated.

Lowell E. Starr
Assistant Division Chief
for Research

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

RESEARCH, INVESTIGATIONS, AND TECHNICAL DEVELOPMENTS
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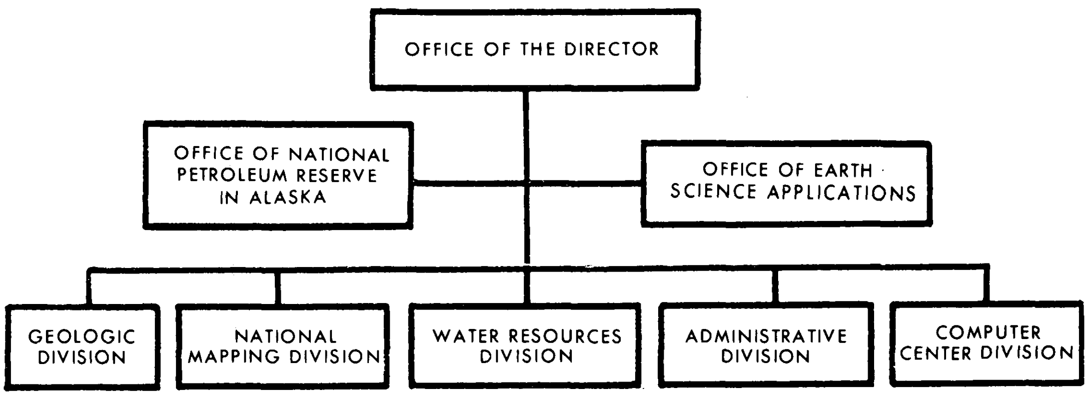
ORGANIZATION

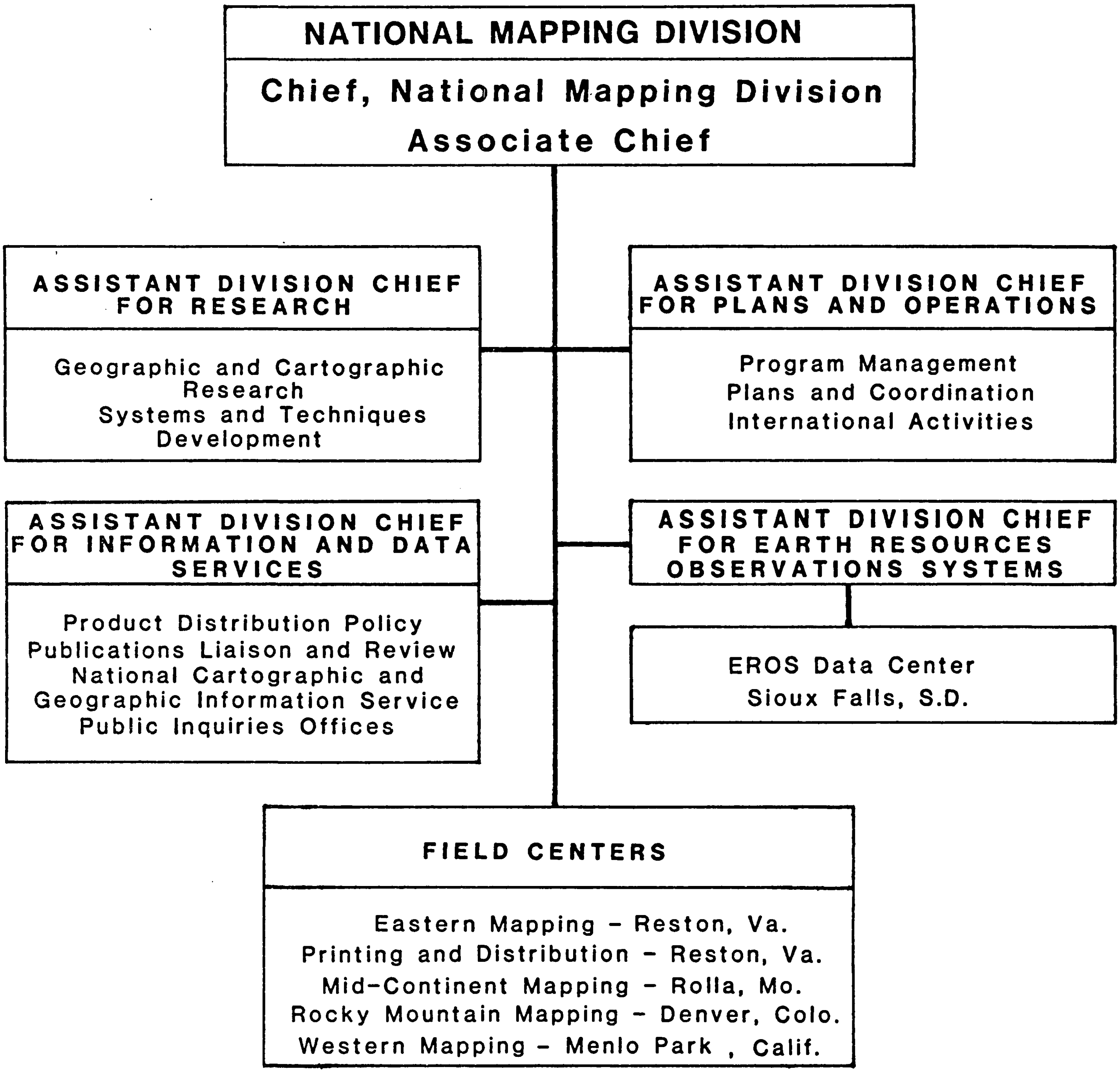
The U.S. Geological Survey Mission and Organization

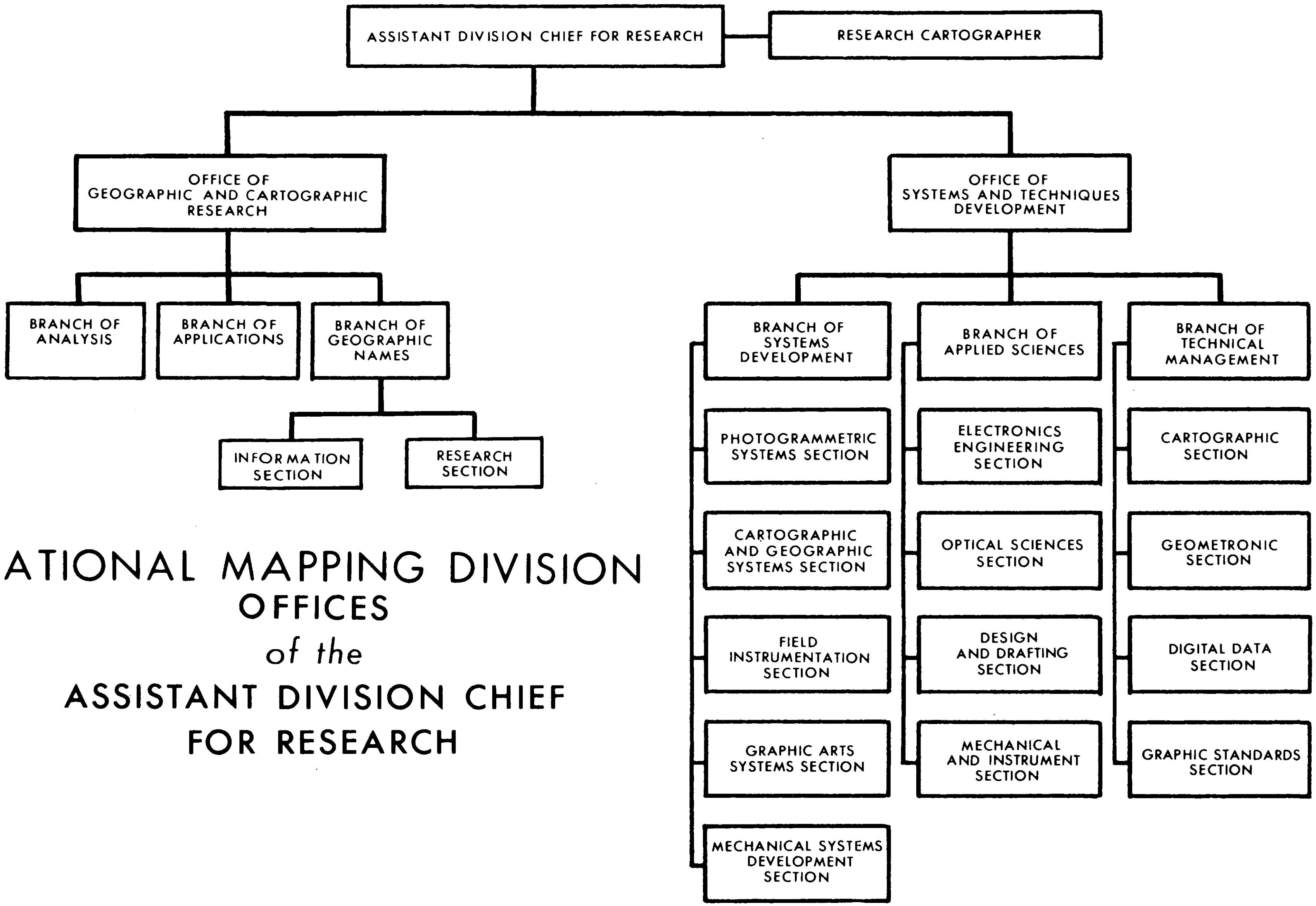
The U.S. Geological Survey was established in 1897 and charged with the responsibility for the "classification of public lands and examination of the geological structure, mineral resources, and products of the National domain." Over the years the evolution of the Earth sciences, the need to carefully manage the Nation's nonrenewable resources and to find new sources of critical energy and mineral commodities, and mounting concern over man's impact on the environment have added numerous other duties including geographic research, hazards studies, topographic and geologic mapping, and water resources assessments. The Survey is an impartial research agency that gathers, interprets, and distributes data in order to advance scientific knowledge of the Earth so that managerial decisions related to natural resources can be based on objective information.

The Geological Survey is headquartered at Reston, Va., and maintains a nationwide organization consisting of more than 200 offices located throughout the United States. The Survey is organized into three program Divisions (Geologic, National Mapping, and Water Resources) and two support Divisions (Administrative and Information Systems), each reporting to the Director of the Survey. The Survey's field organization is made up of Regional Offices at Reston, Va., Denver, Colo., and Menlo Park, Calif., and a network of field and special-purpose offices. These offices coordinate and administer the work of the Survey's widely dispersed activities.



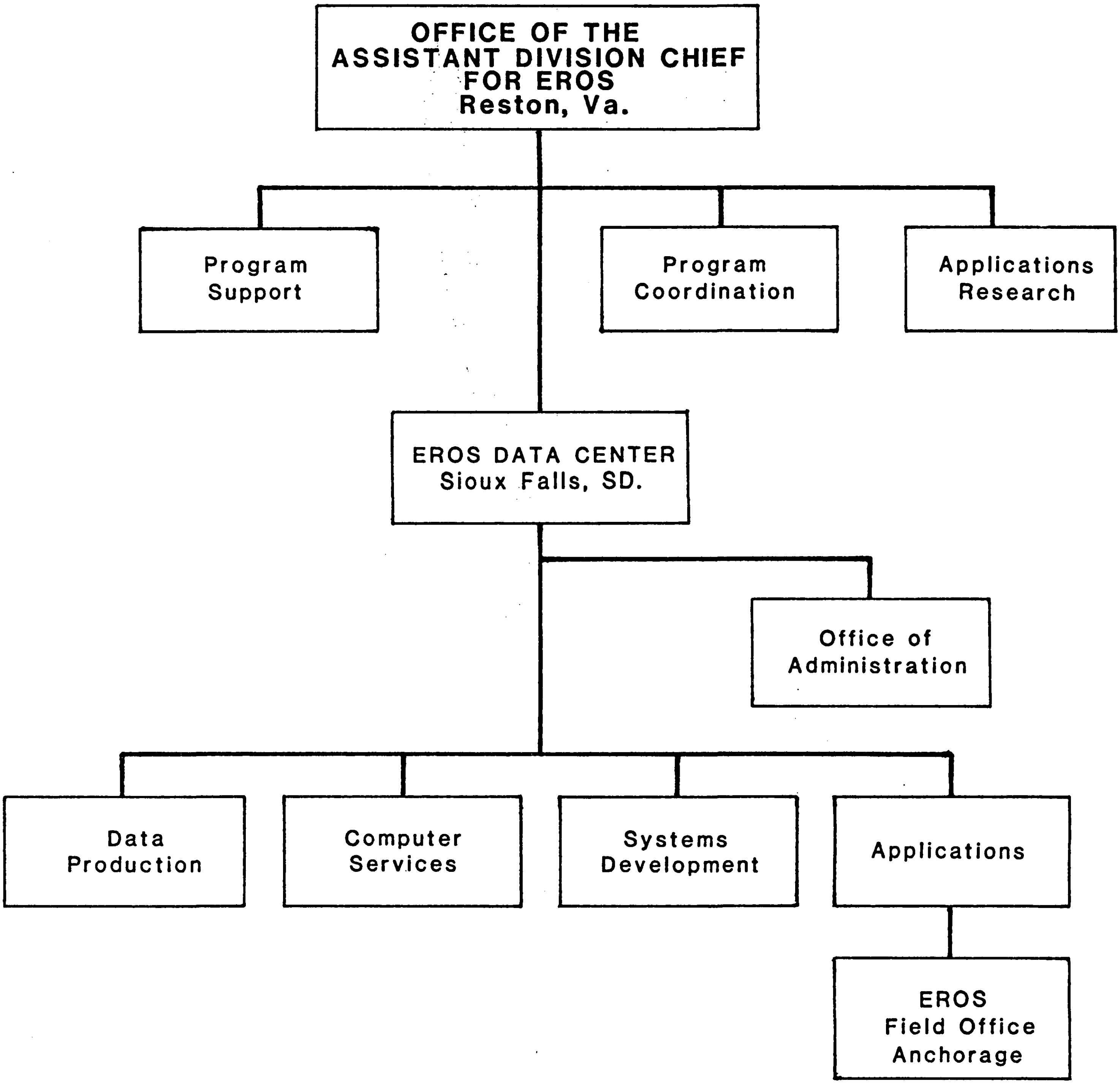
Organization Chart





NATIONAL MAPPING DIVISION
OFFICES
of the
ASSISTANT DIVISION CHIEF FOR RESEARCH

Organization Chart



FOREWORD

The purpose of this document is to report the research, investigations, and technical developments being conducted by the USGS National Mapping Division. The Division collects, processes, and disseminates geographic, cartographic, and remote sensing information and maps; provides technical assistance; and conducts related research that is responsive to national needs. These functions help support the Geological Survey's mission to investigate and classify the Earth and its physical resources. The report covers projects undertaken by staff members in the Office of Research and the EROS Program Office; by personnel in four Mapping Centers, the EROS Data Center, and the Printing and Distribution Center; and through contracts.

In 1982, the Offices of Geographic Research and Cartographic Research were combined, thus continuing the process of reorganization started in 1980. Also, the EROS Program Office and the EROS Data Center were transferred from the USGS Office of Earth Science Applications to the National Mapping Division. Their research and investigation activities are included in this report for the first time. Further realignment of EROS activities has been underway during 1983 and will be reflected in the next report.

Increasing demands for current and accurate cartographic and geographic data have required many new technological developments in data acquisition, processing, and display. Active research and investigations are conducted in the Division to improve the quality and efficiency of map production and to develop new technology to support national earth science needs. Significant progress has been achieved in color image mapping from multispectral remote sensing data. Research continues in digital cartography and the related broad field of spatial data handling to support the development of a national digital cartographic data base. Research on methods to analyze these data in order to locate, predict, and plan for the effects of environmental changes, hazards, and engineering developments will enable decisionmakers at all levels of government or the private sector to more fully utilize this new information. Several illustrated articles describe current developments.

This annual report, therefore, provides a summary of 1982 research and development activities in the USGS National Mapping Division that will be of interest to all that are interested in the advancement and application of the cartographic and geographic sciences.

R B Southard

Rupert B. Southard
Chief, National Mapping Division

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ILLUSTRATIONS

CONVERSION TABLE

U.S. customary units used in this report may be expressed as metric units by the use of the following conversion factors.

Multiply	By	To Obtain
feet	0.3048	meters
statute miles	1.609	kilometers

U.S. metric units used in this report may be expressed as U.S. customary units by the use of the following conversion factors.

Multiply	By	To Obtain
meters	3.281	feet
kilometers	0.6214	statute miles

ABBREVIATIONS

DCDB	digital cartographic data base
DEM	digital elevation model - an array of elevations for ground positions, usually spaced at regular intervals
DLG	digital line graph - line map information in digital form
EROS	Earth Resources Observation Systems
EDC	EROS Data Center
MSS	multispectral scanner aboard Landsat
NMD	National Mapping Division
RMSE	root mean square error
TM	thematic mapper aboard Landsat 4
TMS	thematic mapper simulator
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

RESEARCH, INVESTIGATIONS AND TECHNICAL DEVELOPMENTS
NATIONAL MAPPING PROGRAM 1982

INTRODUCTION

This report summarizes the major research activities conducted in the National Mapping Division during 1982. These research activities range from fundamental studies that are of long range value in the mapping and geographic sciences, to the systems development, technical management, and applied investigations necessary for operational requirements. Numerous continuing activities have been updated from the 1981 report and several new activities have been added. Additional activities in remote sensing and resource information studies reflect the merger of the Earth Resources Observation Systems (EROS) program into the National Mapping Division. Digital cartographic developments continue to be of major importance to further the mission of the Division in developing a national digital cartographic data base.

In order to complete nationwide large-scale map coverage by the late 1980's, the Division continues to improve the production process for Provisional Edition topographic maps. Provisional maps will be prepared for all remaining unmapped 1:24,000-scale 7.5-minute quadrangle areas in the conterminous U.S. They will also be prepared at 1:63,360 scale for remaining unmapped 15-minute areas in Alaska.

The organization of activities has been changed from last year's report and eight major subject areas serve to group activities of common interest. Inevitably there will be some overlap of interest for various readers and some activities include a number of interrelated topics. An index of selected topics is provided.

There were several activities of special interest during 1982. These included publication of Landsat image maps of Dyersburg and Las Vegas, the first 1:24,000-scale Provisional Map produced by automated techniques, the compilation of a national 1:2,000,000-scale digital cartographic data base, the development of a remote information processing system, the development of digital cartographic data standards, the mapping of the vegetation and land cover in arctic Alaska from Landsat multispectral data, the development of a display and evaluation system for digital elevation data, and the publication of the first chapter (New Jersey) of the "National Gazetteer of the United States of America." In addition to the reported activities, selected references to articles published by National Mapping Division authors during 1982 are included.

CARTOGRAPHIC SYSTEMS AND TECHNIQUES

Producing Provisional Maps by Automated Techniques

A new era has evolved in the production of maps. The decision by NMD to accelerate complete coverage of the United States at 1:24,000 scale by introducing an interim or provisional map (see article "Experience with Provisional Maps"), coupled with modern digital production techniques, has resulted in a product with a different appearance than the standard manually produced 7.5-minute map. Some provisional maps are being prepared using essentially automated techniques, from the photogrammetric data collection stage through the generation of color separates ready for printing. This automated process further shortens the map production cycle for provisional maps and places the product in the hands of the user at an earlier date. It also allows greater flexibility in manipulating available information.

Three stages of the production cycle are computer assisted. They are (1) data collection, (2) data editing, and (3) cartographic plotting of map separates. During the data collection stage on digitized stereoplotters, data are recorded on magnetic tape along with attribute codes which identify each feature digitized. Data capture allows coordinate information to be accurately determined and passed on to the recording device.

Data are interactively edited to correct errors and deficiencies that cannot be effectively handled by batch computer methods. Symbology is also interactively applied to properly portray map features. Due to certain variations in data collection procedures, line joins between models are not always effected and these are accomplished by interactive editing methods on an Intergraph Interactive Graphics Design System (IGDS) driven by a DEC PDP 11/70 computer.

User commands and other computer programs developed on the IGDS permit complete lettering of the provisional map. The Graphic Map Production System (GRAMPS) is a group of experimental computer programs designed to further process and edit the digital map data and add symbology, as well as to place certain descriptive lettering, contour labels, and control elevations. Collar (marginal) information can be accurately and rapidly placed in the design file on the IGDS through the use of a program that leads the operator through a prescribed sequence to key in the required information.

User commands developed to aid the IGDS operator in positioning interior lettering are utilized to place names and labels for the map. These commands choose type style and size, as well as the mode of placement, thereby eliminating most possibilities of error in the lettering operation.

The public land net and boundary information is manually digitized and processed through standard NMD structuring software whereupon these DLG data are merged with the edited file on the IGDS. With aesthetic refinements completed, lettering done, and boundary and land net information added, a verification plot is generated on an electrostatic plotter for review before graphic separates are plotted on a precise photoplotter.

The map projection and UTM grid are computer generated and plot tapes are produced. All files are plotted on reproduction quality film and registered to the base manuscript. A portion of the first provisional edition 1:24,000-scale topographic map produced by these automated procedures is shown in figure 1.

Experience with Provisional Mapping

During 1982 NMD completed the first maps under a new and accelerated program for the production of provisional edition topographic maps at 1:24,000 scale. Under provisional mapping standards certain conventional mapping procedures have been modified, making it possible to produce provisional maps at less cost and on a more timely basis than standard topographic maps.

Essentially the same level of information is shown on provisional maps as on standard maps. Specification changes have been tailored to maintain map accuracy and content. Final rescribing of the contour, planimetry, drainage, and woodland plates for publication has largely been eliminated. Stereocompilers produce the original scribed compilation manuscripts that are used as the final published version. This added responsibility requires improved scribing quality and careful hand lettering of descriptive labels and contour numbers. Costs in the compilation phase are somewhat higher for provisional mapping, but this appears more attributable to the increased responsibility for quality control than to the actual compilation.

Since many standard maps were in various production stages during the transitional period from standard mapping to provisional maps, a number of internal cartographic map finishing problems faced NMD. Most of these now appear to be resolved. With the elimination of the final rescribing phase, some touchup of manuscripts is necessary. The editorial process has been successfully lessened from a three-stage operation for standard maps to a two-stage procedure. Automated techniques for interior type placement and creation of map collars (exterior type) as described in the article "Producing Provisional Maps by Automated Techniques" should significantly shorten the provisional map production cycle. When fully implemented in a production environment, this technology has the potential of improving production rates by performing labor-intensive and time-consuming operations like those described above. This technique also offers noteworthy byproducts, like the adaptation to derivative map scales and formats which are characteristic of contemporary NMD programs. Examples of interior type placement techniques are shown in figure 2.

Overall, the first year of provisional map production has been successful. Experience and fine tuning of procedures, together with potential implementation of digital lettering, should continue to pay off in improved map cycle time and efficiency. Users have made little adverse comment about the noticeable format change and several positive comments have been received.

