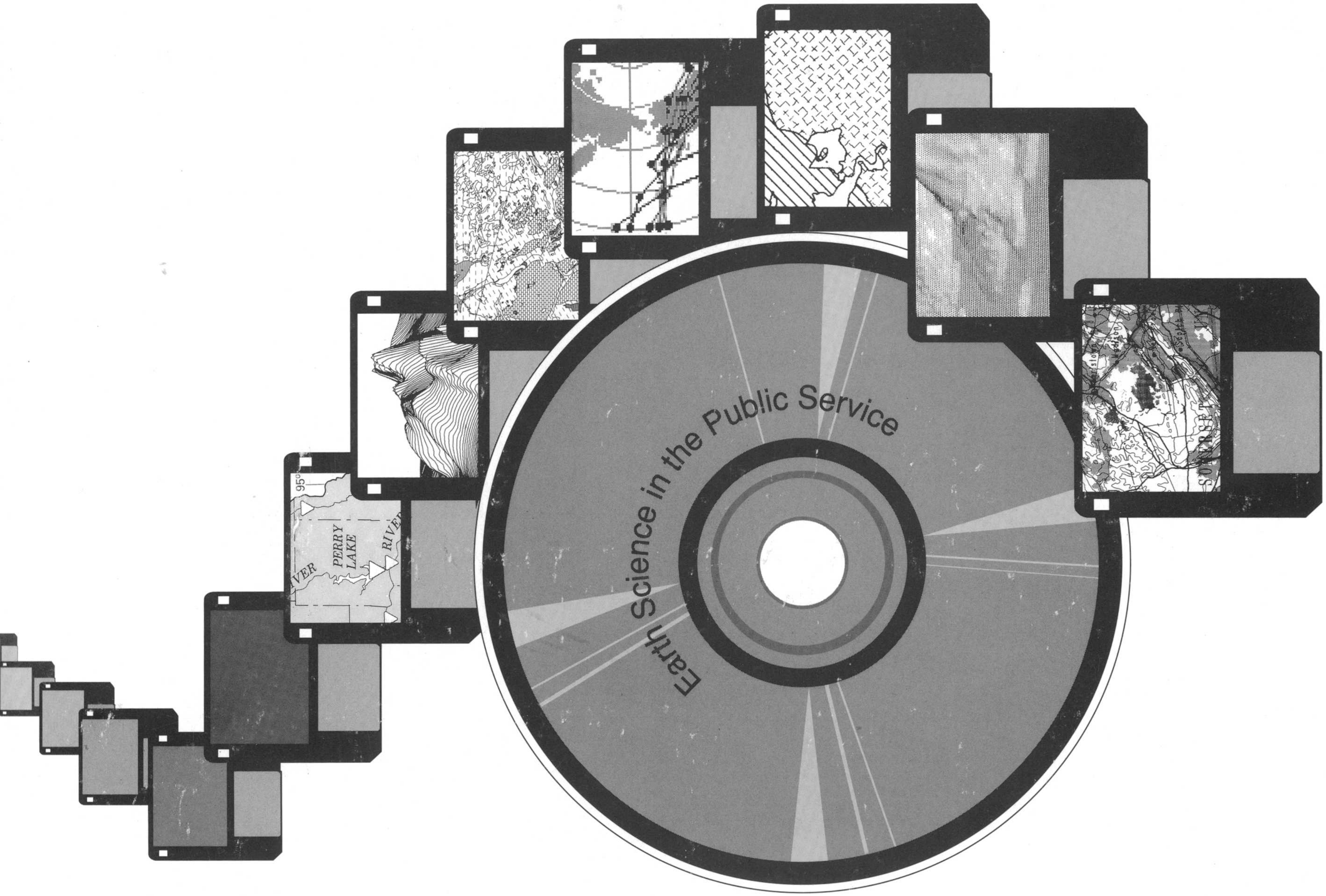
U.S. GEOLOGICAL SURVEY



1991

About the Cover.—A geographic information system (GIS) is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information; that is, data that have been identified according to their locations. Capturing the many types of data available and needed to make effective use of GIS technology is the time-consuming component of GIS work. The U.S. Geololgical Survey (USGS) is intensively involved in the acquisition of earth science data for use in GIS through its mission-mandated research and investigations. The theme chapter of this Yearbook describes many of the applications that the USGS is employing using GIS technology. In addition to the acquisition of the data, the USGS is involved in the coordination of geographically referenced or spatial data used in GIS. The backbone of GIS technology is reliable and usable data that can be easily disseminated to and accessed by the many agencies at Federal, State, and local levels, as well as the private sector, who use GIS to solve problems of resource assessment, land use applications, and environmental issues. CD-ROM (compact disk, read-only memory) technology is providing GIS researchers with an excellent medium by which to disseminate the vast files of spatial data that are crucial to GIS.

Counterclockwise from bottom:

Map produced by using a GIS (see p. 23).
Digital elevation data portrayed in a three-dimensional perspective view (see article, p. 96).
Digital geologic map of a section of southeastern Puerto Rico (see article, p. 4).
Arctic Data Interactive—Climate change data available on CD-ROM (see Information Systems Activities, p. 91).
Hypothetical seismic zonation map produced by using a GIS (see article, p. 7).
Digital map used in a GIS (see p. 23).
Areal distribution of atrazine concentrations in the lower Kansas River basin (see article, p. 76).

Back Cover.—The way maps and other data have been stored or filed as layers of information in a GIS makes it possible to perform complex analyses. The illustration on the back cover of the Yearbook is an example of a computer screen generated with a GIS. The information stored about the location, displayed here graphically, that can be retrieved from the GIS includes the latitude, longitude, projection, and coordinates of an exact location and additional information, such as the road system in the area, the closeness of a location to wells, sources of pollution, and the slope of the land (see p. 23).

U.S. GEOLOGICAL SURVEY YEARBOOK
FISCAL YEAR 1991

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., *Secretary*

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, *Director*

United States Geological Survey Yearbook Fiscal Year 1991
ISSN 0892-3442

UNITED STATES GOVERNMENT PRINTING OFFICE: 1992

For sale by the Book and Open-File Report Sales, U.S. Geological Survey
Federal Center, Box 25286, Denver, CO 80225

CONTENTS

Message from the Director

For centuries, maps and geographic information have helped people understand and manage their environment. From simple street plans to complex representations of land surface, maps have helped form our understanding of the Earth. The advent of the satellite era and new remote sensing technologies allowed us to view our home from space and to collect global data. Great advances in computer technology permitted scientists to compare massive amounts of information and to develop new insights into the land on which we live. Our view of the Earth began to change. Today we are combining the strengths of traditional printed maps with the force of remote sensing data and the power of modern computing in geographic information systems (GIS) to help us visualize new ways of understanding and managing our planet.

The U.S. Geological Survey is using GIS technology for such diverse projects as tracing the distribution of glacial sediments in three dimensions to assist in accurate assessments and balanced use of our Nation's resources. These powerful computing tools also allow scientists to pinpoint geological hazards so that realistic prevention, mitigation, and disaster response measures can be taken. Actions to protect or restore water supplies are aided by the complex analyses that can be handled efficiently by using GIS. By applying GIS technology in such areas as water resources protection, land management planning, and natural disaster prevention, scientists are providing citizens, resource managers, and decisionmakers with vital environmental information faster than ever before.

The USGS is not alone in creative uses of GIS. More than 95 Federal agencies are using GIS, and thousands of State and local government agencies and private companies are tracking land use and ownership and making land management decisions with this new technology. The success of GIS technology is based firmly in the availability of high-quality digital data. Developing those data is a considerable challenge, and billions of dollars are being invested each year to meet these expanding data needs.

The Secretary of the Interior has been assigned the challenge of coordinating the Federal Government's geographic data activities as head of the recently established Federal Geographic Data Committee. Interior Secretary Manuel Lujan, Jr., has asked the USGS to chair this committee on his behalf. Serving as the broker between data users and producers and attempting to ensure that appropriate, high-quality data are available at the lowest possible price, the USGS is coordinating with other agencies within the Department of the Interior, as well as with the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, State, and Transportation. We are also working closely with the U.S. Environmental Protection Agency, Federal Emergency Management Agency, Library of Congress, National Aeronautics and Space Administration, the Smithsonian Institution, and other independent agencies.

This year, the Survey's mission of "Earth Science in the Public Service" was put to the test before, during, and after the eruption of Mount Pinatubo in the Philippines. Countless lives and billions of dollars in equipment were saved through the hard work, sophisticated instrumentation, and dedication of all involved. The USGS, government of the Philippines, Philippine Institute of Volcanology and Seismology, Department of Defense, and Agency for International Development worked together as a team during the volcanic crisis. Because of the quick deployment of monitoring equipment and the preparation of a volcanic hazards map by Filipino and USGS scientists, there were accurate warnings of impending eruptions. The effective communications among the governments and agencies involved and the confidence in the professionalism of all the scientists and officials ensured that the cooperative effort at Mount Pinatudo was both a scientific and a humanitarian success.

USGS water resources monitoring programs, such as tracking the effects on water quality of pesticide use in the Nation's agricultural regions and studying potential interactions between ground water and low-level radioactive waste, provide the information and understanding to support the President's water-quality initiative. In 1991, National Water Quality Assessment program studies that began at 20 sites across the country are the first phase in an eventual 60-site assessment of trends and changes in the quality of the Nation's water resources.

Understanding how Earth systems interact is a complex challenge. The use of GIS, the hazards work at Mount Pinatubo, and the National Water Quality Assessment are but three examples of how the USGS is working to advance our understanding of the Earth to help guide environmental and resources development policy in the future.

Cooperative agreements and integrated data enhance USGS investigations into the fundamental processes that mold our planet. As we gain insight into these processes, we will be better equipped to assist the agencies of the Department of the Interior, and other government and private groups at all levels, in reaching our shared stewardship goals and ensuring the preservation and enjoyment of our rich natural resources today and for the future.

Dallas L. Peck

Introduction

Geographic information systems (GIS) technology is a vital part of USGS operations in mapping, data analysis, publishing, and building State and Federal cooperative programs. Although GIS technology is adaptable to a wide variety of uses, many challenges must be faced to use it to deliver "Earth Science in the Public Service." These challenges are being met by USGS scientists and technicians who are replacing existing methods with new procedures that are made possible by GIS. Effective data management is vital to the success of every GIS application because data comprise 50 to 80 percent of the total project cost. The Federal Geographic Data Committee (FGDC) efforts in coordinating data and information collection provide a focus for the diverse activities of the 14 member agencies that collect, use, and publish geographic information in digital form. The information sharing that is promoted by the FGDC is the cornerstone of the geographic information base of the United States.

The analytical and graphic output capabilities of GIS allow scientists to more easily portray the results of their studies in mapping surface and bedrock geology, in assessing energy, water, and mineral resources, and in delineating geologic hazards. The map units on the glacial sediments map (see article below), for example, were too small to be printed using traditional peelcoat methods, so the author used GIS technology. Derivative maps that once were produced by manual drafting can now be made by combining digital data sources using GIS software. Combining the many maps that geologists use to assess mineral resource potential demands the storage, retrieval, and overlay capabilities of GIS. Similarly, geologic hazards maps require geologists to combine information from many sources and produce maps for publication. The Water Resources Division Regional Aquifer-System Analysis (RASA) program uses GIS from initial planning to final publication. Timeliness is particularly important in delivering our scientific information to the public and to policymakers. Therefore, the speed gained in analysis and publication is an important GIS benefit.

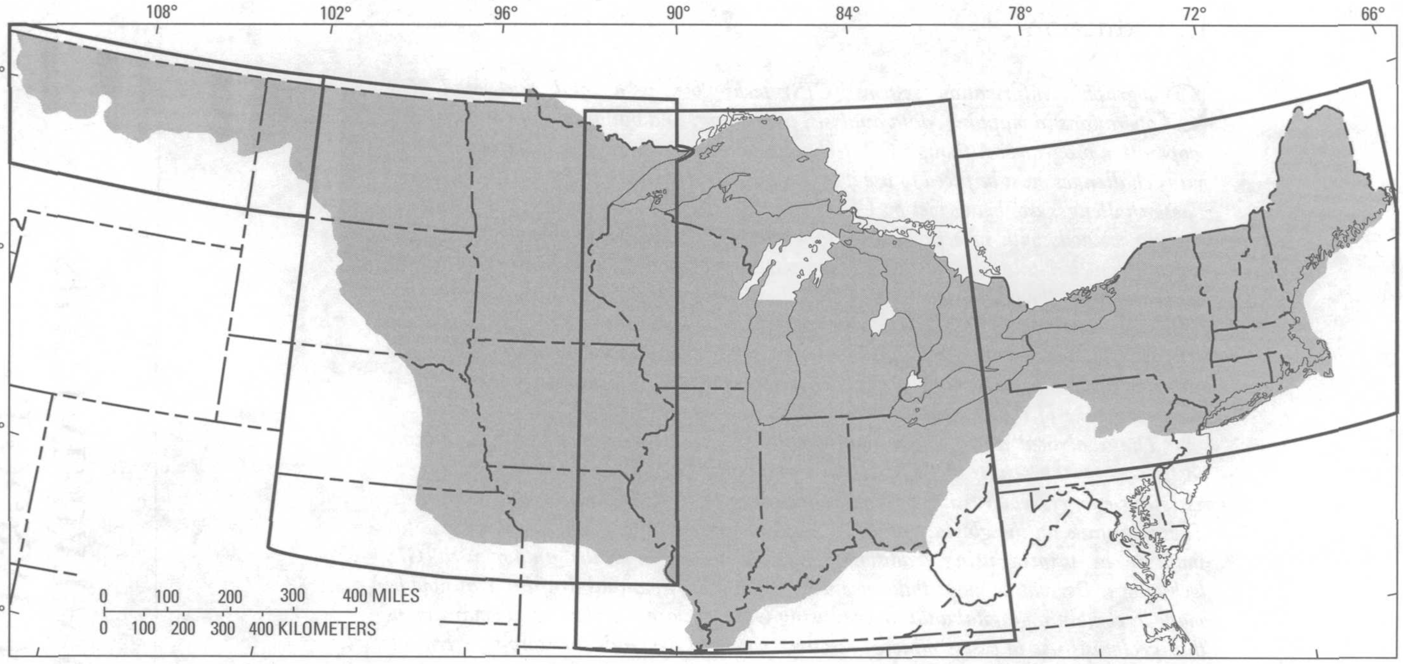
The tremendous storage capacity of compact disc, read-only memory (CD-ROM) makes CD-ROM an excellent and cost-saving medium for the larger digital data sets used in GIS. Each disc holds 640 million bytes of information, enough to accommodate, for example, all the 1:100,000-scale transportation and hydrography maps for the State of Florida. The cost of producing and publishing a CD-ROM is comparable to that of standard map publication. As CD-ROM readers become more available, and because the dics are durable and require relatively little storage space, this technology will be an increasingly important aspect of GIS operations in both the private and public sectors. The innovative uses of GIS described in the following articles provide a glimpse into the variety of ways the USGS is implementing this expanding technology.

Glacial Sediments Map: A Three-Dimensional GIS Product

By David R. Soller and Nick Van Driel

Human impacts on the Earth's physical and biological systems, through the use of resources, disposal of waste, agricultural operations, and construction, have accelerated over the decades. Recently, public awareness of and the motivation to address the management of our resources have also increased. As a result, resource management has become a complex task demanding an interdisciplinary approach that may consider economic theory and societal preferences as well as a variety of earth science and land use data bases. Computerized data bases and GIS technology can can improve such studies because they make it easier to exchange information, present data, and analyze multiple data bases. The USGS is producing new categories of information in both traditional and digital formats that can be adapted to many uses. This information ranges from water quality information at specific places (wells, for example) to geologic or land use maps of large areas.

A regional geologic map showing the extent of glacial deposits in three dimensions is currently being converted into digital (computer-readable) format and developed into a GIS data base to help solve land use and environmental issues. The map shows the thickness and character of Quaternary sediments in the continentally glaciated United States east of the Rocky Mountains, at 1:1,000,000 scale (in other words, a 1-inch distance on the map is equivalent to about



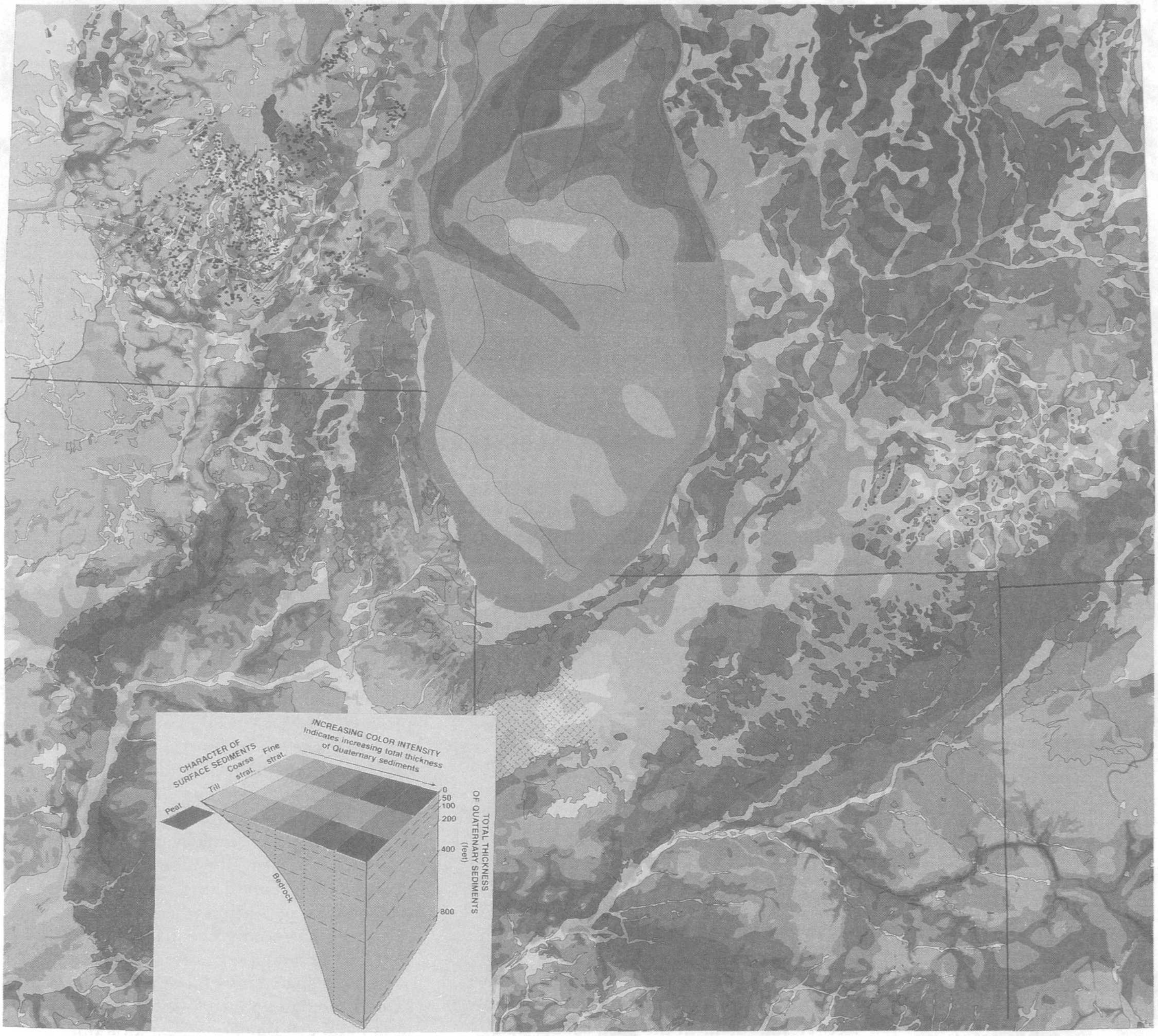
Area covered by map shown in gray. The map will be printed as four sheets (outlined in thick black lines; middle sheets overlap).

16 miles on the land surface). The term Quaternary refers to the glacial and modern-day sediments that lie at land surface above older geologic units. The map includes parts of 23 States and Canada and provides a regional context for the more detailed mapping required to make land use decisions about specific sites. The map area encompasses more than 2.1 million square kilometers, or about one-quarter of the area of the conterminous United States. That area supports about 40 percent of the United States population as well as much of the Nation's agriculture and industry.

Modern geoscience maps contain useful information that is applicable to resource management and environmental issues. To address these issues most effectively, the information must be in a directly usable format; that is, no additional interpretation is necessary. These maps are useful, for example, in the management of ground water resources and the assessment of the effects of different land uses. Typically, such a map shows the texture of the rock and sediments (porous sandstone or glacial lake clay and silt, for example) in three dimensions and to depths of at least 50 meters. Directly usable information is needed because the people who must use the information for land use planning, promulgating regulations, or ensuring compliance are rarely geoscientists. These issues require specific information, and if that information is not presented clearly on available maps, a land use planner must either reinterpret the available information or decline to use it.

Increasingly, more map users are requiring map information in digital form. Commonly, this digital information is examined in conjunction with other types of information in a GIS. For example, geologic map information may be displayed and analyzed with hydrologic or land use information to establish or clarify relationships. Such analyses are especially useful for environmental or land use issues because they are interdisciplinary and therefore require many types of information for a comprehensive study. New map information can be derived from such analyses; such maps are commonly referred to as derivative maps. By providing geoscience information in digital form and using a GIS to make derivative maps customized to the needs of the user, the USGS is creating more opportunities to use the earth science information collected in its research and mission-related investigations.

Digitization and preliminary analysis of the Quaternary sediments map has involved a number of cooperators from different government agencies, which reflect the range of interest and applications for this type of geologic map. Funding and personnel needed for processing and analysis were provided by the USGS, the U.S. Environmental Protection Agency, and certain State agencies. This interdisciplinary and interagency effort will produce not only a digital version of the map, but also new procedures for digital processing and display of map data and models and



derivative maps designed to address specific societal issues.

Certain areas on the Quaternary sediments map are already being tested for applications to societal issues. For example, a GIS method is being developed to identify potential ground-water aquifers and to rank sequences of geologic materials for relative contamination potential. This information will provide a regional perspective on the issue that can enable planners and officials to better support their decisions on the use of agricultural chemicals in the U.S. midcontinent and the potential for contaminating ground water. By using GIS methods, interrelations among information on the Quaternary sediments map and other categories of information (for example, geophysical, elevation, soils, or hydrologic) are also being investigated. In certain cases, derivative maps will be produced from these investigations. The Quaternary sediments map also is being studied for applications of geologic information to risk-based economic decisions. This type of economic analysis using earth science information represents an emerging discipline that links GIS, spatial statistics, and both point and areal geoscience data sets and offers a new approach to viewing spatial data and new arenas for the use of geoscience data.

Black and white image of part of the map in preparation, which will be printed in full color. Darker tones indicate areas of thicker glacial sediment (see block diagram). Map area is centered on southern Lake Michigan and includes parts of Michigan, Ohio, Indiana, Illinois, and Wisconsin (clockwise from upper right).

GIS Technology—Applications to Assessing Mineral and Energy Resources

By W. David Menzie, Walter J. Bawiec, and William H. Wright, Jr.

The assessment of the Nation's mineral and energy resources is one of the basic mandates of the USGS. A resource assessment is used to estimate the amount of identified and undiscovered energy and mineral resources present in an area. These assessments are useful for land use planning, for formulating national policy, and for planning exploration programs. The assessments include an inventory of identified mineral deposits, or oil and gas fields; a delineation of terranes that may contain oil and gas fields or particular types of mineral deposits; estimates of the numbers of undiscovered oil and gas fields, or mineral deposits present in the terranes; and size distributions of the oil and gas fields, or grade-tonnage models of the mineral deposits. Because oil and gas fields and mineral deposits are of different types and reflect the different earth processes that form them, the geologist must synthesize many different kinds of data depending on the types of deposit that may be present in an area. GIS technology is playing a growing role in collecting, editing, manipulating, and analyzing the data used in these assessments and in disseminating and interpreting the implications of the assessments.

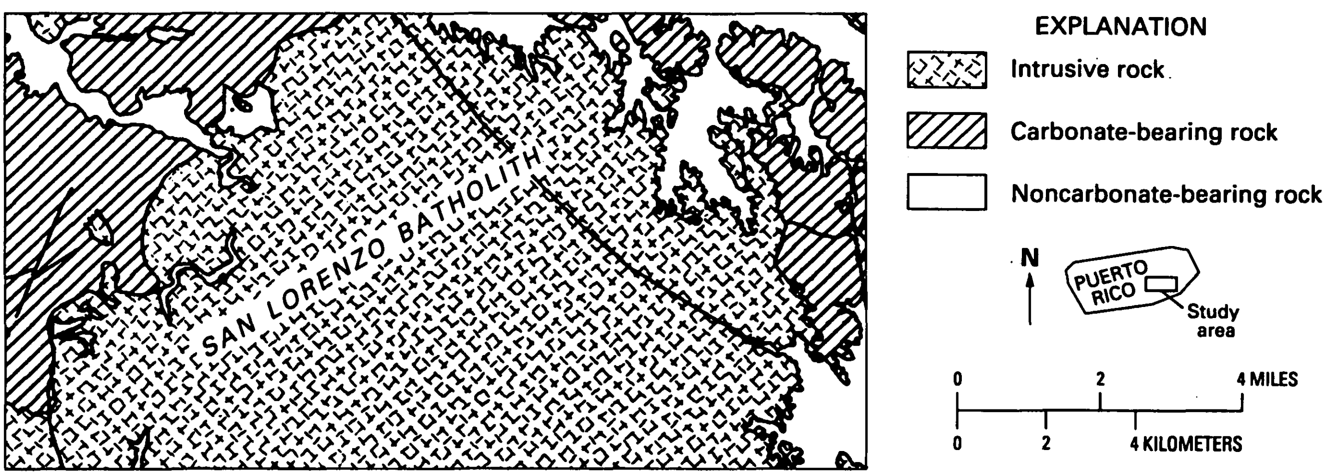
The first and most basic task in preparing a mineral or energy assessment is to collect relevant data. In the past, spatial data were collected and analyzed mostly in hard copy form such as maps. While the capture of spatial data in digital form is often time consuming, it permits a faster, more thorough analysis of the data than was previously possible. The USGS has experimented with several strategies for capturing spatial data, including optical scanning using drum scanners and hand digitization using both GIS and specialty software, such as GSMAP. In using optical scanners, the efforts spent in preparing the material to be scanned save significant effort in editing the data. Once spatial data are captured, GIS software is used for editing and for preparing structured spatial data sets.

An example of the type of information that increasingly is being captured in digital form are geologic map data. Preliminary compilations of geologic contacts, faults, and other features can be hand digitized or scanned, edited, and combined with digital files on terrane and administrative boundaries to produce structured geologic data sets. GIS technology facilitates the preparation and editing of geologic data sets because special plots can be prepared that emphasize one particular aspect of a map, such as the distribution of one rock unit.

GIS technology plays several roles in the analysis and manipulation of energy and mineral resource information. First, individual spatial data sets may be easily transformed to produce new data sets that are relevant to a particular energy or mineral problem. Examples of this type of application include combining particular rock units in a geologic data set or filtering of electromagnetic data. One of the roles GIS technology can play in mineral and energy investigations is in combining geologic, geochemical, and geophysical data sets to aid in predicting where additional resources may occur. The ability to easily combine such data sets offers an opportunity to develop spatial mineral deposit models that extend the descriptive models currently used in mineral assessment and exploration.

Perhaps the greatest potential use of GIS is as a vehicle for ensuring that earth science

Figure 1. Digital geologic map of southeastern part of Puerto Rico.



information is considered in setting public policy on a variety of energy and minerals issues. For example, GIS technology can be used to evaluate the potential impact of proposed land use plans on energy and mineral exploration or to evaluate the affect of mineral and energy development upon the environment. GIS technology is ideally suited to identifying where potential land use conflicts may occur and to calculating how large an area may be affected.

Finally, having spatial data in a GIS facilitates dissemination of the data to the public and interested users. Structured spatial data sets can be easily converted to common formats, such as digital line graph, and released with visualization software on a CD-ROM. CD-ROM's can store large amounts of data (750 megabytes) and are a suitable archiving media. The USGS has established a new publication series, the Digital Data Series (DDS), for the release of large data sets. One of the first releases in the new series is the digital Geology of Nevada, USGS DDS–2 (see article, p. 20).

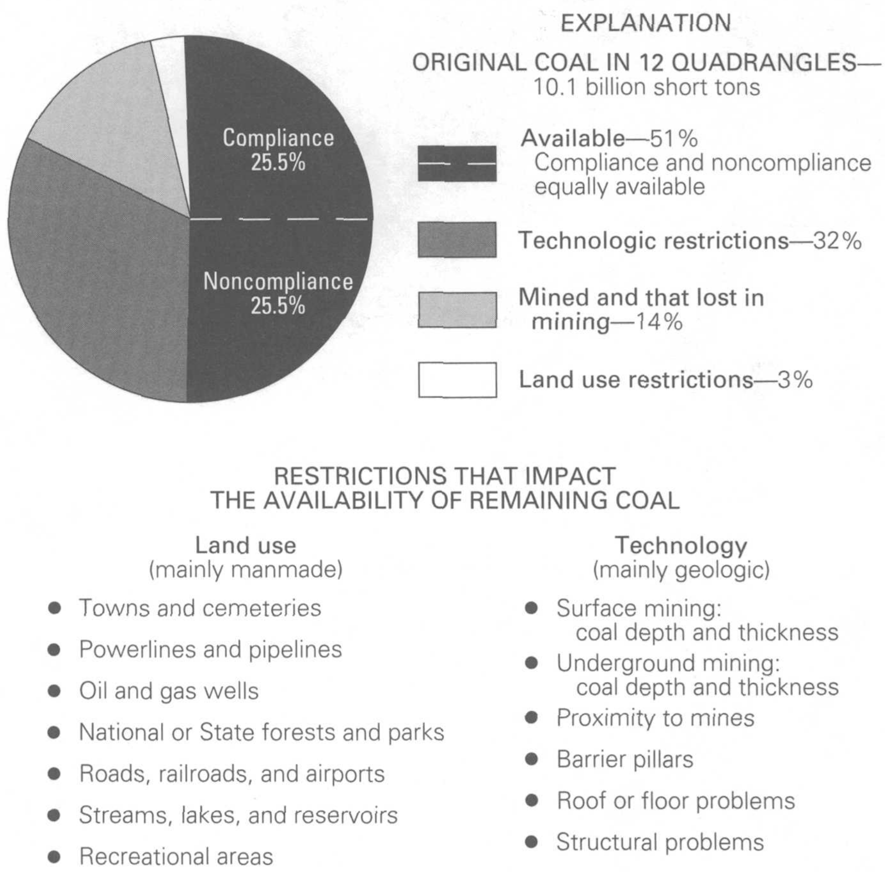
Mineral Resource Assessment of Puerto Rico.—To assess the mineral resources of Puerto Rico, a special project currently is being conducted within a GIS environment. A large number of data sets, including a new geologic map, gravity, magnetic, stream sediment geochemistry, mineral occurrences, and side-looking radar data have been captured in digital form. These data are being combined to delineate terranes that may contain undiscovered deposits. The data sets that are combined vary depending upon the type of deposit thought to be present. For a region such as Puerto Rico that may contain a number of deposit types, being able to combine various data sets digitally can save significant effort. Figure 1 presents an example of how GIS technology can be used to delineate tracts that may contain undiscovered mineral deposits. Carbonate-bearing rocks adjacent to intrusions often host skarn deposits of iron, copper, lead, zinc and gold. Using rock units that may host undiscovered deposits as a starting point, a geologist can add information about known mineral deposits, exploration geochemistry, and geophysics to better predict future deposit localities.

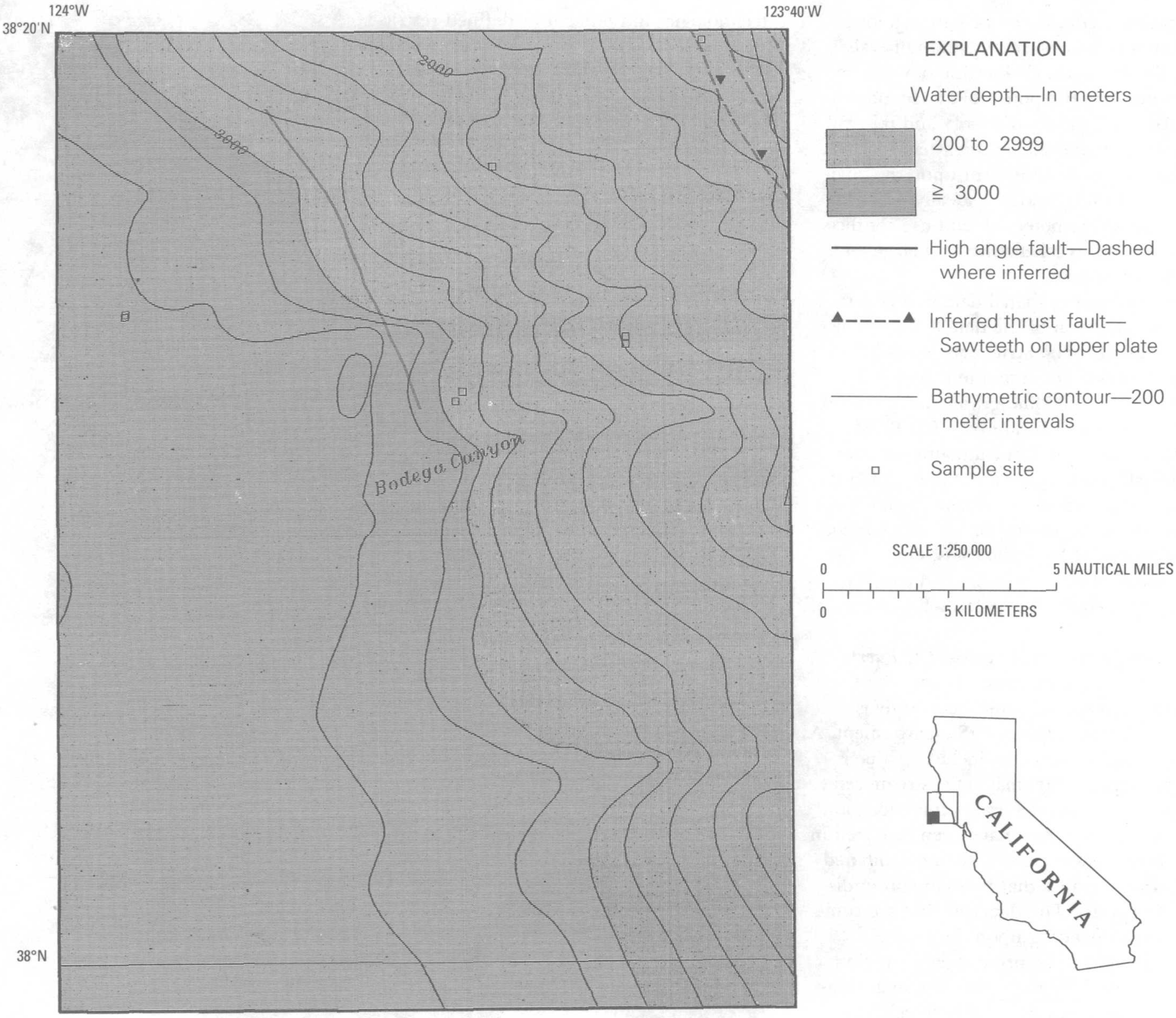
Coal Availability Studies.—GIS technology is rapidly becoming the norm for assessing energy commodities. Coal availability studies are a prime example of GIS technology in action. These studies, conducted in cooperation with State geological surveys, provide the capability to estimate the amount of coal available for production in a given area (usually a 7.5-minute quadrangle), after land use, technologic, and other user defined restrictions (such as coal quality) are taken into consideration (fig. 2). Many of the land use restrictions are fixed; that is, there is little likelihood that they will change—they are, however, modifiable within the GIS system. As extraction technologies change, the system can be updated to reflect these changes, and, if assumptions as to what constitutes compliance coal change, they too can be introduced into the system. After changes are made, the estimating program can again be run to determine the impact of the changes on the estimated amount of coal available for production in the study area.

Through fiscal year 1991, coal availability studies of 18 quadrangles in the Central Appalachian coal region in Kentucky, Ohio, Virginia, and West Virginia were completed. Results of these studies bring into question the estimated 200- to 300-year supply of coal currently being used by energy planners.

In fiscal year 1992, coal availability studies continue in the Central Appalachian coal region. Two quadrangles, one in Kentucky and one in West Virginia, are being studied. Three quadrangles, one each in the States of Ohio, Pennsylvania, and West Virginia, are being studied in the Northern Appalachian coal region, and two quadrangles, one in Kentucky and another in Ohio, are under investigation in the Illinois coal basin.

Figure 2. *Coal availability studies, fiscal years 1987–90.*





Part (see inset) of the new map for the continental shelf north of San Francisco, Calif.

Mapping the California Continental Shelf

By Michael E. Field

Using GIS techniques, USGS scientists have constructed a new map for the continental shelf north of San Francisco. Of note, the map shows diverse types of data that traditionally are not mapped together, such as sediment age, sediment thickness, faults, and sediment particle size. Each type of information is depicted in a different color (shown here in black and white), so as to be useful to a broad community of users, including physical oceanographers, commercial and recreational fishers, and geologists. Using digitized data sets in MAPGEN format, the map is being compiled for formal publication, with partial support provided by the Office of Naval Research, Department of the Navy, which will use the map as background information for the STRESS (Sediment Transport Events on the Shelf and Slope) Program. Under the STRESS Program, researchers from the USGS, Woods Hole Oceanographic Institute, University of Washington and several other universities are examining the role of storms in resuspending and transporting sediment on the continental shelf.

The map includes information on structure, morphology, and surficial geology. One of the strengths of the map is its color format, which permits overlaying contrasting information and no loss of legibility. The map consists of five layers: bathymetry, faults, surface geology, Holocene sediment thickness, and sediment particle size.

Bathymetric contours, digitized from a National Oceanic and Atmospheric Administration data base, are mapped at 20-meter intervals on the shelf and at 100-meter intervals beyond the shelf break (200 meters). Onshore and offshore faults are digitized from a USGS map. The surficial geologic units were mapped by the investigators by using high-resolution seismic-reflection profiling and sidescan sonar. Three main units are shown: pre-Quaternary outcrops, Pleistocene deposits, and Holocene deposits. The pre-Quaternary units include both deformed and uplifted sedimentary beds on the outer shelf and exposures of resistant sedimentary and granitic rocks on the inner shelf. The broad, thick suite of Pleistocene deposits formed during times of shoreline migration caused by the rise (transgression) and fall (regression) of sea level. The Holocene deposits, primarily composed of sediment that has accumulated during the past 5,000 years, are mapped by thickness as well as distribution, thus showing the position of local concentrations of sediment formed by shoreline and deltaic deposition. Superimposed on all units are contours showing average particle size (in millimeters) of the upper few centimeters of sea floor sediment.

The map has many potential uses for the public and for research investigations. For example, the particle size information is useful to researchers for predicting movement of sediment during storms. The location of outcrops and the textural character of the sea floor are valuable to fishers for locating shellfish and certain types of bottom fish. Location and thickness of Holocene sediment are important for future assessments of placer-mineral and aggregate resources. Decisions about continental shelf use, such as locating suitable disposal sites for dredged material, need this type of definitive information about bottom sediment type and morphology. Other applications will doubtlessly emerge as use of the continental shelf increases.

GIS Technology and Its Application to Geologic Hazards

By Arthur C. Tarr

GIS technology is transforming geologic hazards research in the 1990's. Complex hazards analyses once thought to be impractical or impossible are now routine. GIS technology automates the process of acquiring geologic data by replacing drafting vellum with a computer screen, a greenline with a digital base map, and a set of drafting tools with a digitizer tablet and a mouse. Finished, full-color maps portraying results of research are produced and distributed in weeks or months instead of the years needed to produce a traditionally printed map.

Geologic research is a lengthy, deliberate process of data acquisition, analysis, peer review of results, and finally, publication of a report or map. Until the last decade, geologic mapping and map compilation employed cumbersome tools and laborious techniques. GIS has changed that. In the USGS, GIS is now used widely to study and depict earthquake hazards in the San Francisco Bay area, the Pacific Northwest, and the Central United States and to study the landslide hazard in numerous areas of the United States and foreign countries.

GIS promises to radically change the methods of field geologists. Imagine a geologist in the field in 1996 mapping fault breaks resulting from a recent large earthquake. The geologist begins by entering field data into a lightweight, battery-powered computer. Simultaneously, geographic coordinates of the geologist's position are computed by a Global Positioning System (GPS) unit and recorded for each field observation. The GPS unit receives radio transmissions from a constellation of navigation satellites and is small enough to be stashed in a backpack. Back at the office, the geologist transfers the images and the data from the portable computer to a workstation where the geographic coordinates and other data are converted into a standard map projection in a GIS-compatible format. The new field data and selected video frames are then displayed together on the high-resolution screen of the workstation where the data can be edited and interpreted.

"Complex hazards analyses once thought to be impractical or impossible are now routine."

A colorful multispectral satellite image of the study area and previously mapped geologic or geophysical data also may be displayed as backdrop layers. The geologist retrieves additional field data from a colleague's computer in another State. Within the computer environment, the scientist can compose maps portraying the new data on a topographic base retrieved from a USGS data base and then plot the maps on a desktop color printer or perhaps on a large format color plotter. After revising the color maps, the geologist can make them available over a computer network to colleagues across the United States and in foreign countries.

Although some elements of GIS, such as computer analysis of spatial data and automated mapping, have been used in earthquake and landslide hazards research for decades, these elements were not originally integrated to work together as a system. For example, the geological hazards of San Mateo County, Calif., have been analyzed and mapped since the 1970's using computerized analysis and automated mapping methods. These methods were refined during subsequent years, but progress was slow for several reasons: customized computer programs had to be written for each application; computer hardware was expensive and slow relative to today's computers; and necessary spatial data were not available in digital form. These data had to be laboriously acquired from existing source materials by digitizing paper maps.

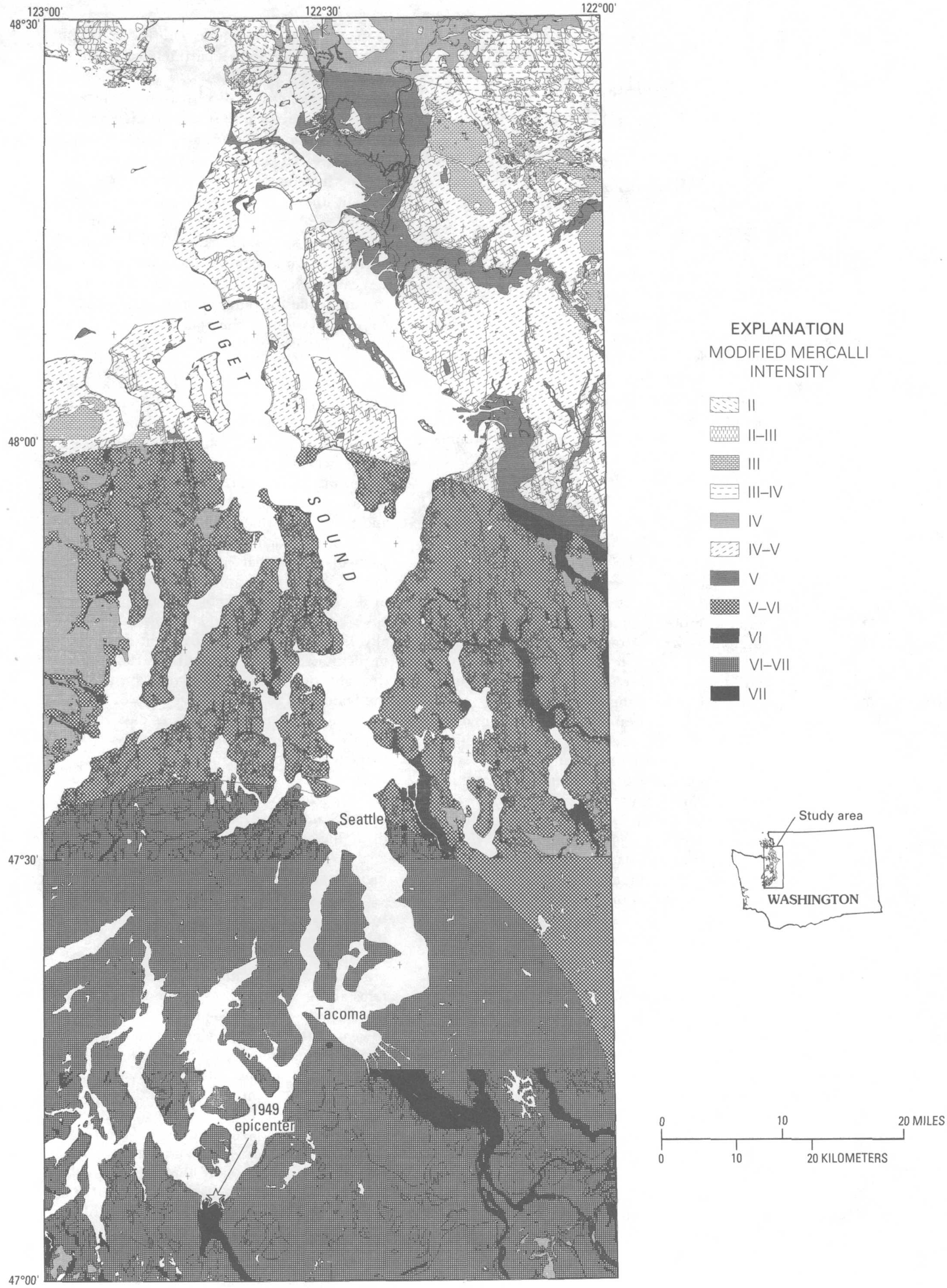
Nevertheless, in the mid-1980's, a USGS-State cooperative pilot study of a small area of the Wasatch Front in Utah demonstrated the feasibility of using GIS as an earthquake hazards assessment tool. The pilot study resulted in numerous thematic data layers portraying societal elements at risk, such as schools, fire stations, and hospitals, and geologic hazards, such as the Wasatch fault and geologic units susceptible to liquefaction. Later, GIS was employed in two different earthquake hazards study areas, one in the Pacific Northwest and one in the San Francisco Bay area; for example, GIS was used in several ground response studies following the October 17, 1989, Loma Prieta earthquake in California. By 1990 GIS was fully integrated into research plans for the New Madrid seismic zone of the central United States, and in 1991 the USGS National Landslide Information Center began incorporating GIS landslide data into a new data base, which will be available to earth scientists worldwide.

The growth of GIS in the USGS led to the establishment in 1990 of a computer graphics laboratory in Golden, Colo., to provide GIS and other scientific visualization tools to geologic hazards projects and to the creation of a Geologic Hazards Data Base (GHDB) to combine earthquake and landslide hazards data under centralized management. The GHDB currently contains more than 1 gigabyte of digital spatial data related to geologic hazards research in the Pacific Northwest, Central United States, Colorado, and San Francisco Bay area. Many data sets in the GHDB are accessible to USGS-sponsored researchers and collaborators over Internet, a global telecommunications network.

The figure shows how the GHDB can be used by illustrating research study results of the expected intensity (as measured on the modified Mercalli intensity scale) of a hypothetical magnitude 7.1 earthquake located near the epicenter of the 1949 southern Puget Sound earthquake. The figure demonstrates a suite of GIS functions and one technique that uses a particular algorithm to calculate circular intensity contours based on a point earthquake source (intensity is the dependent variable and has been adjusted for the effects of site geology). GIS can accommodate other algorithms that produce noncircular intensity contours (such as those from a line source instead of a point source), multiple intensity adjustments (to correct for depth to bedrock or depth to water table), or a different dependent variable (such as acceleration). Also, the technique can be generalized to produce landslide and liquefaction susceptibility maps.

What may we expect from GIS in the next 5 to 10 years, especially as it applies to geologic hazards research? Computer hardware costs probably will continue to decrease even as the hardware becomes more powerful. Therefore, GIS software will take advantage of affordable, higher performance hardware to provide additional functions and speed to existing applications. Enormous spatial data bases, such as large-scale maps of extensive areas and high-resolution satellite images, will be distributed widely on optical media, such as CD-ROM, at low cost. High-speed computer networks linking online data bases in the United States and in foreign countries will permit USGS scientists to access and exchange large data sets with their collaborators. In the 1990's, geologic hazards research will become increasingly efficient, comprehensive, and timely because of advances in GIS technology.

Hypothetical seismic zonation map, produced by using GIS, of a portion of southern Puget Sound, Wash., for a magnitude 7.1 earthquake (star). ▶


123°00'
122°30'
122°00'
48°30'
48°00'
47°30'
47°00'
PUGET SOUND
Seattle
Tacoma
1949 epicenter
EXPLANATION
MODIFIED MERCALLI INTENSITY
II
II–III
III
III–IV
IV
IV–V
V
V–VI
VI
VI–VII
VII
Study area
WASHINGTON
0
10
20 MILES
0
10
20 KILOMETERS

Use of GIS Technology in Preparing Water-Resources Publications

By Gregory J. Allord and Richard W. Paulson

The USGS National Water Summary (NWS) program documents national assessments of the water resources of the United States in a series of USGS Water-Supply Papers. Each Water-Supply Paper presents information on hydrologic and meteorologic conditions for 1 or 2 water years (October to September) and focuses on a particular topic, such as water quality or water use. The information is presented in a series of articles and in State-by-State summaries. By using GIS technology, the USGS has speeded up the analysis, presentation, and publication of this information.

The national assessments that are presented in these NWS reports aggregate existing data from USGS and other Federal and State data bases. Because the NWS reports are intended for a nontechnical audience, the often-complex data are presented in specially designed formats for that audience. The multicolor graphics that can be produced with GIS technology are an effective method of presenting this complex data.

"By using GIS technology, the USGS has speeded up the analysis, presentation, and publication of this information."

The State summaries provide for comparison of water-resources conditions between States because each State summary shares a common organization of text, tables, and illustrations. Manual preparation in a timely manner of the text and illustrations for each State summary rarely is possible because of the large quantity of data represented, the need to replicate common presentation formats, and the deadlines of report preparation. Consequently, the preparation of computer-based text and illustration data sets allows the information to be combined and compared in needed formats.

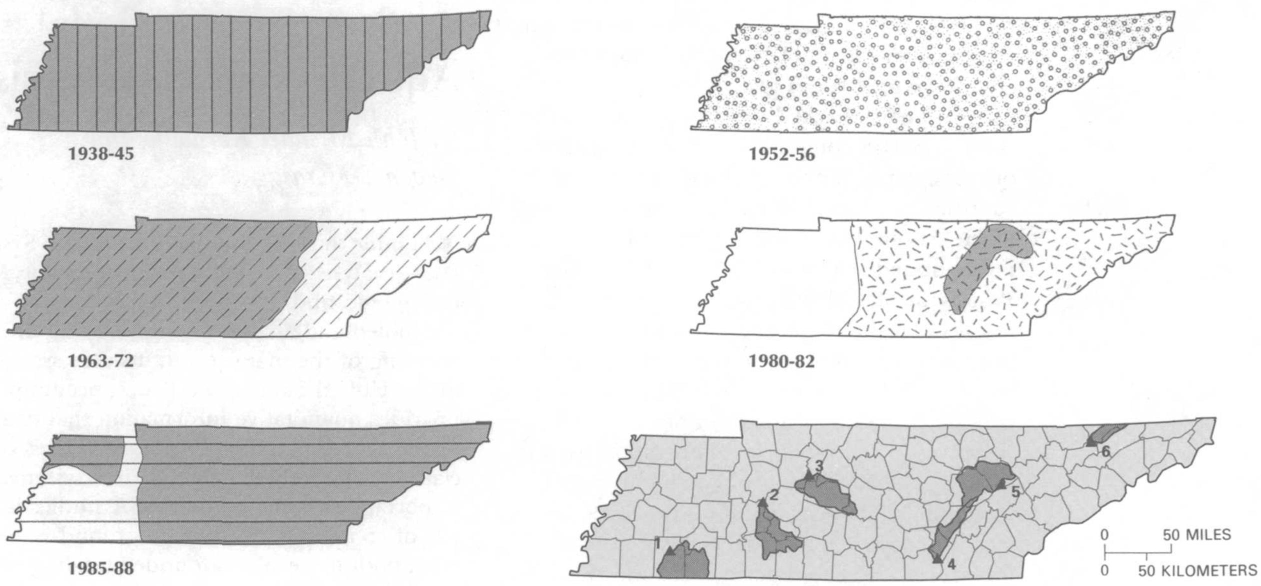
Examples of small-scale, national digital data sets that have been created in support of the NWS reports include State and county boundaries; hydrography; hydrologic unit boundaries; average annual runoff; population growth and distribution; location of waste sites; water withdrawals and use by county, aquifer, and drainage basin; and areal extent of major floods and droughts in each State. Digital data sets that currently are being prepared include land use, physiographic provinces, updated population distribution, and water-quality trends and conditions at selected sites. A national digital wetlands data set at a scale of about 1:2,000,000 also is in preparation in cooperation with the U.S. Fish and Wildlife Service, Department of the Interior.

Because most USGS hydrologic studies are local or regional in scope, and few result in the creation of nationwide, small-scale data sets on a specific subject, organizing and displaying hydrologic data in NWS reports present unique problems for the compilation, analysis, and review of the data. The topical information selected for the NWS, however, is aggregated on a regional and national basis and must be consistent from State to State and at a scale for publication as page-sized maps. Almost all of the State-summary illustrations are now prepared using GIS-based techniques.

The figure (facing page) is a black and white example of a multicolor, GIS-produced State-summary illustration. The illustration shows six time-series graphs of data from USGS stream-gaging stations that show periods of major drought, a State map that shows the locations of the stream-gaging stations, and State maps that show the areal extent of droughts. Each drought is identified by a particular color that links a highlighted period in the time-series graphs with the areal extent of the drought on a State map and with the color key in the map explanation. Additionally, if the severity of the drought fluctuated in the State, as in the case of the 1980–82 drought, two shades of the color are used on the State map to show areal extent of classes of drought severity. Time-series data from the six hydrologic stations in Tennessee were extracted from the USGS National Water Data Storage and Retrieval System data base and analyzed to identify the major droughts in the State. The areal extent of each major drought was then defined on the basis of the analysis of data from as many as 40 hydrologic stations.

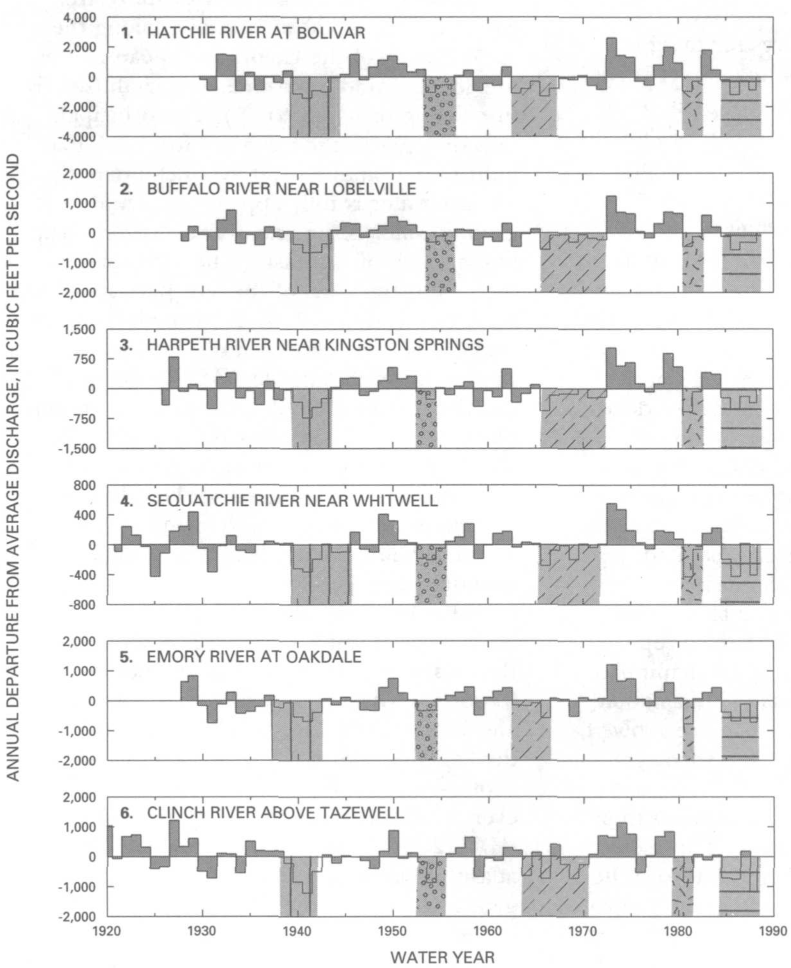
Links between ARC/INFO, the GIS used by the Water Resources Division, and the traditional publishing process have been created for the preparation of illustrations, and several software applications and computer systems are used. For example, desktop publishing software on a personal computer was used to lay out the different elements of the drought illustration. In conformance with the overall design of the illustration, individually scaled graphic elements, such as the drought maps, graphs, and illustration explanation, were first put in position using Adobe Illustrator 3.0. The horizontal and vertical page position coordinates were then determined, and the graphic elements were digitized and entered into an ARC/INFO file in one of the USGS Distributed Information System (DIS) computers. This ARC/INFO map then was converted to PostScript format, a page

Areal Extent of Droughts



U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Annual Departure



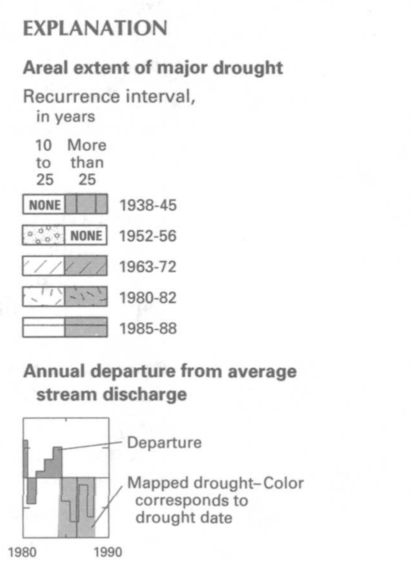


Figure 4. Areal extent of major droughts with a recurrence interval of 10 years or more in Tennessee, and annual departure from average stream discharge for selected sites, water years 1920–88. (Source: Data from U.S. Geological Survey files.)

Example of an illustration, modified from the 1988–89 National Water Summary, Water-Supply Paper 2375, prepared using GIS technology.

description language that conveys this spatial information to a variety of printers and other high-resolution image setters. A non-GIS software system called TELLAGRAF was used to create the time-series graphs in the drought illustration. TELLAGRAF also operates on the USGS DIS computers and has a PostScript output format. The horizontal and vertical coordinates of the block of time-series graphs in the Adobe Illustrator 3.0 layout then were incorporated in the TELLAGRAF file. The PostScript files of the block of time-series graphs and the maps and illustration explanation then were merged to create the digitally mosaicked illustration. The DIS image setter produced the high-resolution prescreened negatives of the mosaicked illustration used in printing the NWS report. The highly automated illustration-preparation process was used to prepare 52 drought illustrations (one for each State, Puerto Rico, and the U.S. Virgin Islands) and 52 flood illustrations, which have a design similar to the drought illustrations.

The illustration-preparation process used in the NWS reports relies extensively on computer-assisted procedures for manipulation of data. The human touch and creative eye are still important in the preparation of illustrations, but the large number of illustrations for a typical report could not be prepared efficiently without extensive use of GIS and other computer technologies.

The increasing use of GIS in support of NWS reports has paralleled the implementation of GIS technology within the USGS. The preparation of NWS reports has identified and led to the solution of many GIS problems, such as data accuracy standards, documentation, archiving, and distribution of geographic data. GIS-based illustration production methods have progressed from simple ink-pen plots of geographic linear data to the creation of prescreened color-separated negatives for point, line, and areal data.

GIS technology is integral to the analysis of data and the planning for future reports. Specific problems concerning the manipulation and extraction of thematic information from hydrologic data bases have been solved, but the integration of symbolic hydrologic data and text wholly within a GIS system to prepare NWS illustrations still remains to be fully defined and implemented. The use of GIS techniques will continue to improve the content, quality, and efficiency in the preparation of illustrations. The GIS techniques that have been developed for the preparation of multicolor NWS illustrations are being documented and distributed so that these techniques can be used in preparing other USGS publications.

GIS—A Pioneering Approach to Regional Aquifer-System Analysis

By John Michael Kernodle and Steven D. Craigg

Under the USGS Regional Aquifer-System Analysis (RASA) program, geologic, hydrologic, and geochemical information are assembled and analyzed to develop an understanding of the major ground-water systems in the United States. The RASA program provides quantitative information that enables Federal, State, and local water-resources officials to effectively manage aquifer systems. An important element of the RASA studies is the use of computers to simulate ground-water flow, both to develop an understanding of the natural hydrologic system and any changes caused by human activities and to provide a method of predicting regional effects of future pumping or other stresses.

The San Juan Basin RASA study area covers about 19,500 square miles along the eastern edge of the Colorado Plateau in New Mexico, Colorado, Arizona, and Utah (see figure, facing page, top right). The principal uses of water in the basin are for municipal, industrial, domestic, and livestock purposes. Surface water is fully appropriated and ground water is the only source of water supply in much of the basin. The study area is defined as that part of the San Juan structural basin that contains Triassic through Tertiary rocks. The San Juan Basin RASA was the 20th of 25 studies in the RASA program, but was the first to use GIS technology to accomplish the major objectives of the study. These objectives were to define and evaluate the basin's aquifer systems, assess the effects of ground-water use on aquifers and streams, and determine the availability and quality of ground water.

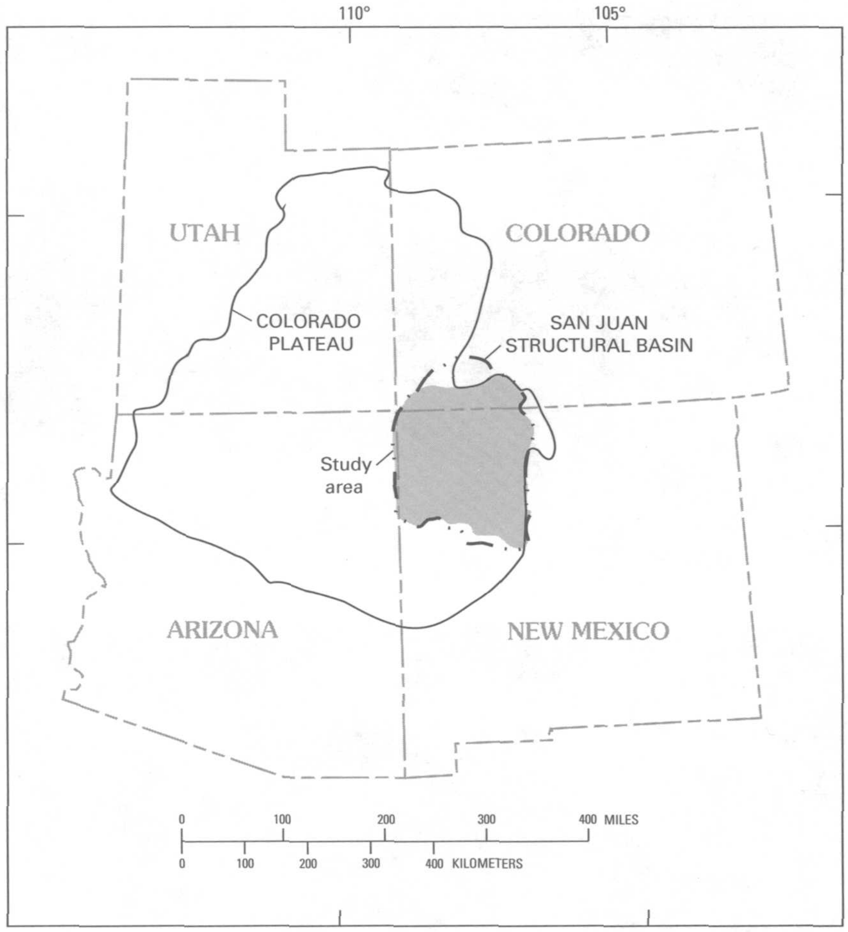
Traditionally, the results of RASA studies have been published as USGS Open-File Reports, Water-Resources Investigations Reports, Hydrologic Investigations Atlases, and Professional Papers. The final results of the San Juan Basin RASA will be published as Professional Paper 1420. In the interim, however, 10 Hydrologic Investigations Atlases (HA–720 A–J) have been published. These atlases describe the geology, hydrology, and geochemistry of major hydrogeologic units in the San Juan Basin. The GIS data bases used in the preparation of these atlases serve dual functions: cartographic bases for thematic illustrations in the atlases and data for input into ground-water-flow and geochemical models. Publications created with

GIS technology are not just maps and words; rather, they are a form of reusable data that document areal geologic, hydrologic, and geochemical interpretations. By using GIS, both the areal hydrogeologic information and the finite-difference model data can be constantly revised until the very last phases of the investigation.

The GIS applications used in the San Juan Basin RASA saved labor, time, and money. Compared with limitations encountered during many hydrologic investigations, such as relatively short project length, limited funds, and induced deadlines, the San Juan Basin RASA was unique. For example, the project spanned more than 5 years; funding was adequate; deadlines mainly were internal and self-imposed by the project staff; and the study was continually well staffed. Taken in context, these factors enhanced the benefits of using a GIS during the San Juan Basin RASA, which include problem analysis that previously would not have been possible using traditional methods.

Several digital data bases and their resultant GIS data layers were created during the San Juan Basin RASA, and different amounts of time and labor were required to produce them. For example, the digital base map was produced in about 1 year. Digitizing the basinwide geologic map required about 6 months of continuous labor and even more time to check the work and code the geologic units. Acquisition of a commercially available oil and gas test-well data base and associated geochemical brine data base required about 4 months. Ongoing acquisition of other data bases, such as basin topography, land ownership, and precipitation took several months. In addition, because GIS was a new and continuously evolving technology, the training of project personnel in the applications of GIS and other digital techniques was a constant consideration.

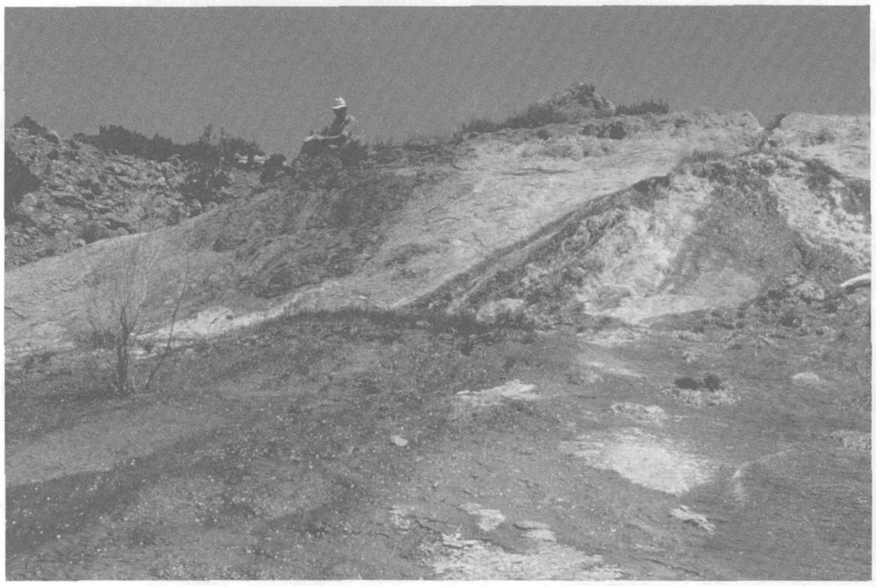
Once the GIS data bases and layers were in place, the true benefits began to be realized. One benefit was the development of an accurate base map for the study area that can be transferred with accompanying thematic data into the formats and media that meet USGS publication standards. Another benefit was the development of interfaces with additional analytical software and data bases that are maintained by other public agencies and private firms, which makes the data from the San Juan Basin RASA more available and useful for the officials and managers who need the information. In addition to simple data-transfer mechanisms, these interfaces have been used for analysis of the occurrence of oil and gas in the San Juan Basin, analysis of the top of hydrogeologic units in the subsurface, regression-analysis of surface-water runoff



GIS coverage showing location of the Colorado Plateau, the San Juan structural basin, and the San Juan Basin RASA (Regional Aquifer-System Analysis) study area.

An abandoned windmill along the Rio Puerco (Pig River) drainage in the east-central part of the San Juan Basin. The well was probably abandoned because of small yields and poor water quality.

STEVEN D. CRAIGG



JOHN MICHAEL KERNODLE

An active, cratered travertine spring mound along the southeastern margin of the San Juan Basin. Saline ground water discharges at a rate of about 10 gallons per minute to the land surface from late Paleozoic and Triassic strata after migrating upward through fractures associated with a major reverse and thrust fault zone.

Top, *The central cratered part of the mound encircled by a travertine rim. The crater is about 40 feet in diameter and at least 50 feet in depth.*

Bottom, *The arcuate travertine mound (about 50 feet in height), discharge of water from the crater rim on the right side, and recently deposited travertine (marked by light-colored areas on the mound slopes).*

and ground-water recharge, and analysis and GIS presentation of data from the ground-water flow model.

A third benefit was simply a reduction in time and effort needed to create ground-water flow-model-input data sets. A minimum of 14 hydrogeologic units needed to be represented in a ground-water flow model of the aquifer systems in the San Juan Basin. If the model simulations were restricted only to one finite-difference representation of these 14 units, more than 1.4 million manual data entries would be required, which would have taken at least 100 uninterrupted 8-hour work-days of continuous data entry just to prepare data input for each version of the ground-water flow model, excluding time to verify the accuracy of the data entry.

A preliminary model of the Gallup Sandstone, Dakota Sandstone, and Morrison Formation part of the flow system had been prepared in 1987; the Hydrologic Atlases for these units were in review, and therefore the GIS data bases for these units were available for construction of the ground-water flow model. From these and other GIS data bases of outcrop, thickness, and altitude of the top of the aquifer, and of precipitation, topography, and hydrography, a steady-state ground-water flow model was constructed in 2 days.

The expanding data bases are not limited to the study area of the San Juan Basin RASA. The GIS data bases have encouraged a freer exchange of information between other agencies and the public. The free exchange of information in a common format is reason enough for using the GIS; however, because the areal coverage from the shared information greatly exceeds the area covered by the San Juan Basin RASA, the expanded data bases also are serving as the basis for new GIS-based investigations in other parts of the Southwest.

A GIS and its associated data bases are not end products. Rather, the various data layers are used as input to digital ground-water flow models of basin aquifer systems and as input to geochemical models of rock-water interactions. For the San Juan Basin RASA, the new GIS technology accomplished a traditional task more efficiently and resulted in increased productivity. Tasks that were once considered to be too labor intensive, impractical, or impossible when traditional methods were used can now be accomplished with the aid of a GIS in a timely and cost-effective manner.

Cooperation—The Key to Unlocking the Benefits of Geographic Data

By Michael A. Domaratz

A broad spectrum of complex problems face our Nation today, including emergency preparedness and response. . .global monitoring and modeling. . .economic development. . .intelligent vehicle and highway systems. . .agricultural pest management. . . water-quality assessment. . .range and forest management. . .crisis management. . .mineral, oil, and gas leasing. . .wetlands analyses. . . census taking. . .facilities siting. . .mapping and charting. . . mail delivery. . .all of which require accurate and reliable geographic data for solutions.

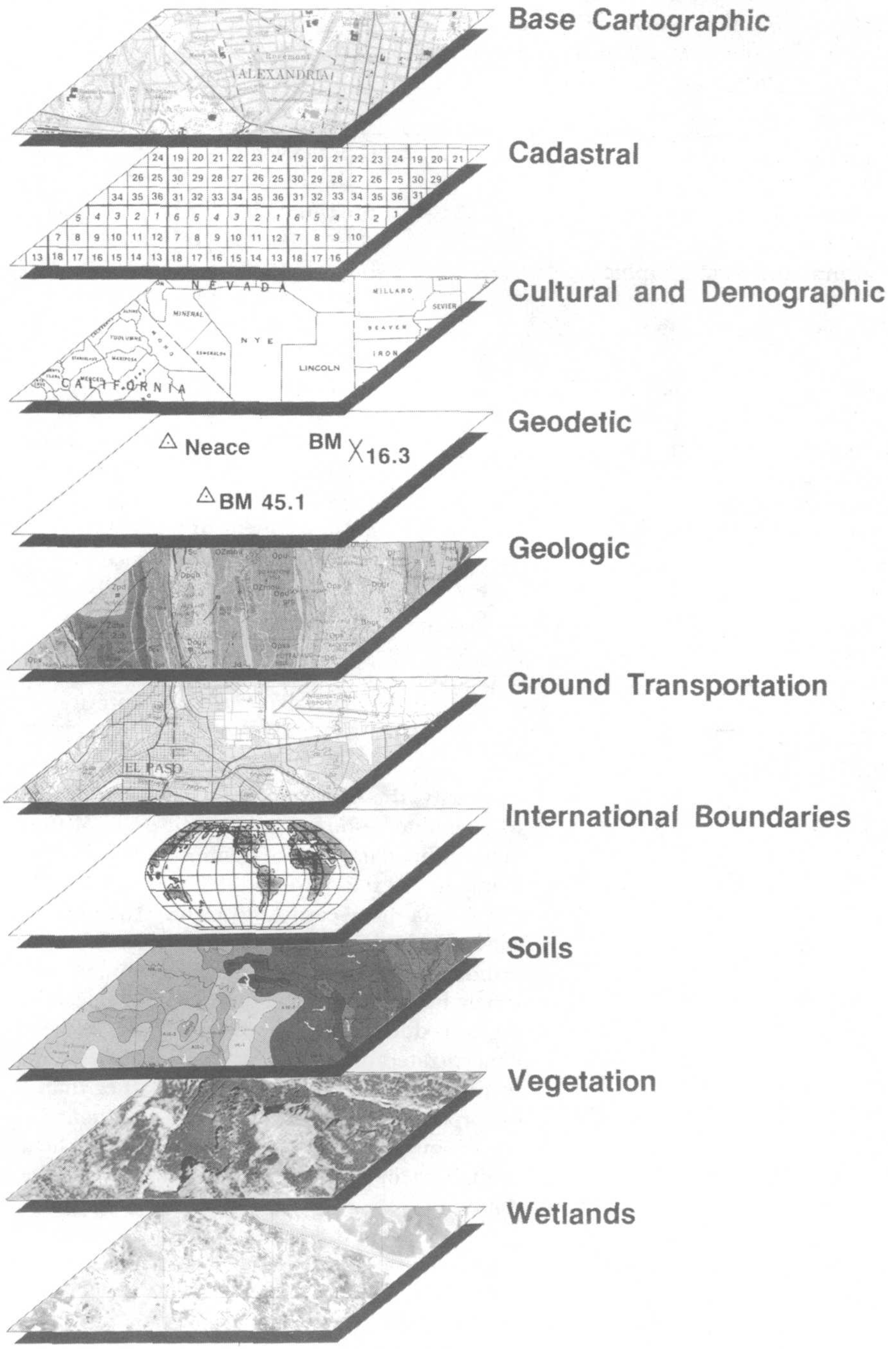
Government agencies are being asked to respond quickly in addressing these problems. To add to the complexity, new and growing administrative and regulatory responsibilities have placed tremendous pressure on information delivery systems. Geographic data sets, such as environmental, natural resources, and socioeconomic data, can be used to understand national problems and to unlock answers.