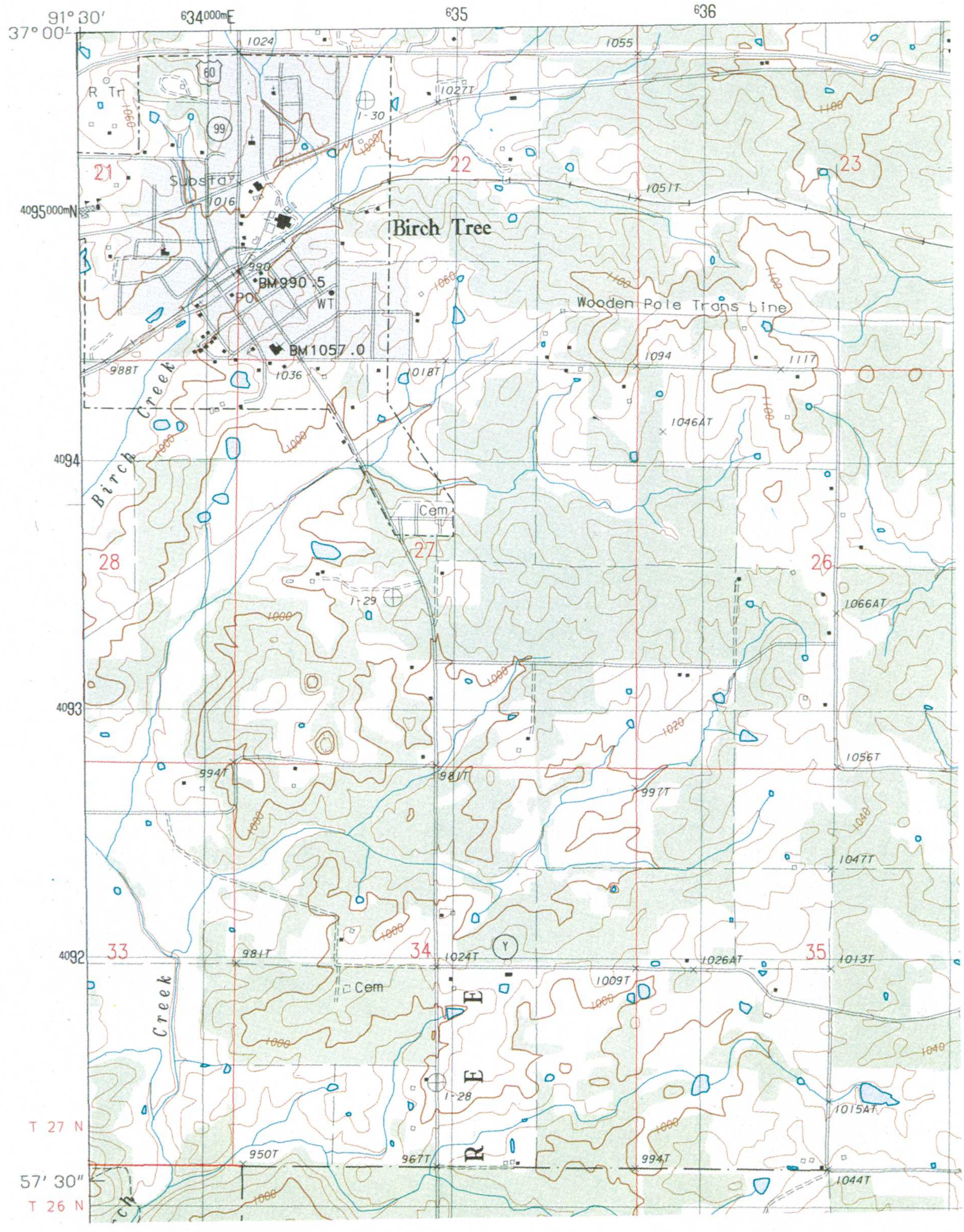


Figure 1.--Portion of the Birch Tree, Missouri, 1:24,000-scale provisional edition topographic map--the first computer-generated topographic map published by the U.S. Geological Survey.

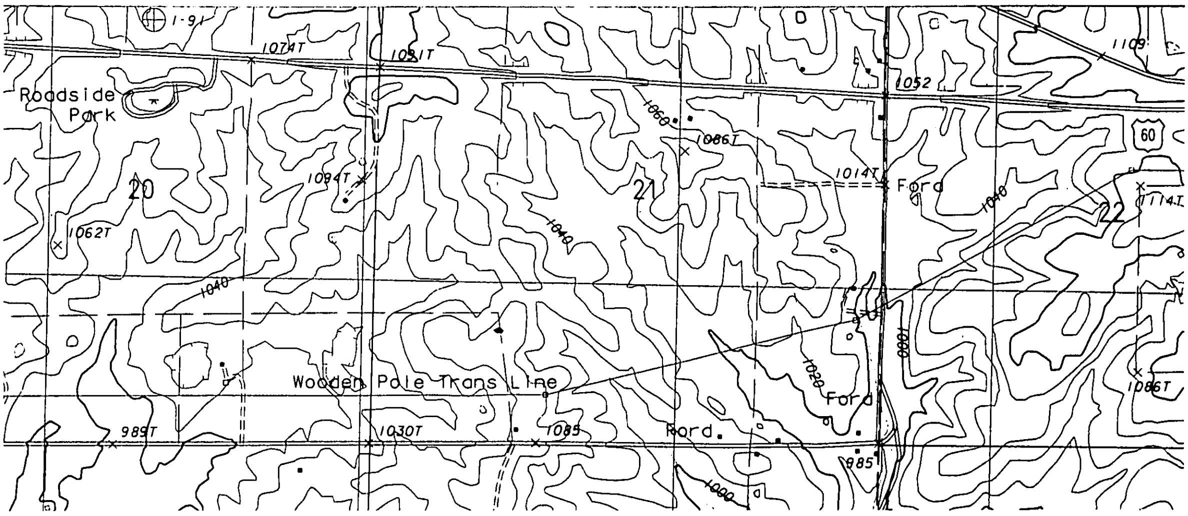


Figure 2A.--Photoset type on a Standard Edition topographic map.

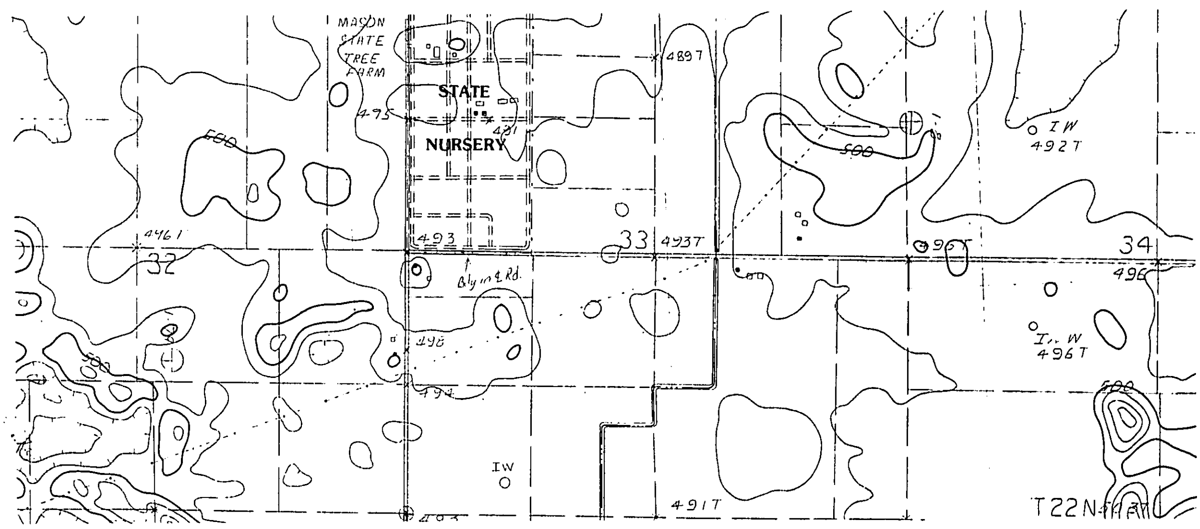


Figure 2B.--Manually scribed lettering on a Provisional Edition topographic map.

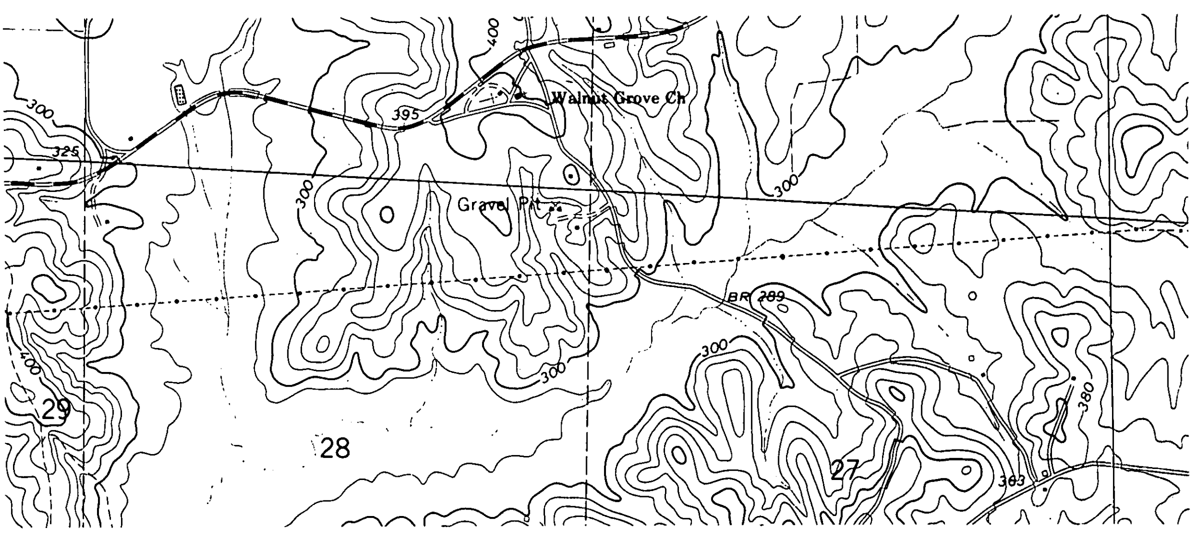


Figure 2C.--Computer-generated lettering on a Provisional Edition topographic map.

Mapping at Scales Larger than 1:24,000

The Division prepared an experimental 1:5,000-scale map to aid in the determination of requirements from Federal agencies for a map product at this or a similar scale. This experimental map was produced on eight overlays using digital methods with an accompanying DEM.

The map was produced for display purposes only, because much of the information was not verified, and some was simulated. It was designed to depict a reasonable presentation of information that may be required by Federal agencies in the future.

The compilation and production techniques used to produce this map may be used in the near future to research the production of map products at nested (multiple) scales. Implementation of the research project will depend on the results of a requirements study presently underway using this experimental map.

Investigation of Map Revision Utilizing Digital Techniques

A major goal of the National Mapping Program is to incorporate cost-effective digital mapping techniques into the map revision process. In addition to meeting National Map Accuracy Standards, the digital cartographic data collected for revision must be suitable for incorporation into the DCDB. When sufficient data become available in the DCDB, it will be used as a resource in future revision procedures. A three-phase plan has been developed to design and implement a digital revision capability.

Phase one, the design of a comprehensive operations research/systems analysis of the cartographic processes involved in generation of revised graphic products, and concurrent production of a digital cartographic data base, is nearing completion. Phase two will be the collection of pertinent information defining the present manual methods of map revision concurrently conducting pilot projects to test new applications of hardware, software, and digital techniques. Consolidation and analysis of this information will be used to develop appropriate digital approaches to the various procedures in the map revision process. Finally, phase three will be the design and implementation of a system tailored specifically for digital map revision.

Experienced personnel and ongoing activities from throughout NMD will be utilized to expedite achieving the digital revision capability. Production personnel in the mapping centers will conduct pilot tests and contribute most of the information needed to clearly define and analyze the existing revision procedures. Research personnel are already involved in several projects that are critical to the digital effort. Some areas of common interest are automated type placement, symbolization, and names processing.

Map Revision by Photointerpretation

Two studies looking into a number of factors affecting our ability to successfully utilize photointerpretation techniques for map revision were completed. The first study compared the interpretational reliability in using high-altitude (40,000-foot) black-and-white (B/W) aerial photographs, a lower altitude (14,400-foot) B/W photographs, and 14,400-foot flight height color imagery. A second study was to determine whether limited or possibly complete revision can be accomplished, and a standard-accuracy map product produced, utilizing modified revision techniques with minimal field verification.

The assumption that both lower altitude and the use of color photography will increase the quality of photointerpretation for photorevision has been verified. However, additional investigation into the cost effectiveness of the alternatives and the overall need for higher quality revision was recommended. Further study is also recommended in the use of modified photorevision techniques including the establishment and implementation of acceptable specification standards for limited revision that recognize the cost of verifying the identification of certain features, balanced against their overall importance as a mapworthy feature.

Map Projections

Research continues to provide refinements in map projections. The Space Oblique Mercator (SOM) projection, conceived and mathematically defined by USGS personnel during the 1970's, is being used in its refined form for mapping of imagery from Landsat 4, launched in 1982 by the National Aeronautics and Space Administration (NASA). The first comprehensive manual describing all map projections used by the USGS (Bulletin 1532) was published late in 1982 and is receiving favorable response not only within the USGS, but by government, university, and private cartographers in various parts of the world.

More recent research includes a computer program to permit practical determination of the projection parameters used for a given map that was not sufficiently labeled. This allows the accurate transfer of data from this map to another map or to a data base. The use of polynomials for efficient transfer of very large quantities of data between maps of different projections has received renewed attention with a computer program to transfer data among a wide variety of projections. Other projections may be added with relative ease because of the use of least squares in determining polynomial coefficients.

The ability of the computer to process vast quantities of data has also been used to select parameters for the optimum conformal map projection of a given type to suit a given geographic region. This is done with a least-squares analysis related to a large number of points in and near the region under consideration. It is thus possible to determine the quantitative improvement resulting from changing to a better projection, or from using better parameters for an existing projection.

Least squares analysis has also been combined with conformal map projection transformations using complex algebra, to develop still lower-distortion conformal projections. One such product (fig. 3) is a map of the 50 States and adjacent land and water bodies with a scale error not exceeding ±2 percent, as contrasted with a +12, -3 percent variation on a standard 50-State map currently published by the USGS.

A related product is a map of Alaska, including all of its islands, with a scale error not exceeding ± 0.3 percent while current maps of the State have a scale range of + 2, -0.4 percent. Applying these techniques to even larger regions, similar types of reduction in scale error have been experimentally found for maps of North and South America.

Automated Cartographic Lettering

A research experiment is in progress to modernize the labor-intensive process of map lettering. The Mergenthaler Omnitech 2100, a fourth-generation laser typesetter, available in all NMD mapping centers, is being used to develop automated type placement methods. The Omnitech has 30 graphic-arts-quality digital fonts with point sizes ranging from 4.5 to 127.5 that image with a resolution of 724 scan lines per inch on 12-inch-wide film or paper. In addition to full editing capabilities, software allows the type to be expanded, condensed, or slanted to meet a variety of requirements. Type can also be positioned on 11- x 17-inch film or paper using the page makeup feature to key in x,y coordinates. Type alignment is limited to horizontal placement.

In phase I of this research experiment, type orders were coded manually for placement using a pica grid overlay. This data in addition to type-setting commands were then keyed into the Omnitech. The output was 11- by 17-inch portions of a map lettering overlay containing all horizontal map labels and margin information. The 11- x 17-inch portions were spliced together using register ticks generated on the Omnitech printer to form a map lettering overlay. The purpose of phase I was to verify techniques and establish procedures for the second and final phase of the experiment. In phase II, an Altec Digitizer will be used to generate x,y coordinates for type placement and typesetting commands will be entered by a voice recognition terminal. This data will be recorded on tape and read into the Datapoint minicomputer for transmission of the typesetting and type placement information to the Omnitech. The output will be processed and spliced together as in phase I. A contact film type overlay will be produced from the spliced overlay and curved or angled type will be added by conventional means.

Electrostatic Color Reproduction System

The USGS Rocky Mountain Mapping Center has obtained a Kimofax 6185 electrostatic printer, manufactured by Kimoto, for the purpose of printing color proofs of line and photoimage composites. Several modifications of the original equipment have been made by the company to make it more adaptable to Survey needs. The particulate (toner) size was reduced by 70 percent

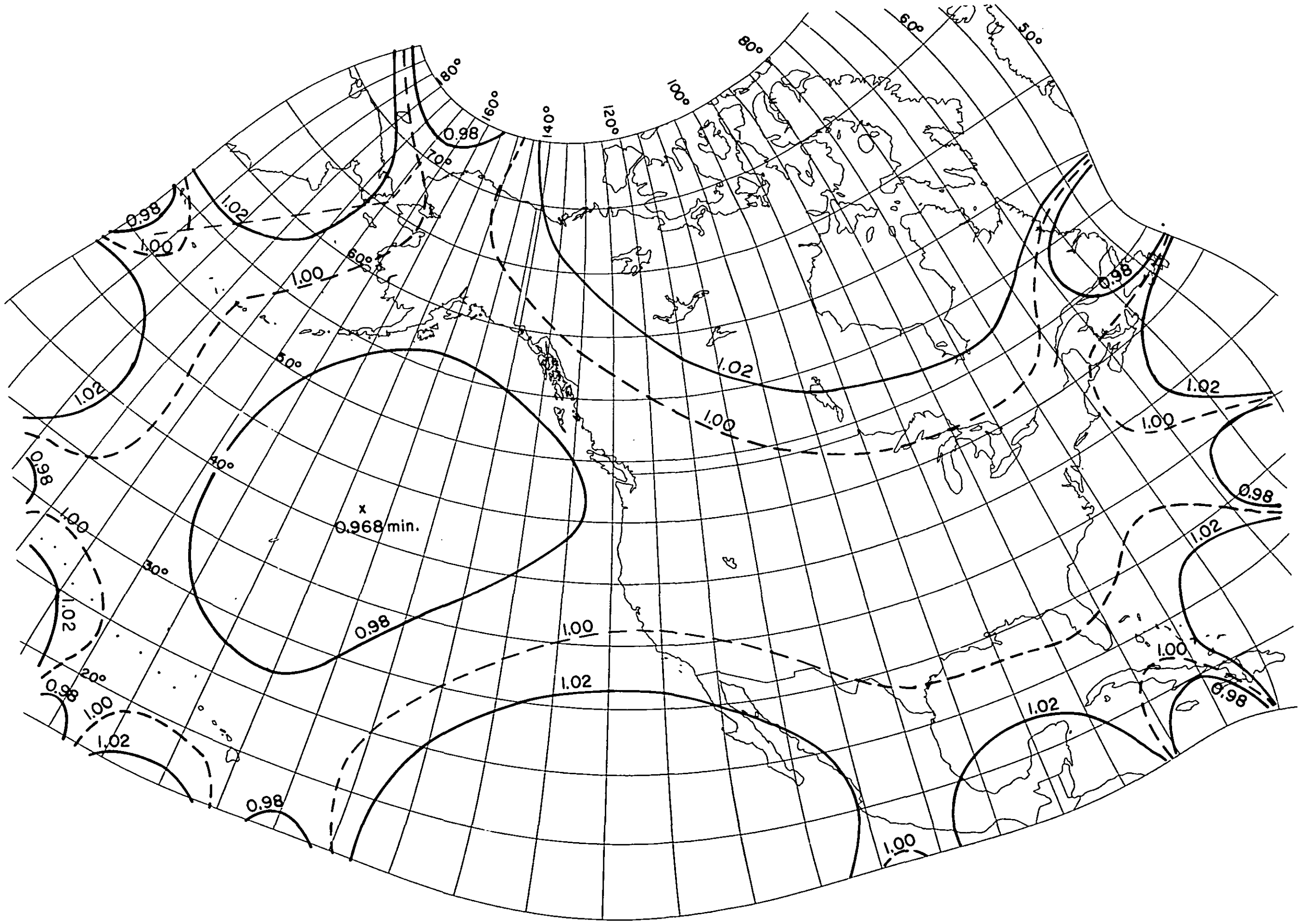


Figure 3.--A 50-State outline map generated by computer and using a complex conformal transformation of the oblique stereographic projection. The superimposed manually drawn lines of constant scale show that the region of the 50 States and adjacent land and water bodies do not vary in scale by more than 2 percent from the nominal map scale which applys along the dashed line marked 1.00.

to produce finer line reproductions. Toner colors were changed to conform more closely to USGS standard map colors. The equipment was modified to accommodate a negative-to-positive mode and a retraction stud registration system was installed. A larger processor has been added to bring the fixing time for negative-to-positive down from over 3 minutes to the 30-second rate of positive-to-positive fixing. While not all of the requested modifications are in place yet and some production performances remain to be resolved, the potential quality and economics of the system continue to look favorable. Prints can be made on most all materials used in mapping. Printing quality can be observed prior to fixing and can be completely erased if unacceptable, thus saving materials. Weak images can be multi-exposed to build up the density.

Reprographic Data Processing System

Each step in the reproduction process from the original imaging by optical or electronic device on sensitized material through the final printing of ink on paper requires control to insure proper tone reproduction. The Reprographic Data Processing (RDP) system has been developed as an aid in the control of tone reproduction. Hardware for the system includes:

- A Tektronix 4051 desktop graphic computer with magnetic tape cassette and a single floppy-disk drive for data storage.
- A Tektronix-electrostatic printer, and a Tektronix 4662, 8-pen plotter for printing alphanumeric or graphic data.
- A digital densitometer with interface to the Tektronix computer. The densitometer is equipped to read either reflective or transmission copy.

Software programs have been written to accept data directly from the densitometer or by keyboard entry from the desktop computer. Using the data, the programs will compile, manipulate, plot, and retrieve the information needed to process photographic and lithographic materials for proper tone reproduction.

Applications developed in 1982 include:

- Orthophotoquads -- Input densities from continuous-tone positive images produce exposure and filter information necessary for proper tone reproduction based on halftone screen, film, and darkroom facility specifications.
- Tone reproduction curve -- Input densities from photographic film or paper, press plates, or printed copy are used to produce D log E tone curves on graph paper or other specified grids. The tone reproduction curve program will calculate gamma, speed shift, and curve compressions needed in the quality control of photographic and lithographic materials processing.

Programs under development include:

- Screenless printing -- D log E tone curves will be made from photographic image densitometric values to provide processing specifications to fit the density range of the screenless printing plate.

- Color proof exposure determination -- Color correction filters and exposure times will be calculated to produce desired tone curves for photographic color paper prints.

Applications and Techniques Development for Raster Formatted Data

The NMD is developing software and techniques with respect to raster-formatted data for digital cartographic applications. These efforts center on the capabilities of the Scitex Response 250 map scanning and digitizing system. This system is composed of four major subcomponents: (1) two large-format (36- x 36-inch) color raster scanners capable of encoding up to 12 colors or gray levels; (2) two interactive digital graphic editing and design consoles; (3) a large-format (42- x 75-inch) laser printer capable of producing raster-format positive and negative film transparencies; and (4) a DEC PDP 11/60 minicomputer for raster-to-vector data conversion and batch-oriented processing. These stations run on an upgraded version of the vendor-supplied software, which is presently being tested.

Developments during the past year have focused primarily on automatic capture and editing of various categories of digital data. Procedures have been tested for the collection of hypsography, hydrography, and transportation networks at both 1:24,000 and 1:100,000 scales. Color separates are raster scanned at a resolution determined by the density and widths of the linework. The data are then reduced to one-cell-wide center-line form, and displayed and edited to remove extraneous symbology, to close unwanted line gaps, and to color code categories of data. Line spurs, overruns, and other spurious artifacts of the scanning and data reduction process are deleted. Following the raster editing procedures the data are processed through the vendor-supplied raster-to-vector conversion software. The file is then output to tape and reformatted for input into a vector-oriented editing station for additional editing and attribute tagging. The success of the vendor-supplied raster-to-vector software has greatly improved the efficiency of the process, and preliminary production procedures for collection of hypsographic data are nearing completion.