Computerized technologies for handling geographic data, such as GIS, have emerged as highly efficient and effective tools for solving complex issues. Federal agencies have realized the advantages of these technologies. More than 95 Federal organizations use these technologies in a variety of applications such as those listed above. State and local governments and private companies also are actively using geographic data in applications such as governing land ownership and use, locating sites from which to provide services, routing vehicles, maintaining public works, managing land, and marketing products.

The Nation must act quickly if it is to maximize the benefits of using this technology. These powerful technologies are acutely dependent on the availability and quality of computer-readable, or digital, geographic data. Development of the needed digital geographic data is invariably the largest cost factor in computer-assisted analysis of complex issues. With billions of dollars being invested in geographic data and related technology by Federal, State, and local governments and the private sector, interest in means of reducing costs and duplication of efforts to increase the return on this national investment has grown quickly. Many decisions on these investments will be made over the next few years, and it is important to lay the foundation for cooperation and coordination now.

With these concerns in mind, the Office of Management and Budget issued a revised Circular A–16, Coordination of Surveying, Mapping, and Related Spatial Data Activities, in October 1990. Such circulars establish governmentwide policies as well as responsibilities for implementing these policies.

A major objective of revised Circular A–16 is development of a national digital geographic information resource. As an analogy, just as the connectivity and standards of the Nation's electric power distribution network provide benefits of increased convenience, markets, and economies in generating



Data categories coordinated under the revised Office of Management and Budget Circular A–16. These categories form the data foundation for many applications of geographic data.

Data coordination responsibilities assigned by the revised Office of Management and Budget Circular A–16

Geographic data category	Lead agency
Base cartographic	U.S. Geological Survey Department of the Interior
Cadastral	Bureau of Land Management Department of the Interior
Cultural and demographic	Bureau of the Census Department of Commerce
Geodetic	Coast and Geodetic Survey Department of Commerce
Geologic	U.S. Geological Survey Department of the Interior
Ground transportation	Federal Highway Administration Department of Transportation
International boundaries	Office of The Geographer Department of State
Soils	Soil Conservation Service Department of Agriculture
Vegetation	Forest Service Department of Agriculture
Wetlands	U.S. Fish and Wildlife Service Department of the Interior

electricity, the development of this geographic information resource will benefit users of the geographic data. Sets of commonly used data, produced to standards, will enable users to share data more easily and reduce the need for individual agencies to collect data. Use of standards will encourage the development of larger markets and economies of scale, leading to reduced costs for data. Efforts can be concentrated on improving the use of these technologies in solving problems rather than on producing data or servicing a fragmented user community. Users will benefit from the availability of more timely and higher quality data.

The circular assigns to Federal agencies the responsibilities of leading coordination activities for 10 categories of data (see figure, p. 15). These categories form the data foundation for many applications. Agency responsibilities include providing governmentwide leadership in developing data standards, assisting information and data exchange, and coordinating data collection. The categories and lead agencies are listed in the table above.

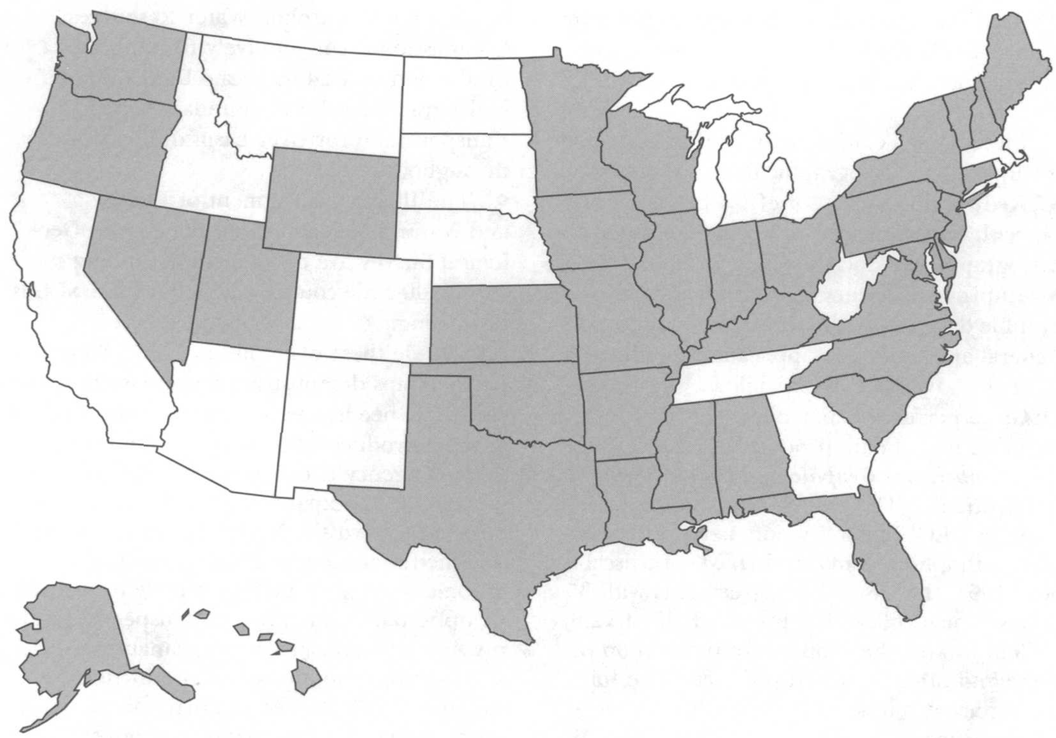
The circular also establishes an interagency committee, the Federal Geographic Data Committee (FGDC). This committee promotes the coordinated development, use, sharing, and dissemination of geographic data and also oversees and provides policy guidance for agency efforts to coordinate data categories. The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior, State, and Transportation; Environmental Protection Agency; Federal Emergency Management Agency; Library of Congress; National Aeronautics and Space Administration; National Archives and Records Administration; and Tennessee Valley Authority. The Departments of Education, Health and Human Services, Justice, and Labor, the National Capital Planning Commission, and the Smithsonian Institution also participate in FGDC activities. The USGS chairs the committee on behalf of the Secretary of the Interior.

The FGDC promotes the development, maintenance, and management of geographic data bases. These activities ensure that geographic data are maintained and made available for wide and varied use. By encouraging the development of standards and specifications, the committee ensures that data can be used with various commercially available hardware and software. By sharing experiences of using new technologies, the committee can help others make informed decisions on implementing new technologies for their own applications.

The successful development of the Nation's geographic information resource depends on all parties—Federal, State, and local governments, the private sector, and academia—working together. Building innovative partnerships and improved coordination processes will reduce duplication of effort and produce data that is of mutual benefit to all. The FGDC provides guidance and promotes cooperation between the Federal and non-Federal geographic data communities.

The committee cooperates with other groups that have coordination responsibilities, such as the Committee on Earth and Environmental Sciences of the Federal Coordinating Council on Science, Engineering, and Technology, and the Nation's water information coordination program. These cooperative efforts encourage the sharing of advances made by the groups and of networks to reach their communities, while allowing the groups to pursue issues important within their communities.

The immediate need for, and large cost of, high-quality digital geographic data is creating opportunities to build partnerships among Government institutions and between the public and private sectors. Through revised Circular A–16 and the FGDC, the Federal community is striving to take advantage of these opportunities and to reap the dividends of the growing national investment in geographic data. These efforts ensure the availability of data needed to meet the challenges of improving the Nation's competitiveness in world markets and its ability to respond to complex issues.



States (shaded) having cooperative mapping agreements with the USGS for fiscal year 1991.

USGS-State Partnerships in the National Mapping Program

By Max M. Ethridge, Katherine F. Lins, and Larry L. Amos

A mission of the USGS National Mapping Program is to provide up-to-date maps, digital cartographic data, and remotely sensed data in response to requirements of Federal, State, and local government agencies. These requirements are identified and coordinated under the auspices of Office of Management and Budget Circular A–16, Coordination of Surveying, Mapping, and Related Spatial Data Activities (see article, p. 15). Through the revised Circular A–16, the USGS has been challenged to balance its role as provider of federally required cartographic data with an increased responsiveness to State and local cartographic data requirements.

A technological revolution in spatial data analysis is occurring throughout government and industry because of GIS. This revolution, coupled with increased pressure on land and other natural resources, has dramatically increased the demand for map information in digital form. The annual requirements for the USGS standard cartographic products, identified from the expanded A–16 solicitation, exceed USGS capacity to produce these data. To obtain required data, many public agencies are offering to augment the USGS capacity by entering into partnerships with the USGS in the production of standard cartographic products.

Increased Emphasis on USGS-State Partnerships.—The USGS has a longstanding cooperative program that provides other government agencies the opportunity to influence production priorities for those standard map products, digital cartographic data, and remotely sensed data that would otherwise not be produced as soon as required. To address the rapidly increasing needs of State and local governments for standard cartographic and remotely sensed digital and graphic data, the USGS is emphasizing partnerships with States through a variety of mechanisms. Such partnerships are beneficial to all map-using agencies—Federal and State—because increased resources accelerate the availability of multipurpose cartographic products to all users. These cartographic products include topographic maps and derived digital line graph (DLG) data; digital elevation models (DEM); photoimage products, including aerial photographs and orthophotoquads; and thematic map products, including land use and land cover data.

The major objectives of the USGS-State partnerships are to accelerate the availability of data through the National Digital Cartographic Data Base, which is the digital spatial repository of base category data, and to accelerate the production of revised digital cartographic and thematic products. A companion effort supported by the States is to acquire systematic aerial photographic coverage through the National Aerial Photography Program (NAPP; see article, p. 50). Cooperative agreements with State partners will enable the USGS to:

- Meet more Federal, State, and local needs for up-to-date cartographic data,
- Reduce duplication of effort by cooperating with other agencies to produce standard cartographic products,
- Improve efficiency as more digital cartographic data are made available to support Federal and State GIS applications, and
- Take advantage of capabilities outside the USGS to perform major phases of map revision and digital data production.

Cooperative Graphic and Digital Data Applications.—The States are primarily interested in DLG's, map revision, aerial photography, orthophotoquads, and DEM's. In fiscal year 1991, the USGS had agreements with 35 States, which collectively provided about $2.8 million toward the cooperative production of these and other standard products. The following are examples of typical USGS-State partnerships.

- The Florida Department of Natural Resources is cooperatively funding a statewide program to revise USGS 1:24,000-scale topographic maps and produce DLG's. Through this program, the USGS is updating all maps made before 1980, producing DLG's for these new maps, and producing DLG's for existing maps made after 1980. These products support the State GIS applications in management and analysis of State-owned lands and wetlands and also support the Federal Wetlands Inventory program.
- The Pennsylvania Department of Environmental Resources is cooperatively funding statewide programs to revise 1:50,000-scale county maps and 1:24,000-scale topographic maps. These maps are used by about 15 different State agencies. In addition, the State and the USGS are preparing 1:100,000-scale DLG hydrography data for the entire State. These data are augmented by selected features from 1:24,000 DLG hydrography files. The resultant data will be used for GIS applications in point-source pollution monitoring and analysis.
- The Delaware Geological Survey is cooperatively funding 1:24,000-scale DLG's to prepare a statewide GIS for multiple uses, including environmental monitoring, watershed modeling, and pollution source detection. Delaware also is supporting maintenance of the 1:24,000-scale topographic maps of the State.
- The New Hampshire Office of State Planning is cooperatively funding statewide coverage using 1:24,000-scale DLG's to help develop a GIS intended to support analyses of the State transportation network, water quality assessments, and geologic investigations.

"States provide funds to ensure that the photographs they need will be acquired on time."

- The South Carolina Water Resources Commission is cooperatively funding the production of 1:24,000-scale DLG files of hydrography, political boundaries, and transportation for river basin drainage areas throughout the State.
- The Illinois Department of Energy and Natural Resources and the Kansas Geological Survey are cooperatively funding 1:100,000-scale county maps that the USGS is producing.

While these examples of USGS-State partnerships demonstrate a response to specific State needs, the resulting standard cartographic products also satisfy a wide range of Federal agency needs in these same areas. A portion of the expanded partnership effort is directed toward the NAPP. NAPP is optimally designed to achieve national aerial photographic coverage on a 5-year cycle to provide an up-to-date source for map inspection and revision programs, resource management needs, and orthophotoquad production. Because NAPP images and orthophotoquads are in demand by State and local government agencies, States provide funds to ensure that the photographs they need will be acquired on time. Four States—Maine, Minnesota, Mississippi, and Washington—are participating in NAPP for fiscal year 1991.

Requirements for orthophotoquads are increasing significantly. Because of their shorter production cycle, relatively low cost, availability in digital form, and geometric fidelity, these image maps are popular for GIS applications and revision of existing maps. The States of Connecticut, Maryland, and Minnesota currently require orthophotoquads. The USGS is currently conducting pilot projects on the next generation of land use and land cover data and is in the process of developing a User-Needs Assessment. Once the next generation of land use and land cover products is defined, the USGS plans to invite State and local agencies to participate in preparing land use and land cover data. Colorado, Connecticut, Georgia, Illinois, and North Carolina have expressed interest in land use and land cover data for GIS analyses.

Mechanisms for USGS-State Mapping Partnerships.—Public law authorizes the USGS to enter into cooperative mapping projects with the States, provided that the USGS does not use its appropriated funds to pay more than half the cost of topographic mapping carried on in cooperation with any State. The USGS has developed a number of mechanisms to work effectively with the States. The principal mechanism for cooperative agreements is the Joint Funding Agreement. While project costs are estimated for planning purposes, the State partner's contribution must equal at least half of the actual cost of performing the work. More recently, States are looking for cost savings by participating in partnerships with the USGS through nonfunded agreements where each agency does a portion of the work.

Cooperative agreements are carried out through one or a combination of the following funded and nonfunded agreements:

Funded Agreements

- Joint Funding.—The State partner agency reimburses the USGS by a transfer of funds. The work may be performed entirely by the USGS, or some or all of the work could be contracted to a third party.
- Supplementary Funding.—This mechanism is similar to joint funding, except that the State partner agency performs the work (except for final approval, quality review, archiving or printing, and distribution), and the USGS transfers funds to the State partner agency to collect the data to USGS standards.

Nonfunded Agreements

- Work Share.—The State partner agency, by agreement with the USGS, performs a portion of the work and the USGS performs the rest. If the two portions of work each cost the same to perform, no exchange of funds takes place.
- Data Exchange.—The State partner agency, by agreement with the USGS, collects map information for a specific area and the USGS performs the same task for a different geographic area. For example, the State partner agency could collect a whole digital file for an area, and the USGS would collect a digital file for another area of mutual interest. The two agencies then exchange the data but do not exchange funds.

Outlook.—Because of budgetary constraints, it is mutually beneficial for Federal and State organizations to coordinate their activities and eliminate duplication of effort whenever possible. Partnerships such as those in the USGS-State cooperative mapping program present an opportunity for both State and Federal Governments to meet their mapping needs at lower cost.

Sound Data Management— A GIS Benefit

By Kathryn D. Gunderson

Data management has been defined as the function of controlling the acquisition, analysis, storage, retrieval, and distribution of data. Recently, much attention has been focused on poor data management practices at some Government agencies. GIS research data present a challenge and an opportunity for data managers and serve as a catalyst for increased awareness of the importance of sound management practices. GIS research consists of gathering large amounts of data from a variety of sources. Quite often the collected data represent a unique configuration of particular data sets, and there is not always a systematic approach or means to accomplish judicious data management practices. The need to access, integrate, and display data from various sources places an urgent emphasis on data management issues such as compatibility, transfer standards, and accessibility.

Several activities are underway at the USGS to support and promote sound data management practices. The Information System Council (ISC), a bureau level group that recommends policies, coordinates research and technology, and provides guidelines for major computer systems and information management programs and systems of the USGS, has established a Data Management Subcommittee. Subcommittee assignments include identifying the current data management policies and mechanisms that are in place at the USGS, identifying data management issues and activities that are specifically related to global change, and coordinating standards for earth science data elements. The ISC works closely with the newly formed Geological Survey Geographic Data Committee to develop policy for managing the digital spatial data sets that are collected and used in GIS applications.

"The need to access, integrate, and display data from various sources places an urgent emphasis on data management issues. . . ."

The interest in GIS and spatial data has encouraged USGS participation in the Interagency Working Group (IWG) on Data Management for Global Change, an ad hoc committee comprised of representatives from scientific agencies involved in global change research. The purpose of the IWG is to make it as easy as possible for scientists and others to access global change data. As with researchers who use GIS technology, global change researchers must be able to easily locate relevant data that are well documented. The IWG recently succeeded in establishing as Federal policy a set of data management principles targeted at global change data but relevant to other data and information activities, including GIS data. In July 1991, the Director of the Office of Science and Technology Policy, the Executive Office of the President, D. Allan Bromley, approved the following set of policy statements for Federal Government data management for global change research:

- The Global Change Research Program requires an early and continuing commitment to the establishment, maintenance, validation,

Data Management Components

These data management components have been agreed upon by the ISC:

Acquisition of Data
- Collection
- Entry
- Description
- Conversion (analog to digital)

Analysis of Data
- Quality control and validation
- Data base design
- Processing

Storage of Data
- Archiving
- Refreshing
- Purging
- Protection and security

Retrieval of Data
- Accessibility
- Security
- Standards
- Dictionaries
- Documentation

Distribution of Data
- Policies
- Exchange standards
- Reproduction

description, accessibility, and distribution of high-quality, long-term data sets.

- Full and open sharing of the full suite of global data sets for all global change researchers is a fundamental objective.
- Preservation of all data needed for long-term global change research is required. For each and every global change data parameter there should be at least one explicitly designed archive. Procedures and criteria for setting priorities for data acquisition, retention, and purging should be developed, both nationally and internationally. A clearinghouse process should be established to prevent the purging and loss of important data sets.
- Data archives must include easily accessible information about the data holdings, including quality assessments, supporting ancillary information, and guidance and aids for locating and obtaining the data.
- National and international standards should be used to the greatest extent possible for media and for processing and communication of global data sets.
- Data should be provided at the lowest possible cost to global change researchers in the interest of full and open access to data. This cost should, as a first principle, be no more than the cost of reproduction and distribution. Agencies should act to streamline administrative arrangements for exchanging data among researchers.
- For those programs in which selected principal investigators have initial periods of exclusive data use, data should be made openly available as soon as they become widely useful. In each case the funding agency should explicitly define the duration of any exclusive-use period.

The overall purpose of these policy statements is to facilitate full and open access to quality data for global change research. Because these principles have applicability across all data management issues, including GIS research, the USGS supports the adoption of these principles as general data management policy for all earth science data.

CD-ROM and the USGS

By E.J. McFaul

The management of digital data presents a great challenge as well as an important opportunity for the USGS. The fact that much of the Survey's data are now in digital form has led to an unprecedented demand for them. The primary reason for this lies in the proliferation of relatively inexpensive desktop and workstation computers that are empowering scientists and researchers with capabilities which, until a few years ago, required mainframe computers.

Data management is challenging because it entails a complex interaction of many activities, including the collection, dissemination, and archiving of data. Each of these activities has been drastically changed in the last 5 years by the transition from analog or paper-based data collection to the capture of data in digital form. However, the management of digital data has been significantly enhanced by the advent of CD-ROM optical storage technology.

CD-ROM technology offers a significant improvement to data dissemination and data archiving. CD-ROM is replacing magnetic tape for both disseminating and archiving data (fig. 1). The standards inherent in CD-ROM make it an ideal digital dissemination medium, while the stability of the medium offers an improved method for long-term storage of valuable data. Additionally, the convenience and low cost of CD-ROM allows for multiple copies of an entire data archive to be produced, thereby eliminating the possibility of a catastrophic event destroying the only copy of a priceless data base. CD-ROM can be used to store the data used by GIS software, thereby freeing up space on the hard drive of personal computer workstations.

Some recent CD-ROM products generated by the USGS include two discs in the Digital Data Series (DDS)—the National Uranium Resource Evaluation (NURE) program CD-ROM and the Geology of Nevada (figs. 2 and 3)—and the US GeoData series. The DDS is available through the Federal depository libraries and can be purchased from the USGS. The US GeoData series is available in the USGS Earth Science Information Centers (see p. 108).

NURE CD-ROM.—During the last year, the USGS began the new formal DDS publication series. The first CD-ROM disc in

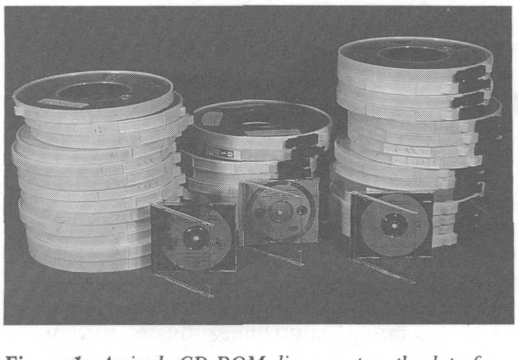


Figure 1. A single CD-ROM disc can store the data from 25 to 50 magnetic tapes.

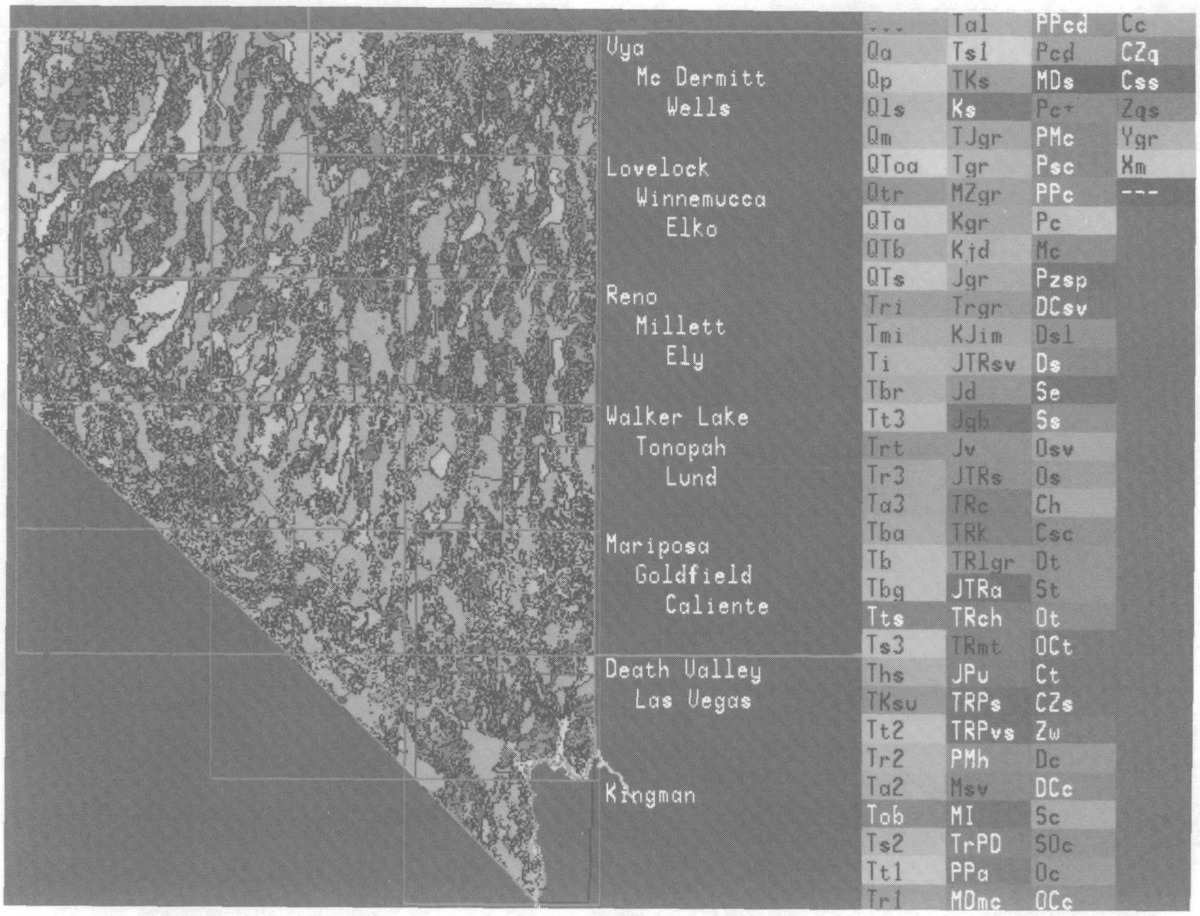


Figure 2. *Computer display (actual image uses 256 colors) for the Geology of Nevada CD-ROM.*

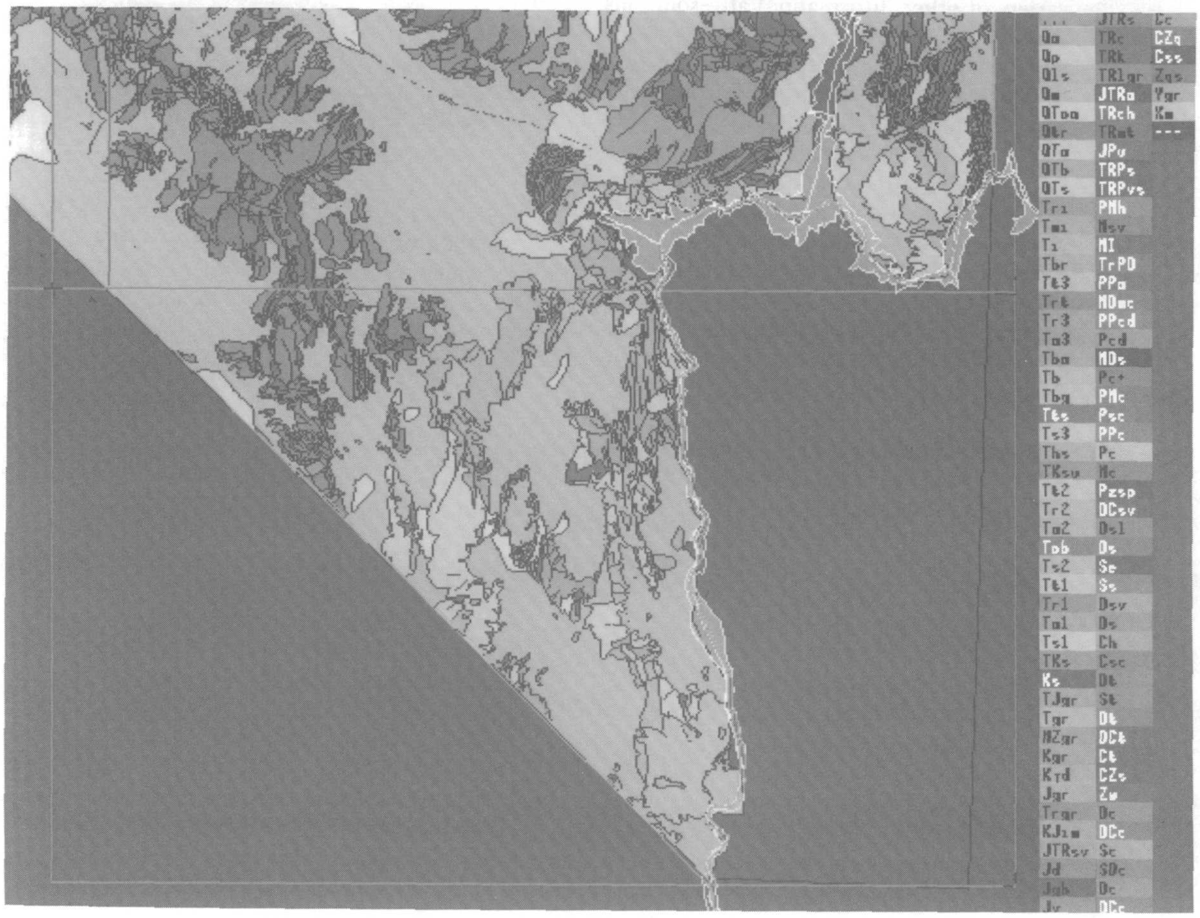


Figure 3. *Zoom of image showing highlighted areas from the Geology of Nevada CD-ROM.*

the USGS DDS contains geochemical data, collected under the NURE program, that covers the western half of the United States. This disc contains nearly 400,000 sample records compiled by the USGS and the Department of Energy over many years. These records are accessed by using a retrieval system called GSSEARCH that provides answers to complicated searches within seconds. Subsets of data can easily be created from the CD-ROM and passed through other processing programs, such as statistical packages for detailed analysis and display. Probably the most significant aspect of the NURE CD-ROM is that now hundreds of scientists and researchers will be able to have their own copy of this massive data base directly accessible through their desktop computers or workstations.

Geology of Nevada.—The second release in the DDS represents an important milestone for the USGS. This disc contains the first geologic map in digital form placed on a CD-ROM. The accompanying display software called MAPPER was also developed by the USGS and provides a soft-copy version of the geologic map of Nevada, displayable on inexpensive personal computers equipped with color monitors (fig. 2). This disc is not intended to replace the printed map but to complement it. The software allows the user to zoom into an area of interest and display the color geologic formations (along with a variety of other information) at resolutions that bring out minute detail. In addition, subtle or obscure geologic formations can easily be highlighted and identified in conjunction with the color key chart (fig. 3).

The US GeoData Series.—US GeoData are CD-ROM's that contain cartographic and textual data in digital form. The US GeoData Series includes (but is not limited to) the standard USGS digital line graph map series (1:24,000, 1:100,000, 1:250,000, etc.). Other data included in the US GeoData Series are Geographic Names Information System data and 1:100,000-scale digital elevation model data.

Many other CD-ROM discs are being developed at the USGS. One very interesting disc will contain high-resolution color images of core samples and related geophysical information, thus allowing the user to preview these valuable geological archives anywhere in the world. Another disc will provide a combination of sonar, bathymetric, spatial, and attribute information about the bottom of the Boston harbor, including actual color-digitized photographs of selected areas.

Significant economic reasons support the Federal Government's increasing use of CD-ROM. The use of this technology can produce considerable reductions in the cost of accessing and disseminating information. Not only can agencies internally distribute mainframe-sized data bases on these inexpensive discs, but also the public now has access to these same data bases at significantly reduced cost. For example, the digital mapping data produced by the USGS in the form of the nationwide cartographic data base, at 1:2,000,000 scale, previously cost more than $1,400 when purchased on multiple reels of magnetic tape. It can now (1991) be purchased at any USGS Earth Science Information Center on a single CD-ROM, including display software, for $32. The first in a series of 1:100,000-scale digital mapping discs is just now being released and will offer even more cost savings to the public.

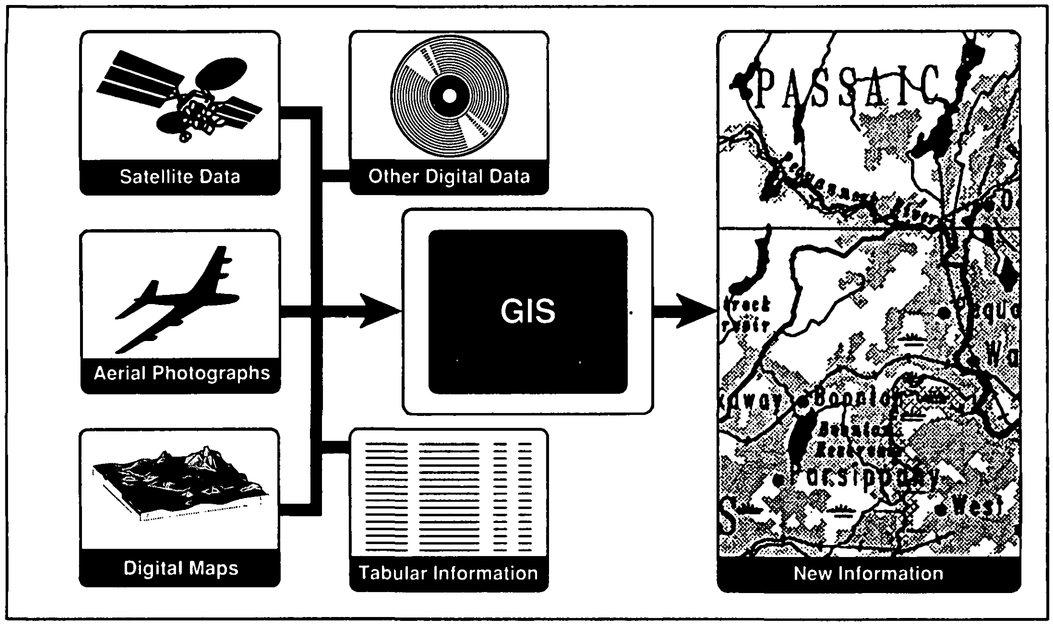
Special Interest Group on CD-ROM Applications & Technology

SIGCAT

The USGS sponsors the U.S. Government's Special Interest Group on CD-ROM Applications and Technology (SIGCAT), which supports a worldwide membership of more than 5,000 users and producers of CD-ROM technology.

In 1986 the USGS established SIGCAT to share CD-ROM knowledge and experience with other government agencies.

For more information, call the SIGCAT information line at (703) 648–4452.



GIS Focus of Special Leaflet

GIS, computer technology designed to store and manipulate geographic data, is explained in a four-color leaflet published by the USGS.

The leaflet, "Geographic Information Systems," defines what a GIS is, how the system works, and what makes it special. Nick Van Driel, Chief of the Geographic Information Systems Research Laboratory at the USGS headquarters in Reston, Va., one of the authors said, "GIS is used throughout the public and private sectors. People experience the effects of GIS almost every day and don't realize it. GIS is used for taxes, private delivery services, political redistricting, and electric and telephone utility management, just to name a few instances."

To order a copy of this 22- by 34-inch leaflet, call 1–800–USA–MAPS.

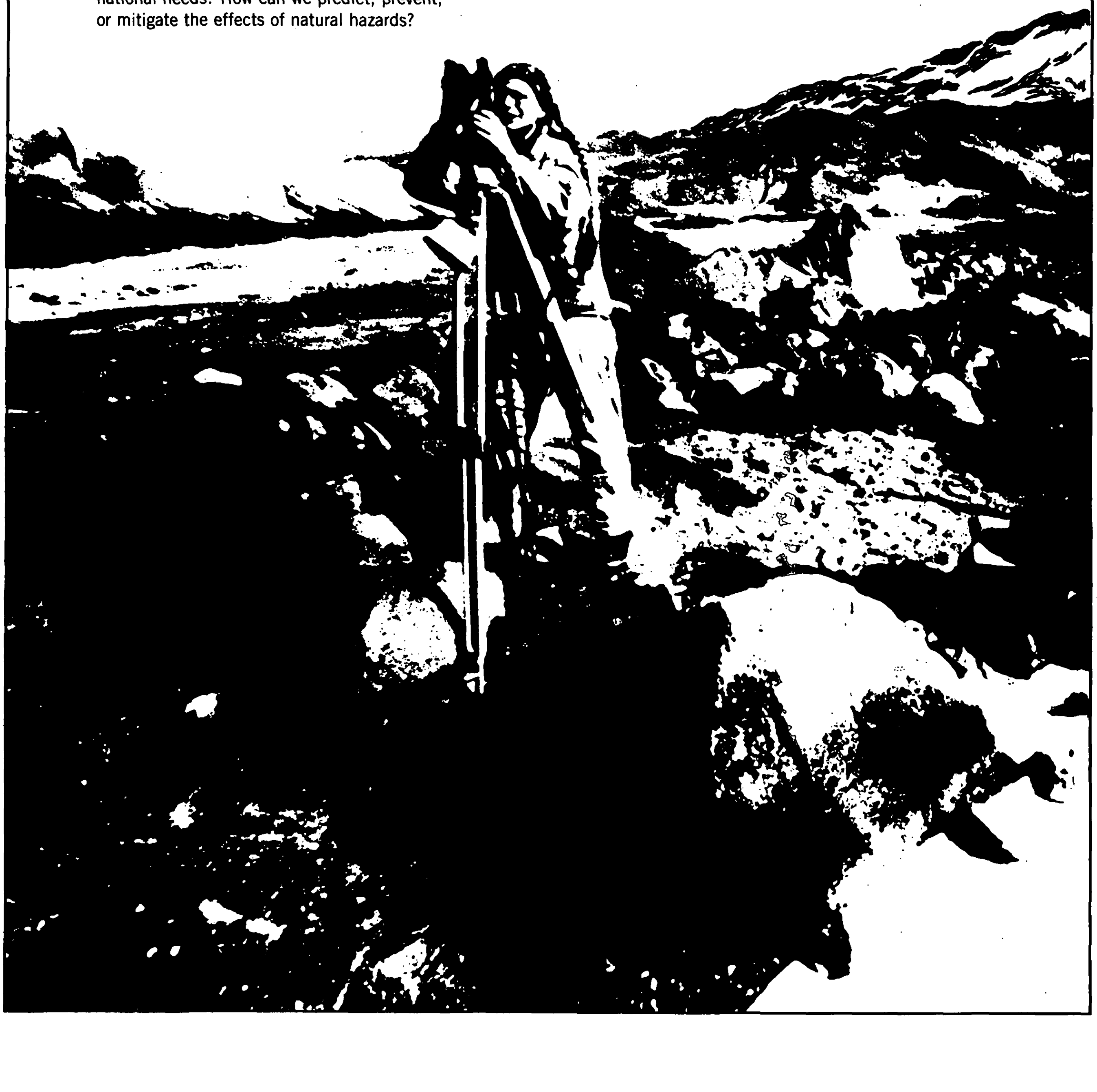
Mission

The U.S. Geological Survey, a bureau of the U.S. Department of the Interior, was established by an Act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain."

As a Nation we face serious questions concerning our global environment. How can we ensure an adequate supply of critical water, energy, and mineral resources in the future? In what ways are we irreversibly altering our natural environment when we use these resources? How has the global environment changed over geologic time, and what can the past tell us about the future? Will we have adequate supplies of quality water available for national needs? How can we predict, prevent, or mitigate the effects of natural hazards?

Collecting, analyzing, and disseminating the scientific information needed to answer these questions are the primary mission of the USGS. This information is provided to the public in many forms, such as reports, maps, and data bases, that provide descriptions and analyses of the water, energy, and mineral resources, the land surface, the underlying geologic structure, and the dynamic processes of the Earth.

As the Nation's largest earth science research and information agency, the USGS maintains a long tradition of providing "Earth Science in the Public Service."



USGS Programs

Scientific programs are administered through the Geologic, Water Resources, and National Mapping Divisions and supported by the Information Systems and Administrative Divisions. The National Center of the USGS is located in Reston, Va., near Washington, D.C. Research and investigations are carried out through an extensive organization of regional and field offices located throughout the 50 States, Puerto Rico, the Virgin Islands, and the Territory of Guam.

National Mapping Division

The headquarters office of the National Mapping Division is located in Reston, Va., and is composed of five primary organizational units: Program, Budget, and Administration; Coordination and Requirements; Production Management; Research; and Information and Data Services. Four mapping centers (Reston, Va.; Rolla, Mo.; Denver, Colo.; and Menlo Park, Calif.) and the EROS (Earth Resources Observation Systems) Data Center (Sioux Falls, S. Dak.) perform operational mapping, remote sensing, printing, product distribution, and data dissemination activities.

Mapping Coordination.—The USGS annually coordinates requirements for maps and digital cartographic data of Federal agencies under authority of Office of Management and Budget (OMB) Circular A–16. In October 1990, OMB revised Circular A–16 to broaden the scope of Federal spatial data activities to be coordinated (see article, p. 15). Under the new circular, the USGS also coordinates requirements of State and local agencies for maps and map-related products. In the area of digital cartography, the USGS chairs both the Interior Geographic Data Committee (a departmental committee) and the Federal Geographic Data Committee (a multiagency committee) established under the new Circular A–16. The USGS provides leadership in the use of spatial data and in the development of digital data exchange standards. The USGS also provides staff support to the U.S. Board on Geographic Names, an interdepartmental board that determines the choice, form, spelling, and application of official geographic place names for Federal use.

Map and Digital Data Production.—The USGS prepares base maps, image map products, digital cartographic and geographic data, and selected thematic maps of the Nation that are used extensively for land planning, land and resource management, and recreation purposes. Of rapidly increasing importance is the production of digital geographic data in various electronic media. Reproductions of aerial photographs and satellite images also are available. Digital data are available from the National Digital Cartographic Data Base as digital line graphs or digital elevation models.

Primary topographic maps, including 7.5-minute maps mostly at 1:24,000 scale for all areas of the lower 49 States and 15-minute maps of Alaska at 1:63,360 scale, are especially useful where detailed information is needed for all types of land and resource management. These detailed maps are periodically inspected and revised to maintain data currentness.

Also available are smaller scale topographic maps, such as the intermediate-scale maps prepared at 1:100,000 scale and the 1:250,000-scale map series. These map series are widely used by Federal and State agencies and the private sector for preparing their own special-purpose maps and depicting their unique data. Other maps available include 1:500,000-scale State base maps and smaller scale U.S. base maps.

The land use and land cover maps, primarily at scales of 1:250,000 and 1:100,000 for selected areas, provide the only systematic nationwide inventory of land use and land cover data. The USGS also prepares special-purpose map products, such as orthophotoquads, small-scale image maps, U.S. National Park maps, and thematic maps.

Research and Technology.—The USGS has pioneered investigations that have led to significant developments and changes in surveying and mapping. Mapping research activities, which are centered primarily on the geographic and cartographic disciplines, currently emphasize spatial data analysis, applications of remote sensing and geographic information systems, and advanced techniques for producing digital cartographic data.

The Division has embarked on a major research and development plan to move from manual to digital production and revision of map products. The goals of the map modernization effort are to implement the advanced cartographic systems and procedures required to automate map production and to provide digital cartographic data required by Federal and State agencies for computer-based analysis of spatial data.

Information Services.—The USGS disseminates much of the Nation's earth science information through its Earth Science Information Centers (ESIC), 62 State ESIC-affiliated offices, and the Tennessee Valley Authority. The information is provided in many forms, from maps and books to computer-readable magnetic tapes and compact discs. About 130,000 different maps, books, and reports and about 9.5 million aerial and space images are available for purchase. USGS maps are also available from more than 3,000 authorized commercial map dealers nationwide.

Water Resources Division

The headquarters office of the Water Resources Division is located in Reston, Va. The Chief Hydrologist, the Associate Chief Hydrologist, and five Assistant Chief Hydrologists are responsible for the overall direction of the Division. National water-research programs are developed at Division headquarters under the direction of the Assistant Chief Hydrologist for Research and External Coordination.

General direction of the Division's field programs is conducted through four Regional Hydrologists, located in Reston, Va.; Norcross, Ga.; Denver, Colo.; and Menlo Park, Calif. Forty-two District Offices conduct the water-resources investigations and data-collection programs of the Division in all 50 States, Puerto Rico, the Virgin Islands, and the Territory of Guam.

National Water-Quality Assessment.—The National Water-Quality Assessment (NAWQA) program seeks to provide nationally consistent descriptions of the quality of the Nation's water resources over a large, diverse, and geographically distributed portion of the country; provide a baseline for evaluating future trends in water quality and, where possible, define trends in water quality over recent decades; and provide an understanding of the factors influencing water quality. This information provides the basis to forecast change and evaluate the likely effect on water quality of various proposed remedial actions. In fiscal year 1991, the 4-year transition from pilot to full-scale NAWQA program began and the first 20 study units nationwide were selected.

National Water Summary.—The National Water Summary program provides water information on a State-by-State and national basis to aid policymakers in the analysis and development of water policies, legislation, and management actions. Changing patterns in availability, quantity, quality, and use of water resources are summarized for use by government officials, natural resources managers, and the public.

The principal products of the program are National Water Summary reports that describe hydrologic events and water conditions for individual water years and provide a State-by-State overview of specific water-related issues. In fiscal year 1991, the 1987 report on water use (Water-Supply Paper 2350) was distributed and the 1988–89 report on floods and droughts (Water-Supply Paper 2375) was sent to the printer.

Hazardous Waste Hydrology.—The USGS conducts research and investigations into the disposal of hazardous chemical and radioactive wastes. This information is useful in alleviating the effects of waste on the Nation's water resources. The USGS evaluates the existing and potential effects on water resources of hazardous-waste disposal and provides baseline data on the chemical contamination of surface and ground water to assist the Department of Energy in developing procedures and guidelines for identifying suitable waste-disposal sites.

Radioactive-waste studies are conducted in the Nuclear Waste Hydrology program, the principal emphasis of which is a better understanding of radionuclide transport in ground-water systems.

Nonradioactive wastes are the focus of the Toxic Substances Hydrology program, which provides data to mitigate existing and potential contamination problems.

Regional Aquifer-System Analysis.—The Regional Aquifer-System Analysis (RASA) program is a systematic study of a number of regional ground-water systems that represent a significant part of the Nation's water supply. The program includes assessment of discharge-recharge dynamics, hydrogeologic and chemical controls governing response of aquifer systems to stress, and development of computer simulation models. As of fiscal year 1991, more than 800 RASA reports and maps have been produced (see article, p. 12).

Acid Rain.—The USGS provides information needed to improve the scientific understanding of the occurrence and effects of acid rain, so that judgments can be made about effective measures for controlling or alleviating the problem. Components of the acid rain research and monitoring program include determination of the effects of acid deposition in lakes, streams, aquifers, and on building stones and operation of the National Trends Network for monitoring precipitation chemistry. The program is coordinated through the Interagency Task Force on Acid Precipitation. Comprehensive reports on results of the first 10 years of the interagency program were published in 1991, and program objectives were revised to emphasize evaluation of the Clean Air Act Amendments of 1990.

Hydrologic Data Collection.—The Hydrologic Data Collection program provides information on the quantity, quality, location, and use of the Nation's surface and ground water to support the needs of Federal, State, and local governments. Data collection stations are maintained at selected locations to provide records on streamflow, reservoir and lake storage, ground-water levels, and the quality of surface and ground water. These data form an information base that supports national and regional assessments of water resources. In fiscal year 1991, the USGS operated more than 7,300 continuous streamflow stations; collected stage and (or) discharge data at about 5,300 other stream, lake, and reservoir sites; determined ground-water levels in about 34,000 wells; and collected water-quality data from about 3,300 surface-water and 7,600 ground-water sites.

Federal-State Cooperative Program.—The Federal-State Cooperative program, which constitutes more than 40 percent of overall Division activity, is a partnership for water-resources investigations involving 50–50 cost sharing between the USGS and more than 1,000 State or local government agencies. One of the program's unique characteristics is that the USGS conducts most of the work on behalf of the cooperators. Hydrologic data collection activities as well as water-resources investigations and research are included in the program. In fiscal year 1991, water issues of highest priority included maintenance of basic water-resources data networks; surface- and ground-water quality; water supply and demand; wetlands, lakes, and estuaries; hydrologic hazards; and hydrology of global climate change.

National Research Program.—Basic research in the Water Resources Division focuses on increasing understanding of the fundamental hydrologic processes of the Nation's ground- and surface-water systems. Knowledge and techniques derived from these efforts are directed at solving current problems and anticipating future problems. Research studies are concentrated in surface-water hydrology, geochemistry, ground-water hydrology, sediment transport and geomorphology, water chemistry, and ecology.

State Research Institutes.—The State Water Resources Research Institutes program, the costs for which are shared by Federal and State governments, supports 54 Water Research Institutes at land-grant colleges or universities in the 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, and Guam. Research projects at the institutes are conducted in all water-related fields including engineering and the physical, biological, and social sciences.

Research Grants.—The Water Resources Research Grants program supports research as defined in the Water Resources Research Act of 1964. Competitive grants are awarded on a dollar-for-dollar matching basis to qualified educational institutions, foundations, private firms, individuals, or agencies of local or State governments. Research is supported on water-resources-related problems of national interest.

Water Data Activities Coordination.—The Office of Water Data Coordination is responsible for providing leadership to coordinate the water-data acquisition and information sharing activities of all agencies of the Federal Government. The office was created as part of the U.S. Department of the Interior's implementation of Office of Management and Budget Circular A–67. The scope of the activities includes the quality, quantity, and use of streams, lakes, reservoirs, estuaries, and ground water.

Much of the program is accomplished through two committees that advise the Secretary of the Interior on programs and plans related to the implementation of Circular A–67. Thirty Federal organizations are represented on the Interagency Advisory Committee on Water Data, and more than 100 representatives of those organizations conduct the activities of the committee. The second group is the Advisory Committee on Water Data for Public Use, which is composed of 16 national organizations involved in water-related issues. This committee operates under the Federal Advisory Committee Act. In March 1991, the Sedimentation Subcommittee of the Interagency Committee sponsored an international conference on Practical Sediment Management in Las Vegas, Nev., attended by 400 planners and managers.

Geologic Division

The headquarters office of the Geologic Division is located in Reston, Va., and consists of the Office of the Chief Geologist and six subordinate offices: Earthquakes, Volcanoes, and Engineering; Regional Geology; Mineral Resources; Energy and Marine Geology; International Geology; and Scientific Publications. Assistant Chief Geologists in the Eastern, Central, and Western Regions act for the Chief Geologist in carrying out general objectives, policies, and procedures for the Division. Project operations are conducted by personnel located principally in regional centers at Reston, Va.; Denver, Colo.; and Menlo Park, Calif.; at field offices in Flagstaff, Ariz.; Anchorage, Alaska; Woods Hole, Mass.; Tucson, Ariz.; Reno, Nev.; and Spokane, Wash.; and at the center for Coastal and Regional Marine Studies in St. Petersburg, Fla.

Geologic Hazards Surveys.—The Earthquake Hazards Reduction Program is a national research effort conducted to reduce hazards and risks from future earthquakes in the United States. Specific tasks include evaluation of earthquake potential for seismically active areas of the United States and operation of global seismic networks (see article, p. 58).

The Volcano Hazards Program conducts research on volcanic processes to help reduce the loss of life, property, and natural resources that can result from volcanic eruptions and related hydrologic events. The Hawaiian Volcano Observatory on the Island of Hawaii and the Cascades Volcano Observatory in Vancouver, Wash., are the principal field research centers for this program. The Alaska Volcano Observatory, a cooperative effort with State and academic organizations, is located in Anchorage.

The Landslide Hazards Program emphasizes field and laboratory research on the active earth processes that result in ground failures such as landslides, mudflows, and debris flows.

Geologic Framework and Processes.—The National Geologic Mapping Program conducts basic geologic research to acquire fundamental data on the Nation's geologic structure and the environmental and dynamic processes that have shaped it. Geologic mapping, geophysical research on the properties of Earth materials, age determinations of rocks, and modernization of mapping techniques are the main components of the program. Geologic maps provide the data required to address many societal and environmental issues, such as water-quality and toxic-waste issues; earthquake, volcano, and landslide hazards; and potential ground-water contamination by agrichemicals.

The Deep Continental Studies Program conducts research to obtain information on the composition, structure, formation, and evolution of the middle and lower crust and upper mantle of the Earth.

The Geomagnetism Program measures and interprets changes in the strength and direction of the Earth's magnetic field. Eleven geomagnetic observatories provide data for continually updating global navigational charts and maps produced by Federal agencies.

The Climate Change Program conducts research on the natural variability of past climate, on the extent of human influence on natural patterns of change, and on the magnitude of climate change demonstrated in the geologic record in support of Federal global change research efforts.

The Coastal and Wetlands Program provides geologic information on the nature, extent, and cause of coastal erosion. This information is used by Federal and State agencies to mitigate coastal retreat and land loss.

Offshore Surveys.—The Offshore Geologic Framework Program conducts scientific investigations to acquire an understanding of basic geologic and geophysical characteristics of the continental margins, adjacent slope and deep-ocean areas, and the U.S. Exclusive Economic Zone. Results of these studies and analysis of new information are essential for energy and mineral resource evaluation and assessment.

Mineral Resource Surveys.—The National Mineral Resource Assessment Program provides comprehensive multidisciplinary surveys to identify undiscovered mineral resources in the conterminous United States and Alaska and provides mineral-resource information for planning the use of public lands.

The Strategic and Critical Minerals Program provides comprehensive information on domestic and world resources of nonfuel minerals that are essential to a strong national economy and defense.

The Development of Assessment Techniques Program conducts basic and applied research on the origin and the geologic, geochemical, and geophysical characteristics of mineral deposit systems to develop concepts and techniques to improve the capability to identify and evaluate mineral resources.

Energy Surveys.—The Evolution of Sedimentary Basins Program conducts multidisciplinary research to define the evolution of and the energy and mineral commodities in sedimentary basins in the United States.

The Coal Investigations Program conducts geologic, geophysical, and geochemical research to develop scientifically based assessments of the quality, quantity, and availability of the Nation's coal resources.

The Oil and Gas Investigations Program conducts basic and applied research on the generation, migration, and entrapment of petroleum and natural gas to provide reliable assessments of the oil and gas resources of the Nation that are critical to the development and implementation of national energy policies and strategies.

The Oil Shale Investigations Program conducts research to assess the Nation's oil shale resources, including investigation of the structure and chemistry of oil shale deposits and identification of oil shale deposits suitable for exploitation under current environmental and technological constraints.

The Uranium and Radon Investigations Program conducts basic research to determine the nature and distribution of uranium and thorium resources, including newly forming uranium deposits and daughter products, such as radon, that may be health hazards.

The Geothermal Investigations Program conducts basic research to determine the nature, distribution, and magnitude of the Nation's geothermal resources. These studies define the geologic and hydrothermal regimes of the various classes of geothermal resources and identify the crustal, geochemical, and hydrothermal processes that produce geothermal systems.

The World Energy Resources Assessment Program provides information on worldwide energy resources for use by other agencies in the development of national-energy, international-trade, and foreign policies.

International Activities

The USGS has conducted earth science studies in foreign countries for nearly 50 years. Authorization is provided under the Organic Act, as revised, and the Foreign Assistance Act and related legislation when such studies are deemed by the U.S. Departments of the Interior and State to be in the interest of the U.S. Government.

Current international program efforts focus on technical assistance programs in developing countries and scientific cooperation and research through agreements with other countries as an extension and enhancement of USGS domestic programs. Cooperative research activities range from informal communications among scientists, through formal, jointly staffed projects, to multinationally staffed coordinated programs focused on particular problems or topics.

Related activities that are integral to the international programs include institutional development, exchange of scientists, training of foreign nationals, and representation of the USGS or the U.S. Government in international organizations and at international conferences and meetings.

Information Systems Division

The Information Systems Division headquarters office is in Reston, Va. The Division is composed of five offices: Assistant Director, Computer and Communications Services, Customer Services, Field Services, and Management Services. Service centers in Reston, Va.; Menlo Park, Calif.; Denver, Colo.; and Flagstaff, Ariz., provide a complete range of services to users.

The Assistant Director for Information Systems is the Division Chief. He chairs the USGS Information Systems Council, which is composed of the top automated data processing manager in each Division and in the Central and Western Regions. The council recommends technology-related policies to the Director, coordinates computer science research and technology, and provides guidelines for the sharing, acquisition, and use of major computer systems and information management programs for the USGS.

Administrative Division

The headquarters office of the Administrative Division is located in Reston, Va. The Assistant Director for Administration is the Division Chief. Under his leadership, the Division provides administrative direction and coordination to support the scientific and technical programs of the USGS. The Division is composed of five headquarters offices. Financial Management and Systems Management are centralized headquarters functions. In fiscal year 1991, cash management improvements included bureauwide implementation of a third party draft program (see p. 103); significantly better compliance with the Prompt Payment Act; expanded remote data entry; and a pilot program of using Automated Teller Machines for travel advances.

Facilities and Management Services, Personnel, and Procurement and Contracts provide operational support at headquarters and at USGS field units through Regional Management Offices in Denver, Colo., and Menlo Park, Calif. In fiscal year 1991, Facilities and Management Services' efforts included major construction projects; a laboratory safety program; space renovations, office relocations, and energy conservation; and approval by the National Archives and Record Service (NARA) for disposition of sea floor mapping data on CD-ROM (compact disc, read-only memory), the first time NARA has approved CD-ROM as an acceptable archival medium.

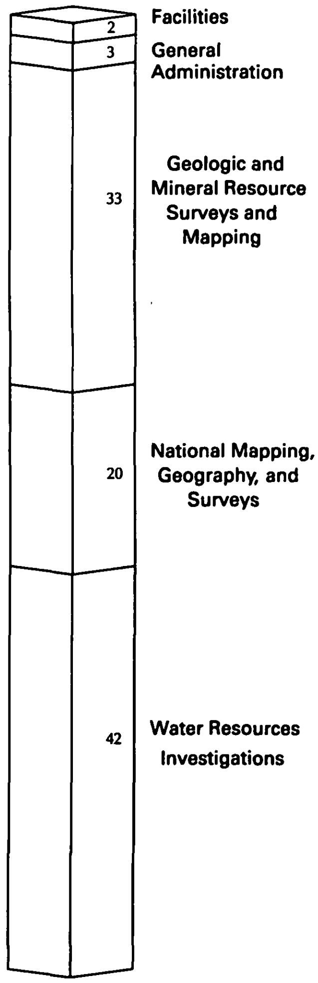
The Office of Personnel implemented a performance recertification program for senior executives in fiscal year 1991, expanded use of automated systems, and implemented a pre-appointment and random drug testing program in support of drug-free workplace initiatives. The Office of Procurement and Contracts established a Qualified Producers List (QPL) of firms capable of providing data digitization services and expanded the General Services Administration's bankcard system as a procurement tool.

The Division also manages the development, maintenance, and operation of the financial management system for the entire U.S. Department of the Interior through a sixth component, the Washington Administrative Service Center.

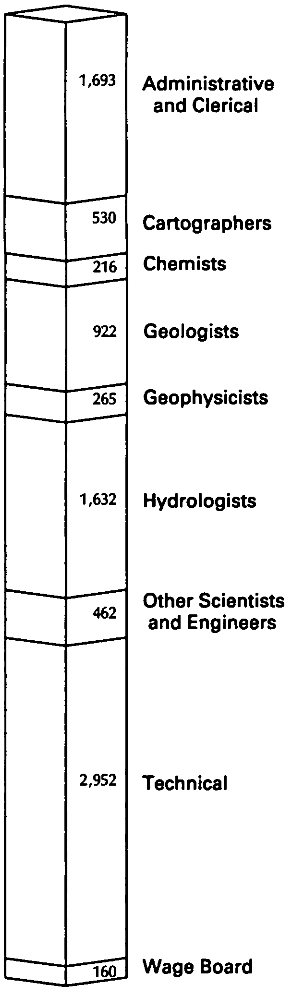
Budget

Cooperative agreements with more than 1,000 Federal, State, and local agencies and the academic community support a large share of research and investigations. In fiscal year 1991, the USGS had obligational authority for $802.5 million, $575.0 million of which came from direct appropriations, $6.9 million from estimated receipts from map sales, and $220.2 million from reimbursements. The USGS was reimbursed for work performed for other Federal, State, and local agencies whose needs for earth science expertise complement USGS program objectives. Work for State, county, and municipal agencies is most often conducted on a cost-sharing basis (see p. 107).

Percentage of Total Funds by Activity



Personnel, by Occupation



People

At the end of fiscal year 1991, the USGS had 8,832 permanent full-time employees. The diversified earth science research programs and services of the bureau are reflected in the workforce, about half of which possess a bachelor's or higher level degree.

Permanent employees are supported by the 2,037 other-than-full-time permanent employees, including many university students and faculty members. This relation with the academic community has made the expertise of many eminent scientists available to the USGS. Students have proved valuable during times of increased workload, especially during the field season. Academic institutions have provided a means of recruiting qualified young professionals for permanent full-time positions upon completion of their studies. The USGS has several innovative programs that provide opportunities for graduate students. Other programs promote interest in the earth sciences at historically black colleges and universities and at Hispanic-serving institutions. (See "Women, Minorities, and Persons with Disabilities," p. 39.)

Outreach and Information Dissemination

In its continuing commitment to meet the earth science needs of the Nation, the USGS collects, analyzes, interprets, publishes, and disseminates earth science information. The results of USGS investigations are published in scientific reports and in topographic, geologic, and hydrologic maps. About 130,000 different maps, books, and reports are available for purchase. A series of general-interest publications is available to inform the public about USGS activities. Research results and investigations are also published in journals of technical and scientific organizations and in publications of cooperating Federal and State agencies. News releases, realtime information on earthquakes in the United States and around the world, and news conferences on reports and events of current interest are other important means by which the USGS provides earth science information to the public.

During fiscal year 1991, the USGS produced 1,480 new or revised topographic, geologic, and hydrologic maps, bringing the total number of maps available to 87,000. Of these, more than 6.5 million copies were distributed. The number of reports approved for publication in fiscal year 1991 was 4,457, 74 percent of which were designated for publication in outside professional journals and monographs and the remainder for publication by the USGS.

More than 125,000 copies of technical reports were distributed. Also, 912 new reports were released as open files, making the total more than 29,000 open-file reports available. More than one million copies of general-interest publications were distributed in response to inquiries from the public. Of the approximately 9.5 million aerial and space images available for sale, about 200,000 copies are sold annually.

Awards and Honors

Each year USGS employees receive awards and honors that range from certificates of excellence and monetary awards to recognition of their achievements by election to membership or office in professional societies. Abbreviations used throughout are NMD, National Mapping Division; WRD, Water Resources Division; GD, Geologic Division; ISD, Information Systems Division; and AD, Administrative Division.

Presidential Rank

Presidential Rank Awards are presented annually by the Office of Personnel Management on behalf of the President to career members of the Senior Executive Service for exceptional service. Presidential Rank Awards, the highest civilian honor awarded to Federal executives, are given at two levels: Distinguished ($20,000 award) and Meritorious ($10,000 award). In 1991, three USGS executives received Meritorious Rank Awards:

Verne R. Schneider, Assistant Chief Hydrologist for Program Coordination and Technical Support, WRD, has provided executive direction for numerous hydrologic programs, most notably the comprehensive long-range plan for the National Water Quality Assessment (NAWQA) Program to support the President's Water Quality Initiative. Dr. Schneider's leadership, managerial competence, and program knowledge are nationally and internationally recognized.

Jack J. Stassi, Assistant Director for Administration, has pursued an aggressive campaign of modernizing and streamlining USGS administrative support activities for the past

5 years. He has had a significant role in the acquisition and implementation of a standardized accounting and payment system for all Department of the Interior bureaus, and he has pioneered advancements in automated personnel processing. These achievements have drawn attention from other Federal agencies and have been recognized by the President's Council on Management Improvement.

Robert L. Wesson, Chief, Office of Earthquakes, Volcanoes, and Engineering, GD, has devoted his significant technical and managerial talents to the development of research programs in support of the USGS mission to reduce the loss of life and property resulting from earthquakes, volcanoes, and ground failures. Under his leadership, the USGS has been given responsibility for all scientific post-earthquake activities and coordination, regional earthquake hazards assessments have intensified, and a new Alaska Volcano Observatory has been established. Dr. Wesson is recognized as an international authority on seismograph networks.

Distinguished Service

The highest honor given by the Department of the Interior to its employees is the Distinguished Service Award. Symbolized by a gold medal, this award for outstanding achievement was presented to nine USGS employees:

K. Eric Anderson, Chief, Eastern Mapping Division, NMD, was cited for his many achievements in the development of the National Digital Cartographic Data Base and the computerized geographic information and land use retrieval system, the first of its kind in the USGS.

Rodney N. Cherry, Chief, South Carolina District Office, WRD, for outstanding contributions to the management of water resources programs.

John N. Fischer, Jr., Associate Chief Hydrologist, WRD, for exceptional contributions to earth sciences as a technical project coordinator and program manager.

Donald T. Lauer, Chief, Branch of Science and Applications, EROS Data Center, NMD, for outstanding service and many valuable contributions to remote sensing and geographic information systems development activities.

Robert L. Schuster, GD, for exemplary contributions to the field of engineering geology and leadership in the geotechnical engineering research community.

Frank Sentfle, GD, for outstanding contributions to nuclear physics and geochemistry and for exceptional leadership to scientific research programs.

Paul K. Sims, GD, for outstanding contributions to programs in mineral deposits and mineral resource evaluation and for many contributions to scientific administration.

Roger G. Wolff, Chief, Office of Hydrologic Research, WRD, for exceptional contributions in ground-water hydrology and research management and administration.

Meritorious Service

The Meritorious Service Award is the second highest award granted by the Department of the Interior and is given for significant contributions to the earth sciences and to management and administration of USGS scientific programs. Recipients are

Office of the Director—Willie McDuffie, Jr.

Geologic Division—Roger P. Ashley, Dennis P. Cox, William L. Ellsworth, Robert B. Halley, David S. Harwood, David P. Hill, David G. Howell, Jay L. Inge, Robert C. Jachens, Bruce R. Lipin, Edwin A. Noble, Fred Peterson, James E. Queen, Eugene A. Shinn.

Water Resources Division—William T. Alley, Mary Jo Baedecker, Daniel P. Bauer, Owen B. Bricker, Charles R. Burchett, James E. Cloern, Richard E. Fidler, Phillip Greeson, Arlen W. Harbaugh, Jerry L. Hughes, Robert D. MacNish, Joe A. Moreland, Gerald G. Parker, Charles A. Pascale, Ferdinand Quinones-Marquez, Joan M. Rubin, Wilbert O. Thomas, Jr., James F. Turner, Jr., Warren W. Wood, Allen L. Zack.

Information Systems Division—Wendy A. Budd.

National Mapping Division—Charles W. Bennett, Jr.

Administrative Division—Audrey J. Andrus, Timothy E. Calkins, Robert C. Edwards, Philip L. McKinney.

Superior Service

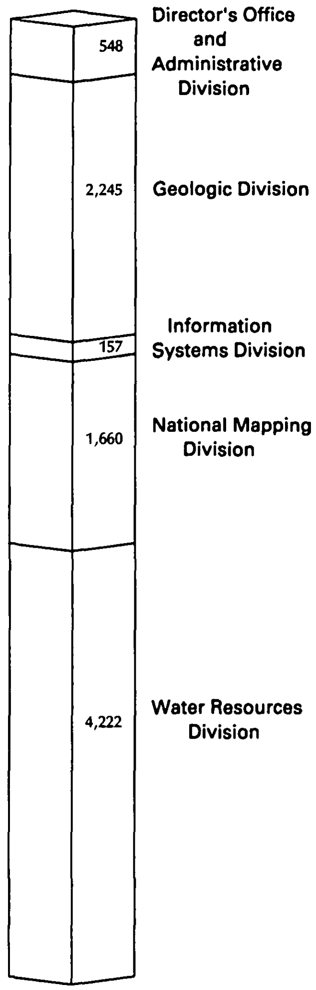
The Superior Service Award is the third highest award granted by the Department of the Interior and is given for significant acts, services, or achievements that materially aid the accomplishment of the Survey's mission. Recipients are

Office of the Director—Catherine L. Hill.

Geologic Division—Robert R. Burford, Cynthia M. Crampsey, John P. D'Agostino, Roy T. Hopkins, Jr., Raymond Jordan, Samuel W. Stewart, W C Swadley, Julia E.H. Taylor, Earl R. Verbeek.

Water Resources Division—Darwin F. Alt, Harvey L. Case III, Sheldon C. Cordes, Jay H. Diamond, G. Louis Ducret, Jr., Robert E. Faye, Michael W. Gaydos, James M. Gerhart, Daniel C. Gillies,

Personnel, by Division



Shirley A. Hammamoto, Richard O. Hawkinson, William F. Horak, Jr., Paul A. Hsieh, Edwin C. Kennison, James E. Kircher, Vincent C. Lai, Edward R. Landa, Melvin Lew, Russell K. Livingston, David J. Lystrom, Wilbur J. Matthes, Philip B. McCollam, John L. Oberg, Beverly A. Pittarelli, James G. Rankl, Linda D. Rann, Barbara J. Ryan, Earl L. Skinner, William R. Stokes, Stephen J. Vandas, Chester Zenone.

Information Systems Division—Kevin W. Laurent, Carol Lawson, John C. O'Donnell, Elizabeth M. Pritchett.

National Mapping Division—Jennie M. Grant, Kathryn C. Neff, Keven S. Roth, Doris K. Walsh.

Administrative Division—Sally L. Hutchison, Barbara J. Shaw, Matthew J. Sliwiak, Cynthia S. Wylie.

Unit Award for Excellence of Service

The Unit award is granted by the Department of the Interior to a group of employees who have worked together as a unit to perform a service so far above and beyond that which is normally expected that it is considered to be superior. The award includes a certificate signed by the Secretary of the Interior.

USGS Library, GD, was recognized for the enormous staff effort, coordination, and teamwork demonstrated by the successful planning and implementation of the extensive and complex move and renovation of the USGS Library in Reston, Va.

Public Affairs Office, Office of the Director, was recognized for its prodigious efforts in developing and fostering a Visitors Center and tour program at the National Center headquarters, in providing information for news media coverage for the Loma Prieta earthquake, and in rendering press and related coverage for the 28th International Geological Congress.

DOI

Stephen Vandas (center) receives the Superior Service Award, in Washington, D.C., from Deputy Interior Secretary Frank Bracken (left) and USGS Director Dallas Peck.

1991 AGI Award for Outstanding Contribution to Public Understanding of Geology

The USGS was noted in this award for its publications and reporting of the Loma Prieta earthquake and Mount St. Helens volcano and for its reporting of the potential and preparations for a New Madrid earthquake.

The award recognizes significant contributions to public awareness of the role of geology in our daily lives leading to a greater appreciation of geologic influences on our environment, economy, and lifestyles.

Awards and Honors Received by USGS Employees in 1991

James E. Biesecker, Assistant Director for Information Systems, ISD, received a Federal Women's Program Achievement Award from the Federal Women's Interagency Board for significant contributions toward improving the status of women in the USGS.

John Bredehoeft, senior research geologist, GD, was elected to the Russian Academy of Natural Sciences (of the Russian Republic) for his fundamental contributions to the study of ground water and its wise use as a water resource and for the study of water wells in helping predict earthquakes.

Ronald C. Circe, GD, received the USGS Safety Management Award for his efforts as Chairman of the newly formed Branch of Atlantic Marine Geology Diving Control Board and his outstanding contributions in creating standards for scientific SCUBA Diving.

George Erickson, GD, became the first recipient of the Geological Society of Chile Herbert Thomas Award for his outstanding contributions to the geology of Chile. He was also named a Corresponding Member of the Chilean National Academy of Sciences.

Anita Harris, GD, received the Pander Society Medal for outstanding and innovative contributions in conodont paleontology.

Richard A. Herbert, Chief of the Kansas District Office, WRD, received the Icko Iben Award of the American Water Resources Association, in recognition of outstanding contributions to the promotion of communications among the various disciplines of water resources.

David Hill, GD, was elected a Fellow of the American Geophysical Union.

Robert D. Jarrett, research hydrologist, WRD, was named Engineer of the Year for the USGS, U.S. Department of the Interior, by the National Society of Professional Engineers.

Peter Lipman, GD, was elected a Fellow of the American Geophysical Union.
Alan M. Mikuni, Supervisory Cartographer, NMD, was 1991 Chairman of the Engineering Cartography Committee, Surveying Engineering Division, American Society of Civil Engineers.
Betty M. Miller, GD, was presented with the J.J. Arps Award of the International Society of Petroleum Engineers for her outstanding contributions to the fields of hydrocarbon economics and evaluation.
Michael A. Newman, Cartographic Technician, NMD, was awarded the Exemplary Act Award of the Department of the Interior for prompt action in averting a life-threatening situation.
Gary W. North, Assistant Division Chief for Information and Data Services, NMD, was elected Chairman of the Federal Delegation to the White House Conference on Library and Information Services.
James R. Plasker, Assistant Division Chief for Production Management, NMD, received the Presidential Award of the American Congress on Surveying and Mapping for outstanding contributions to the surveying profession, and specifically for a special report on surveying and mapping in the United States presented to the International Federation of Surveyors.
Wayne G. Rohde, Chief, Program Development and Control, EROS Data Center, NMD, received the Department of the Army Meritorious Service Medal for Exceptional service in the application of satellite multispectral imagery for Army applications. Mr. Rohde was also selected as the Intelligence Threat and Analysis Center Army Reservist of the Year for 1990.
Malcolm Ross, GD, was elected President of the Mineralogical Society of America and was the first recipient of the Society's Public Service Medal in recognition of his contributions to the understanding of the health effects of mineral dusts, particularly asbestos.
David M. Sherman, GD, received one of the most prestigious awards of the Geochemical Society, the F.W. Clarke Medal, which is bestowed upon a young scientist for a singular important contribution to geochemistry or cosmochemistry.
Norman Sohl, GD, received the Paleontological Society Medal, the highest award of the Paleontological Society, for his distinguished career in paleontology.
David I. Stannard, research hydrologist, WRD, received the C.A. Hogentogler Award from the American Society for Testing and Materials (ASTM), as an author of an ASTM paper of outstanding merit on soil or rock, entitled Tensiometers—Theory, Construction, and Use.