The system's capability to produce screened color separation films was demonstrated through the production of the Vegetation and Land Cover Map for the Arctic National Wildlife Refuge, Alaska. The preprocessed land cover data were read into the Scitex system via magnetic tape and the laser printer was used to simulate dot screens and angles directly onto the color separation films. Printing plates were made from these films and used to print the multicolored digital map.

Additional techniques for automatic symbolization of data for graphic output are being developed. Vector formatted data from other systems can be read into the Scitex via magnetic tape and converted to raster format with the appropriate symbologies. The resultant symbolized raster file can be output to the laser printer to produce color separation films.

Color-Coded Shaded-Relief Map of the Copper River Basin, Alaska

A color-coded elevation zone map was digitally combined with a computer-generated shaded relief map to aid in visual interpretation of physiographic features of the Upper Copper River Basin, Alaska. Six elevation zones were shown in separate colors and shaded relief was shown by variations in the intensity of each color.

DEM data for ten 1:250,000-scale quadrangles were mosaicked and registered to a UTM projection. Selected contours for an eleventh quadrangle, in Canada, were digitized and inserted into the elevation image. The boundary of the drainage basin was digitized and used to mask data outside of the basin.

The gray-tone shaded relief map was generated from the DEM data using a Sun azimuth of 25 degrees east of north, which is perpendicular to the regional topographic trends. Relief was further enhanced by contrast stretching the original digital values.

The elevation image was separated into the three primary color bands and multiplied by the shaded-relief image. This changed the intensity but preserved the hue and saturation of the assigned colors. Combining the three color images then yielded the color-coded shaded-relief map, which gives the viewer the perception of relief while preserving the elevation data.

This technique for combining images has many applications. For example, relief data can be combined with a land cover classification map or a geologic map can be digitally overlaid with a Landsat image or multiband composite. All of these applications facilitate the visual interpretation of different types of spatial data.

DIGITAL CARTOGRAPHIC SYSTEMS

The 1:2,000,000-scale Data Base

The USGS has produced a small-scale digital cartographic data base using the 21 sectional 1:2,000,000-scale maps of the National Atlas of the United States of America (fig. 4). Computer tapes of this data base are now available through the National Cartographic Information Center. Applications of the data for automated map production and computer analysis have begun.

Previous small-scale digital cartographic data bases have been used extensively, although their general content limits their usefulness. The Dahlgren data base was developed in the early 1960's as a global data base of coastlines and international boundaries. The coastlines and the State boundaries of the United States were obtained from 1:1,000,000-scale maps.

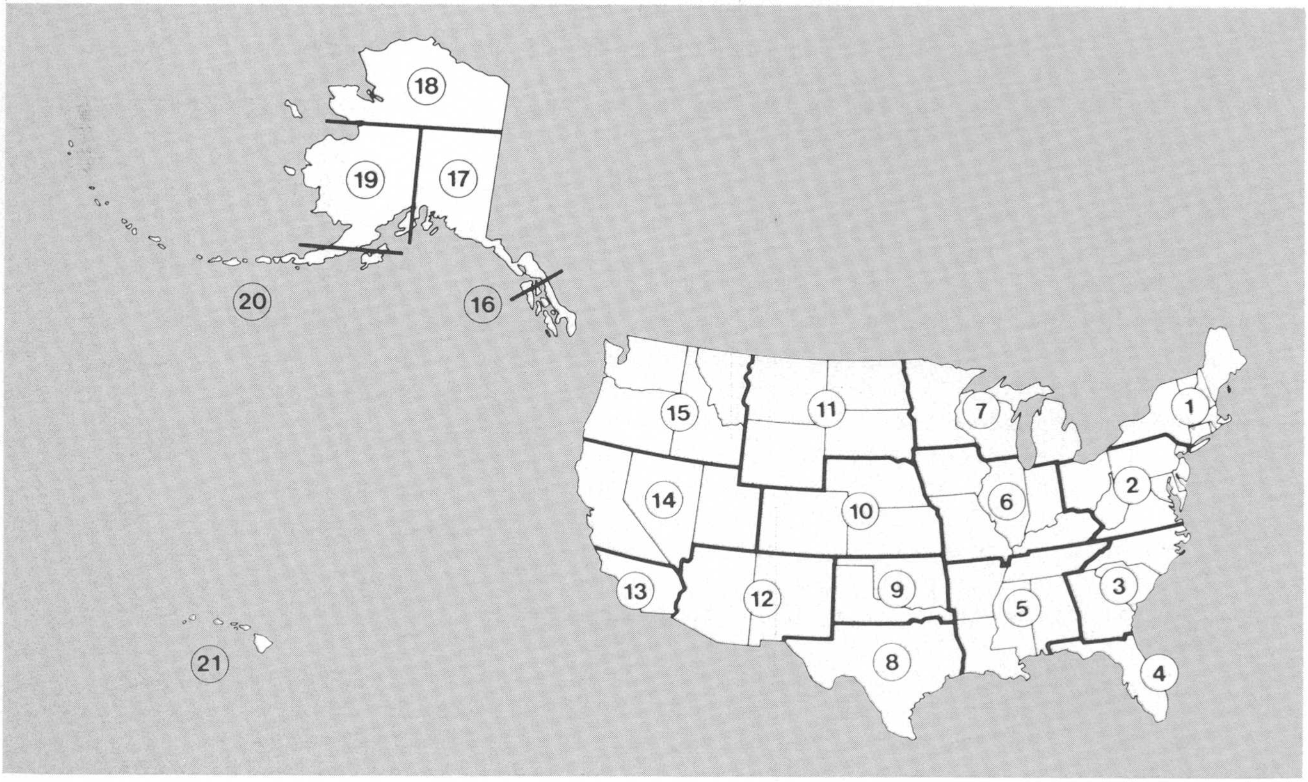


Figure 4.--Index to the 21 sectional maps of The National Atlas of the United States of America.

In the mid-1960's, the Department of Transportation developed a data base as a county boundary file of the United States. County and State boundaries, together with the coastline, were digitized from 1:5,000,000-scale maps.

The World Data Bank I was developed by the Central Intelligence Agency in 1966. It contains world coastlines and international boundaries digitized from 1:12,000,000-scale maps.

A second World Data Bank was completed in 1977 using source maps which ranged from 1:4,000,000 to 1:1,000,000 in scale. This data base contains country and State boundaries, coastlines, islands, lakes, rivers, and selected roads and railroads. Source materials for the United States were digitized from 1:3,000,000-scale maps.

Some of the limitations associated with these earlier data bases are:

- The small scale of the source maps used for digitization;
- The limited range of features digitized;
- The lack of current information;
- Data formats designed primarily for graphic applications;
- Limited flexibility for combining these data with other thematic data available in digital form.

Experience with these earlier data bases has shown that, while they meet their objectives, their content is not sufficient for all user applications (fig. 5).

The content of the Survey's 1:2,000,000-scale data base includes political boundaries (State and county level), Federal lands, transportation networks (roads and railroads), hydrographic features (streams and water bodies), and populated places (fig. 6). These data were entered into the computer in a format that records topologic relations with related features on the source map. This format allows graphic applications, such as drawing streams and roads for automatic map plotting, as well as analytical applications, such as area calculations and verifying the data for consistency and accuracy. The format also permits automatic smoothing to produce maps at scales ranging from 1:2,000,000 to 1:10,000,000.

An important feature of the attribute coding is that individual features within each category are ranked from the most significant to the least significant. This scheme allows the user to select a minimal amount of data and selectively increase this amount to the level of detail needed to support the theme and scale of the desired map. The data can also be grouped together in various ways to produce logical sets of information.

Political boundary data are organized into international boundaries, State boundaries, and city and county boundaries. Federally administered lands, such as national forests, national parks, national wildlife refuges, and

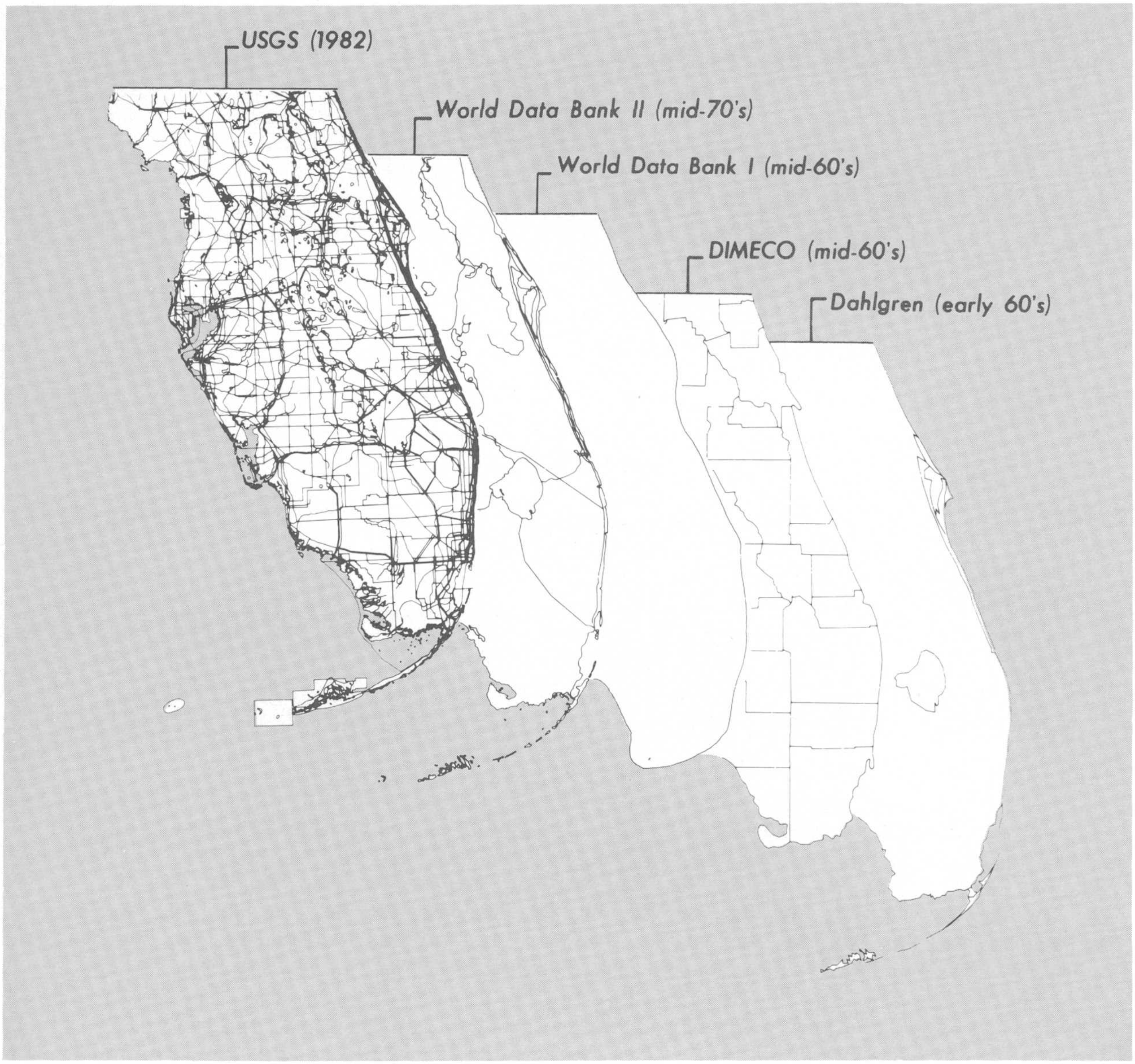


Figure 5.--Content of various small-scale digital cartographic data bases.

others, are classified by the length of their longest dimension. This allows the user to select the types of federally administered lands to be displayed and to control the amount of detail for each type selected.

Road and trail data are organized to display densities of connected networks, starting with major limited-access highways and continuing through major national and State routes to other roads and trails. The railroad data are organized by annual tonnage, starting with the connected network

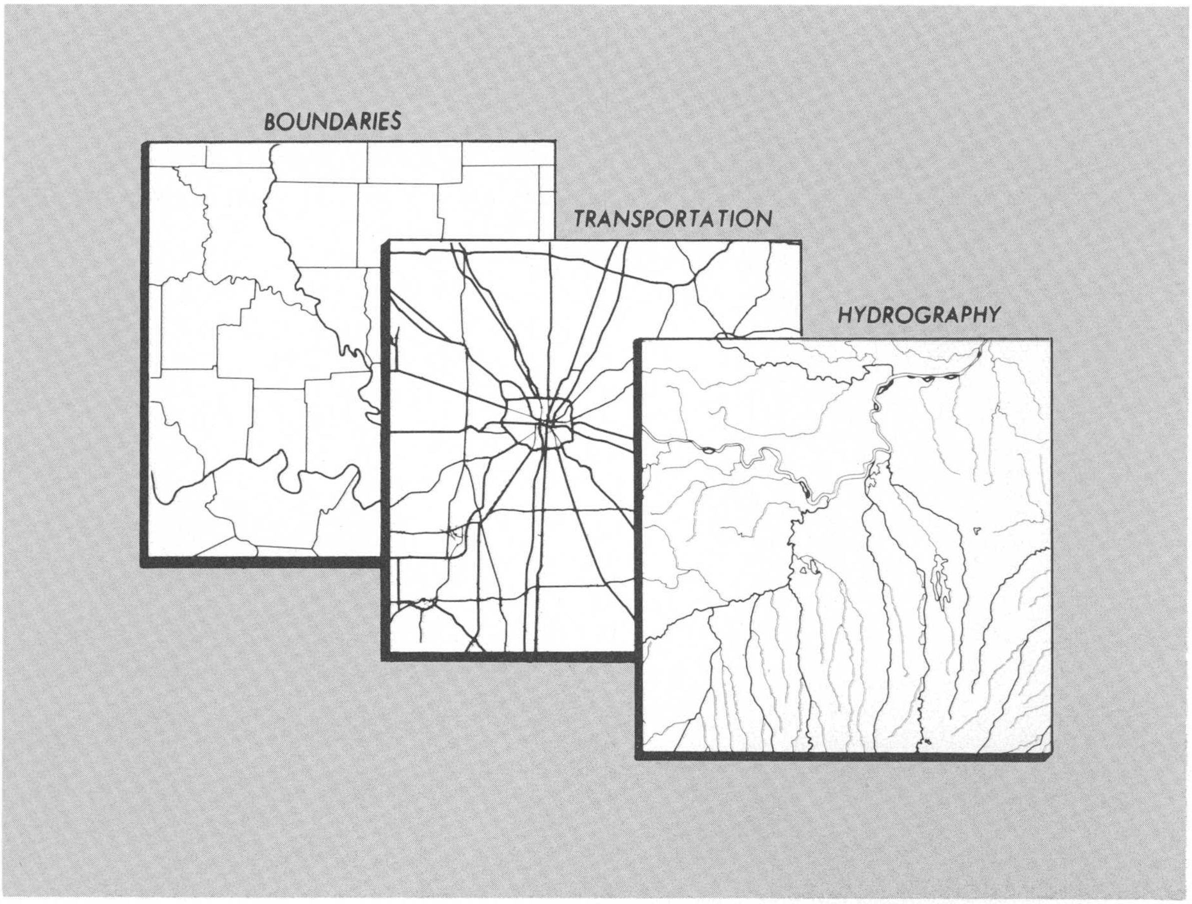


Figure 6.--Content of USGS 1:2,000,000-scale data base.

of the primary rail routes. Stream data are organized by length, beginning with the longest stream drainage for an area. Stream segments are also identified as perennial, intermittent, or canal.

Water-body features are organized in a way similar to that used for federally administered lands. They are classified by length so that the user may select from the different types of water bodies to be displayed and also control the detail for the types of water bodies chosen.

Digital Cartographic Data Standards

Along with the development of the digital cartographic data base, NMD is primarily responsibile for developing technical standards governing the digital cartographic data that are being archived. A memorandum of understanding, signed in February 1980 by the National Bureau of Standards of the Department of Commerce and the U.S. Geological Survey, further defines this responsibility. Under the terms of this memorandum, the U.S. Geological Survey has assumed the leadership in developing and maintaining earth-science data element and representation standards for use in the Federal establishment.

During 1982, NMD initiated an effort to compose formal technical standards for the various types of digital cartographic data in the DCDB. Drafts were completed of technical standards addressing DLG attribute codes for Public Land Survey System data and accuracy testing and verification of DEM's. Work was begun on technical standards addressing DLG attribute codes for hydrography, DLG collection procedures, and attribute codes for 1:100,000-scale DLG's.

Recognizing the need to involve the user community in the design of digital cartographic standards, the NMD actively supported the work of the National Committee for Digital Cartographic Data Standards (NCDCDS). Founded in January 1982 under the auspices of the American Congress on Surveying and Mapping, the goal of the NCDCDS is to provide a professional forum for Federal, State and local public agencies, private industry, and professional individuals to express their opinions, assessments, and proposals concerning digital cartographic data standards.

DEM Display and Evaluation System

The Division is developing techniques for rapid and economical display and verification of DEM data. By applying digital image processing and color CRT graphics techniques to digital elevation data, it is possible to evaluate overall DEM quality. Prior to this, the most commonly used evaluation method has been to sample the data points statistically. A DEM might be judged acceptable by this latter method, however, localized errors could go undetected.

Applications software has been developed that reformats the DEM data from the data base into a raster scan array and displays it on a digital image processing color display. The basic image unit or image plane is a 512- x 512- x 8-bit array of pixels. Pixel brightness can be assigned proportional to individual point elevations or the display can be enhanced interactively by assigning colors to bands of elevations and also by magnifying the image size. Programs which run on the image processor host computer can be used to process the elevation data by computing the slope between adjacent pixels and assigning brightness for a display in shaded relief. An anaglyphic stereo display can be generated by displaying pixels of the shaded relief image as a function of elevation and assigning them to a second image. The original image is assigned to red and the second image is assigned to green and blue of the image display. Each of the presentations highlights different types of defects, enabling the operator to evaluate overall DEM quality and to identify data which are to be corrected by subsequent editing.

The display system consists of a COMTAL Vision One/10 image display system, a DEC PDP-11/23 host computer, a 30-Mb Winchester disk, and a 9-track tape deck for data input (fig. 7).

Figure 7.--DEM display and evaluation system.

Testing and Evaluation of DEM and DLG Data in the DCDB

During 1982, the testing and evaluation of both DEM and DLG data entered a new phase. Previously all of the testing was done during production by the various mapping centers using procedures peculiar to the equipment in use. With the refinement of software and the accumulation of data, as well as newly developed methods, a centrally administered testing and evaluation program is now possible.

Prior to submission of data to the DCDB, each DLG is processed through a software system to verify data categories and attribute codes used in the file. In addition, all DLG files resident in the DCDB were tested using the attribute verification software. The software used to enter the DLG into the DCDB was modified to test the header records and data categories. All of the existing DLG header records were updated to include the date and scale of the source material and were checked for format. These central processes are performed in addition to the mapping center quality-control procedures.

Testing and evaluation procedures for DEM's must accommodate different data collection methods. During 1982 the software to verify DEM's produced by all data collection methods was completed and testing of files is in progress. The verification procedures allow for identification of logical and physical errors and for classification of DEM files into 7-m or 15-m accuracy categories. The most recent development in the testing and evaluation of DEM's is a viewing system described elsewhere in this report which is in the final stages of preparation for production use. Data supplied by the Defense Mapping Agency (DMA) for distribution by NMD have beem verified by DMA and have been entered into the DCDB without further testing.

DEM Data by Scanning Contours

Long-range plans for the DCDB include digitizing the information from film separates of more than 40,000 published 1:24,000-scale quadrangles. The feasibility of the plan has been evaluated in tests of a raster data acquisition and processing system designed to produce DEM data by scanning contour separates. The system is still in the early stages of development and software systems and procedures continue to be evaluated and improved in order to produce the most cost-efficient process.

The Unionville, New York/New Jersey quadrangle contour separate was selected to test the system. Three phases were identified: raster scanning and editing, raster-to-vector (R/V) conversion, and vector editing and attribute tagging. The contour separate, measuring 17 inches wide by 23 inches high, was scanned at a resolution of 20 points per mm and edited on the Scitex Response 250 system. Raster-to-vector conversion was done using in-house R/V software operating on a PDP-11/70 and the vendor-supplied Scitex R/V software. Vector editing and attribute tagging were performed on the Intergraph Interactive Graphics Design System with a DEC PDP-11/70 computer. This tagging process was almost totally manual; automatic and semiautomatic methods of attribute coding are now being investigated. To complete the DEM production process, a subsystem of the Digital Cartographic Software System (DCASS), was used for gridding the vector data. Other gridding procedures are being evaluated to insure that the DEM's will be produced in the most timely and cost-efficient manner. The prototype system worked successfully and the DEM data were well within a RMSE vertical accuracy of one-quarter contour interval.

In a related effort, NMD has contracted with several vendors to assess their capability to produce DEM data to contract specifications by scanning contours. The NMD-furnished contour and drainage separates for four adjoining 1:24,000-scale quadrangles were selected for their diverse terrain. Valuable information was gained on the benefits of including geomorphological data, such as drainage and ridge lines, in the interpolation process. The study as a whole will aid in the development of standards for future data collection both in-house and by private contractors. The DEM data produced under these contracts have been received and evaluated, and it was determined that they meet the required vertical accuracy.

Digitizing 1:100,000-Scale Maps

Based on requests from a number of Federal and State agencies, the NMD is investigating techniques for digitizing the features shown on 1:100,000-scale maps. This map series was originally designed over 10 years ago with special attention to the number of map separates, line weights, and symbology to eventually facilitate digitizing using scanner techniques. The basic processes being studied include scanning source maps, editing the scanned data, raster-to-vector conversion, attribute tagging, and subsequent processing and archiving in a data base. The scanning, raster data editing, and conversion to vector format are being done on the Scitex Response 250 system. Tagging and additional processing are being performed on the IGDS. Another aspect of this study is to determine an appropriate feature code scheme for data from the 1:100,000-scale source. It is anticipated that the results of these studies will be the establishment of a production workflow to convert 1:100,000-scale graphic source materials into topologically structured and attribute-coded data in a data base similar to the present DLG and DEM data bases. These data would then be available for public distribution. The digitization of this series of maps will provide detailed digital cartographic data more quickly than by digitizing larger scale maps over a given regional area.

Mass Storage Media

A project of major interest in the NMD is the study of mass storage media to archive digital data. Traditional mapping procedures depend on film as a medium for storing map color separates and magnetic tape as the medium for storing digital cartographic data. Film is bulky and not computer compatible, and magnetic tape has a limited shelf life. The new laser optical disk technology offers a long-term archive that is computer compatible, and optical recording may be the breakthrough needed to provide digital storage for future digital mapping systems.

In view of this potential, a team has been working with industry to estimate our future requirements and evaluate optical recording as a means of archiving digital data. NMD will participate in a test of an optical disk drive beginning in November 1983.

Estimates for storing the digital data from 54,000 1:24,000-scale topographic quadrangles range from 10^{13} to 10^{14} bits. One disk (platter) holds 10^{10} bits on one side. One disadvantage to optical disks is that they are nonerasable, but this is an advantage when con- sidering the need for archiving up to 10 years, which is not now possible with magnetic media. By 1985, large capacity "juke boxes" to store and retrieve multiple disk data bases should be available which may make digital mass storage feasible and provide a positive contribution to modernizing the mapping environment for the more digitally oriented future.