Stewardship Award for Science and Technology

In support of his initiative to recognize employees who play active roles in the preservation, conservation, and development of national resources, Secretary of the Interior Manuel Lujan, Jr., presented the Stewardship Award for Science and Technology to **Isaac J. Winograd**, research hydrologist, WRD, in recognition of his unparalleled contributions to the conduct of pioneering earth science investigations that address nationally important environmental issues and for his support of the overall U.S. Global Change Research Program.

Public Service Recognition

Special awards were presented by the USGS to nine employees in 1991 for their outstanding contributions as public servants. These awards were part of the celebration of Public Service Recognition Week activities, to celebrate the indispensable and diverse contributions of the millions of women and men who make up the public workforce. Those receiving Public Service Recognition Awards were
Marcella Bernhard, ISD, who monitors all communication systems in the USGS Western Region, installs local area networks, and serves as the computer security officer for the region.
Michael L. Blanpied, GD, who has embraced the call for outreach in the public service by giving lectures on earthquakes and earthquake hazards and by working with museum staff to develop an earthquake safety presentation.
Wendy R. Hassibe, NMD, who, as Chief of the Earth Science Information Management Branch, has advanced the Survey's professional reputation as a world-class scientific research organization and organized the Earth Science Information network, which has given a new direction and a broadened scope to USGS information outlets.

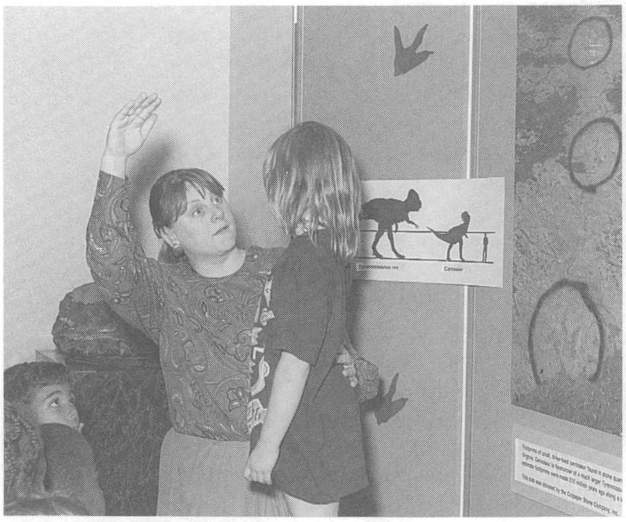
Wendy Hassibe explains details of a map to a visitor at the Earth Science Information Center in Reston, Va.

Emiko "Amy" A. Hirota, NMD, who, as secretary to the Chief of the Western Mapping Center, offers a helpful, cheerful first impression to visitors of the USGS and the Federal Government.

Thomas L. Holzer, GD, whose availability to both scientists and the media after the Loma Prieta earthquake was a key factor in disseminating timely information to the public.

Judy Huffman, AD, USGS expert in employee benefits and awards who has cheerfully counseled thousands of USGS employees.

Anna M. Lennox, WRD, who, as an international water resource program specialist, has made immeasurable contributions to the favorable image of the USGS and the United States held by thousands of scientists, engineers, and governmental officials around the world.



Susan Russell-Robinson and young visitors to the National Center Visitors Center near the dinosaur footprints display.

Deborah M. McLean, WRD, whose ability to produce timely status reports on 25 financial accounts and to keep up with thousands of transactions for these accounts has improved the efficiency and production of her entire office.

Susan L. Russell-Robinson, Office of the Director, who, as information scientist for the National Center Visitors Center, has brought the word of the USGS to nearly 10,000 visitors in 2 years.

Public Service Excellence

The Public Employees Roundtable, which consists of more than 25 professional organizations and societies, each year sponsors a Public Service Excellence Award. The award is given to the organization or organizations that have most improved the image of public employees through increased organizational effectiveness and customer satisfaction. Nominees were evaluated in the areas of productivity improvements, savings achieved through efficiencies, and new and innovative techniques.

The USGS Administrative Service Center was recognized for its outstanding achievements in evaluating, acquiring, and implementing the Federal Financial System, a single departmentwide accounting and repayment system for the 10 bureaus of the U.S. Department of the Interior.

John Wesley Powell

Each year the USGS presents the John Wesley Powell Award to persons or groups outside the Federal Government for voluntary actions that result in significant gains or improvements in the efforts of the USGS to provide "Earth Science in the Public Service."

The Powell Award is named in honor of the second USGS director (1881–84). Powell,

At an awards ceremony in May 1991, the Executive Director of the Public Employees Roundtable, Joan Keston (second from left), presented a 1991 Public Service Excellence Award to the U.S. Geological Survey (USGS) Assistant Director for Administration, Jack J. Stassi (second from right), and the USGS Chief, Washington Administrative Service Center, Philip L. McKinney (far right). Deputy Secretary, Frank A. Bracken (center), and Principal Deputy Assistant Secretary for Policy, Management and Budget, Ed Kay (far left), look on.

DOI

a geologist, Civil War hero, and Indian ethnographer, led pioneer explorations of the Colorado River. Powell award recipients for 1991 are

Michael T. Halbouty, of Houston, Texas, who received the Powell Award for Achievement as a Private Citizen. He was recognized for his more than 30 years of support for the USGS in his various capacities as an official member of the American Association of Petroleum Geologists, as President and Chairman of the Board of the Circum-Pacific Council for Energy and Mineral Resources, and as a private citizen. Dr. Halbouty, a longtime friend of the USGS, has advanced programs and enhanced the careers of countless USGS research scientists.

Peter G. Morros, Director, Nevada Department of Conservation and Natural Resources, who received the Powell Award for Achievement in State Government. Mr. Morros has been a valued advisor to the USGS Director and Chief Hydrologist and an active supporter of the USGS water resources program in Nevada and other western States. An active member of the USGS Advisory Committee on Water Data for Public Use, Mr. Morros' many contributions have significantly strengthened the technical content of the USGS water resources program.

Unocal Corporation North American Oil and Gas Division of Ventura, Calif. Their paleontology team received the Powell Award for Achievement in Industry. The team has been instrumental in helping the USGS accomplish the objectives of the Santa Maria Province Project of the Evolution of Sedimentary Basins Program, enhancing the ability of USGS scientists to reconstruct the geologic evolution of sedimentary basins and leading to a better understanding of the resource potential of this important and geologically complex area. Team members included Gregory Blake, Robert G. Arends, Mark V. Filewicz, Mary Lou Cotton Thornton, and David R. Vork.

Lynn R. Sykes, Professor of Geology, Columbia University, Palisades, N.Y., who received the Powell Award for Achievement in an Educational Institution. Dr. Sykes has served as a faithful source of advice, support, and constructive criticism for the USGS earthquake hazards reduction program. He has brought his personal expertise in seismology and its relationship to plate tectonics to bear on the development and nurturing of the program. Through the rigor of his criticism, as well as his advocacy, the USGS has been able to maintain and strengthen the hazards reduction program for more than a dozen years.

Special Programs and Initiatives

Volunteerism

In 1991, the Volunteer for Science Program once again proved itself a successful complement to the USGS workforce. At any one time, nearly 700 volunteers were actively participating with USGS employees in a variety of earth science research, computer technology, and office administration projects. USGS employees are also very active as volunteers themselves in their communities.

Volunteer for Science.—The program has grown steadily since its beginning in June 1986. In a recent letter, a science teacher volunteer commented, "Hope you can maintain the volunteer program. It was a winner for me." It has been a winner for the USGS, too. In 5 years the Volunteer for Science Program has benefited from the efforts of more than 2,800 volunteers who have donated well over 580,000 hours of service, saving the Federal Government—and American taxpayers—more than $6 million.

We intend not only to maintain the impressive growth of the program but also to encourage even greater participation. A series of promotional tools have been developed to increase public awareness of the program. A recruitment video provides a colorful, closeup view of volunteer opportunities throughout the USGS. Showcasing volunteers from each USGS division, the upbeat, fast-paced videotape will greatly enhance recruiting efforts. The video will also serve as a companion to recruitment exhibits that offer increased program exposure at career and volunteer fairs. These colorful montages, showing volunteers at work in offices, laboratories, and in the field, expressively depict the vast scope of volunteer opportunities throughout the USGS.

Leaflets, posters, and similar promotional items have also been developed to increase awareness and provide program information at schools, career fairs, volunteer conferences, and to professional and community service organizations.

The remarkable success of the Volunteer for Science Program must be attributed, in large part, to the volunteers themselves and the enthusiasm and dedication they bring to a multitude of tasks. To better demonstrate our appreciation of these individuals, we have developed new awards criteria and created a variety of distinctive recognition items.

A Volunteer for Science logo is one key to the program's new look. In April we invited everyone to participate in a logo design contest. We received 80 entries from employees, volunteers, and even elementary school students at a USGS partnership school. The winning design concept was submitted by **Donna Jenkins**, a volunteer in Pasadena, Calif. Her idea can now be seen as the colorful, red, white, blue, and gold logo, with a distinctive "V" shape, on all items associated with the Volunteer for Science Program.

We hope the logo, the new tools for recruitment and reward, and the impressive winning record will not only remind us of how far we have come but will also ensure even greater strides into the future.

Points of Light.—In support of President Bush's Thousand Points of Light, Secretary Lujan hosted a series of lunches during 1991 to recognize Department employees for community volunteer activities. The following USGS employees were recognized for their many hours of service to their fellow citizens and their communities:

Willie McDuffie, Jr., Office of the Director, Reston, Va., for his work in helping to direct young people in Washington, D.C., away from lives of drug addiction, irresponsible maternity, and crime.

Harold J. Cohen, NMD, Reston, Va., for his work in organizing and coaching Special Olympics soccer teams.

Clifford A. Haupt, WRD, Reston, Va., for his work with students and educators at all levels within the Fairfax County, Va., school system.

Education

The USGS has a long-standing commitment to education. That commitment includes providing further educational opportunities for its own employees, for graduate students, and for postdoctoral students. A growing interest and emphasis in precollege educational support stems from President Bush's goal for the United States to attain preeminence in math and science by the turn of the century and from a concern by the USGS that everyone needs an understanding of the earth sciences to be an informed citizen ready to respond to the changing physical world. Also, the USGS and other scientific agencies recognize a need for a qualified pool of scientists for the 21st century and beyond, a pool of scientists that will mirror the changing face of the general employment picture in which women and minorities will figure more prominently.

All of these concerns have led the USGS to commit additional resources to help support Secretary of the Interior Lujan's excellence in education efforts. USGS personnel around the country are involved in educational activities, and the USGS has adopted schools in connection with its offices in several States. These efforts include USGS scientists routinely visiting classrooms to give presentations and share their knowledge and experience with teachers and students, conducting regular summer workshops at several sites for teachers and participates in regional and national meetings of the National Science Teachers Association, developing resource centers at USGS libraries to assist teachers with classroom activities, and hosting more than 5,000 student visitors in the USGS National Visitors Center in the past school year. The following items provide a glimpse of the many exciting educational activities underway.

Partnership in Education.—The USGS has continued to place great emphasis on the expansion of activities in support of existing Partnership in Education agreements and on the establishment of new agreements throughout the country. The USGS Earth Science Education Committee has selected kindergarten through sixth grade as its primary focus, although we are also pursuing and supporting formal partnerships with colleges and universities, such as Lincoln University in Rolla, Mo., and Gallaudet University in Washington, D.C.

The educational partnership the USGS established in 1990 with neighboring Dogwood Elementary in Reston, Va., near the USGS National Center, has been extremely successful and serves as a model for the types of educational exchanges that can occur between academic institutions and government offices. USGS-sponsored activities include inviting students and teachers to special cultural awareness programs, displaying exhibits on glaciers and volcanoes and other earth science topics in the school library, donating cash register receipts to assist in the acquisition of computer equipment, inviting the students to Drug Awareness Day and distributing literature and posters, USGS employees serving as advisors to students for the school's Invention Convention, and donating hundreds of children's books to help establish a library in a community center used by many Dogwood students and their younger siblings.

The partnership with Dogwood Elementary is indeed a true cooperative effort. Not only does the USGS strive to enrich the school, but also the school offers its resources to us, whenever possible. For example, the students of Dogwood Elementary threw a birthday party in honor of our 112th birthday, a teacher conducted training on different learning styles for interested USGS employees, the principal of Dogwood Elementary invited the USGS to several meetings and conferences focused on establishing strong educational partnerships, and the school also invited the USGS to attend a seminar on cultural diversity conducted by a well-known clinical and industrial psychologist. This very productive and rewarding academic year culminated in a ceremony in which the Fairfax County Public Schools presented an appreciation plaque to the USGS, which is proudly displayed at our National Center in Reston.

The USGS had traditionally been a strong supporter of earth science education and has been involved in the Partnership in Education Program since its inception in 1984. However, most of our involvement has been through informal outreach and assistance to schools. Presently, USGS offices throughout the country are being encouraged to establish formal Partnership in Education agreements with local schools. A second formal partnership agreement has already been established in our Central Region with Cole Elementary School, a predominantly Hispanic school in Arizona, and we are in process of establishing others.

Reaching Out to Teachers and Into the Classroom.—Teacher input and guidance in the development of educational materials and activities is an important component to the USGS education effort. To assist in this effort, the USGS hosts specialized workshops in each region and provides field programs on specialized topics. In connection with some of the workshops and field activities, teachers are granted college credit through cooperative agreements with local colleges and universities. In-service programs are coordinated with local school programs so that teachers who want to hone their earth science skills can attend special programs and receive in-service credit for participating.

As examples of these efforts, the USGS hosted an intensive 1-week field program for 55 teachers in the Denver, Colo., area called GEOTEACH, in which such nearby features as dinosaur tracks and geologic formations in local parks augmented the program; a 2-week field and lab program for Native American Indian teachers on the Pine Ridge Reservation in South Dakota provided the teachers and USGS scientists a unique opportunity to blend Native culture with earth science teaching; internship opportunities are available at numerous USGS office sites for teachers who have been teaching for many years and for those who are still preparing to teach; the USGS also provides for its own special recognition of teachers who receive nationally recognized awards for excellence in science teaching.

Interacting with students is also an important component of USGS education efforts. Tours and special programs for school groups are hosted where facilities permit. The USGS Volunteer for Science program also provides an excellent opportunity for students to get an on-the-job taste of what it is like to work as an earth scientist. Scientists go to classrooms and participate in science and career fairs and judge science contests. One exciting new project is developing fossil collections that can be used by scientists visiting in classrooms and for teachers to borrow and use themselves.

The successful Joint Education Initiative (JEdI), a multidivision, multiagency, academic and industry cooperative project, has brought realtime scientific data and images into the classroom using CD-ROM technology. The JEdI project has proved so successful that it is being written into textbooks, implemented in a new program for community colleges in California, and written into new standards for secondary education in science. The USGS, which oversaw the prototype development of the project, has turned it over to the University of Maryland for further development and distribution.

The USGS is also involved in more than 40 coalitions and partnerships to further earth science education across the Nation. Many alliances are with individual universities or colleges or with local school districts. Most effective for the USGS are those programs that provide an established inroad to the teaching community in a regional area or those that deal with national issues in science education reform. Some examples are the Bay Area Earth Science Institute, a large coalition effort in the San Francisco Bay area to train teachers in earth and physical science; DEEP, the Denver Educational Excellence Program, dedicated to supporting outstanding minority junior and senior high school students; MESA, the Mathematics-English-Science Achievement program, which supports field trips for Hispanic students; and FIRST and FEST, which are the Field Investigations Research for Science Teachers and Field Education for Science Teachers of the Wisconsin Geological and Natural History

At an April 1991 ceremony in the office of Deputy Interior Secretary Frank Bracken (left), Kenneth D. Reid (center), executive director of the American Water Resources Association (AWRA), received a plaque from Dallas Peck, director of the USGS, commemorating the assistance of AWRA in the cooperative Water Education Initiative.


DOI

Survey, the University of Wisconsin, and the Wisconsin Academy of Sciences, Arts and Letters. Coalitions have been useful to the USGS in helping to identify outside sources for reprinting and distribution of publications.

Cooperative Water Resources Education Initiative.—In response to President Bush's challenge to Americans to become "Number One" in the world in math and the sciences, the USGS has begun a water-resources education program. The USGS, Bureau of Land Management, U.S. Fish and Wildlife Service, and Bureau of Reclamation of the U.S. Department of the Interior and the U.S. Environmental Protection Agency are working in a partnership, which began in fiscal year 1990, with the American Water Resources Association (AWRA) and the National Science Teachers Association (NSTA) on this program. The AWRA, a nonprofit educational organization dedicated to the advancement of interdisciplinary water-resources research, planning, management, development, and education, has approximately 3,000 members worldwide. The NSTA, the world's largest organization dedicated to the improvement of science education at all grade levels, has a membership of approximately 60,000 educators.

The objective of the water-resources education program is to stimulate interest in and provide a basic knowledge of water resources to students from kindergarten through the 12th grade. To meet this objective, the program is designed as a cooperative effort among Federal and private agencies to provide several different teaching aids. The first teaching aid is a series of three sets of water-resources educational posters designed to capture the attention of the students (the first set in the series, on water use, was released in April). The second teaching aid, which is a set of water-resources educational training packages designed to be taught in the classroom or after school by water-resources professionals and other interested individuals, is currently being reviewed by NSTA representatives.

The first set of posters in the series covers water use and has been distributed by the NSTA to about 43,000 science teachers in the United States. Each of the three posters in this first set demonstrates the importance of water to society and shows how water is used and reused. Two of the posters also were inserted in the May issues of two different NSTA publications: *Science and Children*, for science teachers of kindergarten through the fifth grade, and *Science Scope*, for science teachers of sixth through the eighth grade. The two posters, which are in color, were accompanied by articles that provide background material for the teachers. Because the posters have two different audience levels—grade and middle school students—appropriate texts were placed on the reverse of the posters earmarked for the two different magazines. The third poster, a black and white version printed for children to color, has no text. The posters presently in preparation are on wastewater treatment and wetlands.

The formal agreements established among the Federal agencies mentioned above with the AWRA and the NSTA are planned to insure long-term viability for the education initiative. The education initiative represents a unique commitment among government and private agencies to improve communications between the scientific and education communities.

Computer Links to Understanding Earth Science.—The USGS is exploring the use of hypermedia technology for designing and developing educational tools for the precollege education community. Multimedia computer technology offers exciting new possibilities for navigating through multiple layers of information. Hypermedia or hypertext is defined as a software development environment for creating nonsequential data bases containing associative links between a mix of information, such as graphics, text, animation, sound, and video.

Research and development projects at a variety of universities have shown that this type of computerized information tool enhances understanding of complex scientific processes. Hypermedia improves learning by focusing attention on the relationship between ideas rather than on isolated facts. The associations provided by links from within a hypertext system may improve concept formation and understanding. The use of graphics and animation contributes to the effectiveness of hypermedia as a learning tool. The interactive nature of hypermedia may also contribute to its appeal to young learners much in the same way that computer video games have become so popular in the last decade.

During the coming months, the USGS will be developing a hypermedia system for children to explore the water cycle and to understand maps and earthquakes.

What? Me a Scientist?—This eye-catching title headlines a poster depicting women and minorities actively working in scientific endeavors. The poster was produced by the USGS in cooperation with the U.S. Bureau of Mines and the Association of Women Geoscientists. The poster provides a positive visual image of women and minorities and seeks to encourage young people to pursue a career in science. A tag line at the bottom of the poster asks the student, "Will your picture be here in the year 2000?"

Women, Minorities, and Persons with Disabilities

International Training Opportunities.—Employment projections for the year 2000 indicate that there will be a higher percentage of women and minorities in the workforce. Employers will be increasingly required to provide training, tutoring, or remedial education in the workplace to enable the workforce to reach optimum productivity. Additionally, greater emphasis will have to be placed on the development and advancement of women, minorities, and persons with disabilities into supervisory, managerial, and executive positions. The year 2000 is upon us, and it is clear that special training efforts must begin now in anticipation of a well-prepared workforce.

In this regard, the USGS has already begun to focus on providing career development and training opportunities to the women, minorities, and persons with disabilities within our existing workforce. During the past fiscal year, training needs surveys were conducted to determine the special needs of these targeted groups. Individual and group training was offered, including courses such as Basics of English Grammar and Usage, Writing Skills, Speaking and Listening, Sign Language, Communicating with Disabled Employees, Dealing with Difficult People, Men and Women Working Together, and Coaching and Counseling Hearing Impaired Employees. Special efforts were made to provide career and manager development opportunities to women, minorities, and persons with disabilities. Numerous employees attended undergraduate and graduate courses and participated in special developmental training such as the Women's Executive Leadership Program, the Departmental Manager Development Program, and Executive Seminars.

Furthermore, the USGS recognizes that with the changing composition of the workforce, it is necessary to provide all employees with an understanding and appreciation of a wide variety of cultures. In fiscal year 1991, in our initial efforts to provide training to USGS employees on the topic of cultural diversity, we trained close to 1,500 employees at our major centers and offices across the country. Because many of our employees are located in remote field locations and classroom training is not always practical, we purchased several sets of a video series on cultural diversity. We realize it is important for all of our employees to receive exposure to this extremely significant topic; therefore, the videotapes are readily available for loan to employees. Also, managers and trainers are strongly encouraged to use the videotapes in meetings and conferences.

The USGS is committed to the development and maintenance of a well-prepared workforce, and we will continue our concentrated training efforts to train and develop all employees.

Specialized Equipment and Services for Disabled Employees.—The Selective Placement Program Advisory Committee, which comprises representatives from each division, met for the first time this year to evaluate the needs of disabled persons within the USGS and to provide necessary equipment or training, or other enhancements. The committee approved $14,000 for interpreting services for hearing impaired employees to be used in government training courses, staff meetings, supervisory sessions, and other gatherings where sign language interpretation is required. Other purchases include

- Telecommunications equipment to provide telephone access for hearing impaired employees and members of the public who call USGS offices,
- For visually impaired employees, automated workstations and equipment, such as software that magnifies print size for use in offices and libraries by employees and library patrons and high-resolution monochrome display monitors that provide a magnified high-contrast black and white display,
- "Ergo-Arms," keyboard adaptive devices for individuals with arm and wrist weaknesses that make it difficult to use a keyboard,
- "Power-Bar," a device that attaches to milling equipment for use in the Earth Resources Observation System Data Center, Sioux Falls, S. Dak., to permit a wheelchair-bound employee to make adjustments to machinery, and
- Voice recognition systems that enable two physically challenged individuals to operate their computers by using voice commands.

The committee continues to evaluate equipment and training programs that will increase the potential of employees with disabilities. The USGS has a leading record among bureaus of the Department of the Interior for employment of disabled individuals.

Outreach.—The USGS has continued its full-scale efforts to locate, interest, and attract minority, female, and disabled individuals toward research and career pursuits in the field of earth science. Efforts to support and further affirmative outreach initiatives established by President Bush and Secretary of the Interior Lujan have focused on recruitment at all levels of education as a means to encourage targeted individuals to explore careers in earth science and to identify viable career opportunities early in their educational pursuits.

Beginning with job fairs in Albuquerque, N.M.; Washington, D.C.; and Dallas, Tex., the bureau provided representation and career information at seven national or regional career fairs that targeted minority, female, and disabled individuals. Throughout the year, program officials, line managers, and personnel specialists joined forces to stand at fair booths and introduce job seekers to the exciting field of earth science exploration and research. Young people and seasoned scientists alike stopped to find out what the USGS has to offer and to learn from the employees themselves the issues and policies of national significance that USGS scientists routinely study.

In 1992, plans for active participation in job fairs will produce more recruitment teams in locations throughout the Nation at career fairs, professional conferences, college campus career days, and seminars. These teams give on-the-spot information to interested participants. Two special emphasis outreach coordinator positions have been established in the Personnel Office specifically to provide leadership and planning for outreach activities and to successfully meet the challenges of recruitment for today's changing job market.

Working closely with the Environmental Careers Organization, Inc., a nonprofit organization having a large resource of minority and handicapped students, the USGS has established workstudy partnerships for students pursuing degrees in the environmental and earth sciences. The USGS in St. Petersburg, Fla., initiated the first partnerships program with Environmental Careers Organization, Inc., in which three students have been assigned to scientific projects. Similar agreements have been developed in other locations with water resources and geologic programs. We look forward to enhancing academic development and practical work experience opportunities for these students with the goal of providing employment opportunities upon completion of their education.

Minority Colleges Cooperative Activities.—The USGS has a long history of active support of cooperative activities and special programs with the Historically Black College and University (HBCU) and the Hispanic Association of Colleges and Universities (HACU). Hampton University, an HBCU, and New Mexico Highland University, an HACU, are two of the colleges with which the USGS has ongoing programs.

Hampton University.—For the last 3 fiscal years, USGS employees have visited Hampton University, located in Hampton, Va., to attend job fairs, interview potential full-time and cooperative education employees, and implement a guest lecture exchange program.

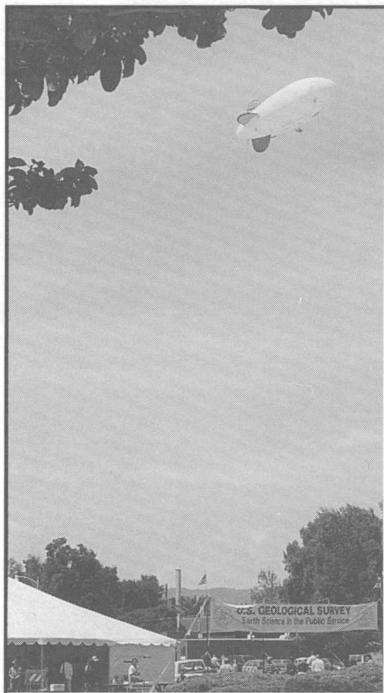
The USGS had two cooperative education agreement appointments with Hampton University in place for fiscal year 1990. The appointees worked in the computer visualization (graphics) and technology assessment (research) fields. In addition, the USGS hired two full-time Hampton graduates during fiscal year 1990. These graduates are working in the areas of earth science data base maintenance and development and computer operating systems. The USGS will continue its emphasis on recruitment efforts in these two areas.

The USGS initiated a Guest Lecture and Information Exchange Program with Hampton University's Computer Sciences Department. The lecture series began in the first quarter of fiscal year 1991 with a USGS computer scientist speaking on object oriented programming. The lecture presented an overview of object oriented programming including definitions, a comparison with procedural programming, and realworld applications. The second lecture on parallel processing described typical parallel processing architectures, provided insight into how algorithms and programs for these systems differ from traditional computers, and described USGS experiments with parallel processors. These lectures were tailored to Hampton University's curriculum.

New Mexico Highland University.—The USGS has initiated a similar program with New Mexico Highland University located in Las Vegas, N. Mex. During an initial visit, USGS representatives met with the President of the University, the Director of Career Services, and the Vice President for Academic Affairs. The meetings resulted in several innovative ideas that the USGS is currently pursuing. A summary of the USGS cooperative education program was presented to two introduction to information systems classes. A New Mexico Highland University student is scheduled to visit the USGS Denver Field Center in Colorado to pursue a cooperative education appointment. The student will spend time touring the field center and meeting with employees.

A graduate of Hampton University working in the USGS as a mathematician.

Fossils, Faults, and Friendly Folds—USGS Opens Its Doors



Looking at the Earth from above. . .

Learning how to read topographic maps, finding out what is in the water, and looking at fossils under microscopes were some of the more than 150 displays of USGS research and activities at the third public open house at the USGS in Menlo Park, Calif., May 18–19, 1991.

Good weather, excellent displays, and extensive employee involvement and visitor turnout combined to make the occasion an enormous success. Between 15,000 and 20,000 people visited the Menlo Park facility during the 2 days.

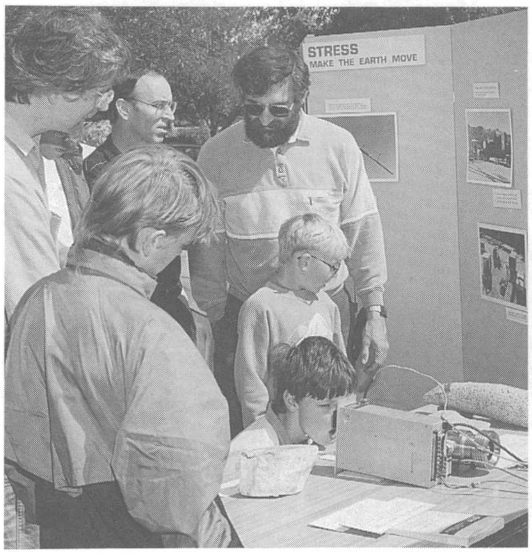
What stories do the rocks tell?

You can see for miles and miles. . .
as far as 93 million miles. . .

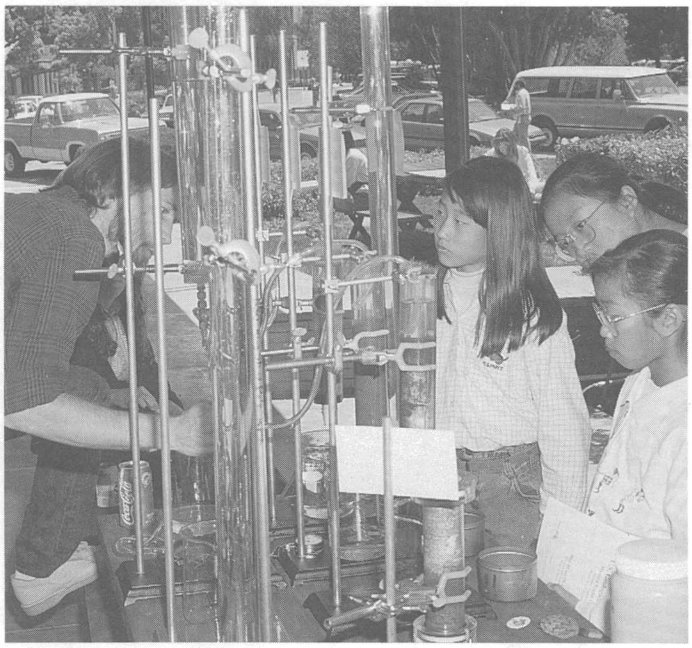
Displays of USGS research showed the remarkable breadth of work in the earth sciences. Highlights included interactive video programs on regional seismicity; spectacular 20-foot-long sidescan sonar images of the sea floor; the invasion of an Asian clam into San Francisco Bay; and computer animations of landslides and debris flows. A popular attraction was the ask-a-scientist booth, which was intended mainly for young people and their favorite mystery rocks but was thronged by adults bringing in geologic treasures. The Marine Facility at the Port of Redwood City, a few miles from Menlo Park, opened USGS research vessels, the *S.P. Lee* and the *Polaris*, for public tours.

Public response to the Open House was overwhelmingly favorable. One frequently voiced complaint was that there was not enough time to see everything. Also, adults commented that the children hogged the interactive computer displays, not giving the adults enough time on the keyboards. The public was pleased that the USGS had taken the time and effort to share their work with taxpayers.

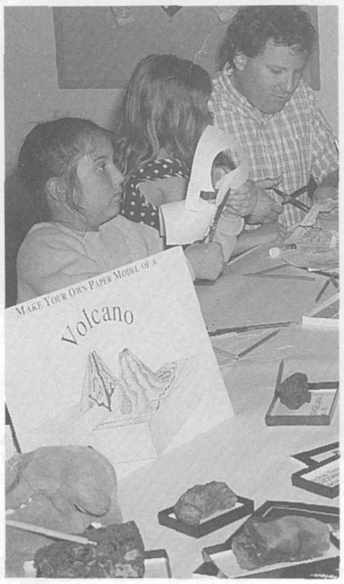
As part of its nationwide effort to reach out to the public in fulfillment of its mission to provide "Earth Science in the Public Service," the USGS hosts open houses on a rotational basis at its regional facilities in Menlo Park, Calif., and Denver, Colo.; and at its headquarters in Reston, Va. The 1992 open house was held April 25, 1992, in Reston. The USGS in Denver will host the 1993 event. (Photographs by Jay Prendergast and Pat Jorgenson.)



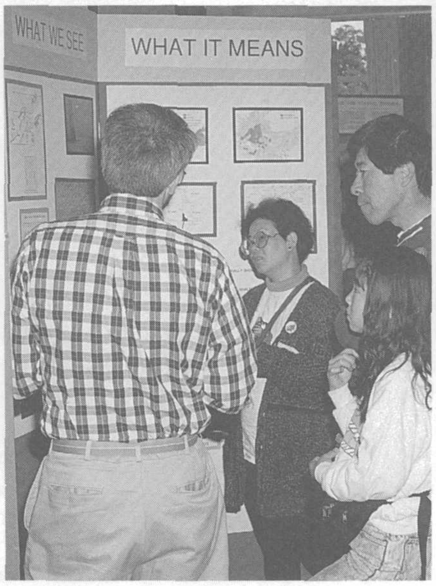
. . .and how does the Earth handle stress?



Pondering the complexities of scientific research. . .

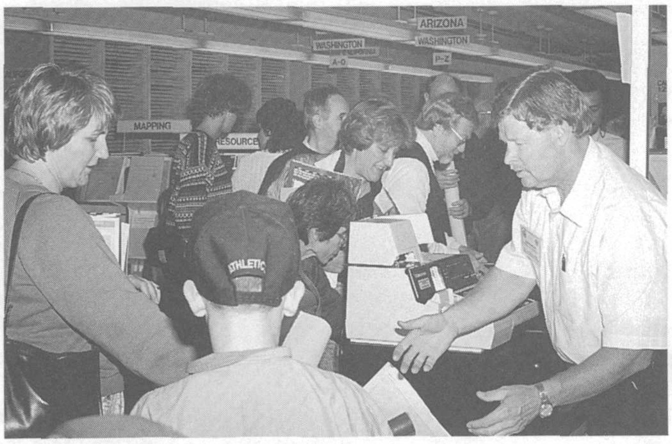


Making your own volcano model.



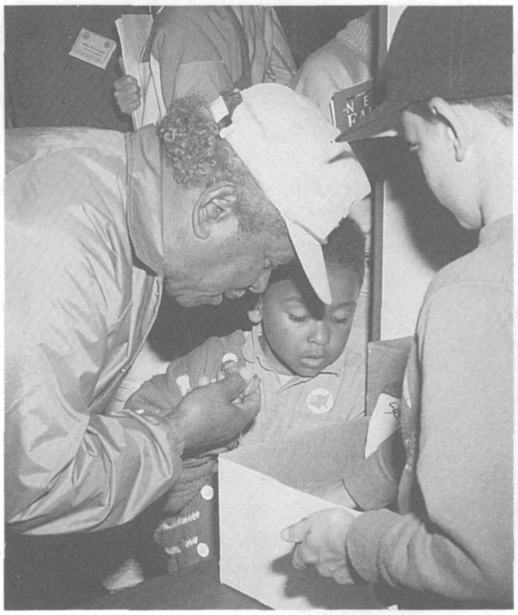
Science explained. . .

Jumping feet make an earthquake "happen."

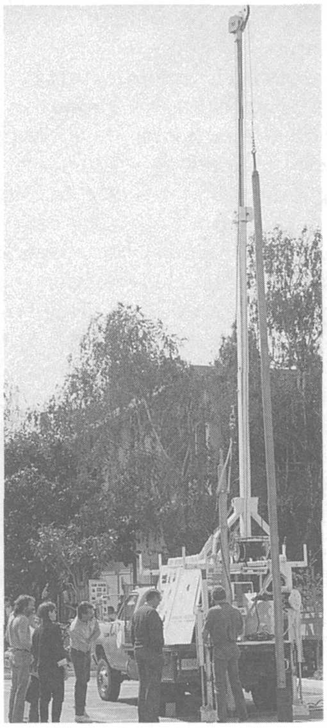


A map is worth a thousand words. . .

Imagining life on another planet. . .

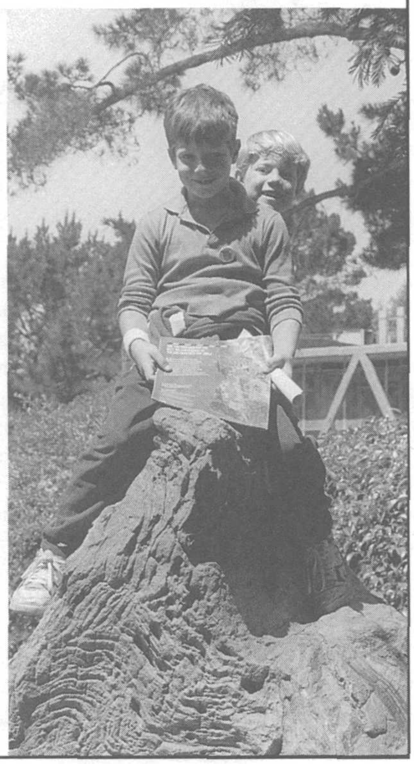


Discovering Earth's treasures together.



. . .and deep beneath the surface.

Rock with a view.