Alpha Prime Implementation

The U.S. Geological Survey is primarily responsible for developing and maintaining a national Digital Cartographic Data Base (DCDB), which will be the largest digital data base of cartographic and geographic information in the United States. In February 1980, the NMD Digital Steering Committee recommended that the Division adopt a three-phase digital data base program that would provide an efficient maintainable system which could expand to meet the majority of user needs by 1990. The first, or Alpha, phase was expressed as the collection of hardware and software systems and techniques currently available. The second phase was seen as the Alpha system replacement about 1985, with the third phase projected to be realized after 1990 based on research conducted over the next 5 years.

In June 1981, the Division completed the Alpha system study, a comprehensive analysis of the digital mapping software and hardware capabilities in the National Mapping Program. The study team felt that inadequacies and incompatibilities in the current collection of systems and techniques, coupled with the need for an operating system until the second phase is completed, required further implementation of an interim system. This interim system, called Alpha Prime, was to be created by enhancing existing capabilities. The study made specific technical recommendations to effect the transition.

In February 1982, the Alpha Prime implementation plan was put into effect. The plan identified 15 specific projects which addressed all phases of the digital production system. These projects include modifications to data collection processes intended to improve overall system speed and accuracy and improvements to documentation and maintenance procedures for hardware and software systems. Five projects were completed during 1982:

(1) Correction and documentation of GPM2 RESAMPLE software
Known processing errors were corrected in the software used to test elevation data produced by the Gestalt Photo Mapper 2 (GPM2) and restructure the data into the NMD standard DEM format. This software was also documented to established NMD standards.

(2) Development and documentation of DEM verification software
Software to test NMD standard format DEM's for structural consistency and spurious spikes was written, tested, and documented to NMD standards.

(3) UCLGES deck set-up software
The software used to generate jobstreams which create, manipulate, and validate DLG's via the Unified Cartographic Line Graph Encoding System (UCLGES) was upgraded. This upgrade enforces standard formatting of DLG header records. The software documentation was also upgraded to NMD standards.

(4) Update the DLG data base to consistently reflect the currency and scale of the data
All DLG files resident in the DCDB were updated to reflect the currency and source of the data in a standardized header record. Quality assurance procedures were also implemented to insure that all new DLG's contain this information.

(5) Validate and correct the DLG data base to reflect a consistent attribute coding structure
All DLG files resident in the DCDB were tested to identify invalid attribute codes, as well as outdated codes used in early trial projects. All DLG's flagged in this process are being corrected by the production centers. The software developed to test attribute codes is also being used in production to validate all new DLG's.

Online Aerotriangulation Data Collection and Editing System

The Division has designed a system of software which runs on a desktop minicomputer to facilitate the collection of aerotriangulation data. Coordinate data from aerial photographs are presently collected manually on monocomparators, stereocomparators, and stereoplotters. The Online Aerotriangulation Data Collection and Editing System (OADCES) interfaces with these same instruments via Altek digitizers. The system allows online verification of the data and performs various computations in order to detect blunders and transform the coordinates into the proper form for input into an aerotriangulation program. The choices of computations include interior orientation, image coordinate refinement, relative orientation, computation of model coordinates, and model joins. Each computer is interfaced to a flexible-disk drive; the diskettes replace punched cards as the storage medium. Data from each individual system is then transferred from the diskette to magnetic tape for input to a program on a larger computer. Each mapping center has one system consisting of a microcomputer, flexible-disk drive, magnetic-tape drive, and printer.

The majority of the program modules have been written and tested. Major tasks remaining include system integration, final documentation, and installation and training. All work is being performed by NMD personnel. The system is in production operation.

The OADCES is expected to increase the throughput of the aerotriangulation mensuration phase by (1) relieving the comparator operator of some of the present bookkeeping tasks, (2) performing online data verification, (3) allowing online data editing, and (4) making the aerotriangulation mensuration process operator-friendly.

Instrumentation for Orthophoto Production

The USGS and the Defense Mapping Agency currently have a contract with Baker and Associates for the development of a large-format Offline Orthophoto Printing System (OLOPS). USGS will use the system to accommodate a variety of source materials, to take advantage of the increased availability of digital elevation data, and to replace equipment that is approaching obsolescence. The OLOPS will be used in the Eastern Mapping Center of the NMD to scan aerial photographs. The scanned photographic images will then be electronically transformed to produce orthographic projections of the terrain surface, rectified photographs, stereomates, or digital representations of the aerial photograph. The system components include:

- a scanner subsystem with a 254- x 508-mm input stage
- a printer subsystem with a 600- x 762-mm output stage

- a control computer with 128k 16-bit-word memory, and

- a CRT display terminal including: a line printer, a magnetic 800-1,600 tape drive, and a 10 Mb disk drive

The system specifications are:

- Accuracy
  - static 4 microns RMSE
  - dynamic 16 microns RMSE

- Magnification - 1x to 32x

- Resolution - 60 lines per inch at 1x

- Input image data
  - frame photographs
  - panoramic photographs
  - digital images

Testing and Calibration of Aerial Cameras

During the past year the NMD has conducted calibrations on 79 aerial mapping cameras and has continued investigations in areas of calibration accuracy, and lens and camera performance. The cameras for calibration were submitted from private mapping contractors, Tennessee Valley Authority, USDA Forest Service, NOAA National Ocean Service, and highway departments of Indiana, Louisiana, and New Mexico.

The NMD camera calibration data bank now contains 438 camera/magazine calibrations. A total of 326 of the calibration data sets are suitable for fully analytical aerotriangulation. The data bank includes the camera owner, manufacturer, number, lens type, lens number, magazine number, platen alphanumeric symbol, calibration constants, and number of fiducial marks. Calibration of a camera is required for NMD contracts for mapping photography. Data on a particular camera must be obtained from the owner.

Two lenses used for human eye implants were also submitted for measurement of focal length and related optical constants.

Vertical Control for Mapping Using a Low-Cost Total-Station Theodolite/EDMI

The objective of this study was to determine which surveying equipment will fulfill the present and future surveying needs. In recent years there have been many advances in the electronics industry which have significantly increased the capabilities and versatility of surveying equipment. Proper selection of surveying instruments to satisfy present and future requirements is critical to the success of the U.S. Geological Survey mapping program.

Research was conducted to make operational comparisons between an alidade, which is currently used, and a total-station theodolite/EDMI (electronic distance measuring instrument) as fourth-order vertical control instruments. A total-station theodolite/EDMI is a theodolite with built-in EDM capabilities. A small microprocessor built into the total station allows traverse computation such as vertical angle reduction and point resection to be computed in the field. Many total stations have sufficient computer memory to store up to 500 observations. The Topcon 10-D Guppy was chosen as the test theodolite due to its initial test results and instrument availability. Rates of production, error of closure, and ease of use were the main criteria in evaluating the instruments.

Production comparisons were made on traverse by each instrument over the same courses under identical operational conditions. Monitored in these tests were the speed of production and the number of instrument setups along the traverse. Errors of closure were also monitored in each traverse. The type of terrain was an important factor in comparing each instrument's accuracy.

Ease of use comparisons were performed by three individuals who varied in levels of experience with the alidade ranging from 1 week to 20 years. The results shown in the following table are representative of the overall comparison evaluations.

TEST CATEGORIES	Field Exper. 1 week		Field Exper. 3 yrs.		Field Exper. 20 yrs.	
	alidade	EDMI	alidade	EDMI	alidade	EDMI
Number of Lines traversed	4	5	4	2	3	4
Average mi/hr production	0.5	2.0	1.4	2.3	1.6	2.1
Average error of closure	1.3'	0.2'	0.75'	0.4'	0.6'	0.3'
Percent of excessive line closures	50%	0	25%	0	0	0

Generalized Adjustment by Least Squares (Phase II)

Development of a software package to perform all of the least-squares-related functions in a typical adjustment program is continuing. Generalized Adjustment by Least Squares (GALS) is a software subsystem which must be executed from a higher level program. It can be viewed as a subroutine package with somewhat involved interface requirements. Knowledge of the detailed internal operations of GALS is not essential for its use and it is possible to employ GALS as a callable routine and create very involved adjustment systems.

A prototype of GALS was completed in FORTRAN to run under IBM OS/MVT. The prototype required the services of IBM's OS Sort/Merge program. The software package has the following characteristics: 29 subroutines, 6 separate executable tasks, and 14 data sets.

The primary purpose of the prototype implementation was to test the concepts on which GALS is based, define problem parameters, and arrive at a workable model that could be verified in a simulated working environment. These objectives were met and a decision was made to proceed with a production version of GALS (Phase II). This version was designed for implementation in the following environment:

PL/I programming language
IBM OS/MVT operating system
IBM OS Sort/Merge program

This implementation will result in a single load module for GALS that will become a member of a load module library. Access to GALS can be achieved through this library.

Satellite Surveying System

A geodetic receiver using the NAVSTAR Global Positioning System (GPS) is being developed in a joint effort by the USGS, the Defense Mapping Agency, and the National Geodetic Survey. GPS is a navigation system being implemented by the Department of Defense and, when fully operational in the late 1980's, will consist of a constellation of 18 satellites (fig. 8) providing worldwide all-weather satellite navigation and positioning capabilities. Use of GPS to obtain geodetic positional data will require less time and effort than is now needed for current field data collection methods.

The University of Texas Applied Research Laboratory (ARL) is working under contract to develop a geodetic receiver (GEOSTAR) to use GPS signals to provide positional data. GEOSTAR is a single-channel multiplexed receiver and will track several satellites simultaneously and can achieve submeter accuracy. ARL has subcontracted the hardware development to Texas Instruments, with the Naval Surface Weapons Center developing the navigation processor software.

Aerial Profiling of Terrain System

The Aerial Profiling of Terrain System (APTS) has been under development since 1974. It will be a precision airborne surveying system capable of measuring elevation profiles across various types of terrain from a relatively light aircraft at flight heights up to 1,000 m above the ground (fig. 9). A laser profiler measures the distance from the aircraft to the terrain, and an inertial measuring unit (IMU) and a laser tracker provide the aircraft position datum. The tracker measures the distance to previously placed retroreflectors to provide a high-precision positional update to the IMU.

The fabrication, integration, and extensive laboratory testing of the components (navigation, tracker, profiler, and video subsystems) have been completed at the Charles Stark Draper Laboratory in Cambridge, Mass. The components have been installed in a Twin Otter aircraft which is based at Hanscom Field, Mass. Soon after, both ground and flight tests will be made

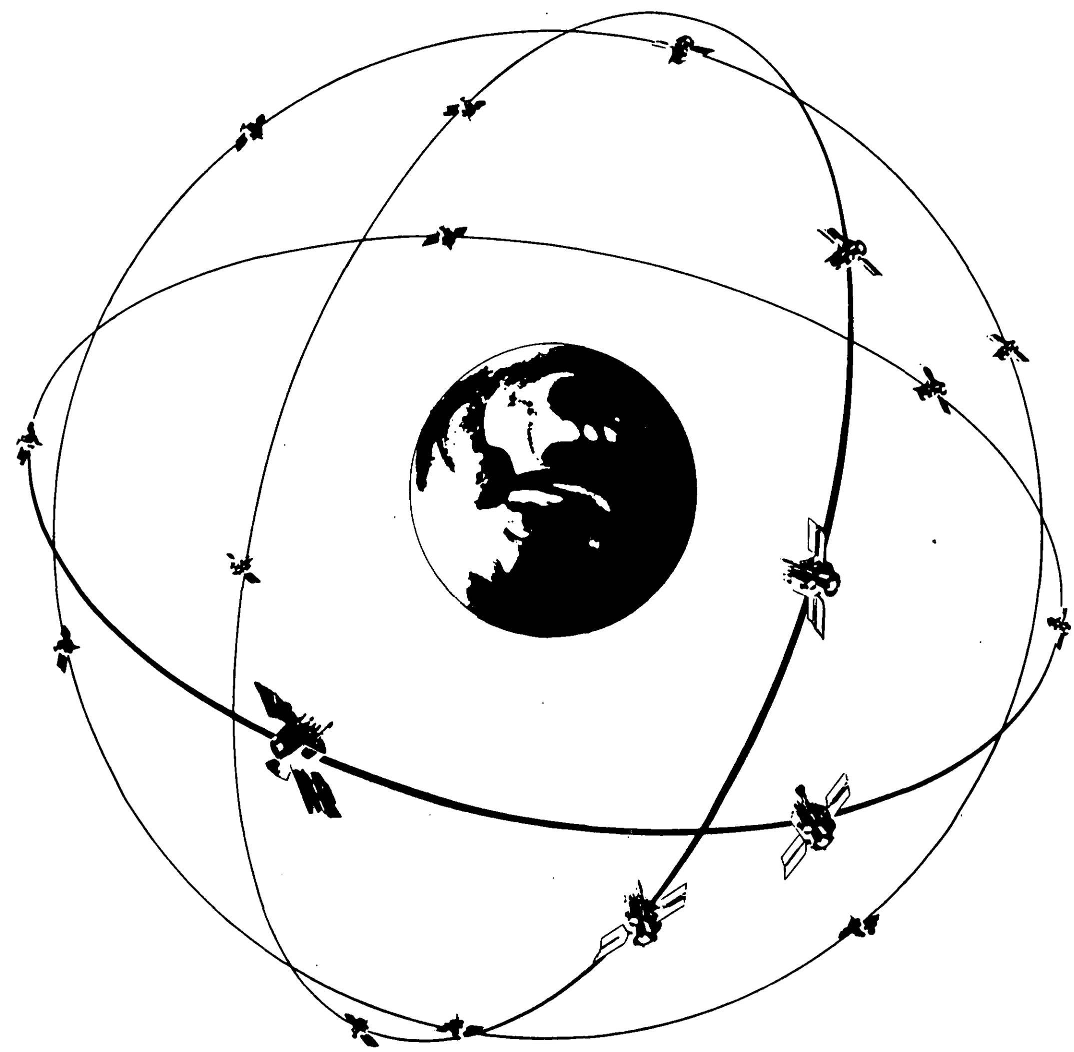


Figure 8.--The Global Positioning System will consist of 18 satellites in several planes around the Earth.

to determine system accuracies and identify and correct any remaining problems. System simulations and laboratory testing to identify and calibrate systematic error sources continue to support system accuracy goals of ± 0.5 feet vertically and ± 2.0 feet horizontally.

To measure the accuracy of the APTS, a calibration range was established in an area west of Hanscom Field, Mass. Two types of survey data are now available within the 10- x 30-mile calibration range:

- Survey sites where precise latitude, longitude, and elevation are known. Retroreflectors will be placed at these sites for testing the laser tracker and inertial navigation system.

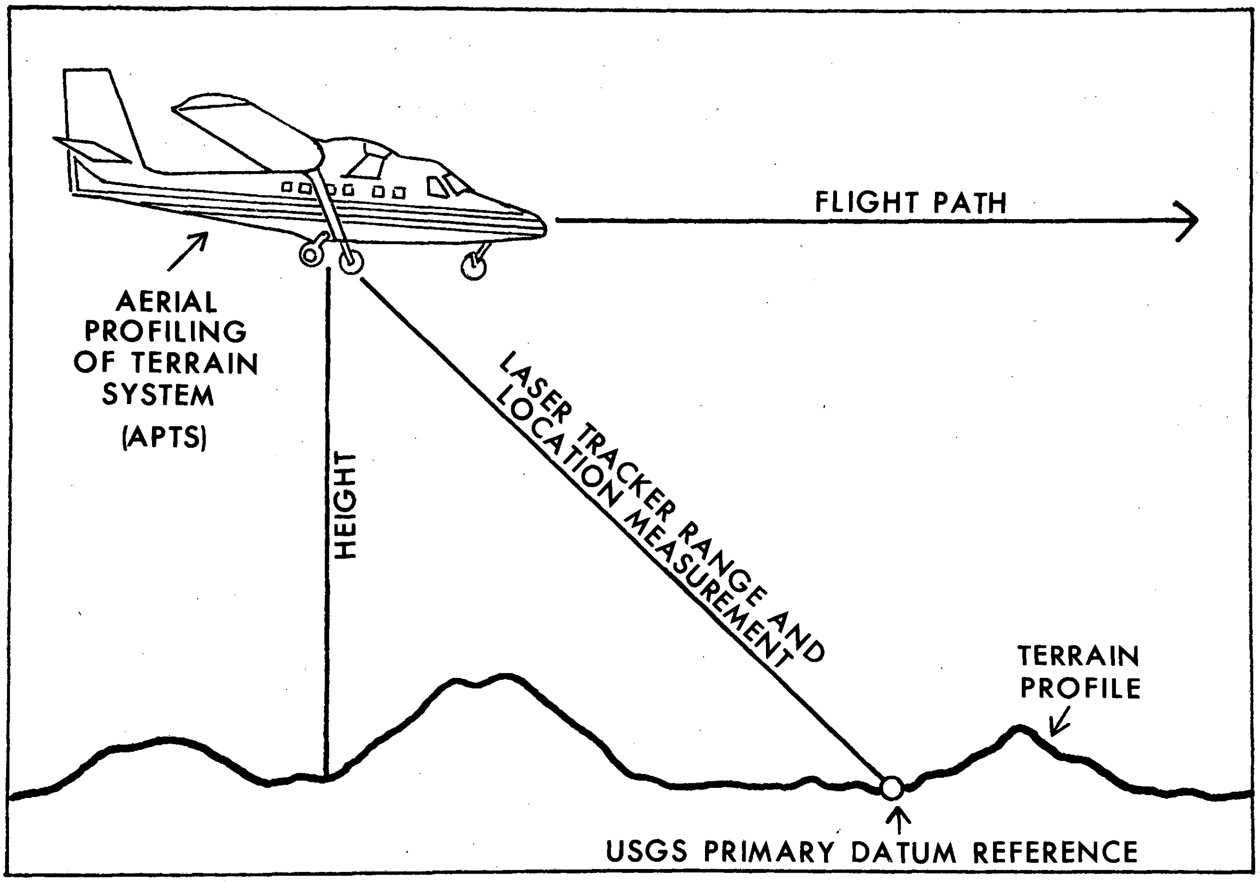


Figure 9.--Airborne surveying with the Aerial Profiling of Terrain Systems (APTS)

- Selected parking lot areas around shopping centers will be mapped at large scale to provide precise position and elevation information for testing the APTS when operated in the profiling mode.

Using four USGS Doppler satellite receivers operated in a simultaneous tracking mode, the surveys needed to obtain precise positions were completed. Ten four-station quadrilaterals that overlapped and interlocked with one another were observed and fitted together by a least-squares adjustment. Data reduction is still underway, but preliminary computations indicate that the ±10 cm relative position accuracy goal was achieved.

Elevations for all sites were established by second-order leveling instruments and procedures. Gravity was measured at all sites and at a scattering of points covering the whole range. These gravity data will be used to correct the inertial sensors for this source of error during the testing phase.

Standards for Inertial Surveying Operations

The accuracy of inertial surveying instruments has improved dramatically since 1966 when the U.S. Army Engineer Topographic Laboratories first applied an inertial navigation instrument to surveying work. The product of that research was the Position and Azimuth Determining System (PADS), capable of establishing positions to a 10-m accuracy level. Subsequent refinements in procedures and data processing by users of the instruments (Bureau of Land Management, Geodetic Survey of Canada, Defense Mapping Agency, and Span International Inc.) have increased the accuracy to the decimeter level, and this method of survey can now compete with traditional methods for establishing horizontal geodetic control.

Specifications have been developed for performing horizontal geodetic surveys with inertial instruments that will meet the Federal Geodetic Control Committee (FGCC) second- and third-order standards. The specifications address instrument calibration, survey reconnaissance, observing procedures, and final computations. They are considered preliminary and will be reviewed by members of the FGCC and experts in the application of inertial surveying instruments.

IMAGE MAPPING

Image Map Research

The Dyersburg, Tennessee/Arkansas 1:100,000-scale image map was the first compiled from Landsat 4 Thematic Mapper (TM) data and the techniques developed to process the data may serve as guidelines for processing future TM products (fig. 10). The TM data set consists of 7 wave bands; therefore, there are many possible color combinations for a simple three-color image map. Moreover, each band can be processed, enhanced, or combined in a wide variety of ways which offer endless additional possiblities. The final choice for the Dyersburg image map was as follows:

Band 2, 0.52-0.60 µm (green), printed in yellow
Band 3, 0.63-0.69 µm (red), printed in magenta
Band 5, 1.55-1.75 µm (near infrared), printed in cyan

Each band was subjected to a multiple-point linear stretch to spread the various radiometric responses (brightness differences) so that each band has a photographic density that is near optimum for processing. In addition to the radiometric stretch, an edge enhancement was imposed which accentuates the boundaries between areas of different response. The Dyersburg image map and the standard line map were printed back to back with a UTM grid printed on both versions to facilitate correlation, identification, and positional determination. Both products meet U.S. National Map Accuracy Standards. This means 90 percent of the well-defined features are within 51 m of true position.

Early in 1982, a test area was sought to exercise the newly developed geometric registration and mosaicking capability at the EROS Data Center. The Las Vegas 1:250,000-scale quadrangle was selected because the quadrangle contains a diversity of land cover categories (urban area, desert, mountains, lakes, rivers, and irrigated agriculture), is covered by parts of four Landsat MSS scenes, and because of the availability of ground control point files from NASA and DEM data from USGS.

Subsequent measurement and evaluation resulted in a decision to develop the Las Vegas mosaic for use as an image map base, requiring more stringent geometric standards, different contrast stretch and resampling parameters, and different density standards. In December 1982, the following procedures and parameters were in place to produce a refined Las Vegas quadrangle image map: (1) retransform and mosaic the image data using more ground control points and image tie points and adding approximately ¼" of image data around the edges, (2) use cubic convolution rather than nearest neighbor resampling, (3) use 5- x 5-pixel edge enhancement, (4) insert a gray scale near the top of the image prior to contrast stretch and edge enhancement, (5) perform a multiple point linear stretch rather than a straight-line contrast stretch, and (6) produce laser beam recorder first-generation negatives having Dmin = 0.40, Dmax = 1.40, D = 1.0.

The initial transformations were performed using the existing ground control point files. The resulting images showed significant misregistration, so additional points were selected from 1:24,000- and 1:62,500-scale quadrangles. Grid files were created which were used to

Figure 10.--Reduced version of the image from Landsat 4 Thematic Mapper data used to prepare the Dyersburg, Tennessee/Arkansas image map at 1:100,000-scale. It is printed here at approximately 1:520,000-scale.

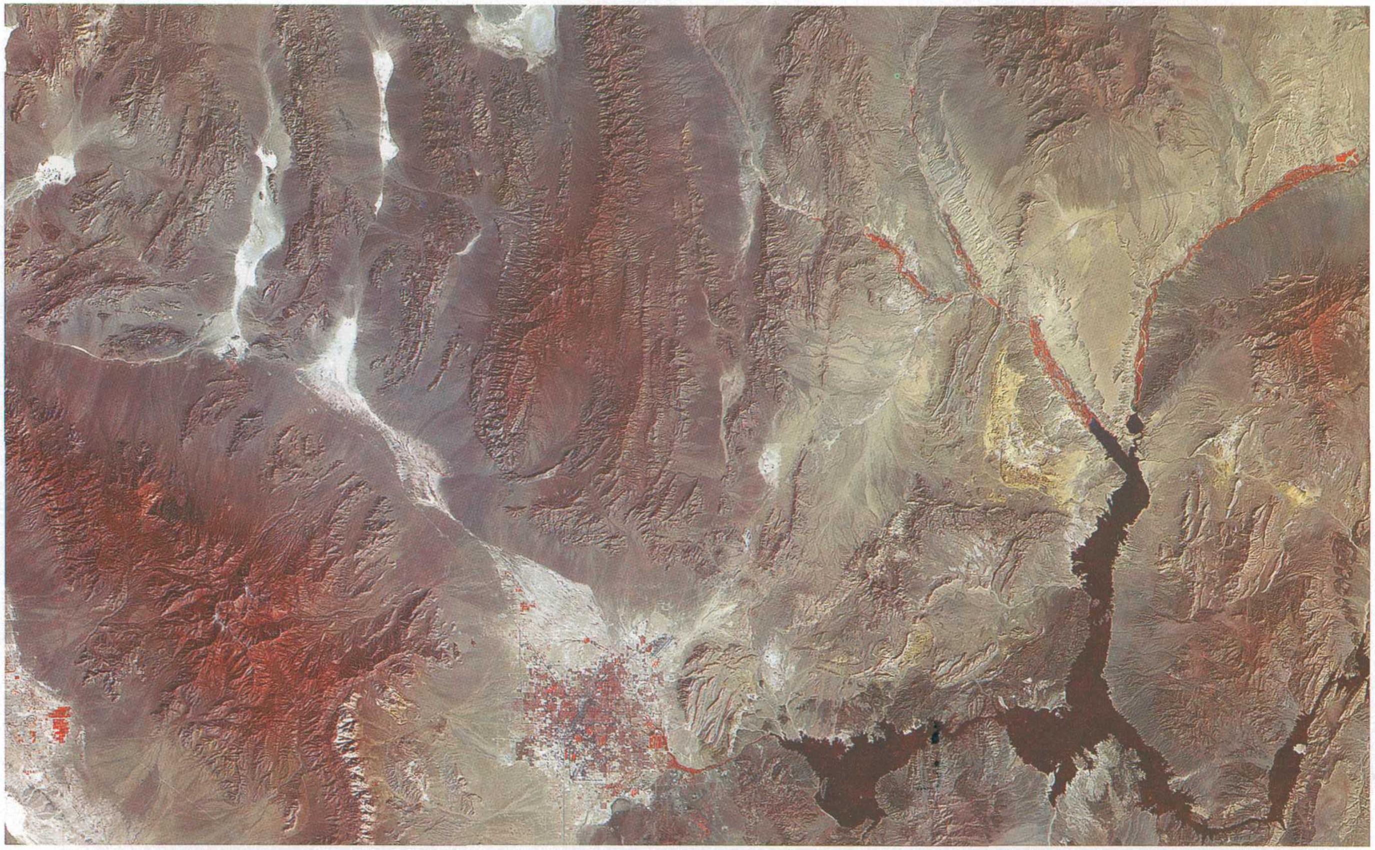


Figure 11.--Reduced version of the image from Landsat multispectral scanner (MSS) data used to prepare the Las Vegas, Nevada image map at 1:250,000-scale. It is printed here at approximately 1:1,030,000-scale.

transform the data to the UTM projection and merged to form a digital data file which covered the Las Vegas 1:250,000-scale quadrangle. The data were processed through a laser beam recorder to produce black-and-white film transparencies at a scale somewhat smaller than 1:1,000,000. These were subsequently enlarged and combined to produce a false-color composite (fig. 11).

The Las Vegas image map was digitally mosaicked from four separate Landsat scenes and the digital data were resampled with a cubic convolution algorithm. Radiometric enhancements, including a multiple point linear stretch and a 5- x 5-pixel edge enhancement, were also introduced and the data were converted from digital to image form with precise control of the image density. The images for the separate bands were enlarged on a Hell scanner/printer to the final 1:250,000 scale. This image map reflects a conventional color-infrared portrayal based on the following band selection:

Band 4 - 0.5-0.6 µm printed in yellow;
Band 5 - 0.6-0.7 µm printed in magenta; and
Band 7 - 0.8-1.1 µm printed in cyan.

Although many image maps have been printed, the Las Vegas MSS image map was the first color image map using the MSS as the primary data source printed by the USGS in standard 1:250,000-scale quadrangle format. The 80-m pixel data of the MSS, when properly processed, provide resolution, geometric accuracy, and informational content comparable to the 1:250,000-scale line map.

This image map was designed to complement the standard line map printed on the reverse side. This is the largest scale for which there is complete standard line map coverage of the United States. Both maps were fitted with a UTM grid. With respect to this grid, the image map has a positional accuracy of 100 m RMSE.

Landsat Image Mapping in Alaska

The NMD is preparing 25 Landsat-3 image maps at 1:250,000 scale of the north slope of Alaska for the Department of the Interior, Minerals Management Service. Original plans were to use only RBV images. However, due to the lack of suitable RBV images, it has been found necessary to use MSS images for 11 of the map quadrangles. The image is overprinted with a full-line black UTM grid, a dashed white line township public land survey, and a white dropout names plate. The collar includes a scene location diagram and a scene center diagram. To date, three quadrangles--Ikpikpuk, Meade River, and Teshekpuk--have been completed.

Experiments in Lithography of Remote Sensor Images

A variety of prototype image maps have been produced in the photographic/ lithographic research laboratory from electro-optically acquired data and from film photographs. This is an on-going effort to improve image processing techniques, to ensure quality printing with predictable results, and to improve operational capabilities of production personnel in cartography and printing.

Saudi Arabia

Experimental printings were conducted to establish standards for a series of 1:500,000-scale image maps using Landsat bands 4, 5, and 7 printed in process colors. The imagery was enlarged to publication scale by electronic graphic arts drum scanners/plotters that simultaneously generate halftone dots. Tone curves could be manipulated to fit one-quarter, midtone, and three-quarter density aimpoints. Use of a scanner for enlargement produced better image definition than optical enlargements. Controlling the tone curve by computer prior to optical enlargement resulted in some improvement in the imagery, but optical system problems related to lighting, focus and lens defînciency were not as easily solved.

Halftone and screenless processes were combined in an experimental printing of a 1:2,000,000-scale map. A 150-line per inch (ℓ/i) halftone negative of a published 1:1,000,000 map was photographically reduced. Due to a lens deficiency, the resulting 300-ℓ/i halftone dots were not opaque in the map corners. To retain image definition, screenless lithography was used to print these gray dots that had been lost in the halftone process. A series of 1:250,000-scale duotone maps using Landsat band 7 are being printed by screenless lithography with black and brown ink.

Mexico

Using 1:1,000,000-scale imagery acquired over a period of 7 years from different seasons and processed by the EROS Data Center, a series of 31 Landsat maps at a variety of scales were printed in process colors. Lettering and cartographic augmentation for the maps was completed in Mexico and an American firm mosaicked, halftoned, and chemically etched the imagery to improve tone match. These maps used white lettering with a black halo to improve readability.

Kenya

A Landsat image map of East Africa was printed in September 1982 using halftone color separations that were produced from 1:1,000,000-scale mosaicked color photographic paper prints. Use of the paper prints, although economical, resulted in considerable loss of definition in the final images.

Meade River, Alaska

The Meade River quadrangle in Alaska was printed in September 1982 using Landsat RBV images. Printing of the duotone prototype map was done using both the screenless process and a 175 ℓ/i halftone process. A photographic paper print was used to proof the screenless process, while Cromalin halftone proofs were made for a black and blue separation version and for a black and black separation version. Double printing of RBV images increases contrast significantly by using the second ink for an accent shadow.

Las Vegas, Nevada

Experimental prints at a variety of scales were made to evaluate techniques for preparing a 1:250,000-scale map using Landsat 3 MSS images. Tests of optical systems and scanner/plotter equipment are being evaluated.

Tests have shown that tone-matched imagery from the same orbit and season can be printed with excellent results. Computer tone matching is recommended if more than six scenes are to be mosaicked or if the imagery is of poor quality. Computer processed data and electronic imaging equipment allow for more control of the photographic process. Screenless lithography produces high image definition and hue fidelity due to a fine (10 micron) random-dot structure produced by the lithographic plate. Photographic color prints provide the best pre-press proof for screenless lithography.

Geometric Registration System

During 1982, EDC implemented a prototype production system for the registration of satellite images to geometrically controlled topographic maps. Although EDC has had the capability for several years to geometrically correct digital images, the system and procedures were geared toward an iterative approach rather than a production-oriented registration system. The new geometric registration system has been developed in response to the need for a production mode system. The hardware consists of a DEC PDP-11/60, three 300-Mb disk drives, two tape drives, an Image-100 image analyzer with five-channel display capability, and a sonic digitizing table.

The system possesses three main capabilities. The first is image-to-map registration involving the identification of approximately 30 evenly dispersed picture elements (pixels) in an image and corresponding control points from large-scale maps (for example, 1:24,000-scale). A second-order transformation is applied to the image based on these control points. Control points are automatically generated from the NASA ground control point library through a cross-correlation technique. Variations in the output image can be obtained by specifying the desired study area, projection, and pixel size. The image transformation is performed using cubic convolution or nearest neighbor resampling options. The accuracy of the transformed image can be evaluated by comparing various features with those on the large-scale maps.

The second capability is the registration of an image to a previously transformed image. This is accomplished in a semi-automatic mode which uses cross-correlation to compare small portions of each image and identify the pixels that correspond most closely. The newly transformed image will possess the characteristics and parameters of the reference image including pixel size, study area, and projection. Verification consists of examining various features on both images, at an enlarged scale.

The third capability is the creation of mosaics of several images by the joining of adjacent images. Contrast enhancement is used to render image junctions unnoticeable and to enhance image tonal qualities. A special algorithm has been developed which allows higher quality data to be inserted into the mosaic to replace poor-quality data or clouds.

In September 1982, BLM requested that EDC produce 18 registered Landsat MSS scenes in the Florida panhandle, Central Florida, North Dakota, Illinois, Alabama, Ohio, Arkansas, and Missouri. Nine of these scenes require the image-to-map registration process; the remainder will use the image-to-image process. The first available computer compatible tapes of the selected scenes were processed in October. Delivery began on a staggered schedule in November 1982 and will be completed by July 1983. All complete scenes have met user accuracy requirements.

Cartographic Accuracy of Landsat 4 Data

Evaluations are being conducted on the cartographic accuracy of both MSS and TM data and on the performance of EDC processing systems. Cartographic accuracy is essential for integrated data bases being developed for use in a broad variety of projects requiring registration between TM and MSS data. The greater data volumes and the higher resolution of TM data will require optimal methods of data handling and film generation.

First consideration was given to full-scene geometric verification of MSS and TM data. Landsat 4 digital images produced by NASA are either system-corrected or precision-corrected (ground control points applied) and include parameters required to cartographically register each pixel of an image. Data fields provided on the standard Landsat 4 MSS and TM digital tapes describe the map-projection coordinate system overlaying the image-coordinate system. Therefore, given a location in map projection coordinates, the image coordinate location can be calculated. The image's geometric accuracy is verified by comparing the calculated image coordinates of a point location with the actual image location obtained from visual selection via interactive display. Images of both precision-corrected and system-corrected MSS data were verified for accuracy.

Another area of investigation addresses the registration of MSS to TM images, two sensor data types with dissimilar spectral characteristics, pixel sizes, and radiometric dynamic range and calibration. Scientists have expressed a desire to use integrated data sets of this type in support of biologic and geologic classifications. An MSS-TM registration procedure using a cross-correlation approach has been developed and tested.

REMOTE SENSING DATA ANALYSIS

Remote Information Processing System

During 1982, the first phase of a research and development project for the Remote Information Processing System (RIPS) was completed with a successful demonstration of the feasibility of using microprocessor-based image analysis equipment for the support of remote sensing projects. Specifications were prepared based on the three experimental units designed and built at EDC. A request for bids was announced and a vendor selected for production of the 18 prototype units for delivery during 1983. Five Government agencies (Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service, U.S. Army Corps of Engineers, and USGS) provided funds to procure RIPS units through the contract.

A RIPS Teleconferencing System has been developed, tested, and documented as an interagency communication mechanism for use by RIPS cooperators. This teleconferencing capability allows exchange of messages relating to problems and solutions, and will be used for final testing and evaluation. Sample floppy disks of 7.5-minute Landsat subscene areas have been developed in support of RIPS and other microprocessor-based systems.

Spatial Variance in High-Resolution Images

Recent developments in digital cartography, spatial data analysis, and remote sensing increase the need for defining and quantifying the spatial characteristics of maps and images. The increasing variety and spatial resolution of digital map and image data further suggest the need for the development of new techniques for the analysis of these spatial data. A study was begun to characterize the spatial variability of brightness values of high-resolution multispectral digital images through the use of power spectrum analysis and to evaluate the utility of this technique.

A power-density spectrum is a Fourier transform of the auto-covariance of a series of data. By resolving the auto-covariance function into its frequency components, the Fourier coefficients represent the variance density as a function of spatial frequency. To the extent that spectral analysis can be shown to characterize spectral variance, it might be used to study relationships between different types or sets of spatial data.

Image data were obtained for an area near Moab, Utah, in May 1981 using the Environmental Protection Agency's Daedalus D-1260 digital scanner flown at about 1,000 ft. altitude six times over the same flight line during 1 day (nominal ground resolution of 0.75 m). Image aspects of the most interest are the changes of spatial variance with spatial resolution, electromagnetic spectral bands, time (Sun angle for reflected bands), and environmental influences such as weather, topography, and surface material.

Two strips, 32-pixels wide, were extracted from 512- x 512-pixel images. One strip was parallel to the flight direction and the other parallel to the scan direction. The strips were defined by the same coordinates in each of the images but, because the data are not well registered, they do not necessarily represent the same ground areas nor are pixel sizes from different flights always the same. Pixels were aggregated to simulate the effects of lower resolution. One-dimensional power-density spectra were calculated for subsets of the strips.

The overall shape of spectra seems to be a good indicator of the relative distribution among spatial frequencies of variance structure of different data sets such as the landforms in two different digital elevation maps. The spatial frequencies where map or image information occur can be quantitatively described at least in a general fashion.

Comparisons between electromagnetic spectral bands indicate that spectra are typically similar for the green, red, and near-infrared bands, although counter examples can be found. There is a generally poor correspondence between features in bands of thermal-infrared and reflected energy spectra. Thus, it is not likely that texture in the reflected energy bands can be used to estimate texture in thermal-infrared images.

When pixels were aggregated to simulate larger pixel sizes, power-density spectra indicated that aggregation to 4- x 4-pixels (and probably 8- x 8-pixels) did not cause significant loss of information in these images. This is a subjective evaluation based on a loss of what appeared to be noise in the spectra versus what appeared to be feature. Power spectra may be useful in determining minimum resolution requirements in geographic data bases.

NASA Magsat Data Investigation

NASA's Magnetic Field Satellite (Magsat) was the first satellite designed to provide globally uniform magnetic data for the Earth. This investigation is part of a NASA/USGS effort to interpret, apply, and determine the utility of the data and to recommend possible future missions. Magsat data have been evaluated to determine the magnetic anomaly signatures and their geologic associations for various types of tectonic provinces.

Comparison of a Magsat anomaly map with a continental tectonics and oceanic physiography map suggests that older uplifted provinces produce anomalies of one sign (negative at low latitudes, positive at high latitudes), whereas basins exhibit anomalies of opposite sign. Older uplifts and deeper portions of basins tend to have stronger anomalies. This association has been attributed to a greater bulk magnetic susceptibility above the Curie point isotherm for the older, more uplifted shields, and to a lesser bulk magnetic susceptibiity above the Curie isotherm in the deeper portions of basins.

Some of the anomaly patterns cross from continental to oceanic crust. As NASA's Magsat anomaly maps were intended to be prepared to remove anomalies from sources in the core, remaining sources have been considered to be predominantly or exclusively from crustal sources. However, the anomalies just described are broad enough in wavelength to have been caused by sources in the mantle, heretofore considered an unlikely source for magnetic anomalies. Part of the anomaly patterns crossing from continental to oceanic crust may be due to the mechanism of collecting and processing Magsat data; however, it may be premature to rule out the mantle as a possible source for some of the anomalies. If so, this would be a significant contribution to global geology by Magsat.

Rangeland Assessment and Monitoring

Range conservationists for the Bureau of Indian Affairs are responsible for the administration and management of grazing use on 42 million acres of rangeland. Information on the degree of use and trends in ecological status within specific management units is needed so that adjustments in grazing allotments can be made on a timely basis. Investigations are being conducted in the use of remote sensing data to (1) determine the requirements for mapping indexes of range utilization and (2) assess vegetation trends.

A basic strategy for rangeland monitoring and assessment was developed prior to the initiation of this cooperative project. Each range capability class is a unique soil/vegetation landscape within a management unit (pasture). Dominant range sites are determined by aggregating specified soil series polygons. Range capability classes within range sites are determined by mapping vegetation types according to a set of decision rules which use current vegetation as an indicator of successional status.

The range capability polygons are used as a mask for extracting spectral data, or greenness/brightness transformation data, and transferring the parameters to a statistical file. Statistical analyses result in indexes which can be mapped or presented in a tabular summary.

The initial phase of this study considered the feasibility of developing and mapping an index of range utilization for the Crow Creek Indian Reservation in central South Dakota. Field data were collected at 65 locations within Buffalo County on four dates during the 1982 growing season. Due to the unusually good growing conditions in central South Dakota, a low percentage of utilization was recorded during the entire growing season. Repetitive cloud-free Landsat data were acquired in March, August, and September 1982. Both the August and September scenes have serious data drop (line-start) problems; therefore, data analyses have been limited to assessing the ground data and looking at relationships with Landsat parameters derived from pre-1982 scenes.

A strategy was developed for using brightness and greenness indexes derived from principal components analyses to estimate utilization. Data analyses indicate that pre-inventory images, along with current season field estimates of litter and bare ground, allow a quick assessment of ecological condition.

Arctic Lake Automated Inventory Project

The tens of thousands of lakes which exist on Alaska's North Slope represent an immense water supply. Of particular interest are lakes, typically deeper than 2 meters, that do not freeze to the bottom, thereby providing a source of water for activities such as petroleum production during the region's long, extremely cold winters.

A procedure using Landsat data has been developed to automate the inventory of lakes. Using digital image analysis techniques, each lake was detected, its area determined, and the location of its center computed. This information will be used by the USGS Water Resources Division and by the Bureau of Land Management which handles the leasing for petroleum on Federal lands on the North Slope. The areas to be inventoried include the National Petroleum Reserve in Alaska (NPRA), the northern part of the Arctic National Wildlife Refuge, and the area between the two.

The basic data for the inventory are the lake-water and lake-ice classes derived from a computer-processed land cover classification image of the NPRA. Lakes smaller than approximately 5 acres were eliminated from the inventory. The perimeters of lakes were used to determine areas of the water and ice classes. The lake label, latitude and longitude of center, total area, and area of each water and ice class are kept in computer files which are generated for each 1:250,000-scale quadrangle. Field data on water depth and other attributes for any lake can be added to the files. Any of these data on lakes can be retrieved by specifying a range of values for any variable or set of variables. For example, lakes larger than a given size within a particular range of latitude and longitude could be retrieved. Lake water/ice data from both a 1:63,360-scale quadrangle (Harrison Bay C-5) and a 1:250,000-scale quadrangle (Teshekpuk) were successfully inventoried in tests. Approximately 5,000 lakes were inventoried in the Teshekpuk quadrangle, and an additional 12,000 lakes, with areas of fewer than 5 acres, were eliminated. Data from an additional 15 quadrangles remain to be inventoried.

Radar Studies

The USGS during 1982 acquired synthetic-aperture X-band side-looking airborne radar (SLAR) strip imagery of the following six data acquisition sites (fig. 12):

Project Area	Area (sq. mi.)
Aleutian Arc	4,897
Tonopah Nevada	7,472
Central Appalachian	39,976
New Jersey	927
New England	18,000
Virginia	2,300
TOTAL	73,572

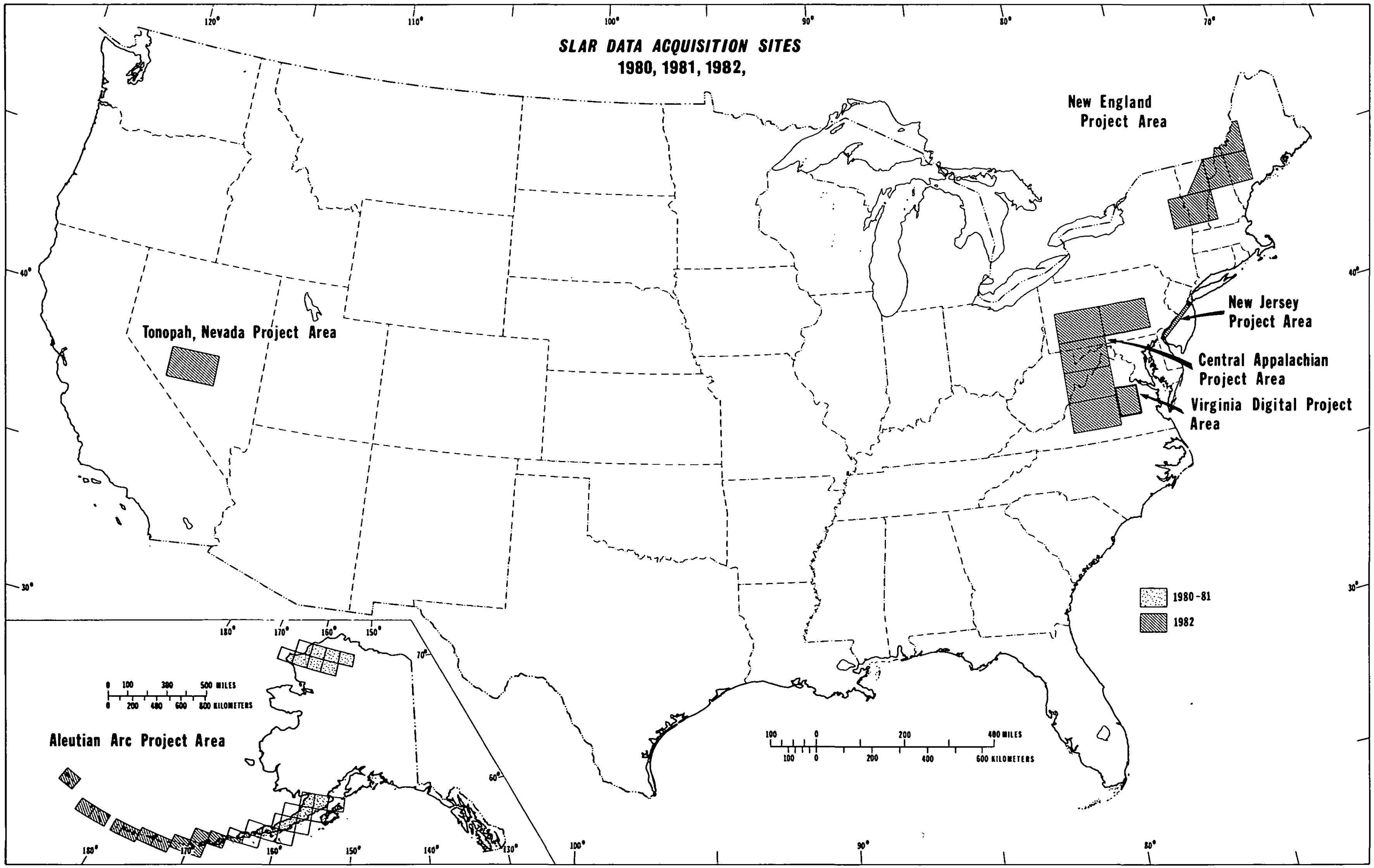


Figure 12.--Side-looking airborne radar data acquisition sites--1980, 1981, 1982.