Contributions to U.S. Operations Desert Shield and Desert Storm

The USGS provided professional support and earth science expertise to national defense efforts for operations Desert Shield and Desert Storm. USGS personnel also served on active duty during the operations. The following are some USGS activities that were part of the U.S. military operations.

Desert Studies Support.—During the late summer, autumn, and early winter of 1990, the United States led a massive multinational military buildup on the Arabian peninsula to counter the invasion and occupation of Kuwait by Iraq. The USGS desert studies group participated in developing plans and strategy for possible military action by providing technical and scientific expertise in Landsat image processing and terrain analysis of desert environments to several government agencies.

One phase of the participation involved the training of terrain analysts in (1) landform characteristics and trafficability and (2) Landsat image processing and interpretation techniques used to construct maps of surface materials. Another phase was directed at preparing a manual, entitled *Remote Sensing Field Guide—Deserts*, for the Army and Marine Corps. That manual describes and illustrates various landform and terrain types found in desert regions. More than 100,000 copies of the manual were printed and distributed to troops as part of their training. A third phase involved direct exchanges with military tactical units to train them in the geologic conditions in the Middle East that could affect aerial combat operations.

Throughout Operation Desert Storm, a team of USGS scientists was stationed at Air Force Headquarters to provide advisory support for several aspects of the air war. That team was reinforced by nearly continuous technical and scientific help from the Survey's Desert Studies Group, which prepared trafficability maps and other information for the U.S. Army and Marine Corps using remotely sensed digital image data. Scientists of the teams provided assistance to the Air Force on a range of special technical needs, such as geophysical expertise developed for large-scale explosion shock-wave processes. USGS participants in operations Desert Shield and Desert Storm have been commended by the Secretary of the Air Force, the Defense Intelligence Agency, and the Army Engineering Research Institute for their dedication and major contributions in support of the military actions.

Enhanced Satellite Images Produced for Desert Storm.—The USGS Earth Resources Observation Systems (EROS) Data Center supported Department of Defense (DOD) and intelligence agencies by supplying digital data and satellite images for Operations Desert Shield and Desert Storm beginning in early August 1990.

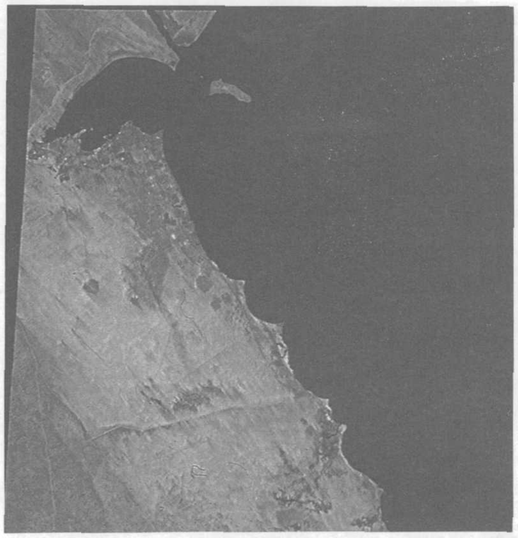
Enhanced Landsat Thematic Mapper (TM) satellite images were produced at scales ranging from 1:50,000 to 1:250,000, for change detection, map updates, and terrain analysis of Kuwait and portions of Saudi Arabia and Iraq, including Baghdad. From meteorological satellite data a photoimage mosaic of the Middle East was prepared for DOD agencies. Landsat TM satellite image data were acquired in the final phases of Operation Desert Storm to evaluate the extent of the Kuwait oil field fires and the oil slick in the Persion Gulf. These data were used to aid military operations and to assist in environmental monitoring. During operations Desert Shield and Desert Storm, the EROS Data Center coordinated the distribution of a digital data archive and catalog system of all civil satellite data purchased and products produced for DOD agencies.

Advanced very high resolution radiometer (AVHRR) data products of the Kuwait-Persian Gulf area during the period of conflict were provided to the United Nations Environment Programme (UNEP) offices in Geneva, Switzerland, and Nairobi, Kenya. UNEP also provided a copy of the digital data to the government of Japan to assist in developing funding alternatives to aid in the reconstruction of Kuwait.

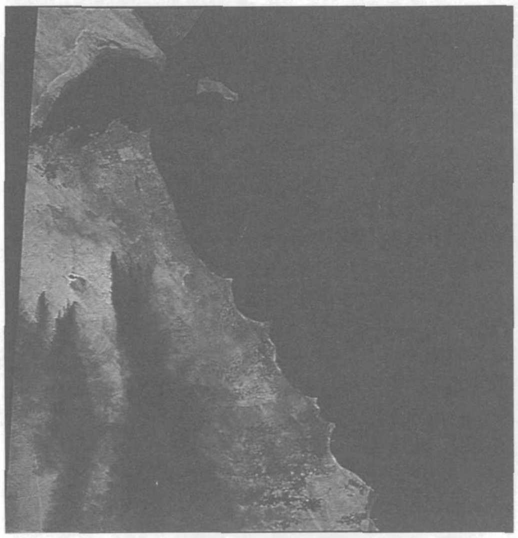
USGS Mission in Saudia Arabia Receives Citation.—USGS employees and their families were recognized with a special citation from the Secretary of the Interior for their efforts as part of the United States presence in Saudia Arabia during the Gulf War.

Although the city of Jiddah, headquarters of the USGS Saudia Arabia mission, was never under attack, the group of scientists and administrators lived under constant tension resulting from civil demonstrations, threats of terrorism, and reports of Iraqi aircraft and missiles in Yemen and Sudan. USGS personnel responded by performing their scientific and managerial assignments well, despite these trying and sometimes dangerous circumstances. The USGS group become a critical resource to the U.S. Consulate General because of their long-established mission and their contacts with the business and professional community of Jiddah. The Saudi mission members became valuable adjuncts to the Department of State and essential members of the American team in the Kingdom of Saudi Arabia.

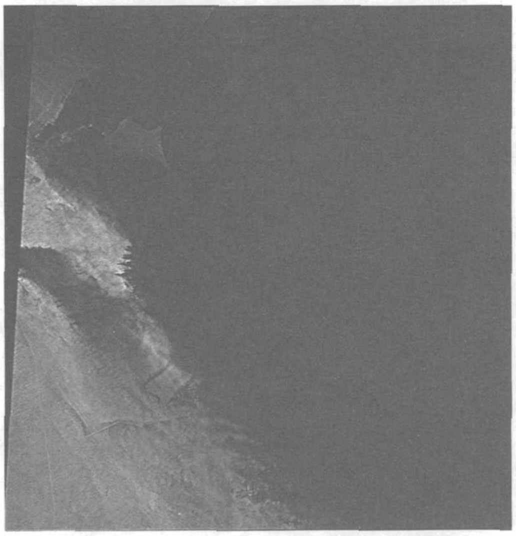
Acting as unofficial spokespersons, USGS personnel aided the American presence in the area. Their business-as-usual attitude helped



August 31, 1990, about 4 weeks after Iraq invaded Kuwait.



February 15, 1991, 1 month after the beginning of the coalition air campaign.



February 23, 1991, shortly after the start of the coalition ground campaign (note plume extending over water).

to keep operations running smoothly and was an aid to diplomacy. For their outstanding performance of duty in times of stress and for their extra efforts as part of the American team in the Kingdom, the members of the USGS Mission in Saudi Arabia were granted the Unit Award for Excellence of Service of the Department of the Interior.

The following USGS personnel, who were stationed in Jiddah, Saudi Arabia, and who were recognized for their contributions are PHILIP J. ARUSCAVAGE, KEITH M. BEARDSLEY, ARTHUR A. BOOKSTROM, PAUL S. BOSCH, JERRY J. CAPE, RICHARD B. CARTEN, RALPH P. CHRISTIAN, GEORGE V. DEMEGLIO, ELLIOT T. ENDO, THOMAS J.W. LEE, CARTER H. MILLER, KENNETH A. SARGENT, PAUL W. SCHMIDT, PAUL W. TOGANS, RICHARD L. TYNER, BRUCE M. WALKER, PAUL L. WILLIAMS, and BRUCE M. WOOD.

The following contractors to the USGS are not U.S. Government employees but are full-time members of the USGS mission: PETER R. JOHNSON, RICHARD P. SHELDON, and GEORGE J. VRANAS.

USGS Employees Called to Active Duty During Operations Desert Shield and Desert Storm.—BERI N. FRALEY, Nashville, Tenn.; ANNE E. GARTNER, Menlo Park, Calif.; WALTER H. MCDONALD, Reston, Va.; GEORGE S. OUTLAW, Nashville, Tenn.; BOBBY R. RICHARDS, Jackson, Miss.; and THEODORE F. SAUNDERS, Reston, Va.

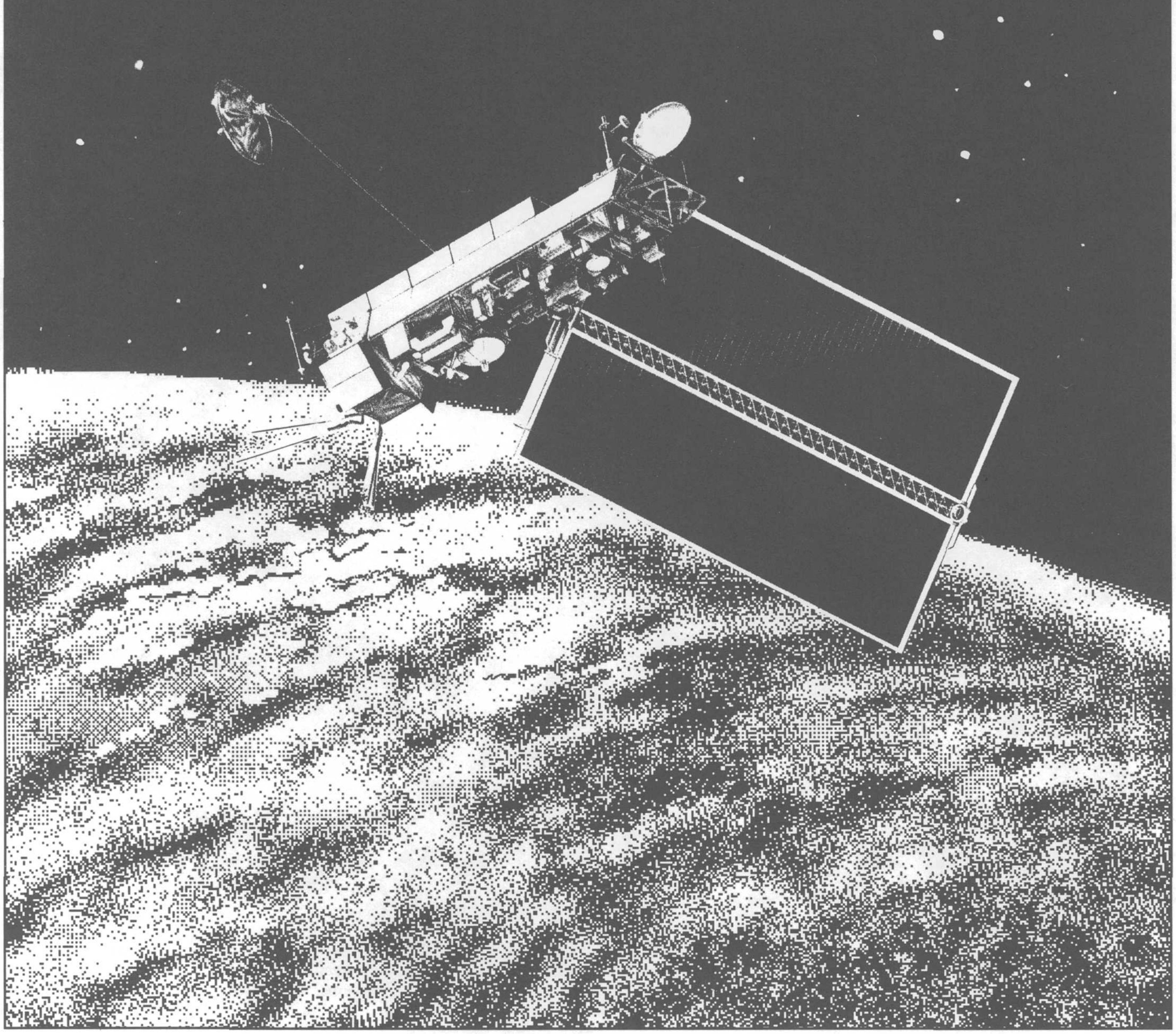
Three satellite images of the Kuwait oil fires were acquired from an altitude of 435 miles by the thematic mapper sensors aboard the Landsat satellite. The USGS EROS Data Center processed the data and printed the images. The images show the expanding smoke plumes from the fires.

Mission

The National Mapping Division provides accurate and up-to-date basic cartographic information for the United States in forms that can be readily applied to present-day problems. Maps, digital data, aerial photographs, satellite images, and geodetic control information represent some of the cartographic products available. Topographic maps at various scales, which illustrate detailed and precisely referenced information about natural and manmade features on the Earth's surface, continue to be important products.

These maps provide basic cartographic information that is needed by Federal, State, and local government agencies in dealing with key issues ranging from satisfying energy demands to conserving natural resources, from identifying environmental problems to developing acceptable solutions, and from locating commercial facilities to designing public works.

In addition to maps, cartographic data in computer-readable form are becoming increasingly important. These data are used in computer-based resource and geographic information systems to evaluate alternative management plans and to study the effects of different management policies.



Message from the Chief, National Mapping Division

As the use of computerized geographic information systems (GIS) has grown, the focus of the National Mapping Program has shifted from our traditional paper map products toward digital data and the establishment of automated data bases for GIS applications. The Division's emphasis for the future will continue to be on the development and production of advanced information systems to support policy and operational decisions concerning resource management and earth science issues. Cartographic data are central to analyses and decisions related to land, transportation, housing, energy, defense, boundaries, demographics, pollution, crime prevention, development, and conservation issues. Digital image data, such as orthophotoquads and satellite data, and land use and land cover data will also play an increasing role in these advanced information systems as different layers of information are combined for various applications. The NMD is taking important steps to provide the fuel (digital spatial data) for these advanced information systems.

The NMD is active in coordinating a wide range of spatial data activities with other Federal organizations to establish common standards for digital data, create links between data bases, facilitate the exchange of data, and eliminate duplication. We are seeking partnerships with others to make our resources more effective and to meet additional critical requirements. We are conducting pilot projects to learn about new applications and are introducing advanced computer technology into our production systems. We are establishing new data processing and archive facilities to support global change research. Also, by improving and automating existing data bases, we are able to support internal and external requirements for information such as geographic names.

These activities are integral to the process of providing advanced information systems to support the Nation's needs for geographic and cartographic data. As the need for spatial data for solving complex, interrelated natural resource, natural hazard, and environmental concerns continues to grow, we remain committed to providing the data and advanced information systems necessary for wise policy formulation and decisionmaking.

Allen H. Watkins

Benefits of Geographic Information Systems

By Stephen R. Gillespie

The value of digital cartographic data depends upon the benefits that can be derived from their use in computerized GIS. Managers of GIS know that there are large benefits to be obtained from the use of GIS technology. However, because benefits are difficult to measure, decisions on acquiring and operating a GIS are often made without a clear idea of the benefits. Also, because cost-benefit studies can be expensive and time consuming and because shortcuts frequently produce erroneous results, detailed analyses of benefits are often avoided or are misleading.

To address this problem, the USGS is developing practical techniques for measuring the benefits of using digital cartographic data in GIS. These efforts will help users to make informed decisions when investing in a GIS and will help the USGS to assess the potential value of the developing National Digital Cartographic Data Base (NDCDB). The NDCDB is a central archive of computer-readable geographic data containing USGS 1:24,000- and 1:100,000-scale maps and will be the cornerstone of national map coverage for GIS applications.

During late 1990 and early 1991, the USGS conducted more than 40 case studies with Federal GIS users. Information was collected on 63 successful GIS applications. The agencies and applications studied represent a broad spectrum of the diverse uses of digital cartographic data in the Federal Government.

Measuring the Benefits of GIS Use.—Most published cost-benefit studies on GIS present detailed quantitative cost information but only sketchy and qualitative benefit information. More reliable benefit information can be obtained by noting that there are two different types of benefits from the use of a GIS and that different techniques must be used to measure each type.

The two major types of benefits are efficiency and effectiveness. Efficiency benefits occur when a task can be done less expensively by using a GIS. Effectiveness benefits

Some predictions from the USGS digital benefits model

Efficiency benefits

Application	Savings due to GIS in percent: Predicted	Savings due to GIS in percent: Measured
Fish and Wildlife Management	62	50
Forestry	74	65
Parks and Recreation	78	80
Urban and Regional Planning	86	92
Energy and Minerals Management	89	95

Effectiveness benefits

Application	Number of applications	Total benefits: Predicted	Total benefits: Measured
Commerce and Economic Development.	4	$1,158,492	$1,017,500
Fish and Wildlife Management	5	616,636	838,100
Forestry	5	171,677	212,900

"In the 40 case studies, the use of GIS technology reduced operating expenses by an average of 75 percent."

occur when using a GIS allows completion of a task that could not otherwise have been done at all. The two types of benefits can be distinguished by comparing the outputs of an application when it is run with a GIS to those when it is run without the technology. If the two outputs are equivalent, then any observed benefits from GIS use are because of efficiency; if the two outputs are substantially different, then the GIS benefits are because of effectiveness.

Efficiency benefits can be measured by comparing the variable input costs of performing the application with a GIS to the variable input costs incurred prior to GIS use. Assuming that the fixed inputs are already in place, how much less does it cost to produce the output using the GIS process? In the 40 case studies, the use of GIS technology reduced operating expenses by an average of 75 percent.

Effectiveness benefits, which depend upon the value of the unique GIS output, can be measured by using a three-step process. First, identify how the GIS output is different from what would otherwise have been produced. Does the GIS generate new products, higher quality versions of existing products, a larger volume, or faster turnaround? Second, determine what effect each change has on the use of the outputs. Do the changes reduce user costs, enable users to improve the quality of their products, or let users more effectively communicate their products? Third, determine the value of each of these effects.

Determining value is a difficult task. However, this three-step process narrows the focus of the study so that value can be more easily and accurately measured. For most of the 40 case studies it was possible to make objective estimates of value. These estimates varied widely but had a median value of $8,000 for a single run of a typical application.

Effectiveness benefits were generally found to be considerably higher than efficiency benefits. That is, the more significant source of benefits from the use of GIS technology was found to be the new or improved outputs made possible by the GIS, rather than the savings obtained from lowering operating costs.

Predicting the Benefits of GIS Use.—The technique used in the 40 case studies permits reasonably accurate and objective measurement of the benefits of GIS use; however, the technique is still difficult and time consuming. The USGS has developed a digital benefits model that uses two equations that predict the two kinds of benefits. In the 40 case studies, the efficiency equation explains approximately 50 percent of the observed variation in benefits and is statistically significant at a confidence level of 98 percent. The effectiveness equation explains approximately 90 percent of the observed variation in benefits across the 40 case studies and is statistically significant at a confidence level of 99 percent.

The equations use a small number of objective and easily collected variables to predict benefits. Some of these variables are the areal extent of the application, the number of megabytes of data, and the maximum number of concurrent overlays. The coefficients of the variables were estimated by using the information collected in the case studies and a statistics software program on a personal computer.

The digital benefits model can be used to help decide the suitability of a particular application for GIS use or to assist in cost-benefit studies supporting the acquisition of GIS equipment. The model is applied in a four-step process. First, list all the applications for which GIS use is planned. Second, for each application, determine if the benefits of GIS use will be efficiency or effectiveness. Third, collect the values of the variables used in the equations. Fourth, enter the values for the variables into the appropriate equation and multiply by the values of the coefficients. The result of the equation is the predicted value of the GIS benefits.

This digital benefits model is much faster and less expensive than traditional benefit analyses. The difficult and expensive process of actually measuring GIS benefits for all applications is eliminated. Only the values of the variables used in the equations are needed to predict benefits. These variables can be measured quickly, easily, and objectively.

At present, the model is limited by the fairly small number of applications used to develop the equations. Cooperative efforts to expand applications are underway with other Federal agencies.

Global Land Information System

By Thomas M. Holm

Returning from a field trip to Kenya, a scientist may need additional information about land use, land cover, and terrain patterns observed in Africa. Where does one go for data on soil conditions, topography, and vegetation conditions? Researchers can now use their personal computers and a modem to access a computer data base in the Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, S. Dak. Once connected, the scientist's computer is linked with the Global Land Information System (GLIS). GLIS allows the operator to zero in on and define the land area of interest and query GLIS for land use, land cover, and topographic and remotely sensed data.

GLIS was developed in support of global change studies to meet the need for information about the Earth's land surface. It represents an important step in meeting the USGS responsibility for providing a land data system for global change. GLIS is, for the most part, a metadata system; that is, the system contents are mostly descriptions of sources of data and images, listed similarly to the descriptions of books and tapes in a library card catalog.

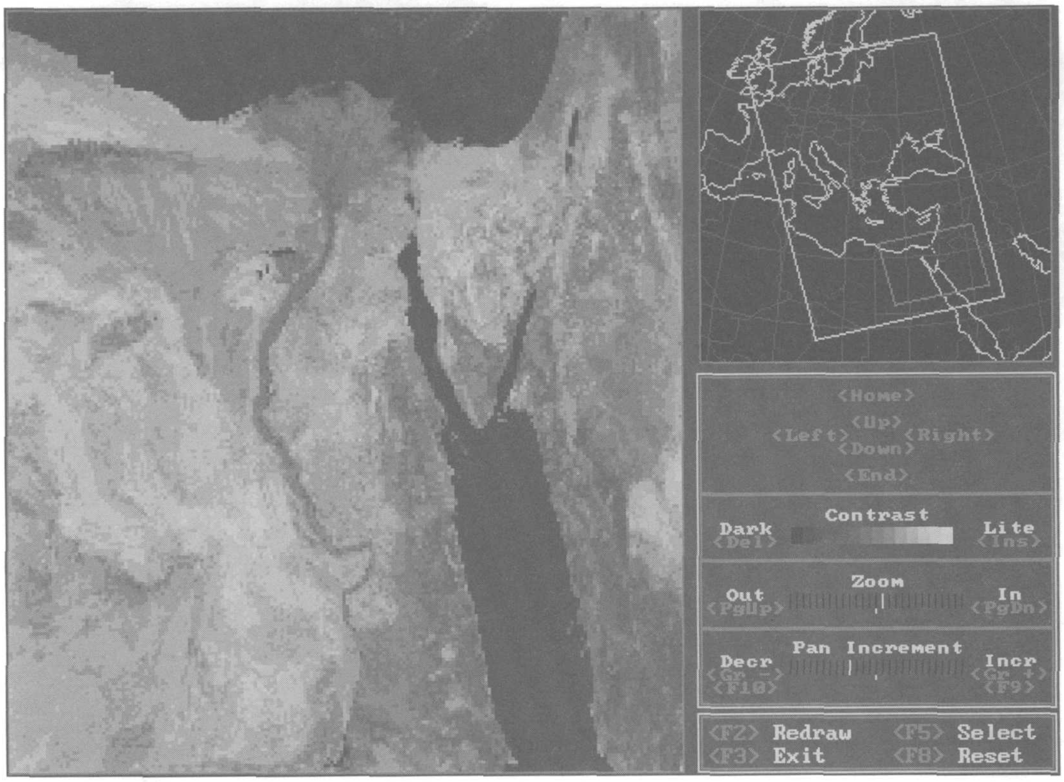
GLIS, developed by the USGS at the EROS Data Center (EDC), is a central interactive source of data about the Earth's land surface. Scientists can use GLIS to assess the potential use of data sets, determine their availability, and place online requests for related data products. The USGS developed GLIS to provide:

- Advanced online information query, data graphics display, and product request capabilities and services to the global change research community.
- A widely accessible data system that allows researchers easy access to information about global land science data stored at locations around the world.
- Network connections to and from other global change data and information systems and other earth science information systems.
- Archival systems assuring long-term preservation of earth science data.

GLIS contains references to a variety of land data sets, such as land use, land cover, and soils, cultural and topographic, and remotely sensed satellite and aircraft data. The data accessible through GLIS reside at USGS and other data centers throughout the world, such as the National Center for Atmospheric Research in Boulder, Colo.

Since 1972, EDC has stored, reproduced, and distributed aerial photographs, satellite data, and other earth science data of the

"GLIS is a central interactive source of data about the Earth's land surface."



A sample GLIS browse screen of an AVHRR (advanced very high resolution radiometer) satellite image of the Suez Canal area and the associated coverage plot graphics.

United States and of other areas worldwide. The continued availability of these data are critical to scientists seeking to understand Earth systems and for predicting the changes in the Earth's lands, oceans, and atmosphere that are caused by both natural and human-induced phenomena. GLIS is used to manage and distribute these vast amounts and varied types of land data needed for global change studies.

The National Aerial Photography Program

By Donald L. Light

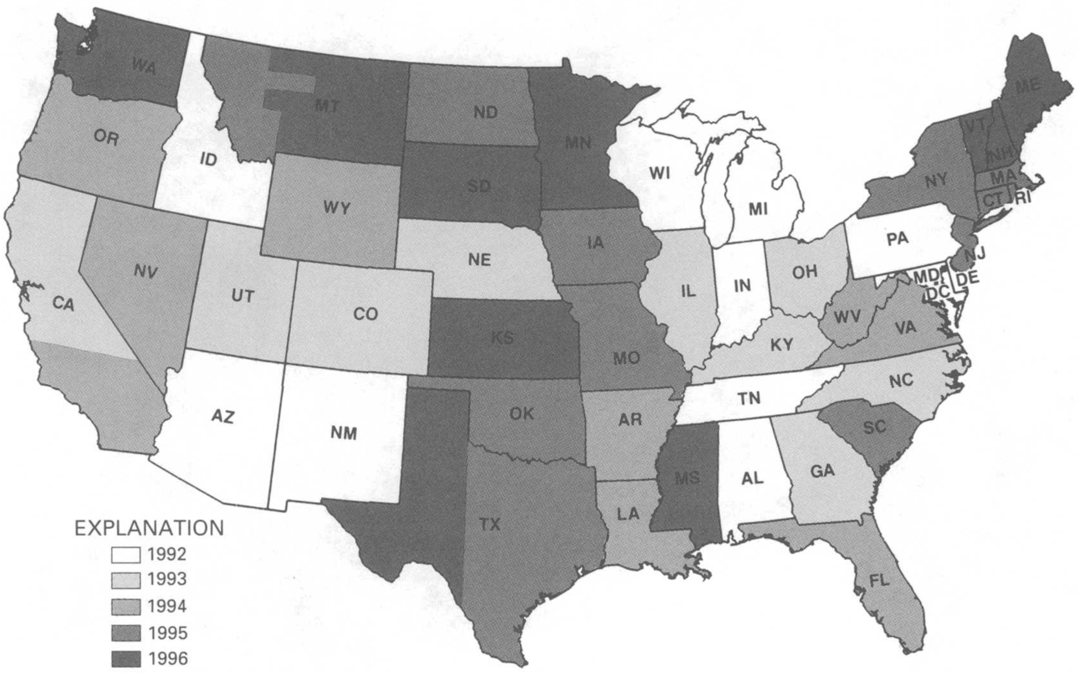
Federal and State agencies are currently participating in the National Aerial Photography Program (NAPP) to support the development of a national photographic data base. A steering committee composed of representatives from cooperating Federal agencies of the Department of Agriculture, Department of the Interior, and Tennessee Valley Authority provides overall program guidance. The USGS administers NAPP under the joint committee's direction.

NAPP was established to coordinate the collection of aerial photographs of the 48 contiguous States every 5 years. The goals of NAPP are to ensure that the photographs are of uniform scale, have good image quality, and meet the requirements of several Federal and State agencies.

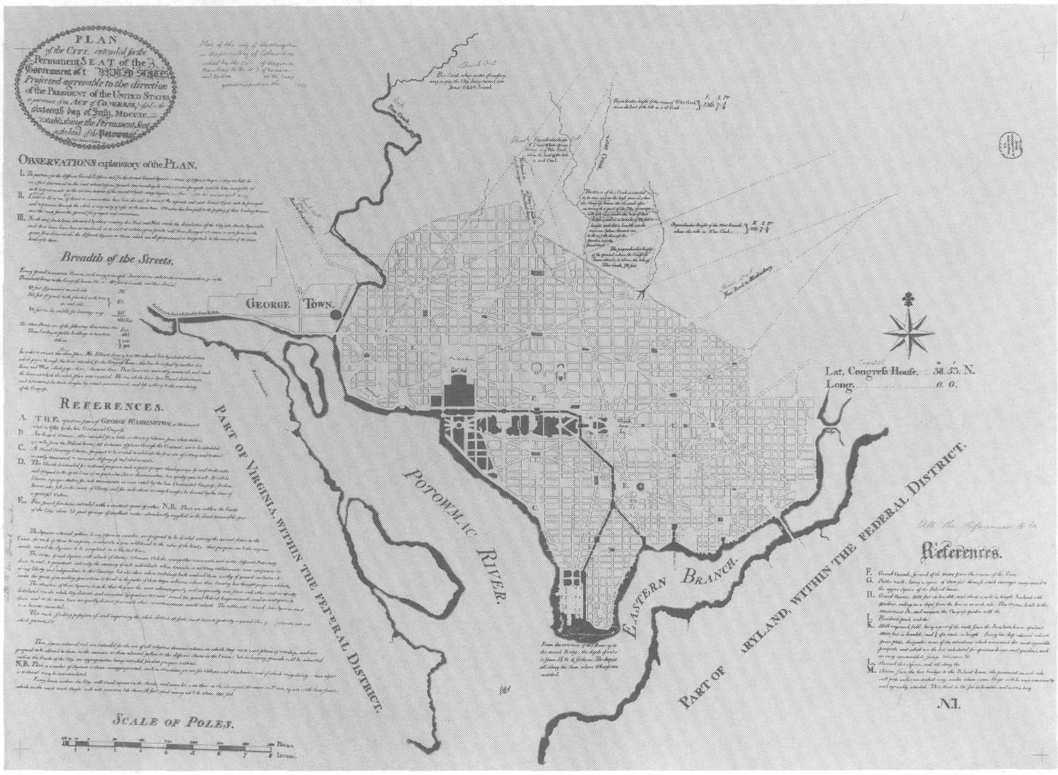
The objectives of NAPP are to complete conterminous coverage of the United States and develop a NAPP data base, to provide updates of the base every 5 years, and to ensure that the photographs are easily available to any user. The map below shows the plan in effect beginning with fiscal year 1992. Actual dates of acquisition may vary depending on the availability of funds and on weather conditions. States can ensure that the photographs they need will be acquired through cooperative funding of 50 percent of the estimated cost prior to the year of planned acquisition.

NAPP provides stereoscopic coverage by overlapping successive pairs of aerial photographs so that a three-dimensional view of the terrain, a stereomodel, is obtained when pairs of photographs are viewed through a stereoscope. NAPP photographic flights follow predetermined north-south lines along center lines of quarters of USGS 7.5-minute quadrangles. Flights are at 20,000 feet above mean terrain to produce a nominal photo-scale of 1:40,000.

To obtain ordering information, contact any Earth Science Information Center (ESIC; see p. 108) or call 1–800–USA–MAPS. You can order directly by sending a map outlining your area of interest to (1) Sioux Falls–ESIC, U.S. Geological Survey, Sioux Falls, SD 57198 or (2) USDA–ASCS, Aerial Photography Field Office, P.O. Box 30010, 2222 West 2300 South, Salt Lake City, UT 84130–0010.



NAPP acquisition program from 1992–96, plan of the States to be considered for aerial photography in NAPP by year. Actual dates of photography may vary.



A computer-generated (digitized) version of the 1791 L'Enfant plan of Washington, D.C., prepared for the Library of Congress by the USGS and assisted by the National Geographic Society and the National Park Service.

L'Enfant Plan Digitized in Cooperative Project

Two hundred years ago, Pierre Charles L'Enfant journeyed to Philadelphia, the temporary headquarters of the new government of the United States, to show President George Washington the unfinished draft of his plan for the Nation's capital city. In commemoration of that event, a cooperative effort among the USGS, the National Park Service, the National Geographic Society, and the Library of Congress has resulted in a new look at a part of American history. L'Enfant's manuscript plan of "The City of Washington" has been digitally reconstructed to make reprinting of the plan a reality.

The digitized version of the plan makes it possible for the first time in many years to discern previously obscured details that Pierre L'Enfant included on his draft plan. Even some penciled notations added later by Thomas Jefferson are now easy to read.

Fading and deterioration of the manuscript had made parts of the plan virtually illegible. A 19th-century effort to preserve the plan by varnishing it had the unfortunate opposite effect of seriously degrading the image.

The 1991 digitally enhanced version (above) of the 1791 L'Enfant plan was made possible by the partnership of three Federal agencies and one private organization, all of which have an interest in the L'Enfant plan and what it represents. This digital process had never been attempted before with a historic map.

The project was initiated in 1987 and financed in part by the National Geographic Society to catalog, restore, preserve, and publish the Library of Congress collection of some 3,000 maps and 250 atlases covering Washington, D.C. The original manuscript of L'Enfant's early plan for the new capital city is the linchpin of that collection. The National Capital Region of the National Park Service was interested in using the new version of the L'Enfant plan to help celebrate the bicentennial of the Nation's Capital, and that agency contributed funds to assist the project.

". . .a new look at a part of American history."

In 1988, cartographic and conservation specialists from the Library of Congress transported the L'Enfant plan to the Eastern Mapping Center of the USGS in Reston, Va., so that it could be photographed with a special camera on high-contrast film to produce one-to-one sized negatives. USGS experts then made photographic prints that were carefully scanned, and the features of L'Enfant's paper plan were converted to computerized format. The resulting digital data were then displayed on computer edit stations, allowing the operators to remove varnish and other stains and blemishes and to enhance the lines, patterns, shading, and text of the original plan.

The original scanned data from the plan were so detailed that the information occupied approximately 30 computer tapes, or 809 megabytes of information. Once all the unwanted background clutter was removed, the data for the final digitized version of the plan were contained on two computer tapes, one for the continuous-tone shading and one for the text and linear information.

Copies of the new, digitally enhanced version of the L'Enfant plan, as well as color facsimiles of the original manuscript, are available for sale from the Library of Congress. For information, call 202–707–2905.

Monitoring Urban Landscapes

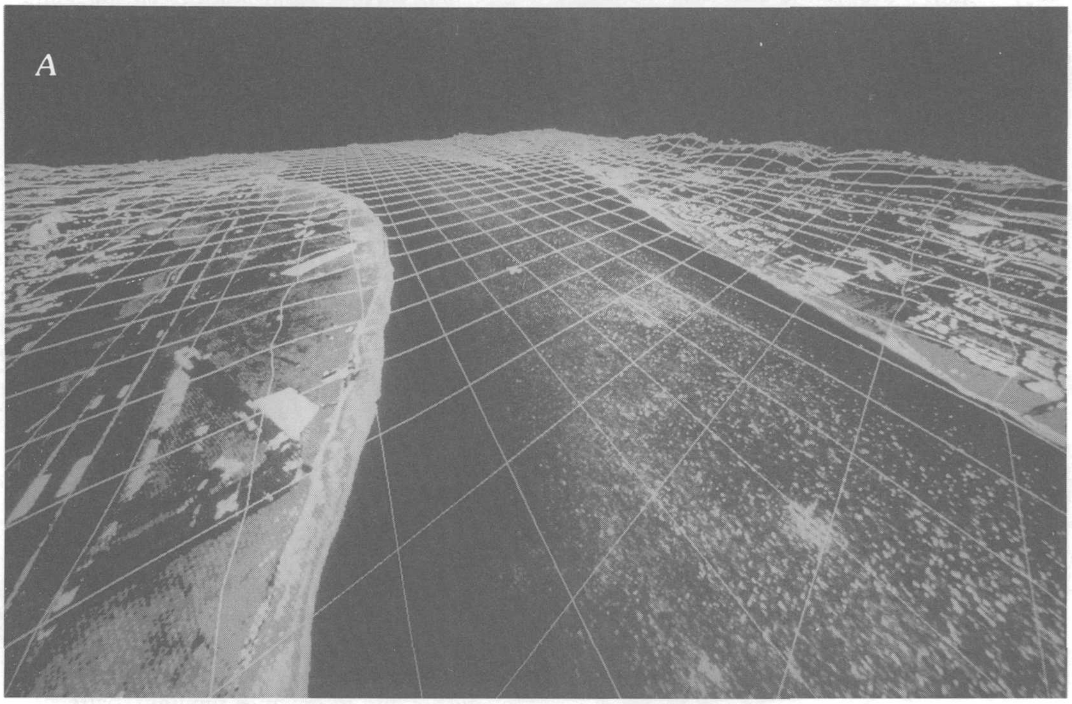
By Robert H. DeAngelis and Jay Donnelly

Tall buildings that alter the skyline of a city, burgeoning populations that put additional stress on existing services, and the associated expansion of roads and regional mass transportation systems needed to accommodate urban growth are among the development issues that concern urban and regional planners. In order to effectively monitor growth and to forecast how an urban area might grow, urban planners need an adequate base of geographic, demographic, land use, and associated spatial data in computer-readable form. A regional planner in the Washington, D.C., area may ask, "Given varous development conditions, what will the Washington metropolitan area look like in the year 2050?"

Scientists with the USGS, the National Capital Planning Commission (NCPC), and the Massachusetts Institute of Technology (MIT) are collaborating to address that question and other urban change issues. Their primary goal is to determine how best to apply digital spatial data to make informed projections and decisions regarding urban growth.

Each collaborator contributes a unique expertise to this research. The role of the USGS in this innovative project is to use spatial analysis tools, such as GIS systems, image processing, transportation analysis, and computer-aided design systems, as components in a modeling system to project and monitor urban change. The Washington region was selected as a test area because a wealth of digital information about this region already exists. USGS large-scale digital cartographic, elevation, and image data are being integrated with other forms of digital urban planning information to assess the demographic, natural, transportation, and architectural resources of the Nation's Capital.

A primary task of the USGS in this project is to provide expertise in methods of integrating and using digital spatial data. For example, the USGS is giving technical assistance to the project collaborators on efficient techniques for data transfer and manipulation. These efforts include designing



A, *A surface model of National Airport as viewed from the south. A mesh has been overlaid on the surface to define relief. Note the aircraft in the center of the image. The model was produced by combining a digital elevation model surface with digital orthophoto image data in a GIS. The surface model can be manipulated to produce different views from different directions specified by the observer.*

intuitive menu driven tools that make it easier to manipulate, analyze, and view urban information.

The NCPC is the central planning agency for the Washington metropolitan region. This Federal commission reviews and coordinates development plans proposed by Federal, State, regional, and local authorities. For this collaborative research, the NCPC will select a pilot area within the National Capital region and provide expertise in regional planning, transportation analysis, employment migrations, architectural concerns, and consideration of the aesthetic impacts of future growth of federally owned properties.

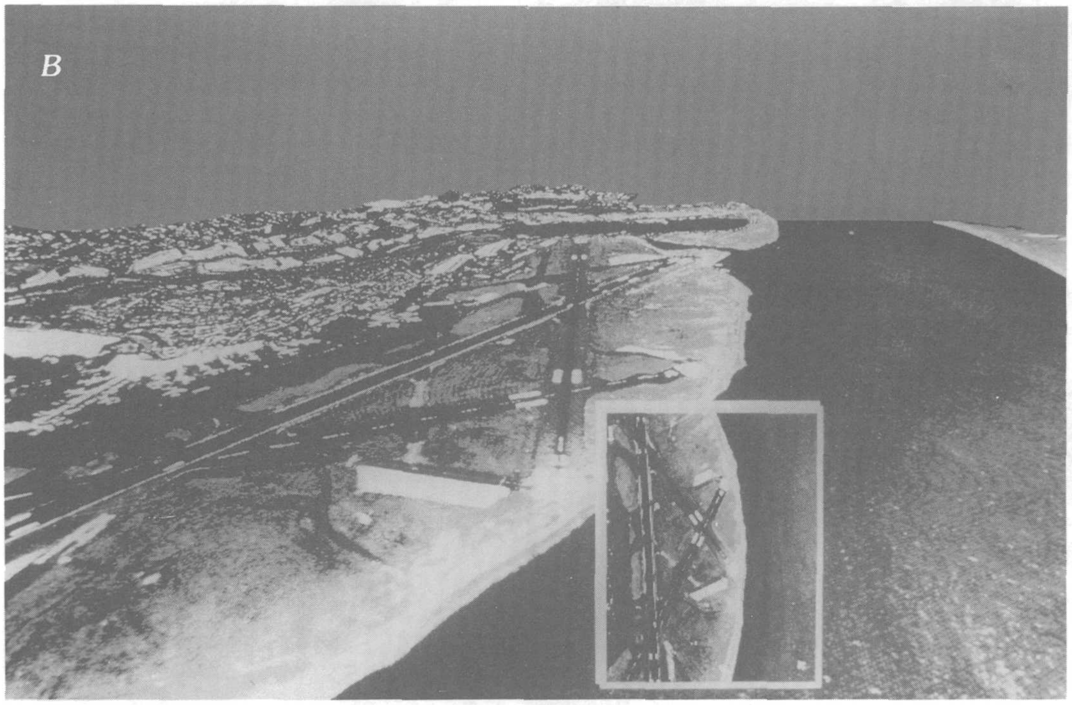
Adapting traditional simulation techniques to new technologies and developing innovative techniques are the responsibility of MIT. Researchers at MIT are developing methods for assessing and visualizing the likely effects of alternative development proposals. MIT scientists are designing a system that will make urban data sets and manipulation tools accessible to users at various locations. Planners can use these data and systems to devise what-if growth scenarios.

The first phase of this project is near completion. The USGS has built spatial data bases from a variety of sources and systems and has gathered current and historic information on the natural, manmade, and cultural resources of the Capital region. Formats for data exchange have been selected. The USGS also has written programs to make viewing and using these data easier. MIT has developed tools for visualizing and manipulating imagery and historical spatial data.

Using advanced spatial analysis tools, the NCPC will be able to select those sites most suitable for large-scale development. Visualization and viewing tools will allow urban planners to assess the aesthetic impacts that constructing a large office building could have on this historic region. Models of the land surface can be generated and manipulated by using digital data visualization tools to represent different viewing perspectives. Information can be derived about demographic change and its effect on regional transportation networks as the workforce shifts to a new facility. From this base of information, planners can evaluate alternative sites and other development scenarios.

Technology transfer is a common goal of this cooperative project. Initiating and encouraging dialog among data providers, earth scientists, and urban planners are essential. The analytical techniques and products developed in this project will be useful in other urban applications.

"...what will the Washington metropolitan area look like in the year 2050?"

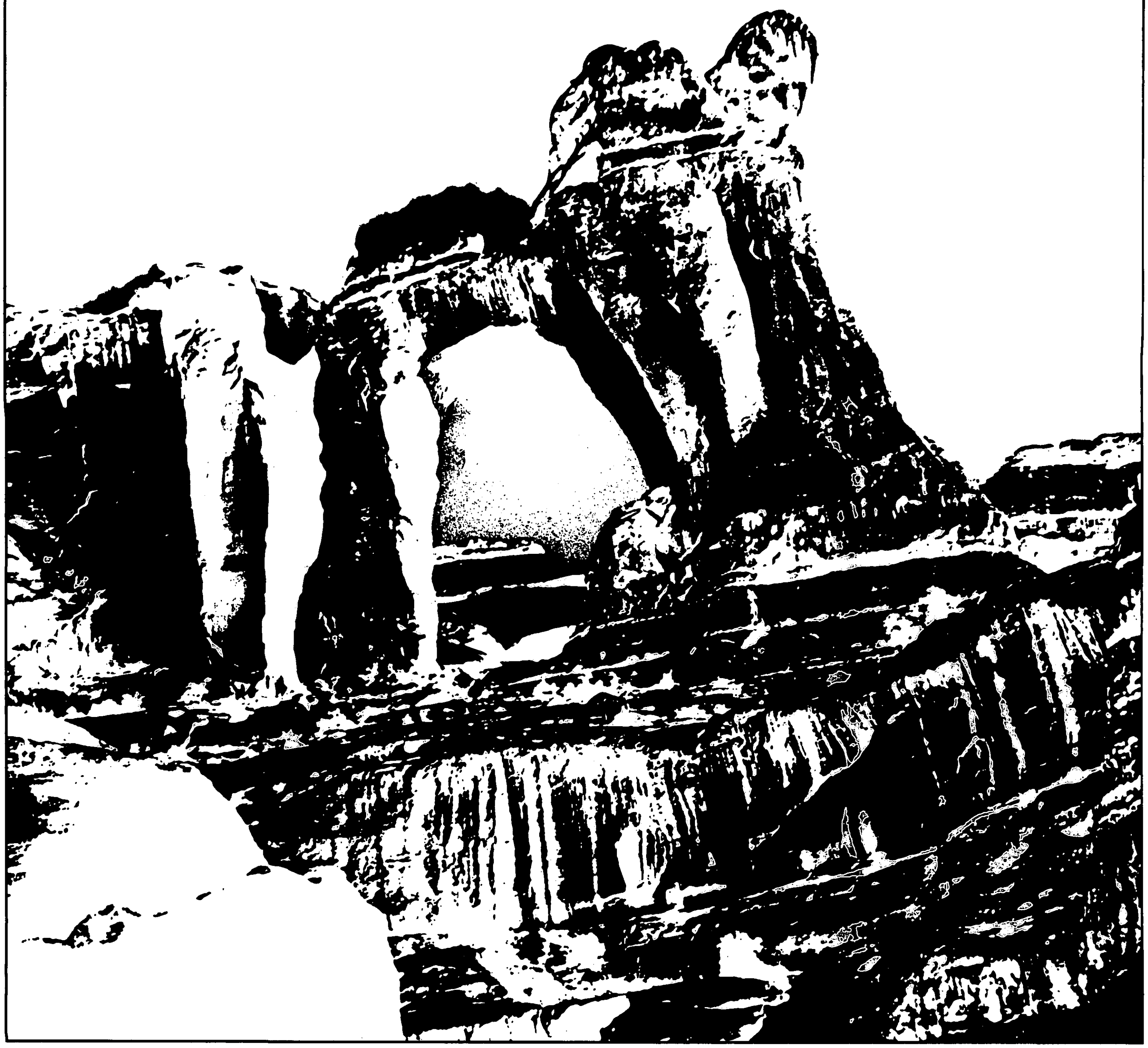


B, *Digital representation of what the pilot of the aircraft* (**A**) *might see on approach to the landing runway. The observer can replicate the pilot's perspective by using the GIS to set viewing parameters such as target, height above the surface, direction, and distance of object to target. Inset: vertical view, including aircraft.*

Mission

The Geologic Division evaluates the Nation's geologic structure and the geologic processes that have shaped it, assesses the Nation's mineral and energy resources, and identifies and investigates geologic hazards.

- Investigations of geologic hazards provide information for predicting and delineating hazards from earthquakes and volcanoes and for identifying engineering problems related to ground failure hazards.
- Regional geologic studies provide geologic maps and regional syntheses of detailed geologic data essential to mineral, energy, and hazard assessments, and to land use decisions such as landfill siting and selection of transportation routes.
- Offshore geologic studies identify and describe the mineral and petroleum resources of the offshore areas of the United States, including the Exclusive Economic Zone, an area one-third larger than the land area of the United States.
- Mineral resource investigations assess the distribution, quantity, and quality of the Nation's mineral resources required for making land use decisions by Federal, State, and local land-management agencies.
- Surveys of energy resources provide assessments of the Nation's coal, petroleum, uranium, and geothermal resources and enhance capabilities to explore for and develop new sources of energy.



Message from the Chief Geologist, Geologic Division

The mission of the Geologic Division provides us with many challenges as we monitor natural hazards and conduct extensive research to mitigate and, potentially, to forecast the occurrence and effects of these hazards. We are also responsible for mapping onshore and offshore geology, the last terrestrial frontier of our Nation.

The Nation needs energy and mineral resources to sustain its economic and national security. Through our energy and mineral resource assessment programs, we are working to provide credible and unbiased estimates of undiscovered and critical resources. The Earth is a complex and dynamic system. Understanding global change, whether it is developing knowledge on changes in climate in the Earth's long geologic history or discerning the complex interactions between the atmosphere and the land surface and the oceans, the Geologic Division is committed to providing the information to help the Nation deal with this vital issue.

While the pursuit of our science is paramount, we also recognize the importance of effective communication of our science to those who need it, communication among our scientists, and the healthy advancement of our diverse scientific workforce. To address this last issue, we have made extensive strides this fiscal year by establishing a Women's Advisory Committee to promote communication with our managers on opportunities, problems, and solutions related to the professional development of women employees in all work categories. We held program planning forums at each of our major regional centers in Reston, Va.; Denver, Colo.; and Menlo Park, Calif., to ensure that information on our programs and funding opportunities are effectively communicated.

The response to our efforts to meet the needs and foster the advancement of our diverse scientific, technical, and support staffs has been overwhelmingly positive, and we will continue to support these efforts as part of our overall mission to provide geologic knowledge and understanding that serves the Nation's needs.

Benjamin A. Morgan III

Thermal Maturity Mapping in Alaska

By Kenneth J. Bird, Mark J. Johnsson, David G. Howell, and Leslie B. Magoon

New information on the temperatures to which rocks were exposed in the past is offering insights into geologic processes and is providing a basis for new assessments of hydrocarbon, coal, and mineral resource potential in Alaska. Knowledge about these temperatures is critical to developing resource estimates because the amount of heating is an important factor in determining whether oil or natural gas are formed, the energy content of coal, and the type of mineral deposits that may form. By knowing the age of the rock and the maximum temperature of exposure, geologists also gain a better understanding of how the crust of the Earth has been reshaped over geologic time. This information furthers our understanding of the workings of plate tectonics—the shifting of crustal plates that make up the Earth's surface—and the geologic evolution of Alaska.

Thermal Maturity.—The temperature of the upper part of the Earth's crust increases with depth at an average rate of about 25°C per kilometer. The ultimate source of this heat is the spontaneous decay of natural radioactive minerals. The presence at the Earth's surface of rock once heated to high temperatures attests to the dynamic nature of the Earth's crust. Determining the past temperature exposure allows for a better understanding of both tectonic processes and hydrocarbon, coal, and mineral resource potential. Geothermometers are mineral or organic indicators of past temperature exposure. High-temperature geothermometers, those indicative of once-molten or near-molten conditions in igneous or metamorphic rock, have been known for a century or more.

Efforts by geologists during the last 25 years have resulted in the identification of reliable low-temperature (<300°C) geothermometers suitable for use in sedimentary rock. Low-temperature analysis is often reported in terms of thermal maturity because most low-temperature geothermometers actually respond not only to the maximum past temperature but also to the time spent at that temperature. The best thermal maturity indicators are little affected by time and give

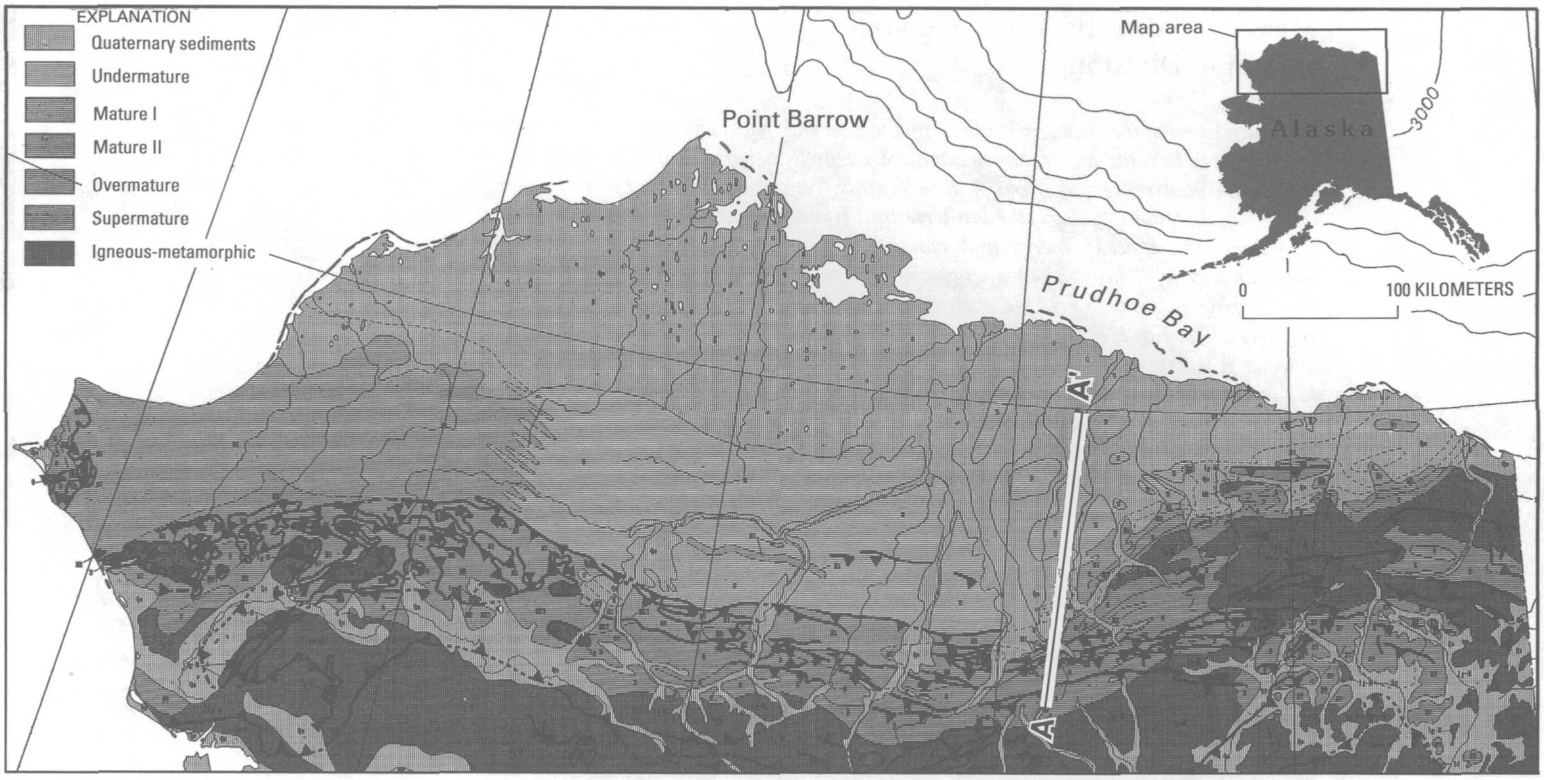


Figure 1. *Thermal maturity map of surface rock in northern Alaska based on more than 2,000 sample stations, including 82 wells.*

fairly accurate measures of past maximum temperatures. By far the most widely used thermal maturity indicator is vitrinite reflectance.

Vitrinite, one of several types of organic particles commonly found disseminated in sedimentary rock, is the fossil remains of woody plant material. Upon exposure to elevated temperatures, vitrinite becomes increasingly reflective. These changes in reflectivity are responsible for the increase in the brightness of coal, which consists primarily of vitrinite, with increasing coal rank: lignite coal is dull, bituminous coal is moderately bright, and anthracite coal is very bright.

Past temperatures can be determined by measuring the amount of light that is reflected off a polished surface of vitrinite, designated as R_o and reported in percent. Typical values range from ~0.2 percent, for vitrinite that has never been subjected to temperatures higher than those found at the Earth's surface, to more than 5.0 percent, for vitrinite exposed to metamorphic conditions (generally exceeding 300°C). Oil is found in samples that give vitrinite reflectance values between 0.6 and 1.3 percent. At values higher than about 2.0 percent, generally only natural gas is present. Other useful thermal maturity indicators are based on color changes observed in fossil pollen, spores, and conodonts (teethlike microfossils) and structural changes in clay minerals.

Thermal Maturity Mapping in Alaska.—During the last 15 years, the USGS has collected vitrinite reflectance data from many parts of Alaska in its study of oil and natural gas resources. These data, combined with data from the oil industry and other scientists, now provide information on thermal maturity at several thousand localities widely distributed over the State. These data have been combined with other measures of thermal maturity, such as conodont color, to produce a thermal maturity map of the surface rock of Alaska. The thermal maturity data are grouped into five categories: undermature (R_o<0.6 percent), mature I (R_o=0.6–1.3 percent), mature II (R_o=1.3–2.0 percent), overmature (R_o=2.0–3.5 percent), and supermature (R_o>3.5 percent).

North Slope Example.—The northern part of the thermal maturity map of Alaska (the Brooks Range and North Slope) is shown in figure 1. This map is based on about 1,100 vitrinite reflectance determinations from surface localities, 3,000 determinations from 82 wells, and approximately 1,000 conodont color analyses. These data provide the most concentrated coverage of any area of the State. They show that the thermal maturity of rock at the surface generally increases from north to south. This increase indicates greater uplift to the south. Assuming an average geothermal gradient of 25°C per kilometer, the maximum reflectance values indicate

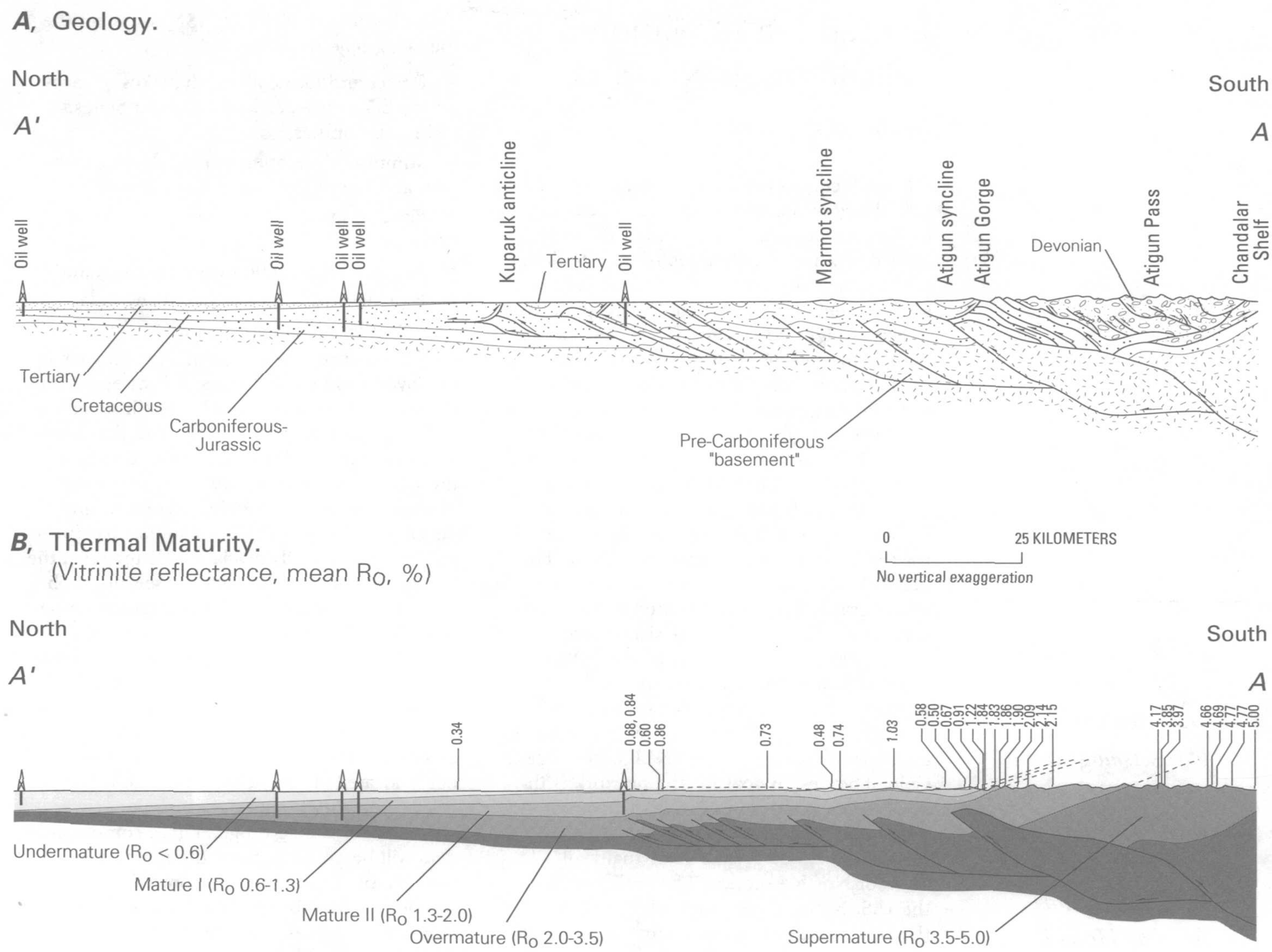


Figure 2. *Cross section along section A–A′ in figure 1, showing geology (upper panel) and thermal maturity (lower panel). Thermal maturity units are identical to those in figure 1. Numeric values in lower panel are representative vitrinite reflectance values, R_o, in percent.*

uplift of 12 kilometers for the central Brooks Range. Uplift apparently decreases to the north, and the rock exposed along the coast east of Prudhoe Bay appears to show no uplift.

A salient feature of the regional thermal maturity pattern is a broad southward extension of thermally immature rock in the central portion of the North Slope. In comparison, rock in regions to the east and west is of higher thermal maturity, indicating that they were at one time buried to greater depths and have therefore undergone greater uplift than rock of the central North Slope. Such uplift in the eastern Brooks Range has previously been recognized, but the uplift in the western Brooks Range and North Slope is recognized only from thermal maturity data. These regional differences in uplift may indicate that mountain building continued longer in the east and west than in the central portion of the Brooks Range.

Vitrinite reflectance patterns within the Brooks Range indicate that maximum burial occurred after the early phases of mountain building. The pattern of vitrinite reflectance values just north of the Brooks Range, however, show a warping of the thermal maturity values (fig. 2)—an indication that the later stages of mountain building continued in this area after maximum heating and burial. Oil and natural gas are expected to have formed primarily at the time of maximum heating of the rock—the time when a thermal signature was imposed. The observed warping of the thermal maturity units means that late-stage deformation may have destroyed early-formed oil and natural gas accumulations or shifted them to new locations. Thermal maturity data thus can be used to infer aspects of the timing of mountain development and have important implications for oil and natural gas exploration.

United States National Seismograph Network

By Robert P. Massé

The frequency of occurrence, geographical distribution, and magnitude of earthquakes are important in assessing the seismic hazard of a region, for establishing the design and construction criteria for critical facilities, such as nuclear reactors, and for responding to large-magnitude events. This information defines the seismicity of a region and can be determined only through the operation of seismograph networks. For many years, scientists and government agencies have recognized the need for a high-quality national seismograph network in the United States.

The USGS has developed and is deploying a broadband digital seismograph network for the United States to meet this need. The network will consist of approximately 150 seismograph stations distributed across the contiguous 48 States and Alaska, Hawaii, Puerto Rico, and the Virgin Islands. Data transmission will be via two-way satellite telemetry from the network sites to a central recording facility at the USGS National Earthquake Information Center (NEIC) in Golden, Colo. The design goal for the network is the undistorted recording by at least five well-distributed stations of any seismic event of magnitude 2.5 or greater in virtually all areas of North America. The entire network, the U.S. National Seismograph Network (USNSN), is a cooperative effort between the USGS and the Nuclear Regulatory Commission (NRC).

"The network will consist of approximately 150 seismograph stations distributed across the contiguous 48 States and Alaska, Hawaii, Puerto Rico, and the Virgin Islands."

The USGS will install and operate the USNSN, and the NRC is providing funds to the USGS for the completion of the network east of the Rocky Mountains. This network will increase the ability to characterize earthquakes in most parts of the United States. However, the USNSN will not, even when complete, eliminate the need for additional dense networks of seismograph stations in specific locations. Such dense local networks exist today in several critical areas within the United States. These dense local networks detect low-magnitude earthquakes (below the 2.5 threshold for USNSN) and achieve high location accuracy. The dense local networks are located in specific seismic risk areas to acquire important data for research in earthquake prediction and ground-motion estimation. The USNSN and the dense local seismograph networks are complementary. Data from USNSN will provide, for the first time, near-uniform high-quality coverage for the entire country.

The design of the USNSN will meet the following objectives:

- Detect and locate all earthquakes of magnitude 2.5 or greater in the United States, within 30 minutes,
- Minimize development risk, development cost, and operation cost of the network,
- Place seismograph stations at low-noise sites,
- Acquire full seismic waveform data, and
- Provide rapid distribution of the data through the NEIC.

To ensure that a high-quality network is deployed within a few years, it is essential that the system design be feasible, that installation and implementation be timely, and that available funds cover all costs. For the USNSN, the USGS will minimize risk by using a state-of-the-art seismic processing system recently developed for the NEIC. All station hardware will be commercially available. Historically, the failure to maintain funding for seismograph networks and arrays has been high operating costs. Therefore, the design of the USNSN is such that operational costs will be minimized.

The lower the nonearthquake background noise at the stations, the better the overall network detection will be. To the extent possible, seismograph stations are being located at low-noise sites. The USNSN will produce high-quality seismic data covering a wide dynamic range. Three-component data will be available from the network stations. Rapid access to data from USNSN will be provided by the USGS. Waveform data for earthquakes will be available in realtime through a broadcast mode satellite transmission from the NEIC and in near realtime through high-speed dial-up to the event waveform data base at the NEIC.

Waveform data for all earthquakes recorded by USNSN also will be provided on CD-ROM (compact disc, read-only memory). Satellite links to participating regional networks also will be provided. The NEIC has taken a leadership role in distributing national and global seismic data to the scientific community. For data from the USNSN, the NEIC is developing procedures to ensure rapid distribution and equal access to the event data for all interested users.

Each station will have three-component seismometers, which will acquire data over a very broad band and high dynamic range. The seismograph stations will have a microcomputer, a satellite transmitter, and an antenna. The event data will be digitized at the station. In addition, stations are being equipped with three-component strong-motion sensors, further extending the total dynamic range of the system. This larger

U.S. National Seismograph Network stations. LLNL, Lawrence Livermore National Laboratory; RSTN, realtime seismic network.

dynamic range will permit even large earthquakes to be recorded on scale.

Data will be transmitted from the station to the NEIC via satellite and a small satellite antenna. The NEIC will receive data from all seismograph stations using a large satellite dish having associated electronics located at the NEIC in Golden, Colo. This data transmission will allow the seismograph stations to be placed at sites that have low background noise and will eliminate dependency on the more costly long-distance telephone lines.

The system is being designed with sufficient capacity to telemeter all data simultaneously in the event of a great earthquake near North America. At NEIC in Golden, a modular real-time seismic processing system can be easily expanded to meet all future USNSN requirements. Many future seismic studies of the United States, including those studies using data from the dense local networks, will be based on the data base obtained from the USNSN.

The functions of the processing system include refining signal detection, determining signal parameters, associating signals, determining preliminary earthquake location, archiving the signal waveform data with associated epicenter information, providing an interactive capability for reviewing all automatic event determinations, and producing final epicenter information for dissemination. Processed results for USNSN in the form of epicenter electronic bulletins will be available as part of the NEIC Quick Epicenter Determination (QED) program. The QED bulletin is already available by dialing the NEIC computers toll free (1–800–358–2663). The QED information also is transmitted over the World Meteorological Organization communications channels to countries all around the world.

RAYMOND P. BULAND

Satellite dish that will receive data from all 150 stations in the U.S. National Seismograph Network, located at the USGS National Earthquake Information Center in Golden, Colo.

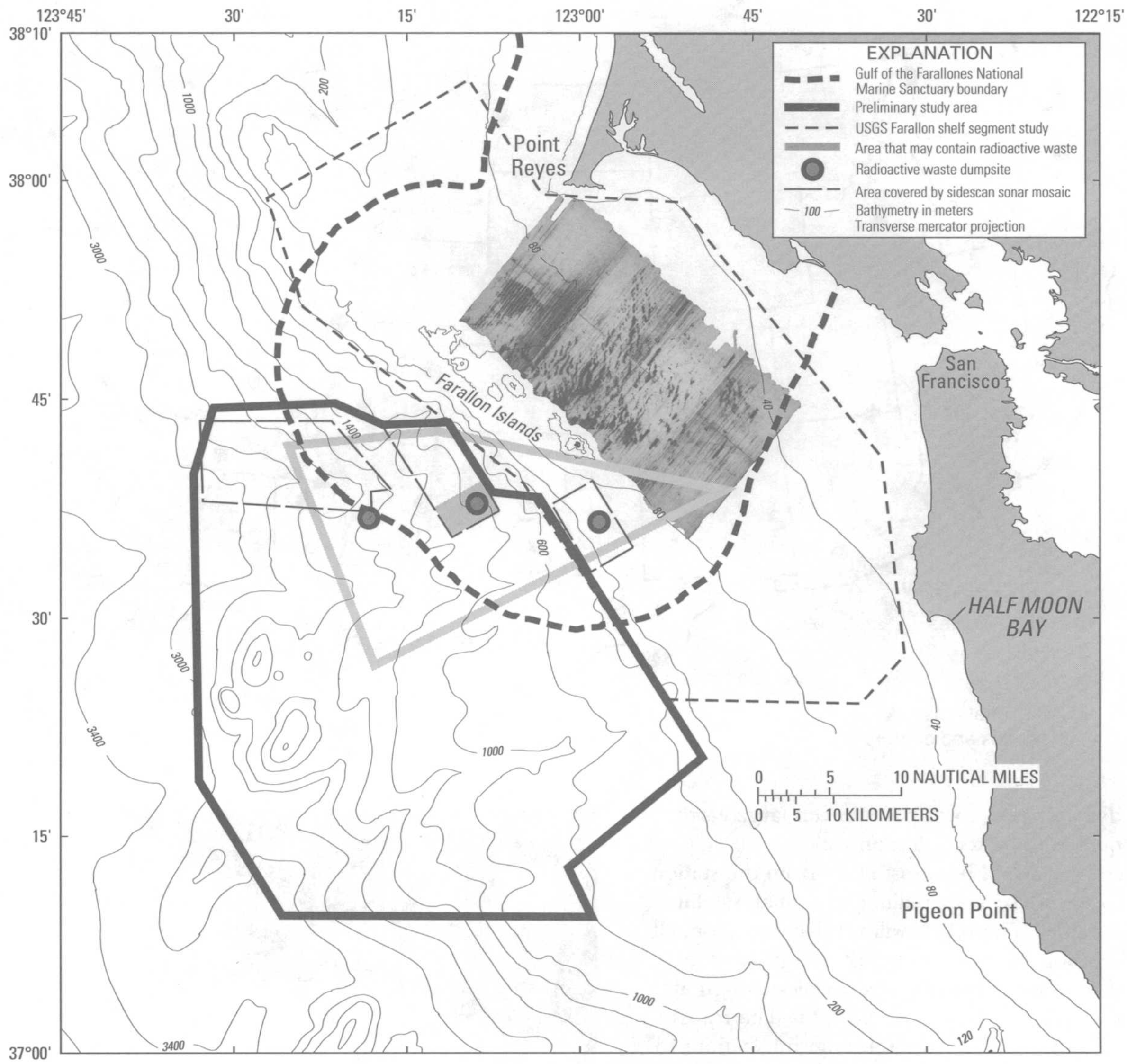


Figure 1. Continental shelf and slope study areas in the Gulf of the Farallones. Inset shows sonograph mosaic of intricate linear scour depressions on the continental shelf. Sidescan sonar coverage was obtained over the entire preliminary study area. The shaded part in the middepth radioactive waste dumpsite is the area of the sonographic mosaic shown in figure 2.

Farallones Region, California—Marine Environmental Research

By Herman A. Karl

The marine environment is now facing important issues of universal concern such as pollution, resource availability and management, natural hazards, and global and climatic change. Concerns about possible environmental damage to the world's oceans were expressed at least 30 years ago but only now are the potential effects of human activities on the marine ecosystem beginning to be fully understood by scientists and the public. The oceans will be used increasingly as a source of food and mineral and petroleum resources, as a place for recreation, and as a repository for waste products. To ensure that these human demands are met responsibly, the public and the public's representatives must have the best scientific data available to guide them in making choices about uses of the marine environment.

The USGS has conducted geologic research investigations in the marine environment for more than two decades. In 1983, President Reagan proclaimed the ocean area 200 nautical miles off the coast of the United States, its island territories, and territorial seas as the U.S. Exclusive Economic Zone (EEZ). The USGS is conducting systematic environmentally focused geologic investigations, called Geologic Inventory projects, on the continental shelf and slope within the EEZ. Areas that are offshore of major population centers have been and will continue to be most impacted by human activities, and, therefore, the initial study sites are adjacent to large urban areas. The first of the Geologic Inventory projects, the Offshore Geology of the Farallones Region, was begun offshore of the San Francisco Bay in 1989.

Concept and Structure of the Farallones Region Project.—Each Geologic Inventory project is designed and conducted as a multidisciplinary research study. The basic research must be relevant to one or more specific social issues and also must provide baseline information that can be used to design other environmental studies. Most importantly, the data derived from the project must be communicated in a timely way that is clearly understandable not only by professional scientists but also by the public and those charged with managing offshore areas. The Farallones Region project demonstrates this applicability of basic marine research to critical social issues.