The normal contract deliverables include mission flight logs, coverage indexes, photo mosaics at 1:250,000 scale corresponding to the sheet lines of the USGS map series at that scale, and SLAR strip images acquired at 1:400,000 scale. For the Virginia area, digital tapes were also provided.

The SLAR data are retrievable through the development of a microfiche system accessed by selection of the 1:1,000,000-scale map name. Users can request copies of the SLAR data by following the ordering instructions on the microfiche. Eventually, the SLAR images will be coded into the computerized main image file. All SLAR material, with the exception of the Aleutian coverage, is currently available from the EROS Data Center. The Division is constructing 12 radar image mosaics of the 1:250,000-scale quadrangles comprising the Aleutian arc. These mosaics will be printed for public distribution.

Radar Reflector Project

In a study to determine the optimum size for radar reflecting targets, aluminum trihedral (corner-cube) targets were placed at 17 sites near Front Royal, Va. prior to acquisition of synthetic-aperture x-band radar imagery. The reflectors were made of ¼-inch thick aluminum in four sizes: 4 ft., 3 ft., 2 ft., and 1 ft. Single reflectors were installed at fourteen sites. Clusters of single reflectors were installed at the remaining three sites. The first site contained four 2 ft. single reflectors welded together into one 4-ft. cluster. The second site contained nine 1-ft. single reflectors welded into one 3 ft.-cluster, and the last site contained four 1-ft. single reflectors welded into one 2-ft. cluster.

Each target was installed approximately 2 or 3 ft. above ground level on a tripod made of 2¼- x 1½-inch galvanized steel. The stands for the larger targets were horizontally cross braced and the bottom face of each target was leveled.

Paper prints of the radar imagery indicate that the 4-ft. and 3-ft. targets (both singles and clusters) are easily seen but the 2-ft. targets are near the limit of detectability. Film transparencies will be studied to determine whether the smaller targets are observable.

Radar Rectification

A procedure is being developed to remove radar layover using a pair of test radar strips in the Lookout Ridge quadrangle of Alaska. Coordinates of conjugate images in the side-lap area of the parallel strips are measured using a comparator or analytical plotter. The images are then digitized on an Optronics drum scanner and a transformation is computed between line and sample numbers (L,S) and the X,Y coordinates of the conjugate images. Through resampling of the digitized images, the L,S system can be made parallel to the radar range direction. Because layover is confined to the range direction, a relatively simple one-dimensional polynominal should suffice to remove it. At present, development has proceeded to the stage of determining the transformation connecting the X,Y and L,S systems.

NOAA/AVHRR Data as A Wildfire Management Tool

Studies were conducted in cooperation with the Bureau of Land Management and the National Oceanic and Atmospheric Administration (NOAA) to evaluate the utility of Advanced Very High Resolution Radiometer (AVHRR) data for monitoring areas of herbaceous vegetation throughout its growth cycle and for estimating fire fuel conditions and loadings. The BLM requires these estimates as part of its fire-management program.

The AVHRR is a multispectral scanner carried aboard the NOAA-series polar-orbiting satellites. AVHRR data have a nominal ground resolution of 1.1 km and cover a swath width of 2,400 km. The visible data (0.58-0.68 μm) in band 1 and the reflected infrared data (0.76-1.1 μm) in band 2 can be used to compute a greenness index, or normalized difference (ND), by subtracting band 1 from band 2 and then dividing the result by the sum of bands 1 and 2:

$$ND = \frac{\text{Band 2} - \text{Band 1}}{\text{Band 1} + \text{Band 2}}$$

Larger ND values indicate areas containing higher amounts of standing green biomass.

In March and April of 1982, AVHRR images of northwestern Arizona were acquired through the spring growth cycle (from dormancy through senescence) of the annual vegetation in this area. The image data were then registered to a cartographic data base containing road and State boundary information. ND values were computed from AVHRR data for five dates and analyzed by the BLM to determine their usefulness in supporting wildfire management decisions.

It appears that AVHRR data can be valuable in the BLM Wildfire Initial Attack Management System. Preliminary investigations have shown that AVHR data can be used to estimate the time at which senescence begins, to document relative amounts of standing green biomass, and to follow the seasonal growth of annual grasses. These data also show potential for use in national or global vegetation monitoring, assessment, and management programs.

Preliminary Investigation of Landsat 4 TM and MSS Data

This project was initiated in September 1982 when the first TM data were received from the NASA Goddard Space Flight Center. Initial data screening, data handling, and program testing were completed on a four-band Detroit scene (E-1432-99TM; July 25, 1982) and a seven-band northeast Arkansas scene (E-1439- TM; August 22, 1982). Landsat 4 data were received in early December for one primary eastern test site (Washington, D.C.-40109-15140; November 2, 1982) and one secondary eastern test site (Allegheny National Forest-40043-15244; August 28, 1982).

Early research results show that: (1) TM data are better than MSS data for identifying resource categories, (2) the most useful three-band color combination of TM data is a near-infrared, a mid-infrared, and a visible band, (3) the hue, intensity, and saturation transformation process provides added flexibility (and improved interpretability) in making TM color-composite images, and (4) application of the digital spatial data base concepts will greatly enhance the use of TM data.

Applications of Remote Sensing to Petroleum Exploration in the Qaidam Basin, People's Republic of China

Under an official government-to-government protocol, a cooperative project has been conducted with the Scientific Research Institute for Petroleum Exploration and Development (China's Ministry of Petroleum Industry). The primary objectives are to exchange information on (1) the applications of remote sensing and ground-based data to petroleum exploration and (2) within the geologic setting and petroleum resource potential of the Qaidam Basin region of western China.

Although informal cooperative studies have been underway for several years, formal activities commenced with the first exchange visit by five Chinese scientists to the EROS Data Center in September and October, 1982. During that visit, scientists from both countries reviewed and discussed their previous work. Chinese geologists presented results of Landsat image interpretations of the geology of the Qaidam Basin and discussed the details of the petroleum geology of the basin as defined by more than 20 years of field mapping, geophysical surveying, and exploratory drilling. They also presented results of geologic investigations of the remote Tibetan plateau. The delegation's scientists reviewed and discussed the digital processing capabilities and research of their institute.

USGS geologists presented results of Landsat image interpretations of four study areas in the Qaidam Basin, and discussed the digital enhancement techniques which had been used. They also reviewed current research on sedimentary rock discrimination using TMS data acquired over sites in the Uinta Basin region of Utah and Colorado, as well as the current efforts to develop and implement a digital geologic data base applicable to petroleum resource evaluation for a portion of the Uinta Basin. The team also spent 2 weeks in the Uinta Basin examining the nonmarine rocks in the region and field checking their interpretations of TMS data.

Satellite Glaciology

Glacier variation is an important indicator of regional (or global) climatic change. Many scientists believe that the increase in carbon dioxide in the Earth's atmosphere, which is caused by industrial activity (primarily burning of fossil fuels) and by deforestation of large areas (primarily in the tropics and sub-tropics) will cause global climatic warming and an ultimate rise in sea level (due to disintegration of the west Antarctic Ice Sheet).

Satellite glaciology is a new field of research made possible by the availability of data acquired by polar-orbiting Earth resources satellites. These data permit the periodic monitoring of the variation in and characteristics of glaciers such as the geographic position of the termini of outlet, valley, surging, and tidal glaciers and of the margins of ice sheets and ice caps. Current radar altimetry data permit the acquisition of ice surface elevation information. The combination of ice area, ice surface elevation, and depth-to-bedrock data (the latter by surface or airborne radio echo-sounding techniques) allows calculation of ice volume. Most of the techniques and instrumentation needed for satellite glaciology research are on hand. Polar regions are being emphasized because glaciers in these regions are the least known scientifically.

The satellite glaciology project, begun in 1981, complements ongoing work by the glaciology project of the Water Resources Division and is coordinated with mapping in Antarctica and other glacierized areas by the National Mapping Division. It contributes to the interagency National Climate Program. Informal cooperative arrangements exist with 30 other U.S., foreign, and international organizations, including the National Oceanic and Atmospheric Administration, the Institute of Geography of the USSR Academy of Sciences, the British Antarctic Survey, the Government of Canada, and the University of Alaska.

Accomplishments during 1982 included completion of the 1:500,000-scale "Index Map to Optimum Landsat Images of Antarctica." The "Table of Optimum Landsat Images of Antarctica" which will accompany the Index is approximately 50-percent complete. Contributions have been made to the new USGS research initiative in Antarctica and to the National Academy of Sciences book entitled Polar Research--A Strategy for the 1980's. Five additional scientific reports which were published in 1982 are listed in the selected references.

Mapping Vegetation and Land Cover in Alaska

A project was completed on mapping vegetation and land cover for the coastal portion of the Arctic National Wildlife Refuge in Alaska. This research using Landsat digital data was done cooperatively with the U.S. Fish and Wildlife Service and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) in support of an environmental impact statement prior to petroleum exploration of the area. Patterns were found in the multispectral data from Landsat after clustering the data into separable spectral classes. Using an interactive color display, these spectral classes were then identified with reference to field notes as specific vegetation classes. The data were geometrically corrected and mosaicked into a digital data set covering the entire study area.

The Scitex laser plotter then was used to plot the land cover and vegetation data on plates for four-color printing of the map at a scale of 1:250,000. The map has been published as USGS Map I-1443, "Vegetation and Land Cover, Arctic National Wildlife Coastal Plain, Alaska" (fig. 13). This unique thematic map depicts 12 land cover classes on a base map comprised of portions of the Barter Island, Flaxman Island, Demarcation Point, and Mt. Michelson 1:250,000-scale quadrangles. The area is bordered on the north by the Beaufort Sea and Arctic Ocean. Fifty kilometers to the east lies the Canadian border. Ninety kilometers to the west lies Prudhoe Bay, present center of petroleum production on the Alaskan North Slope and starting point of the Alaska pipeline.

An area measurement table is printed on a back fold of the published map for ease in comparing land cover statistics for nearly 100 survey townships shown on the map. To prepare the map for lithographic printing in color, a laser plotter was used to portray digital land cover information as thematic area symbols at map publication size and scale. When printed, the symbols appear in multiple colors. These colors are produced by overlaying the four process ink colors--yellow, magenta, cyan, and black--in dot patterns, or screens. The dot screens for the map (120 lines per inch) were also made on the laser plotter. When printed, the land cover theme data are combined with the black lines and lettering of the standard 1:250,000-scale base map. Preparation of the map for printing using computer graphics was the last of five stages.

The first stage was capture of the multispectral data by the scanner aboard Landsat. Landsat data, stored on computer-compatible tape, contain spectral reflectance data for 7.5 million pixels per band and scene.

The second stage is geometric correction of the sensor scan line data to the regular grid cells of a map projection and coordinate system. This is done in two steps, in conjunction with the third, or classification stage. The resulting raster units are 50- x 50-m on the ground (0.25 hectare, or 0.6 acre). They are defined in the UTM projection and coordinate system used on the topographic maps of the refuge area.

The third stage was the computer-aided categorization of the multispectral data into vegetation and land cover classes. This involves not only analysis of Landsat data but also visits to the field and reference to other ground truth. A filtering technique was used to reduce the salt-and-pepper look that characterizes many digital maps portraying spectral classes. Much of the classification work and its refinement was done through interactive computer graphics.

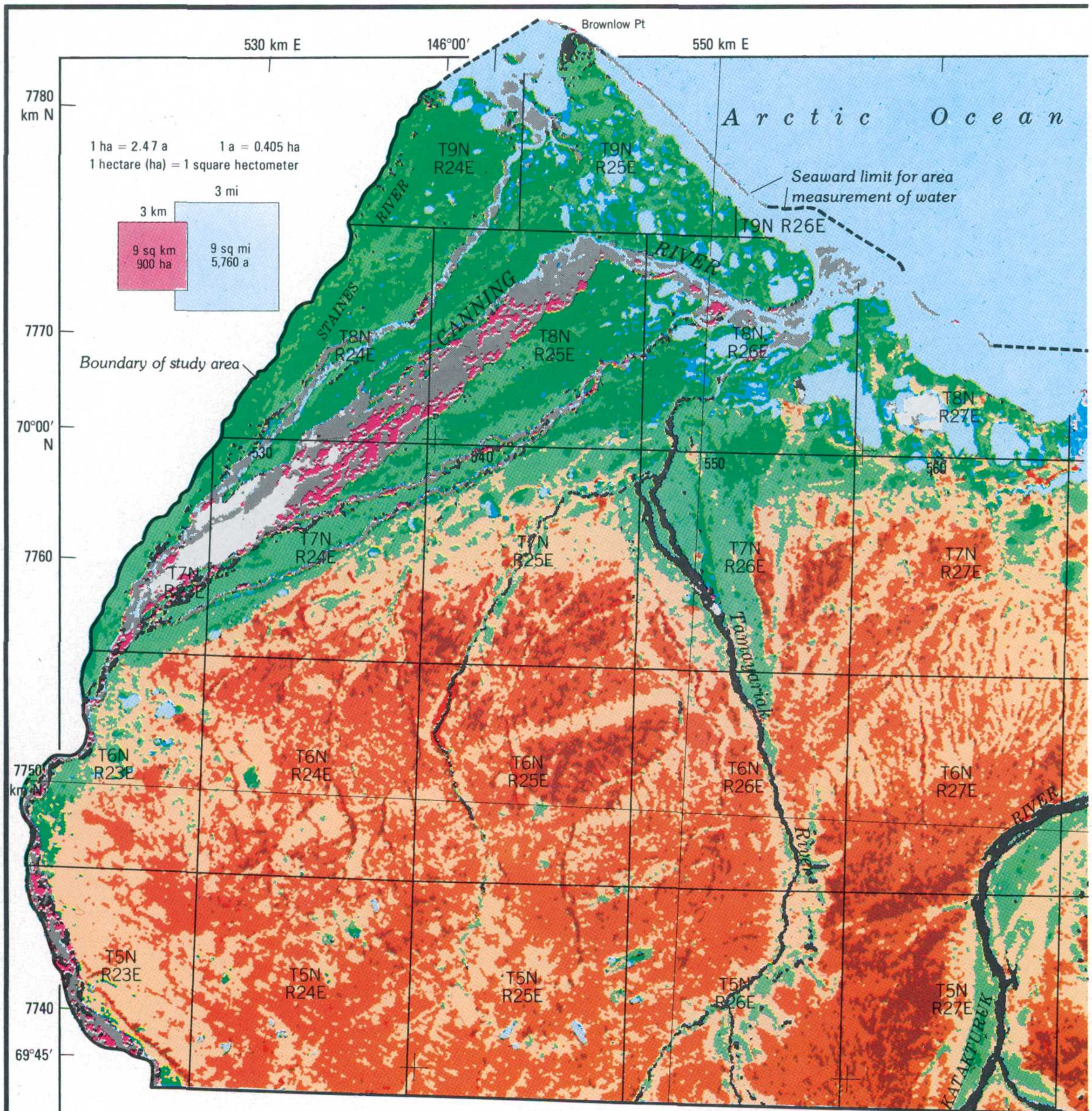
The fourth stage, after some iterations of the second and third stages, produced area measurements of land cover classes and some useful area subdivisions which are shown in the map legend. Data were aggregated by public land survey township; the township boundaries and corners were digitized from USGS 1:250,000-scale topographic maps. The computer calculates surface area simply by counting map cells by class and township.

The fifth stage was the application of computer graphics to the preparation of the theme data (and map base) for printing. The map base was adapted and redrawn by conventional methods from portions of four USGS topographic maps. To prepare cellular land cover theme data for printing, the computer operating the laser drum plotter read the file data (that is, a class code) for each cell. Then each cell and class was converted to a pattern of angled and sized dots. The dots were exposed directly onto publication-size dimensionally stable photographic film from which the printing plates were made.

Production of the map was just a portion of the research effort. Much work was also devoted to describing the vegetation communities and assessing map accuracy. A paper concerning the methods used in analyzing the Landsat data and describing the vegetation and soils as related to terrain was published in 1982 by CRREL as Report 82-37. An assessment of land classification accuracy was begun using data acquired during an August 1982 field trip. This aided in refinement of spectral classes and in compiling a description of the vegetation. Meanwhile, similar work was finished for the Prudhoe Bay region and data were prepared for printing a vegetation and land cover map for the 1:250,000-scale Beechey Point quadrangle.

Land Use and Land Cover Mapping in South-Central Alaska

The USGS and the Alaska Department of Natural Resources (DNR) are cooperating on a project to determine the feasibility of preparing open-file land use and land cover maps from digital data produced by the Environmental Systems Research Institute (ESRI). The demonstration area consists of the Talkeetna, Talkeetna Mountains, Tyonek, and Anchorage 1:250,000-scale quadrangles. ESRI produced an integrated terrain unit polygon map by compositing several natural resource overlays such as landforms, soils, vegetation, and land use. These overlays were prepared by interpreting high-altitude photographs, using 1:250,000-scale topographic quadrangles and Landsat mosaics as map bases. The categories in a modified USGS land use and land cover classification system were retrieved from the digitized integrated terrain unit map. The possibility of incorporating an urban overlay, mapped at greater detail than required by Alaska DNR, into the proposed USGS open-file product is being considered. In 1982, the experimental Talkeetna land use and land cover map was produced and reviewed.



Land cover class, dominant vegetation, and map surface area in acres, hectares, and percent

The total surface area shown is 1,640,627 acres (2,563 sq. mi.), or 663,952 hectares (6,640 sq. km.).

I. Water.—Ocean surfaces, and lake and river surfaces larger than 1 acre. (Area measurement excludes water surface outside seaward limit of study area.) .... 101,355 a (41,018 ha) (6.2 pct).

II. Pond/Sedge Tundra Complex; Aquatic Tundra; or shallow water.—Very wet tundra areas with ponds and/or emergent communities of *Carex* spp. or *Arctophila*; and up to 50% moist or wet tundra...16,964 a (6,865 ha) (1.0 pct).

III. Wet Sedge Tundra.—Wet tundra with little standing water or with up to half of surface area water-covered or emergent vegetation, or coastal areas periodically covered with salt water ..... 260,057 a (105,244 ha) (15.8 pct).

IV. Moist/Wet Sedge Tundra Complex; or Dry Prostrate Shrub, Forb Tundra (*Dryas* river Terraces).—Moist sedge tundra with up to 40% wet sedge tundra; or dense prostrate mat of *Dryas* on river terraces .... 270,565 a (109,496 ha) (16.5 pct).

V. Moist Sedge, Prostrate Shrub Tundra; or Moist Sedge/Barren Tundra Complex (frost-scar tundra).—Better-drained areas on rolling terrain sometimes with tussocks; or sparsely vegetated frost-scar tundra .... 434,512 a (175,845 ha) (26.5 pct).

VI. Moist Sedge Tussock, Dwarf Shrub Tundra.—Well-drained upland tussock tundra in foothills with high percentage of cottongrass tussocks and dwarf or prostrate shrubs .... 414,550 a (167,766 ha) (25.3 pct).

VII. Moist Dwarf Shrub, Sedge Tussock Tundra; or Moist Sedge Tussock, Dwarf Shrub/Wet Dwarf Shrub Complex (water track complex).—Upland tundra with shrubs to 50 cm high; or upland tussock tundra with shrubs in water tracks... 51,148 a (20,699 ha) (3.2 pct).

VIII. Shrub-Tundra.—South-facing slopes in foothills or subalpine, with willow, birch, alder to 2m; or dense shrubs in water tracks .... 3,142 a (1,272 ha) (0.2 pct).

IX. Partially vegetated areas.—Diverse habitats including river bars, alpine tundra and moss mats with barren rock and talus, lichen-covered, sorted stone-nets and beach or mud flats .... 27,678 a (11,201 ha) (1.7 pct).

X. Barren gravel or rock.—Bare light-colored river gravel, gravel and sand spits, alpine barrens (especially dolomite), and cultural barrens (road or runway), often with rich but sparse floras .... 27,642 a (11,186 ha) (1.7 pct).

XI. Wet gravel or mud.—Extensive barren mud in river deltas and wet or dark-colored gravel on beaches or river beds, or dark-colored barren rock in mountains .... 28,402 a (11,494 ha) (1.7 pct).

XII. Ice.—River icings in the braided stream channels of most larger rivers .... 4,612 a (1,866 ha) (0.3 pct).

7730
7720
7710 km N
69°30′
530 km E
146°00′
550 km E
145°00′

AREA MEASUREMENTS, by Survey Township and Land Cover Class, in Percent and Acres–*

Township and Class	Range E 23	Range E 24	Range E 25	Range E 26	Range E 27	Range E 28	Range E 29	Range E 30	Range E 31	Range E 32	Range E 33	Range E 34	Range E 35	Range E 36	Range E 37	Range E 38	Range E 39	Range E 40	Township and Class
T 9 N I		21.9	33.4	89.4						88.7	85.2	49.1	62.3	97.6					I T 9 N
II		4.2	8.4	0.7						0.2	0.5	4.7	5.1	-					II
III		64.3	42.0	7.0						-	6.2	17.0	16.4	-					III
IV		0.2	7.1	0.1						-	3.5	1.3	9.6	-					IV
V		-	0.4	-						-	0.3	0.4	1.3	-					V
VI		-	0.0	-						-	0.0	-	-	-					VI
VII		-	-	-						-	-	-	-	-					VII
VIII		-	-	-						-	-	-	-	-					VIII
IX		0.3	0.4	-						1.0	1.1	4.9	2.5	-					IX
X		2.9	3.0	0.6						5.3	2.0	3.7	1.1	1.4					X
XI		6.2	5.0	2.2						4.8	1.2	18.9	1.7	1.0					XI
XII		-	0.3	-						-	-	0.0	0.0	-					XII
Percent		100	100	100						100	100	100	100	100					Percent
Acres		10,954	16,148	1,755						2,655	13,718	13,876	10,795	2,146					Acres
T 8 N I		3.2	3.9	27.8	55.8	71.2		46.2	33.6	29.3	16.8	9.1	1.6	6.1	18.5	8.4			I T 8 N
II		1.9	2.3	8.1	4.1	5.6		2.5	1.4	1.7	3.3	3.3	1.3	5.6	2.0	1.0			II
III		70.1	64.1	43.8	21.7	13.4		8.5	9.5	28.7	36.7	24.3	45.0	31.7	38.0	23.7			III
IV		2.4	2.6	6.4	5.4	2.6		27.5	33.5	13.9	25.6	39.0	33.4	23.8	24.8	22.3			IV
V		0.0	0.6	2.2	5.8	3.4		11.9	17.4	3.1	7.7	23.3	11.1	28.5	13.6	36.2			V
VI		-	0.0	0.2	0.6	0.4		0.4	1.9	-	0.1	0.3	0.0	-	-	-			VI
VII		-	-	0.0	0.0	-		-	-	-	-	-	-	-	-	-			VII
VIII		-	-	0.0	0.0	0.0		-	-	-	-	-	-	-	-	-			VIII
IX		5.0	5.4	1.2	0.1	0.0		3.0	1.5	7.2	3.7	0.5	2.8	2.1	0.9	3.8			IX
X		2.4	2.3	2.0	0.2	0.3		-	0.1	1.9	1.4	0.1	3.0	1.6	1.1	3.1			X
XI		14.7	18.8	8.1	2.7	3.0		-	1.1	14.2	4.7	0.1	1.8	0.6	1.1	1.0			XI
XII		0.3	0.0	0.2	3.6	0.1		-	-	-	-	0.0	0.0	0.0	0.0	0.5			XII
Percent		100	100	100	100	100		100	100	100	100	100	100	100	100	100			Percent
Acres		15,724	22,910	22,773	15,491	3,838		235	10,593	20,280	22,152	22,469	22,314	22,602	18,013	5,286			Acres
T 7 N I	3.1	1.6	0.6	0.1	1.5	4.4	18.1	5.3	0.5	1.3	1.2	2.4	4.2	1.1	2.4	8.0	44.8		I T 7 N
II	0.4	0.8	0.6	0.3	0.8	0.1	0.5	0.1	0.5	0.3	1.3	1.6	3.2	0.8	2.1	0.8	1.4		II
III	42.7	25.8	13.6	26.8	8.1	29.7	10.0	0.6	2.9	33.7	20.1	23.6	30.9	7.6	26.1	12.8	21.5		III
IV	16.4	9.8	12.8	18.4	9.2	19.1	11.1	8.4	17.1	39.1	45.2	43.9	35.0	22.8	17.9	16.0	18.0		IV
V	3.1	19.2	36.2	28.3	48.3	29.6	38.9	52.4	47.3	16.4	27.3	27.3	17.8	65.9	47.1	59.0	7.9		V
VI	0.6	11.6	23.0	15.3	27.5	9.9	14.2	30.8	28.0	1.4	0.3	1.1	0.0	0.3	0.2	-	-		VI
VII	0.0	2.6	8.2	4.8	3.8	1.3	2.2	0.1	0.0	-	-	-	-	-	-	-	-		VII
VIII	-	0.6	1.3	0.5	0.8	0.1	0.3	-	-	-	-	-	-	-	-	-	-		VIII
IX	6.1	5.9	0.4	0.2	-	0.3	0.3	0.9	2.5	4.0	2.0	0.0	2.2	0.8	3.1	1.8	3.1		IX
X	6.1	2.4	2.1	5.0	0.0	5.2	2.1	1.2	0.3	1.4	1.8	0.1	4.8	0.6	1.0	1.2	1.5		X
XI	11.7	11.3	1.2	0.0	-	0.3	1.7	0.2	0.9	2.4	0.8	-	1.3	0.0	0.1	0.2	1.7		XI
XII	9.8	8.4	0.0	0.3	-	0.0	0.6	0.0	-	-	-	0.0	0.6	0.1	0.0	0.2	0.1		XII
Percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		Percent
Acres	7,915	23,126	22,873	22,840	22,828	21,071	19,867	17,217	22,118	22,406	21,951	22,202	22,055	22,137	22,167	21,657	7,607		Acres
T 6 N I	4.0	0.1	-	-	-	0.1	-	0.3	0.5	0.7	0.0	3.0	0.6	1.7	1.8	0.1	9.7	56.9	I T 6 N
II	-	-	0.0	-	-	0.0	-	0.0	0.8	0.1	0.1	1.7	0.8	1.3	1.1	0.1	1.0	4.8	II
III	11.8	0.4	0.2	1.5	2.2	2.2	1.7	0.3	2.4	16.6	3.1	29.8	18.6	22.1	25.5	27.6	49.7	31.9	III
IV	5.9	0.1	1.0	4.3	4.6	12.3	6.5	2.1	9.2	43.4	18.2	33.5	34.9	24.2	21.7	32.1	24.9	3.0	IV
V	45.4	25.4	30.7	36.8	32.6	36.1	32.6	21.5	35.9	26.6	65.8	29.6	37.4	48.8	46.4	35.6	12.4	0.1	V
VI	26.2	67.9	52.7	47.0	45.6	34.3	51.9	74.7	46.3	5.3	10.6	0.9	0.1	0.0	-	-	0.0	-	VI
VII	0.5	3.5	12.9	7.5	11.8	10.9	5.2	0.1	0.0	-	-	-	-	-	-	-	-	-	VII
VIII	0.2	2.6	1.7	0.4	0.4	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	VIII
IX	-	-	-	-	0.0	0.1	0.0	0.2	3.5	3.5	1.0	0.4	2.2	0.7	1.5	2.4	1.8	1.1	IX
X	0.3	0.0	0.8	2.5	2.8	3.8	1.9	0.8	0.8	1.7	1.1	1.0	4.6	1.1	1.9	1.8	0.3	0.4	X
XI	5.7	-	0.0	-	0.0	0.0	-	-	0.6	2.1	0.1	0.1	0.7	0.0	0.0	-	0.2	1.8	XI
XII	-	-	-	-	-	0.0	0.0	-	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	-	-	XII
Percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	Percent
Acres	15,856	22,395	23,166	23,164	23,017	23,011	23,052	22,487	22,309	22,519	22,137	22,342	22,287	22,378	22,360	22,256	22,139	7,411	Acres
T 5 N I	2.3	0.7	1.2	0.1	-	-	-	-	0.1	0.3	0.4	1.7	1.0	0.9	0.1	-	-	0.7	I T 5 N
II	-	-	-	0.1	-	-	-	-	0.4	0.1	0.2	0.8	0.6	0.4	0.1	0.0	0.0	1.6	II
III	4.7	0.6	3.3	1.7	4.9	0.3	0.1	0.4	4.8	8.1	6.3	14.5	14.2	8.1	10.9	36.2	58.9	63.1	III
IV	2.2	0.1	0.2	7.0	10.4	4.9	2.5	3.4	20.5	38.6	19.6	30.2	30.2	21.6	36.9	44.4	35.8	28.6	IV
V	52.3	32.4	42.9	29.5	23.5	18.8	11.5	6.1	30.0	25.0	38.8	37.0	43.4	61.0	50.1	18.0	3.7	0.2	V
VI	20.8	63.3	51.0	51.7	32.7	35.2	60.8	84.9	35.2	19.3	31.4	13.0	2.2	2.5	1.3	0.2	-	-	VI
VII	1.8	2.0	0.8	6.9	22.4	36.6	21.4	4.1	0.1	0.0	0.0	-	-	-	-	-	-	-	VII
VIII	0.5	0.9	0.5	0.1	0.7	3.7	0.4	-	-	-	-	-	-	-	-	-	-	-	VIII
IX	-	-	-	0.0	0.0	-	1.0	0.8	6.3	2.5	2.1	1.2	3.7	1.9	0.5	0.8	1.5	4.2	IX
X	0.4	-	0.1	2.9	5.4	0.5	2.3	0.3	1.9	3.7	0.8	1.0	4.0	2.9	0.1	0.4	-	-	X
XI	15.0	-	0.0	-	-	-	-	-	0.5	1.2	0.4	0.6	0.7	0.1	-	0.0	0.1	1.6	XI
XII	-	-	0.0	-	0.0	-	0.0	-	0.2	1.2	-	0.0	0.0	0.6	-	0.0	-	-	XII
Percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	Percent
Acres	13,089	22,658	22,463	23,185	23,220	23,000	22,537	22,464	22,220	22,409	22,149	22,302	22,151	22,379	22,343	21,322	12,197	1,894	Acres

Figure 13.--Portion of map I-1443 "Vegetation and Land Cover, Arctic National Wildlife Coastal Plain Alaska." Shown here at approximately 1:315,000-scale.

Land Use and Land Cover Statistics

The nationwide land use and land cover mapping program of the USGS began in 1974 and since that time approximately 65 percent of the United States (excluding Alaska) has been mapped. An important aspect of this mapping effort has been the development of digital data files which can be used to generate areal statistics of land use and land cover. Digital data for approximately 30 percent of the United States are currently available.

Current plans call for publishing reports, on a State-by-State basis, of acreages of land use and land cover with breakdowns by county, hydrologic unit, and areas of Federal ownership. State reports will be issued after the data have been compiled, verified, and formatted for publication. In addition to the acreage data, each report will include written and graphic descriptions of land use and land cover patterns within the State. Reports for 15 States are currently being prepared.

Level III Land Use and Land Cover Mapping in Connecticut

The State of Connecticut has identified a need for Level III land use and land cover maps which can be correlated effectively with water use and evapotranspiration coefficients to produce data for the Connecticut Water Use Information System and for developing water balance models for drainage basins in Connecticut. Research is underway to develop a Level III land use and land cover classification system including definitions and mapping specifications, to conduct mapping on test sites, and to develop documentation for training compilers to map the entire State of Connecticut using remotely sensed data and other source materials.

A preliminary Level III land use and land cover classification system has been developed with established category definitions (USGS Professional Paper 964, 1976). Residential areas are subdivided at Level III according to dwelling unit density, while commercial, services and institutional areas are classified according to percent of impervious surface and how much of it includes buildings. All sanitary landfills, past and present, are mapped using supplemental source material.

The USGS is cooperating with the State of Connecticut to produce Level III land use and land cover maps for the Broad Brook and Ellington 7.5-minute quadrangles and digital tapes of the land use and land cover, hydrologic units and political units data for these same quadrangles. Test sites covering the Norwich, Broad Brook, and Ellington quadrangles have been mapped and are being evaluated by State personnel. Changes may be made to the proposed classification system and specifications after review of the test site maps.

Assessment of Renewable Resources in the Tanana River Basin, Alaska

In cooperation with the Renewable Resource Evaluation Unit of the Pacific Northwest Forest and Range Experiment Station of the U.S. Forest Service, investigations were conducted using Landsat and digital elevation data to map resource cover types on a 20-million-acre area in the western half of the Tanana River Basin, central Alaska. The Forest Service is gathering the information as part of its overall mandate to conduct an inventory of Alaska's renewable natural resources.

Parts of seven Landsat scenes have been extracted and geometrically registered to seven 1:250,000-scale quadrangles covering the project area. Using digital techniques, the MSS data have been analyzed and classified into eight land cover classes. Digital elevation data for the same areas have been registered with the Landsat data to improve the overall accuracy of the final maps.

DEM Processing for Slope-Related Statistics

Digital elevation models generated by NMD may serve as input for a variety of analyses where terrain is a factor. One such application involved a project to assess landslide hazards. Percentage of slope was identified as a fundamental variable in any model that was to effectively predict the pattern of landslides in an area. The problem was to determine maximum and average slope percentage for 100,000 grid cells, each 100-m x 100-m, that covered six separate study areas.

Software was developed to generate slope-related statistics from DEM data and to aggregate the results for a specified grid configuration. Program control allows the user to alter grid cell size and the position of the grid which can represent a subarea of a DEM or span multiple DEM's. The resulting software not only provided slope statistics for the immediate requirements of the landslide hazard assessment model, but will serve broader applications that involve slope-related considerations.

Determination of Irrigation Potential

An investigation was conducted on the applicability of remote sensing and other types of spatial data in a geographic data base to determine the irrigation potential of the lands in the Lower Brule and Crow Creek Indian Reservations. A digital geographic data base was created for the reservations and contained: soil association and soil series data (where available); digital elevation data, primary and secondary road networks, public land survey network; land ownership; groundwater data; the 7.5-minute quadrangle boundary network; and a current land cover classification derived from digital Landsat data.

Changes in agricultural activity over a 6-year period were visually interpreted from 1:250,000-scale Landsat images. Center-pivot irrigation was estimated to have increased by over 10,000 acres during this period, whereas dryland agriculture acreages remained relatively constant.

The soils data, digital elevation data, and land cover data for the reservation lands were combined to produce four irrigation potential classes of excellent, good, fair, and unsuitable. Various layers of the data base were combined to generate map products or tabular information which could be used for Bureau of Indian Affairs management needs. Digital elevation data were combined with crop water use information to calculate potential electric power requirements for irrigation of selected land parcels. Map products showing irrigation potential, land ownership parcels, and the public land survey network were generated. Simultaneously, tabular data were produced to show the acreages of the various classes of irrigation potential associated with ownership parcels or sections of land.

Soil/Vegetation Inventories for Rangeland Management

Land resource inventories are a major activity for several Federal agencies such as the Bureau of Land Management and provide essential data for planning and management. Resource areas are stratified into sites of similar production and management potential prior to field sampling. Evaluation has been conducted on the feasibility and economics of using a digital data base comprised of MSS data, digitized soils maps, and ancillary information for performing such a stratification for the 3.7-million acre Grass Creek Resource Area in the Big Horn Basin near Worland, Wyo.

Three data sets were employed for mapping ecologically significant range capability classes: (1) a 21-class land use and land cover data set derived from Landsat data, (2) digitized soil series data, and (3) digitized boundaries of administrative allotments. Soils data were aggregated to form dominant range sites, which were merged with administrative allotments to create a range site/allotment overlay. Vegetation types (land cover classes) were mapped within range site groups, using a set of decision rules which aggregate land cover classes as indicators of ecological succession and trend for a given kind of rangeland. The final range capability classes were formed by merging the range site/allotment overlay with vegetation groups.

The grid cell data were converted to polygons and mapped as range capability classes at 1:24,000-scale. Each polygon was described in a tabular summary which lists the allotment, range site, dominant and subdominant land cover types, and acreage for each polygon.

The procedures correctly identified more than 90 percent of the soil/vegetation zones in the study area. Cost analyses indicate that the range capability classes can be mapped for less than 8 cents per acre, including the preparation of the digital data base from the basic source materials. The digital data base provides an excellent basis for allocating field data collection samples, and for developing thematic maps for post-inventory analysis and planning activities. Both the time and cost of resource inventories could be substantially reduced as compared to conventional techniques.

Alternate Data Sources for Soil Surveys on Rangeland

Public land management agencies do not always have detailed soil maps for all the land that they administer. Escalating costs and restrictive budgets are reducing the number of new soil surveys which can be scheduled. A cooperative study was conducted with the Soil Conservation Service and the Bureau of Land Management to determine whether the use of digital elevation and Landsat data together with photointerpretation techniques could provide information to reduce the field time necessary for soil surveys.

Slope interval maps were produced from DEM data for three 7.5-minute quadrangle areas in the Grass Creek Resource Area in north-central Wyoming. These slope maps were overlaid on orthophotoquads and combined with other ancillary data such as surface geology and general soil association maps. Photointerpretation procedures were used to produce physiographic maps which were then digitized and entered with tabular summaries into a data base. Landsat MSS data were used to produce spectral classifications of the three quadrangles. Tabular summaries describing each map polygon in terms of physiographic unit, slope, aspect, elevation, area, and spectral data values were then produced from the data base.

Sixty sites within the three quadrangles were visited in the field to evaluate mapping unit delineations on the physiographic maps and the Landsat spectral categories with respect to soils, vegetation, range sites, and overall physiography. These preliminary field evaluations confirmed the feasibility of this approach for producing aids for mapping soils and range sites.

Petroleum Resource Assessment of Undeveloped Federal Lands

The USGS is preparing a series of maps and associated statistics for assessing petroleum potential in undeveloped Federal lands in eleven Western States. These undeveloped lands are administered by the U.S. Forest Service, National Park Service, Bureau of Land Management, and U.S. Fish and Wildlife Service and include designated wilderness areas, wilderness study areas, areas under appeal, areas endorsed as suitable for inclusion in the wilderness system, and areas for which inventories are not complete.

Boundary data were collected on the Altek digitizing systems and processed through the Unified Cartographic Line Graph Encoding System (UCLGES) software. The source materials used for digitizing were BLM maps of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming, and an American Petroleum Institute map of Washington. Boundaries of potential petroleum provinces and geologic basins were also digitized and coded. Film positives were plotted on the Gerber plotter for each of the three polygon overlays of each State.

Software was developed to transform the data from the UCLGES format to the Geographic Information Retrieval and Analysis System (GIRAS) format. These data were then processed through the GIRAS software to perform polygon overlay calculations and, ultimately, to prepare graphics combining geologic provinces having petroleum potential with the various categories of wilderness areas. Area calculations (in acres) were also made for these combinations. Petroleum potential of these areas was further classified, by degree of potential, from low to high. Shaded plots and area calculations were generated using these criteria. The final product will be a series of maps showing the petroleum potential by type of area.

Rolla CUSMAP Project

In order to develop, test, and demonstrate the application of digital spatial data handling techniques to current mineral assessment requirements in the Conterminous United States Mineral Assessment Program (CUSMAP), the Rolla, Mo., CUSMAP Support Project was initiated in May 1982. In cooperation with personnel of the USGS Geologic Division and the Missouri Geological Survey, a digital geologic data base was implemented which incorporated diagnostic criteria for the occurrence of Mississippi Valley type lead-zinc (Pb-Zn) mineralization in the Rolla 1:250,000-scale quadrangle. The data base was used by the CUSMAP team and geoscientists to develop geologic models for evaluating the Pb-Zn potential of the Bonneterre Formation.

The Rolla data base consisted of seven layers of spatially encoded geologic information pertinent to the evaluation of Pb-Zn mineralization in the quadrangle. Limestone/dolomite ratios, anomalous base-metal concentrations, faults and fractures, brown rock, and digitate reef depositional facies within the Bonneterre Formation, as well as known Pb-Zn occurrences and the distribution of outcropping pre-Bonneterre lithologies were encoded as sets of points, lines, and polygons and digitally processed to create either continuous data arrays or proximity maps. Data sets digitized from available 1:250,000-scale maps were registered to a UTM grid within a field of 287 x 448 cells (each cell representing a ground area of 400-m x 400-m).

The data base was used to develop two diagnostic models. A regional model used three variables that characterized the entire quadrangle, and a restricted model used five variables--two of which were available for only a portion of the quadrangle. Assessments derived from these models generally corresponded with known Pb-Zn mines and mineral districts within the Rolla quadrangle, thus supporting the geologic reasoning and digital processing used to develop the models.

Three advantages were realized by using this approach in mineral resource assessment: (1) refinement of qualitative modeling decision rules used in the original Rolla CUSMAP study, (2) consistency in the application of the models developed in this study, and (3) refinement of assessment levels for describing Pb-Zn potential within the quadrangle.

Hydrologic Information System for the Black Hills

In cooperation with the USGS Water Resources Division, multiple spatial data sets were digitized and compiled into a hydrologic information system for the Black Hills, South Dakota and Wyoming. The data sets include digital elevations, land cover, geology, drainage lines and divides (digitized from 1:24,000-scale topographic maps), Landsat MSS data, and streamflow indices.

Geomorphic drainage basin measurements were used to characterize the surface landscape and near-surface materials. These include: (1) total drainage area; (2) main channel slope; (3) average basin slope; (4) stream length measured along the main channel from gage to basin divide; (5) stream length measured from gage to end of defined channel (blue line on topographic map); (6) valley length measured along the flood plain; (7) mean basin elevation; (8) average main channel elevation; (9) percent of basin area above 5,000 feet elevation; (10) percent of basin above 6,000 feet elevation; (11) area of lakes, ponds, and swamps; (12) area of lakes and ponds, and (13) forested area. These parameters, which were previously measured manually and visually, can now be derived from the data sets and related within the information system to streamflow indices by multiple regression procedures.

A part of the study has included investigation of new techniques for basin characterization and for display of results. The topographic relationships of the separate basins in the area are best seen on a shaded-relief map (fig. 14). If a more detailed study of the local topography is required, stereoscopic pairs in a shaded relief format (fig. 15) can be computed and displayed. Recent work has also produced color-coded lithologic and land use and land cover images on a shaded-relief base in both monoscopic and stereoscopic formats. Research is also underway to develop a procedure for automated delineation of drainage lines and drainage divides. If successful, this procedure could be used for an automated delineation of valleys and ridges.

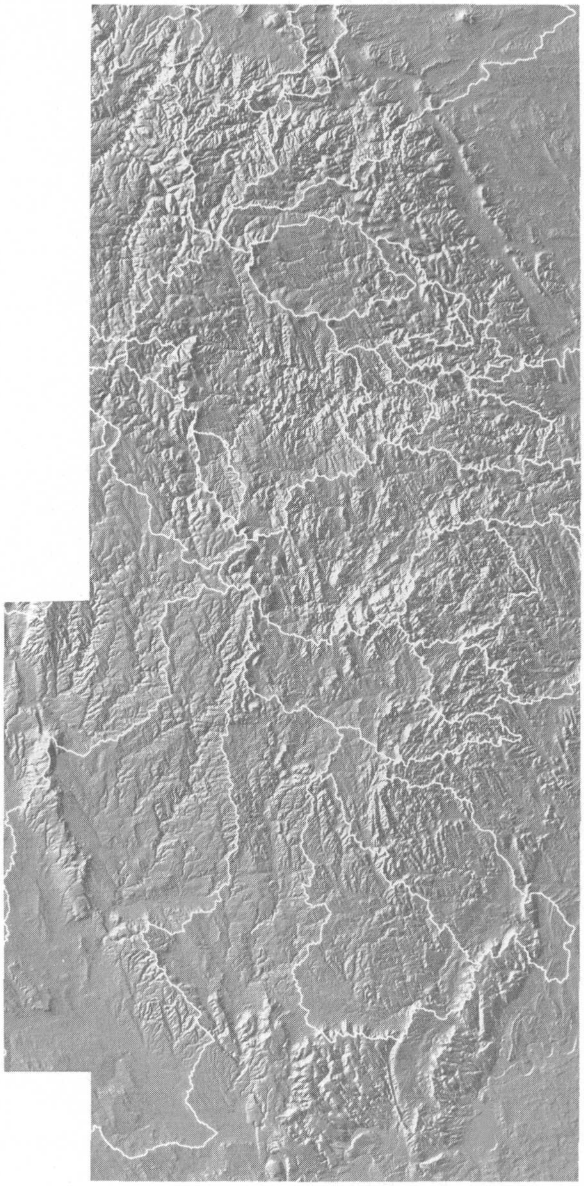


Figure 14.--Drainage basin divides in the Black Hills study area shown on a shaded-relief base, generated from 1:24,000-scale digital elevation data. Scale is approximately 1:876,000.

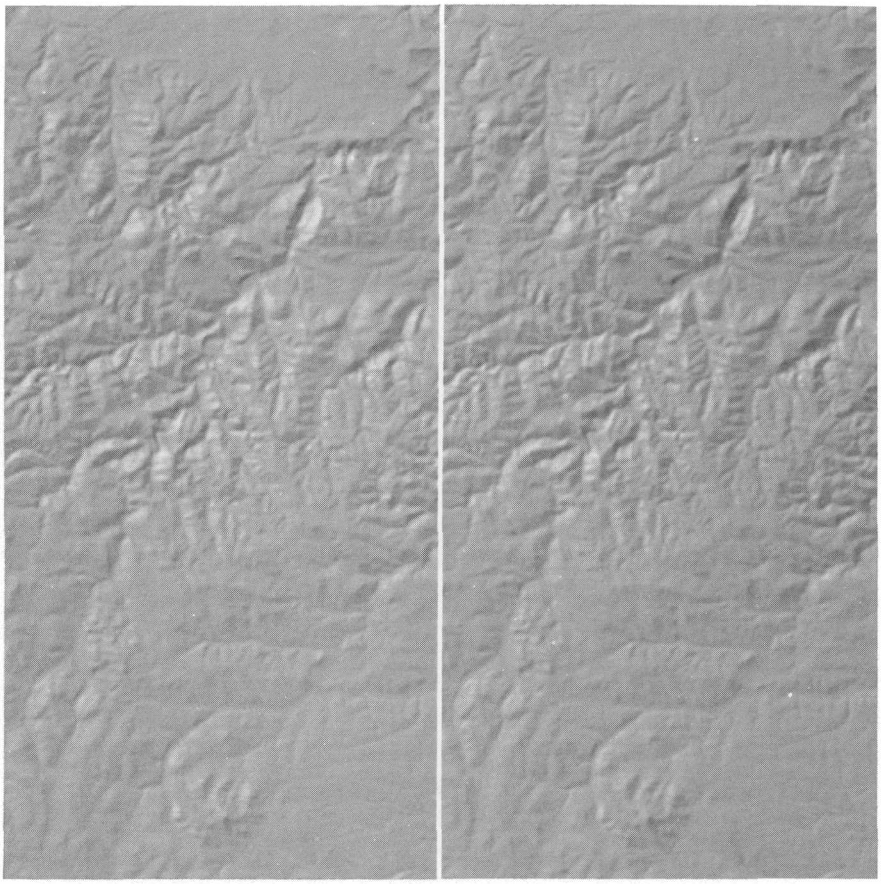


Figure 15.--Shaded-relief images of the Lead and Deadwood area, South Dakota (stereoscopic pair). Scale is approximately 1:219,000.

Land Cover/Terrain Mapping of National Wildlife Refuges in Alaska

Under the Alaska National Interest Lands Conservation Act, 1980 (ANILCA, Public Law 96487), the U.S. Fish and Wildlife Service (USFWS) is required to prepare a comprehensive plan for each national wildlife refuge in Alaska. Because of time and budget requirements, an analysis using digital Landsat and elevation data is being used to develop refuge land cover and terrain maps. The level of detail provided by the satellite data is adequate to meet USFWS planning needs.

The Kenai and Togiak National Wildlife Refuges: Digital data bases and map products that were developed during the summer of 1982 are being used to produce ecosystem/habitat maps and to refine vegetation maps. Parts of two Landsat scenes provided coverage for the 4-million-acre Kenai National Wildlife Refuge in south-central Alaska, and four Landsat scenes covered the 10-million-acre Togiak National Wildlife Refuge in southwestern Alaska.

Landsat MSS tapes and DEM data were registered to a 50-m UTM grid. Training statistics, used to computer-classify cover, were derived from representative sample areas, and qualitative and quantitative descriptions of vegetation cover were obtained at field sites within each sample area using a helicopter. The Landsat classifications and labelling of computer classes were performed on the Interactive Digital Image Manipulation System (IDIMS).

Products for the Kenai National Wildlife Refuge are: (1) land cover and terrain maps for the Kenai, Seldovia, and Seward 1:250,000-scale quadrangles; (2) 12 interpretive habitat maps for wildlife managers and planners; (3) digitized refuge and major watershed boundaries; and (4) acreage summaries for each of the land cover types within and adjacent to the refuge. Products for the Togiak National Wildlife Refuge are: (1) land cover and terrain maps for portions of the Bethel, Goodnews Bay, Dillingham, Hagemeister Island, and Nushagak 1:250,000-scale quadrangles; (2) digitized refuge, watershed, quadrangle, and management unit boundaries; (3) land cover and terrain maps at scales of 1:250,000 and 1:500,000 for the entire refuge; (4) maps and acreage summaries for ecosystem types by management units; and (5) a brown bear habitat distribution model based upon vegetation, terrain, proximity to cultural features, and proximity to salmon streams.

Bristol Bay Land Cover Mapping: The Alaska Fish and Wildlife Service (FWS), and the USGS cooperated in producing land cover maps for nearly 40 million acres in the Bristol Bay subregion in southwest Alaska. In addition, the USFWS has reformatted the land cover data for four national wildlife refuges to produce ecosystem and habitat maps which support the comprehensive planning mandated for these refuges.

Portions of 15 Landsat scenes were required to provide cloud-free coverage of the Bristol Bay subregion. The Landsat and terrain data were registered to a 50-m UTM grid from the 1:250,000-scale quadrangles. Both supervised and unsupervised training statistics were produced from 102 training blocks selected to represent the variety of land cover types in the region. Qualitative and quantitative descriptions of vegetation cover and associated conditions were collected from approximately 1,000 field sites within the training blocks using a helicopter and survey team. Final land cover classifications were produced in June 1982, after corrections to the preliminary classifications were made using terrain stratification and winter Landsat data to discriminate forested and wetland classes.

Land cover maps were produced in July 1982 for all or portions of 20 1:250,000-scale quadrangles in the Bristol Bay subregion: Afognek, Bethel, Bristol Bay, Chignik, Cold Bay, Dillingham, Goodnews Bay, Hagemeister Island, Iliamna, Karluk, Lake Clark, Mt. Katmai, Naknek, Nushagak Bay, Port Moller, Russian Mission, Stepovak Bay, Sutwik Island, Taylor Mt., and Ugashik. Digital data bases containing land cover, elevation, slope, and aspect data were produced for each quadrangle and for each of the four wildlife refuges.

Tetlin and Yukon Flats National Wildlife Refuges: Development of a data base and map products depicting land cover and terrain variables continued in 1982 for the 7 million acres within the Tetlin National Wildlife Refuge.

Field data collected in July of 1982 were used to label spectral classes derived in the modified-clustering approach adapted for this mapping effort. Information for the classification of the Landsat scene was derived from ground reference data and high-altitude color-infrared aerial photographs. Digital elevation data were also incorporated into the land cover analysis to stratify vegetation cover types into alpine, subalpine, and lowland categories. Classification problems caused by sun angle and mountain shadows were remedied by using elevation data and derived slope and aspect information.

An additional byproduct of the mapping effort within the Tetlin National Wildlife Refuge has been the development of an automated lake inventory that provides lake location, surface area, and a generalized description of water quality. Derived products will be especially useful for waterfowl management and planning.

The approach will be duplicated for the 8.63-million-acre Yukon Flats National Wildlife Refuge. A preliminary classification has been completed for each of the six Landsat scenes needed to provide coverage for the refuge area. Fieldwork was completed in August 1982, and the information is being used in conjunction with the high-altitude photographs to classify the MSS data. In addition to the traditional land cover and terrain maps and their associated digital tape files, the automated lake inventory procedure will be applied as well. Completion of the Yukon Flats National Wildlife Refuge project is expected in May 1983. A USFWS refuge manager has been trained to use the IDIMS system thus increasing the ability of USFWS to develop information for comprehensive planning required for all refuges.

Pipeline Corridor Analysis for Southern Alaska Peninsula

The Outer Continental Shelf (OCS) office of the Minerals Management Service (MMS) will be conducting major petroleum lease sales in the southern Bering Sea area during the next few years. OCS believes that a pipeline across the southern Alaska Peninsula, bringing the petroleum to a deep-water ice-free port on the southeast side of the peninsula, is the optimum method of transporting petroleum to market. Alternative pipeline corridors were identified and described so that MMS analysts could be more site-specific in their environmental impact analysis and could address fully the types of transportation and potential petroleum-related development for the Bristol Bay area management plan.

Possible routes were identified on digitally enhanced Landsat images using criteria such as closeness to natural harbors and avoidance of wetlands, active volcanoes, steep relief, and high elevations. These data were integrated with interpreted radar images (flown for USGS in 1981), land cover classifications, and available geologic information, including discussions with field scientists. Detailed resource information about the southern Alaska Peninsula is not generally available due to its remoteness and notoriously poor weather.

Eight alternative corridors were located within the False Pass, Cold Bay, and Port Moller 1:250,000-scale quadrangles. Using maps of physiography, geology, and land cover produced for this project, together with existing data on seismic and volcanic hazards, the corridor sites were ranked according to economic, environmental, and engineering criteria. One highly ranked route crosses a narrow isthmus at the head of Morzhovoi Bay, and another preferred route crosses the highlands in the central part of the Port Moller quadrangle, going up Portage Valley and down Johnson Creek to Albatross Anchorage as shown in figure 16.

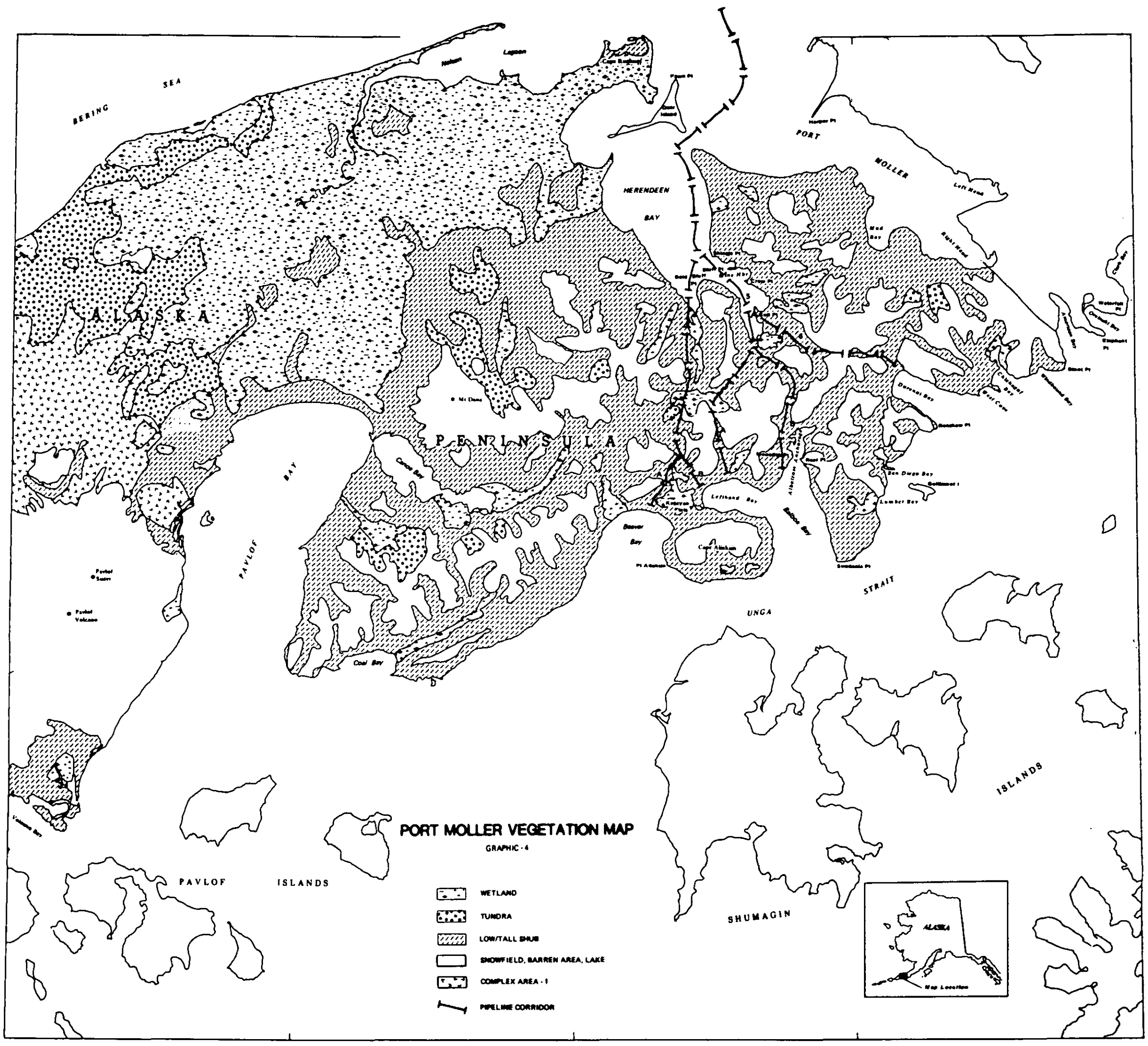


Figure 16.--Routes identified for petroleum pipelines across the southern Alaska Peninsula.

Uinta Basin Project

The Uinta Basin Project, which began in 1981, has undertaken (1) regional geologic analysis and interpretation of standard Landsat MSS images, (2) digital processing and interpretation of thematic mapper simulator (TMS) data, and (3) development and use of a digital geologic data base for petroleum resource evaluation.

To document the types and amount of geologic information that can be extracted from the MSS images and to establish a basis for comparing results of TMS data studies, systematic and comprehensive techniques of image analysis and interpretation were applied to a two-scene MSS mosaic covering the petroleum-rich Uinta and Piceance Basin regions of Utah and Colorado. The images were analyzed for landforms, drainage, cover type, and lineament characteristics. The results were used to construct a geologic map which compared favorably with the Utah and Colorado State geologic maps in defining regional lithologic and structural characteristics.

TMS data were acquired over selected areas in the Uinta and Piceance Basins using a multispectral scanner provided by the NASA Earth Resources Laboratory. The data were digitally processed and interpreted to determine improvements in sedimentary rock discrimination and identification possible using TMS data (and, by inference, Landsat TM data) as compared to Landsat MSS data. For every site studied, TMS data were clearly superior to MSS data (both optimally enhanced for lithologic discrimination) for discriminating sedimentary lithologies. By interpreting TMS ratio images in conjunction with narrow-band spectral reflectance data collected on the ground, the dominant lithologies of most units could be identified.

A digital data base comprised of geologic, gravity, aeromagnetic, geochemical, and other data is currently being developed for a portion of the Uinta and Piceance Basin regions. The data base will be used, in the context of a conceptual geologic exploration model, to identify those areas with the highest potential for the occurrence of petroleum.

The final activity of the Uinta Basin Project will involve processing and interpreting Landsat 4 TM data from selected sites for which TMS data were also collected.

OTHER ACTIVITIES

The National Gazetteer of the United States of America

In November 1982, the New Jersey volume became the first volume of the "National Gazetteer of the United States of America" to be published. The gazetteer for Delaware will be published in 1983, followed by similar volumes for Kansas, Rhode Island, Arizona, and Indiana. No timetable has been established for Gazetteer volumes for the remaining States or territories. All volumes of the "National Gazetteer of the United States of America" will be published as parts of USGS Professional Paper 1200, including an abridged volume containing names of major places, features, and areas for the entire United States.

Each gazetteer entry contains an official geographic name (spelling and form), feature class (type of place and feature named), official status of name, county in which it is located, geographic coordinates (with sources and mouths of rivers, streams, canyons, and valleys identified), elevation of place or feature, and the name of the USGS topographic map or the number of the National Ocean Service chart on which the feature is found. The USGS is researching and compiling additional information on names from various sources in addition to those names on the USGS topographic maps which provided the basic data for the gazetteer program.

Geographic Names Research

Recent activity includes a number of projects including standardization of geographic names and the development and maintenance of the national Geographic Names Information System (GNIS) and depository. This includes developing procedures for the preparation of names data covering the former U.S. Trust Territories in the Pacific, for the complete automation of the U.S. Board on Geographic Names data base, and for the preparation of an abridged gazetteer of the United States. Other work involved utilization of the Geographic Names Information System in automated name placement and other supporting activities of the National Mapping Program. Special emphasis is being directed toward further development of the national geographic names data base to allow users immediate access for specific names information and problem-solving. The data base is being expanded to provide a wider range of user services such as report capability and current information on the status of a name.

New methods are being developed to streamline the process of reporting of controversial names, name corrections on maps, and new names. Currently, reports on names are received in traditional paper format from other USGS offices and Federal and State agencies. However, the use of telecommunication methods to report names and other toponymic information is planned. A pilot study is underway to convert this information into new Board on Geographic Names docket lists to test the value of this new method in assisting the Board and State geographic names authorities in the decision process.

Research Photographic/Lithographic Laboratory

The photographic/lithographic research facility is presently equipped to support basic graphic arts research and steps to modernize this facility and upgrade the equipment to enhance its capabilities have been initiated. An artist's drawing of the proposed layout is shown in figure 17. Construction should begin by late 1983. Equipment recently acquired includes:

- 18- x 25¼-inch Heidelberg single-color offset press
- Tektronix computer graphic system (described in the article, Reprographic Data Processing System)
- Log E/Robertson Apollo copy camera
- 24- x 30-inch drum type Wilkinson processor for color paper/film
- 24- x 30-inch drum type Wilkinson processor for continuous-tone paper/film
- 30- x 40-inch drum type Wilkinson processor for lithographic film and screenless press plates
- 44-inch DuPont Cromalin color proof system

Some of the activities of the laboratory are described in the article, "Experiments in Lithography from Remote Sensor Imagery." Other activities include acquisition and acceptance of new and improved graphic arts equipment and materials, and the development of graphic arts techniques to improve map production operations using conventional and automated methods.

Office of Research Reference and Technical Information Collection

A limited collection of reference works dealing primarily with geodesy, surveying, photogrammetry, and cartography existed prior to the reorganization that formed the National Mapping Division in 1981. During the past year we have been in the process of sorting, eliminating, and arranging these materials and establishing guidelines for an expanded and current collection of reference materials for staff research. This collection will not duplicate basic and historical reference materials already available in the U.S. Geological Survey library.

An advisory committee was appointed to consider and recommend guidelines for subject categories, acquisition of materials, and maintenance of the collection. This committee prepared functional guidelines for the collection and requested staff input through a questionnaire outlining basic subject categories of reference materials and a list of currently received periodicals. Responses received from the staff indicated the following subjects are of high interest: automated data processing and computer sciences, cartography--particularly automated cartography, remote sensing studies and techniques, photogrammetry, photographic processes, geography, Earth resources, environmental studies, geodesy, and statistics.

GRAPHIC ARTS SYSTEMS SECTION
PHOTO/LITHO RESEARCH LAB

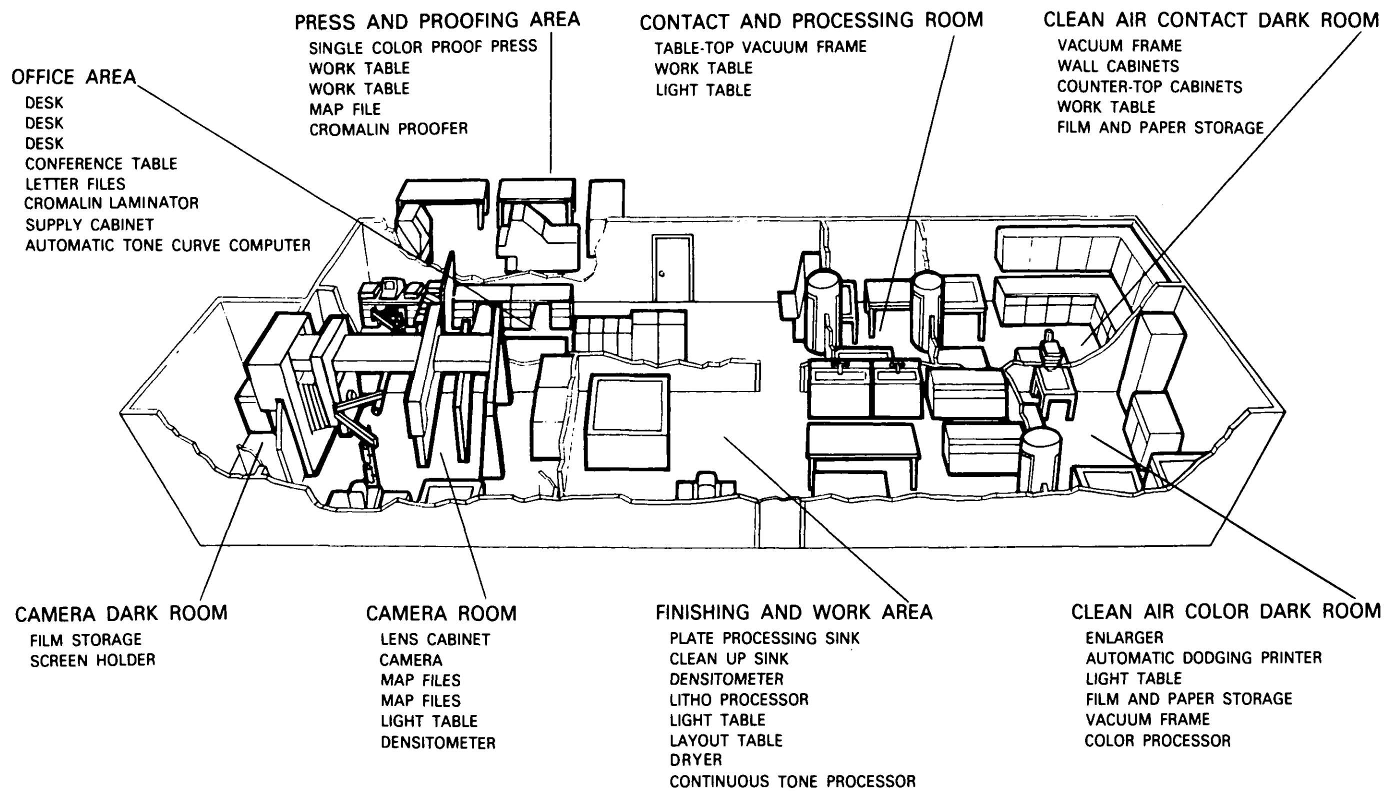


Figure 17.--Layout of equipment in the photographic/lithographic research laboratory.

The function of the reference collection is to provide access to scientific and technical information in the disciplines and areas of pertinence to the research aims of the NMD Office of Research. The collection also will include at least one archival copy of all published NMD research reports and experimental maps.

In order to carry out these functions the reference collection staff will:

- Maintain a current collection of materials including monographs, textbooks, meeting and conference proceedings, bibliographies, dictionaries, indexes and other reference works, atlases, and periodicals.

- Acquire new or additional materials in the above mentioned categories in order to achieve currency and definitiveness of the collection. Receive, classify and (or) catalog and shelve materials.

- Route and (or) provide for circulation, control, storage, upkeep and periodic disposal of unnecessary materials in the collection.

- Provide services for literature searching and compiling of special lists of materials or bibliographies.

- Maintain the NMD historical map collection, providing for its security and control.

- Maintain, classify and (or) catalog, store and control the geographic names reference collection.

Historical Map File

The NMD historical map file is an archival collection of every map and map edition which has been published and printed by the National Mapping Division and the former Topographic Division. Dating from about 1893, this valuable collection presently contains approximately 100,000 maps, with an annual addition of about 5,000 maps. Although this file is not intended for general research use, it serves as the only complete archive of maps published by the Division.

The file has been reorganized with recent maps integrated into the system and all maps placed in special protective boxes constructed from acid-free materials. Currently the Office of Geographic and Cartographic Research is investigating several methods for storing maps in a more effective manner which would better utilize the existing floor space.

Information Systems Network and Applications Software

Progress continued on a multiyear effort directed toward implementation of a high-speed computer network at EDC to support technique development, applications research, and product generation for a variety of spatial data sets and related applications. All computer systems to be included in the original network design were installed by April 1982.

Investigations of software protocol continued through the second and third quarter of 1982. Initial consideration of networking software provided by Network Systems Corporation was superseded by investigation of software acquired from the National Bureau of Standards, which offers a more successful networking system that is in conformance with projected Federal standards for local networking software. Upon acceptance of the NBS standard, software development proceeded throughout the remainder of 1982.

With development and implementation of a computer network at the EDC, design and development of applications software were initiated in early 1982. It was recognized that, although previous systems had concentrated on raster-based image processing capabilities, future applications would require addition of software capabilities to process vector data.

A network applications executive was required that would support a broad range of software functions, provide a user-friendly interface, support data input-output utilities and, in general, provide a software environment where individual applications could be easily installed and maintained while providing standardized user interface routines, system dependent routines, and file handling utilities. Investigation revealed such an applications executive was under development at the NASA Goddard Space Flight Center. This software, called the Transportable Applications Executive, was evaluated and a copy of the prototype software was installed in the third quarter of 1982. A limited number of applications are to be installed in early 1983.

A second element of the network environment is the operating system software used on each of the major nodes of the network. While each system was installed with an operating system provided by the vendor, further investigation has been directed toward the UNIX operating system developed by Bell Laboratories. UNIX can potentially be installed on each of the network computers to eliminate significant interface problems inherent between machine-dependent operating systems.

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