The continental margin offshore of the San Francisco Bay area (fig. 1) was chosen as the site of the first Geologic Inventory project for six reasons: (1) The Gulf of the Farallones is an important commercial and recreational fisheries area. (2) The Gulf of the Farallones National Marine Sanctuary—a unique marine ecosystem—encompasses a large part of the Gulf of the Farallones. Little is known about the geology and oceanography of this area. (3) Selected areas of the ocean floor have been used and are being considered as disposal sites for material dredged from San Francisco Bay. There is a great need to gather information about the geologic and oceanographic processes on the continental margin to understand the effects of these disposal sites on the environment. (4) More than 47,800 drums (55 gallon) and other

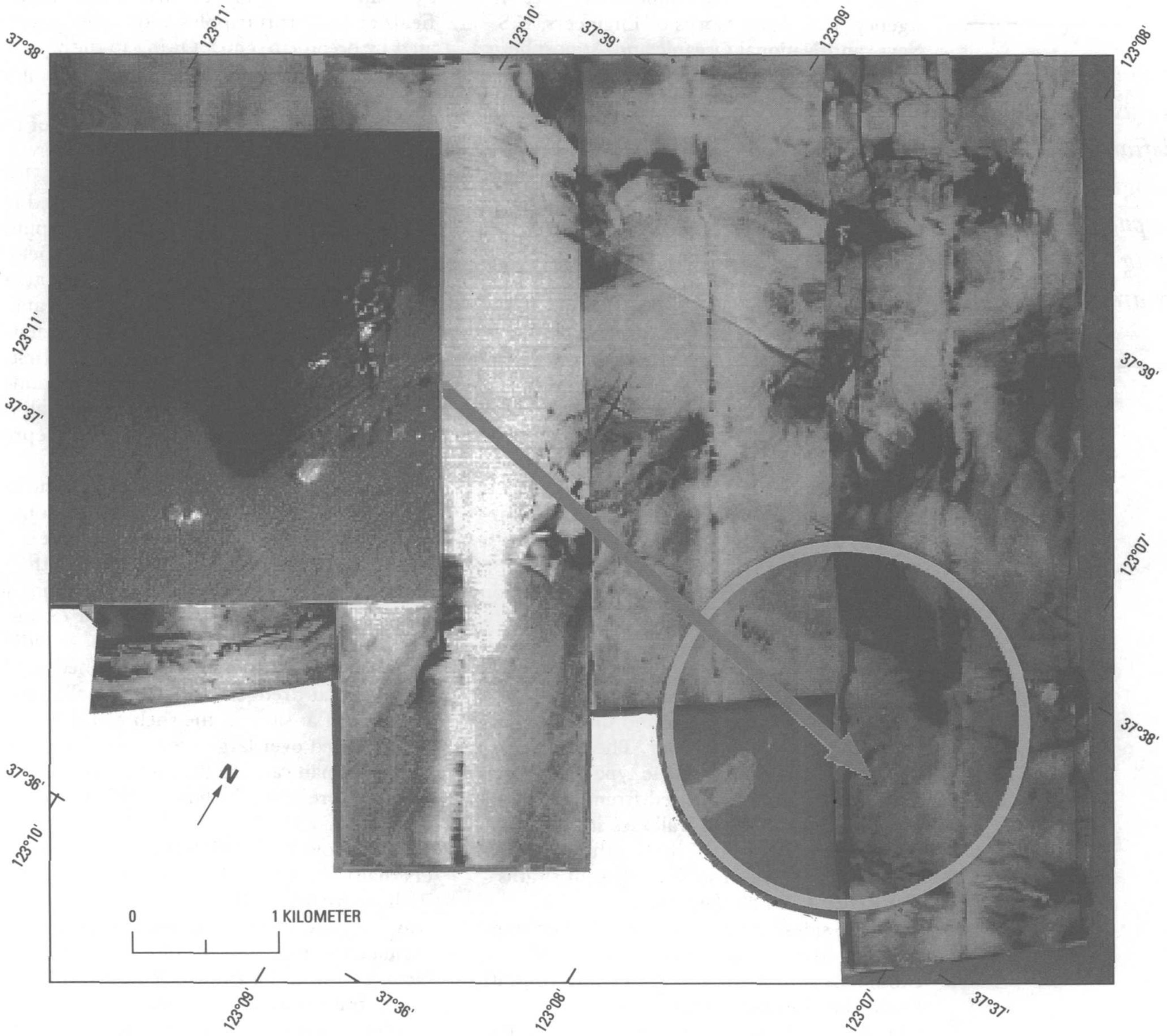


Figure 2. *Part of sidescan sonar mosaic obtained on the continental slope adjacent to the middepth radioactive waste dumpsite. Small dots within the circled area are 55-gallon drums. The arrow points to a particularly prominent cluster of barrels. The barrel illustrated is one of the barrels within the circled area, but it is not possible to attribute the photograph to a specific target (barrel) on the sonograph.*

containers of low-level radioactive waste were dumped on the continental margin between 1946 and 1970. These drums now litter a large area (1,400 square kilometers) of the sea floor within the marine sanctuary (fig. 2). The exact location of the drums and the potential hazard the drums pose to the environment are unknown. (5) Many faults have been mapped in the Gulf of the Farallones; for example, the San Andreas Fault crosses the Gulf near the Golden Gate Bridge. These faults are a potential seismic risk for the cities in the San Francisco Bay area. (6) Study of the open ocean environment complements ongoing USGS investigations of San Francisco Bay and provides an opportunity to study an estuarine shelf-slope system.

The USGS began this multidisciplinary project by mapping and sampling the continental shelf east of the Farallon Islands. In 1990 the project expanded in scope when the USGS conducted an investigation, sponsored by the USGS, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Navy, and National Oceanic and Atmospheric Administration (NOAA), to survey and sample the continental slope west of the Farallon Islands. This cooperative study was designed to provide information about the location and distribution of the drums of low-level radioactive waste and about geologic data on areas being considered as sites for disposal of dredge material from San Francisco Bay.

"The sonographs are used to define the geologic and morphologic setting of the study area. . . ."

Data Collection and Results.—A variety of surveying and sampling techniques and technologies are required to sample and measure the many physical products and processes that characterize continental shelf and slope environments. These include but are not limited to geophysical surveys, sediment sampling, bottom photography, and measurements of ocean currents. One valuable surveying tool is sidescan sonar, which allows scientists to characterize the morphology of the sea floor by swath mapping. Sidescan sonar provides an acoustic image, or sonograph, of the sea floor that is similar to a satellite image of the Earth's land surface. As the sidescan sonar instrument is towed behind a ship along previously determined tracklines, the sonar continuously emits pulses of sound that ensonify strips, or swaths, of sea floor. The width of the swaths depends upon the type of sidescan sonar system. Swaths ranged from 200 meters to 5 kilometers in the Farallones study. When constructing a mosaic of the swath images, tracklines are spaced so that adjacent swaths overlap by 10 to 20 percent.

The sidescan data are processed by computers, and a digital gray-scale mosaic of a chosen area of sea floor is progressively built by overlapping and joining adjacent swaths. The shades of gray define the features of the sea floor and represent varying energy levels of sound returned from the sea floor and, hence, an acoustic image. The differences in the energy of the backscattered sound are related to sediment grain size, surface roughness, hardness, and slope of the sea floor. These sea-floor characteristics reflect the host of geologic processes that have produced the sea-floor environment. The sonographs are used to define the geologic and morphologic setting of the study area, to interpret geologic processes operating on the continental margin, and to provide information relevant to environmental issues.

When information on large areas is required and limited survey time is available, a reconnaissance method is used instead of detailed swath mapping. Data are collected along widely spaced tracklines to obtain an overview of the area. On the continental shelf between Point Reyes and Half Moon Bay, reconnaissance surveys from a high-resolution sidescan sonar system revealed at least four fields of bedforms (ripples and dunes generated by ocean currents). Owing to the widely spaced and non-overlapping sonographs, it was impossible to establish the absolute boundaries and geometric relationships of the bedform fields. Of particular interest were a series of broad (as wide as 2 kilometers), shallow (1–3 meters deep) depressions floored by coarse sand and large wave-generated ripples. To define the pattern and limits of the field of depressions, an 800-square-kilometer area was resurveyed with overlapping swaths and a computer-processed mosaic was constructed on board ship (fig. 1). This study is the first to map and define the field boundaries and thereby establish the geometry and spatial relationships to other shelf features of depressions such as these.

The origin of the depressions is controversial. The intricate pattern of depressions and ripples shows a dynamic and complex sediment transport system that varies with time and space. Information from the mosaic has several practical applications. For example, the evidence of strong currents, as indicated by large ripples in coarse-grained sand, suggests that dredge material and pollutants disposed of at sites on the shelf could be redistributed over large areas. Also, commercial fisherman can use the mosaic to locate substrate preferred by bottom fishes and crabs.

The low-level radioactive waste containers that were dumped in the Farallon Islands Radioactive Waste Dump (FIRWD) may or may not pose a risk to the environment. To evaluate the risk, samples of the sediment, biota, and water must be collected near the concentrations of barrels. However, the exact location of the barrels must be known prior to sampling. The USGS, in cooperation with NOAA, used sidescan sonar to map two areas within the FIRWD. Total sea-floor coverage was obtained, and computer-processed mosaics were constructed on board ship.

Many small nongeologic targets (barrels) were distributed throughout the survey areas, which covered about 70 square kilometers on the shelf and 125 square kilometers on the slope (fig. 1). Analysis of the sidescan data suggests that many of the targets are 55-gallon drums. This interpretation was confirmed at one site by an underwater video and 35-millimeter camera system. Maps of barrel distribution derived from the sonographs are being used to design sampling schemes to evaluate the risk that the levels of radioactivity may have on the biota and environment.

Conclusions.—Geologic Inventory projects such as the Offshore Geology of the Farallones Region are particularly important in ocean areas offshore from major urban centers where human activities have the most impact on the environment and where complex multiple-use decisions are necessary. The data collected during such projects aid in the resolution of geologic and oceanographic questions and critical social problems, such as hazardous waste management and pollution control. Many scientific surveying and sampling techniques, such as the sidescan sonar swath mapping discussed here, are available to help solve environmental problems. Cooperative agency investigations, such as the Farallones Region project, are cost and time efficient. Where feasible, such partnerships can be used to address these important societal and scientific issues.

New State Geologic Maps in New Jersey

By Wayne L. Newell and Mitchell W. Reynolds

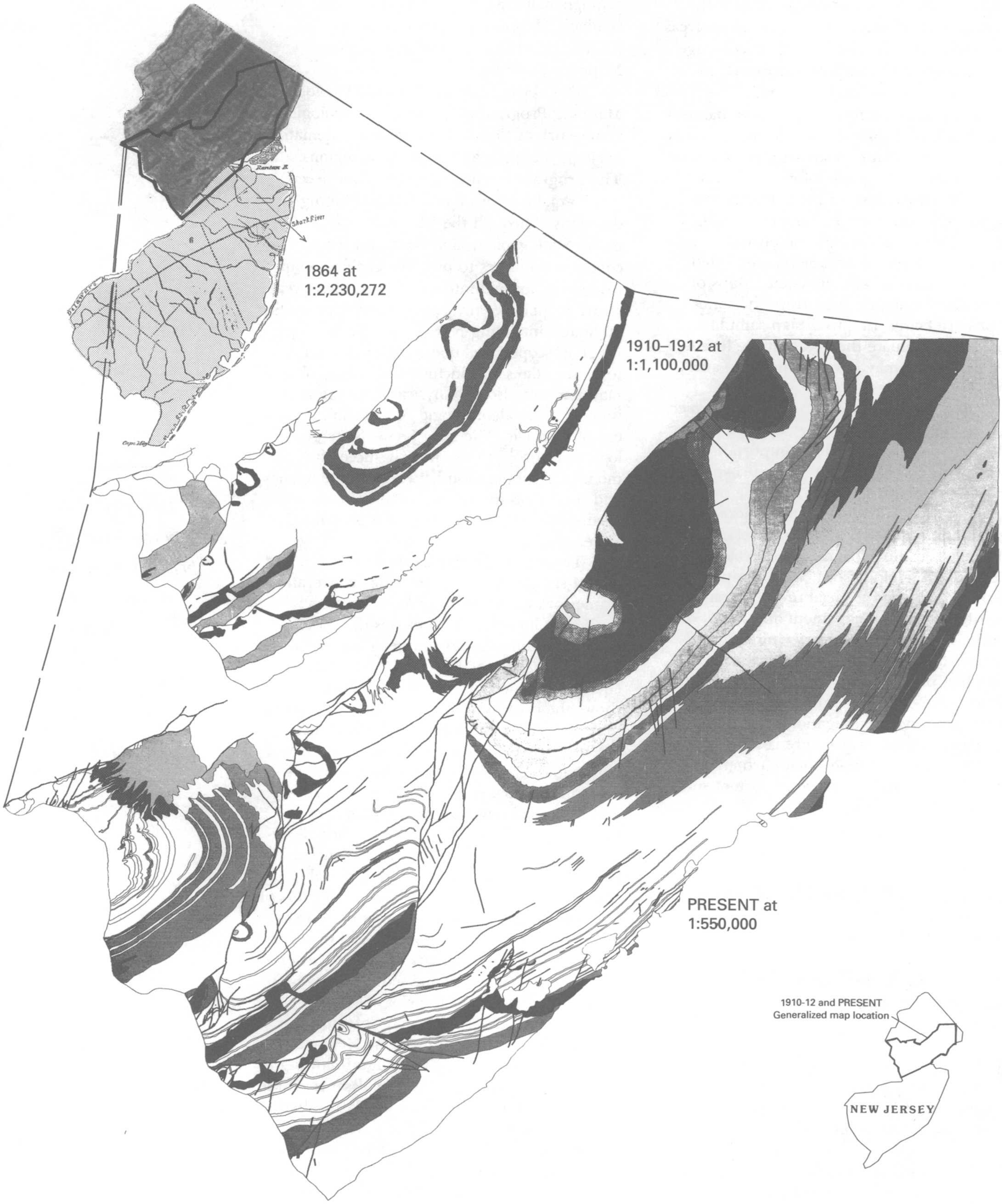
The USGS and the New Jersey Geological Survey (NJGS), part of the New Jersey Department of Environmental Protection, are completing a new series of geologic maps, which present the distribution and structure of bedrock and earth-surface materials across the State. The cooperative geologic mapping project was begun in 1984. The map information enables Federal and State hydrologists, planners, and engineers to accurately model aquifers, identify other resources, and define strategies for mitigating hazards and targeting resources. The project is one of the initial geologic mapping projects of the Cooperative Geologic Mapping program element (COGEOMAP) in the National Geologic Mapping Program.

The objective of the National Geologic Mapping Program is to model the geologic framework of the Nation through systematic geologic mapping and analysis of regions. The program provides geologic data necessary to make informed land use planning decisions. Through the COGEOMAP program, State geological surveys and the USGS combine resources to produce geologic maps in areas of mutual interest. During fiscal year 1991, cooperative projects were in progress in 36 States, including New Jersey. Such projects range in scope from quadrangles or counties to entire States and include not only geologic mapping but also geophysical mapping and isotopic and paleontologic geochronology of earth materials. The New Jersey State geologic map project was an early successful model for cooperation between a State agency and the USGS to produce both bedrock and earth-surface materials maps for an entire State.

Two complete maps, one of bedrock and one of surficial geology, provide an overall framework of the geology of New Jersey. Each map includes three panels that portray the north, central, and southern parts of the State at the scale of 1:100,000 (1 centimeter equals 1 kilometer). The bedrock geologic map shows the distribution of (1) Proterozoic metamorphic and igneous rock faulted against Paleozoic cover rock in the State's northern highlands, (2) early Mesozoic basins, which record the initial stages of continental rifting, and (3) a thick, overlapping sequence of unconsolidated late Mesozoic and early Tertiary sand, gravel, and clay, which fill Atlantic Coastal Plain embayments. The surficial geologic map delineates a variable thickness of Pleistocene glacial deposits across the northern part of the State, the weathered regolith on the unglaciated bedrock, and the Miocene to Recent fluvial to marine sediments overlapping older deposits of the Coastal Plain.

"Two complete maps, one of bedrock and one of surficial geology, provide an overall framework of the geology of New Jersey."

The earliest geologic map information for New Jersey was produced by Henry D. Rodgers more than 150 years ago following a brief but comprehensive reconnaissance of the State. Even though the State legislature had recognized early the need for a systematic detailed survey of New Jersey's natural resources, it was not until well after the Civil War that the work was completed with enthusiastic support from the State agricultural society. At the end of the 19th century, a second State geologic map project was initiated using a new, State-surveyed topographic base for geologic field studies. First printed in 1910–12, the map was a forerunner of



An example of the evolution of geologic mapping in New Jersey, shown by comparison of J. Parkers' 1864 State geological map with parts of J.V. Lewis and H.B. Kümmel's 1910–12 map and the present USGS–NJGS cooperative mapping project (see index map for locations).

modern State geologic maps and has been widely used for 80 years for mineral resources, industrial materials, water resources, and land use planning. The new series of geologic maps, now being prepared for printing, was initiated to provide New Jersey with more reliable geotechnical information to address critical issues concerning water resources, disposal of hazardous wastes, and conflicting interests in land use planning.

Eighty years of progress in geologic research and new uses for geologic information are mandates for compiling new maps. The new State geologic maps are built upon modern concepts, including the collision and rifting of continents, weathering, erosion, the transport and deposition of sediments, climate change, glaciation, and the impact of people on the rates of natural processes. Deep core drilling, seismic profiling, and geophysical maps of the Earth's magnetic and gravitational fields have helped to reliably describe the distribution, shape, and structural configuration of rock types under the surface of New Jersey to depths exceeding several kilometers. This detailed information is essential to understanding the geologic history, the potential for earthquake hazards, and the distribution of resources. Radiometric and paleontologic studies of the ages of the rock units have facilitated the interpretation of the geologic history of New Jersey and aided in such applications as stratigraphic correlations for aquifer modeling.

Beyond the description of rock types and their distribution, the geologic history is an important attribute recorded on geologic maps designed for general-purpose use. Knowledge of the geologic history of New Jersey permits interpretations of the opportunities and limitations presented by geologic processes and environments. Such history permits interpretation of the magnitude and frequency of events such as earthquakes, flooding, climate change, and sea level rise.

Geologic maps and cross sections coupled with an interpretation of the history of geologic processes help map users to predict the suitability of areas for competing land uses. Slope stability, aquifer recharge areas, flood prone areas, eroding coastal areas, and locations along faults can be evaluated using the new geologic maps as a guide. Data from the maps can be computerized and used interactively with other types of spatial data in a GIS to solve many complex earth science problems.

The cooperative project between the USGS and the NJGS has been a pilot for coordinated efforts between State and Federal agencies. The NJGS is responsible for the interpretation of geologic information for regulating site-specific uses. Realizing a need for more comprehensive map information to fulfill that function, State funds were obtained for the NJGS and the USGS to pursue geologic mapping and basic research in a series of collaborative projects.

J.P. OWENS

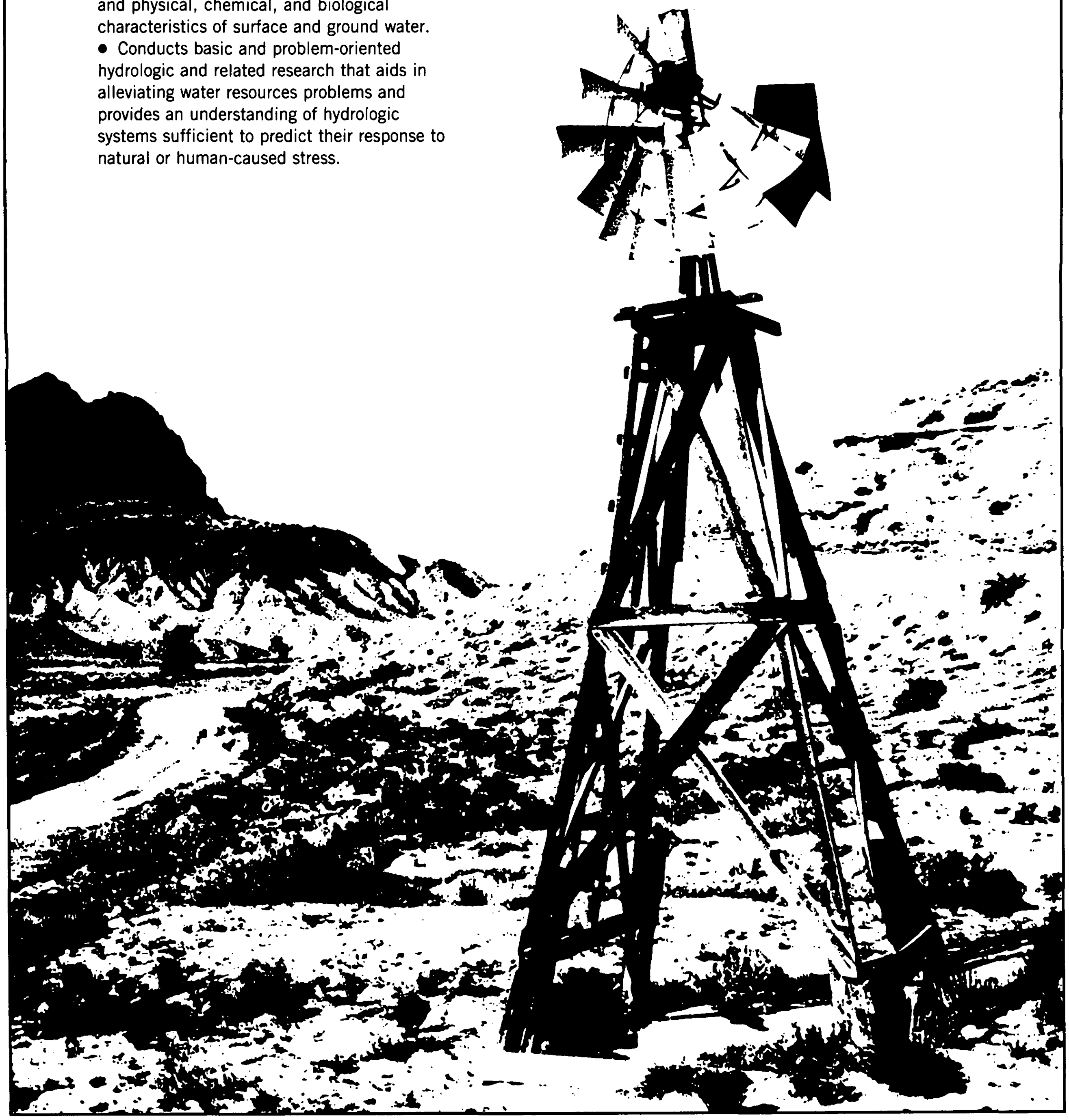
Geologists of the USGS and the New Jersey Geological Survey examine intensely weathered Miocene fluvial deposits in central New Jersey.

The USGS has provided state-of-the-art research skills for geologic mapping. Because the focus of the USGS is national in scope, the collaborative project allows for the geology of New Jersey to be put into a regional perspective across the length and breadth of the Atlantic Coastal Plain, Mesozoic basins, Piedmont, Highlands, and Valley and Ridge provinces of the Appalachians; the project expands the essential national base of geologic information. The NJGS has the detailed knowledge of local geology and extensive archives of information from years of boring for bridges, site investigations, and well logs, which have been essential in developing the overall geologic picture of New Jersey. The involvement of State geologists in the creation and presentation of the new maps ensures that the new geologic data base is most useful and applicable for the NJGS's continuing mandate to apply the information to land use decisions that affect the environment, that provide for responsible use of natural resources, and that impact the well-being of New Jersey citizens.

Mission

The U.S. Geological Survey has the principal responsibility within the Federal Government to provide the hydrologic information and understanding needed by others to achieve the best use and management of the Nation's water resources. To accomplish this mission, the Water Resources Division, in cooperation with State, local, and other Federal agencies,

- Systematically collects and analyzes data to evaluate the quantity, quality, and use of the Nation's water resources and provides results of these investigations to the public.
- Conducts water resources appraisals describing the occurrence, availability, and physical, chemical, and biological characteristics of surface and ground water.
- Conducts basic and problem-oriented hydrologic and related research that aids in alleviating water resources problems and provides an understanding of hydrologic systems sufficient to predict their response to natural or human-caused stress.
- Coordinates the activities of Federal agencies in the acquisition of water resources data for streams, lakes, reservoirs, estuaries, and ground water.
- Provides scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.
- Administers the State Water Resources Research Institutes Program and the National Water Resources Research Grants Program.



Message from the Chief Hydrologist, Water Resources Division

The strength of the USGS program in water resources lies in our nationwide presence and long-term programmatic commitment to objectivity in understanding the physical, chemical, and biological processes that control the distribution and quality of water and in documenting its use. Grass-roots involvement in water issues in every State assures that our studies and data-collection efforts reflect local, regional, and national needs for information. At the same time, we are committed to maintaining nationally consistent, high-quality standards for our data and research, a commitment that is fundamental to maintaining the credibility we enjoy within the water resources community.

In fiscal year 1991, the USGS began a long-term program of regional water-quality studies that ultimately will cover about 50 percent of the land area of the United States and about 70 percent of national water use. The objective of the National Water Quality Assessment (NAWQA) program is to describe the status and trends of regional and national water quality and provide explanations for those observations. Implementation of the NAWQA program is part of a trend that has seen water-quality activities grow from 25 percent of our total water resources program to nearly 45 percent during the past decade.

Our program aspirations for the future include fully implementing the NAWQA program, expanding related water-quality studies of specific problems in our Federal-State Cooperative program, and developing additional expertise in the hydrology and water quality of lakes, reservoirs, and estuaries. We want to expand our capability to predict the effects of climate change on water resources and to increase our ability to address point and nonpoint-source ground-water contamination. Finally, we are looking hard at ways to improve the coordination and integration of water data collected by Federal, State, and local agencies. Clearly, we do not have sufficient water information or fiscal resources to support all the scientific, management, and regulatory programs that should be conducted to assure that the Nation's water resources are wisely used and managed. We can, however, assure that our resources are expended for data collection in ways that complement data collected by others and that the information we have is readily available to all. We believe that investments in these programs now will lay the foundation for water-resources investigations of the USGS well into the 21st century.

Philip Cohen

Distribution of Pesticides in the Sacramento-San Joaquin Delta

By Kathryn M. Kuivila

In spite of a growing concern about the effects of pesticides in surface waters, there is a considerable lack of understanding regarding factors that control the fate of these compounds in the environment. The drainage system of the Sacramento-San Joaquin Delta (fig. 1) includes the Central Valley of California, most of which is irrigated and intensively farmed and serves as an excellent case study. Central Valley pesticide use, which is among the most concentrated in the world, accounts for about 10 percent of the total pesticide usage in the United States (20,000 tons annually, including more than 500 different organic compounds). Thus, the Sacramento-San Joaquin Delta receives diverse organic contaminants that vary widely in their sources, seasonal distribution, environmental behavior, and toxicity.

The Sacramento and San Joaquin Rivers, which together drain most of the Central Valley, probably are the sources of the highest loads of pesticides entering the delta. Local sources, such as agricultural wastewater discharged from delta farmlands, enter the estuary between the rivers and the Pacific Ocean and also contribute pesticides.

Pesticides are applied throughout the year, but application differs seasonally and in areal extent depending on the crop(s) being grown. Therefore, the distribution of pesticides in the delta depends on where and when pesticides are applied, the hydrology of the river-delta system, and the biogeochemical properties of the pesticides.

Streamflow affects transport, residence time, and fate of pesticides in the delta. River inflows to the delta and total freshwater discharge from the delta differ by an order of magnitude between extreme years of drought or floods and even seasonally during some years. The operation of Federal and State water projects that transfer water from northern California sources to the San Joaquin Valley and southern California also affects the flow system in the delta. Typically, most San Joaquin River flow during the summer goes to pumping plants; therefore, the Sacramento River is virtually the sole freshwater source to the estuary. In winter, river inflows are significantly higher and the export pumps have less effect on flow patterns in the delta.

Pesticide Sources and Transport

Three major crops, almonds, alfalfa, and rice, were selected for source and transport studies because the pesticides that are used on these crops include compounds having different biogeochemical properties (fig. 2). Pesticides are applied to these three crops at different times during the year, as is clearly illustrated in the graph of monthly application rates of a representative pesticide for each crop in 1988 (fig. 2*B*). Almond orchards, located primarily along the San Joaquin River, are sprayed with different pesticides, including diazinon, in January and February and again from May through August.

Pesticides, including carbofuran, are applied to alfalfa fields near the San Joaquin and within the delta in March and to rice fields primarily along the Sacramento River from April through June. After a lag time following application, the pesticides are transported in runoff to the river where they move downstream in river water as a pulse (high concentrations that are detected for short periods of time). Pesticide transport is primarily controlled by the hydrology of the river system, and seasonal distributions of the different pesticides are further influenced by the fluctuations in discharge to the delta.

Biogeochemical properties of pesticides are also important factors that influence their distribution in the environment. For example, if a particular pesticide is dissolved in the

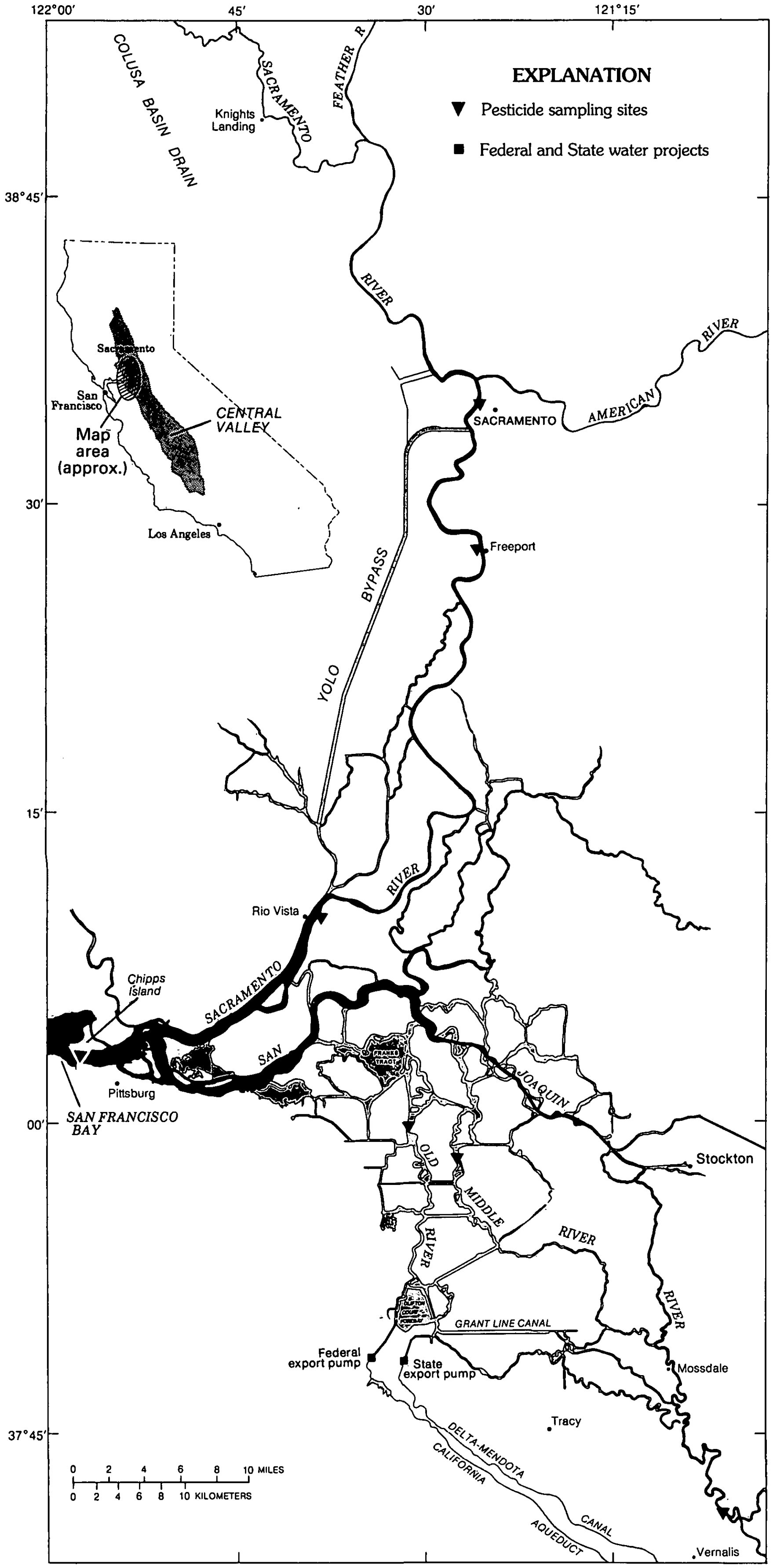


Figure 1. Sampling sites in the Sacramento-San Joaquin Delta, Calif. The major route of water flow in the San Joaquin River from Vernalis to the delta, as indicated by dye studies in February 1991, is past Mossdale, along Grant Line Canal and Old River, and then directly to the Federal and State export pumps.

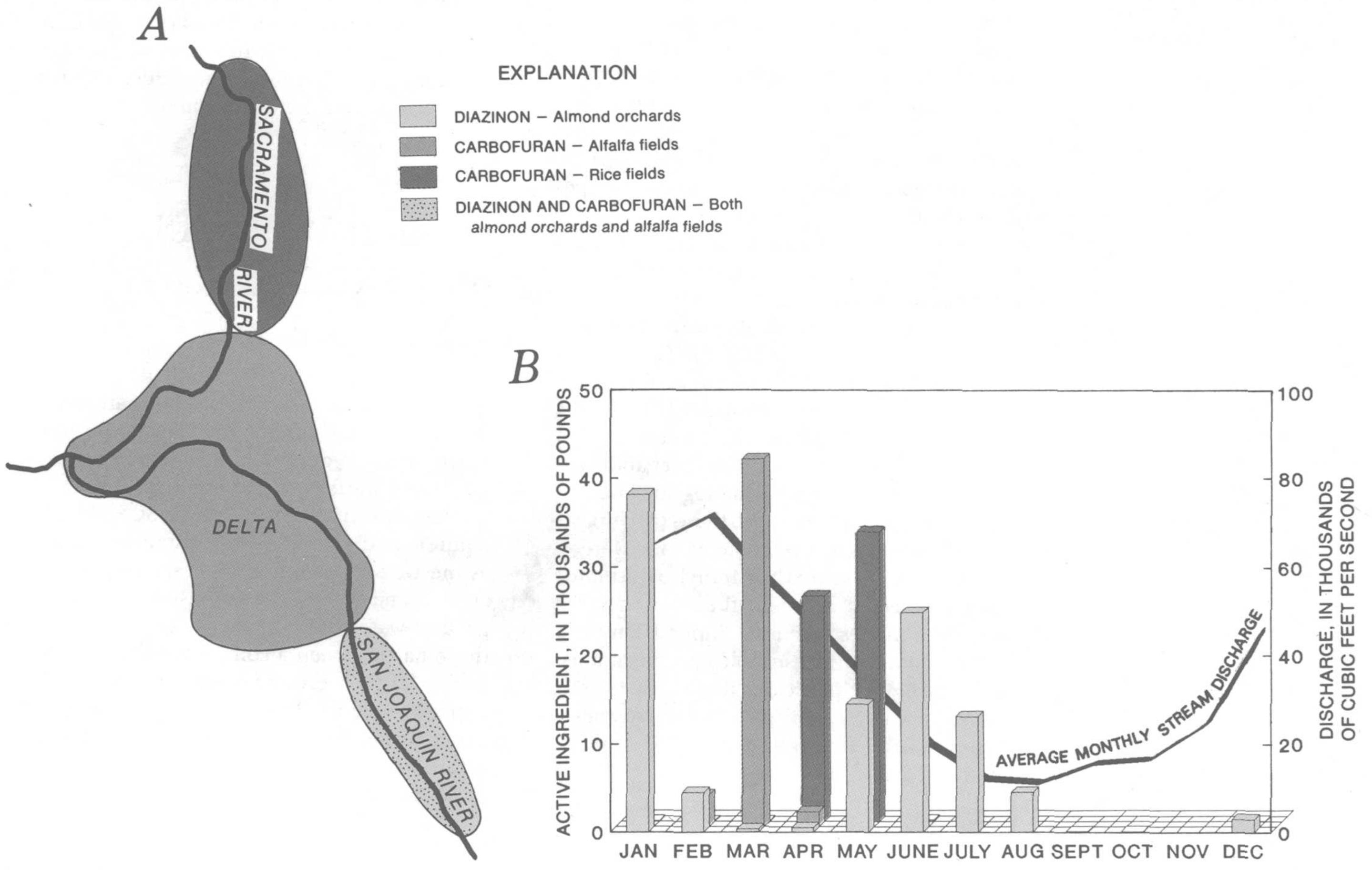
water, it will move with the water; if the pesticide is a particle-bound compound, it will adsorb onto the surface of a particle and be transported in the water with that particle. How long the pesticide will remain in the environment is determined by the rate at which it degrades, either microbially or chemically, into another compound. The resulting degradation compound can be either more or less toxic than the parent compound, and the rate of its degradation depends on whether the pesticide is dissolved or adsorbed onto a particle.

Almond Pesticides.—The primary pesticides that are applied to almond orchards are dissolved compounds (ethyl parathion and diazinon) and the particle-bound compound chlorpyrifos. Almond pesticide loading to the San Joaquin River occurs primarily in February and March. A pulse of diazinon at a maximum concentration of 80 nanograms per liter was detected from February 3 through 12 at a site at the mouth of the San Joaquin River near Vernalis (fig. 1, lower right). The river was being monitored to determine the timing of the almond pesticide pulse in river water from Vernalis to the delta. Only traces of ethyl parathion were detected in the same samples even though six times as much ethyl parathion was applied to the almond orchards as diazinon because ethyl parathion degrades rapidly in the orchards. Chlorpyrifos was not detected in the water samples.

The concentrations of almond pesticides in water samples from the delta, at the end of the pulse detected at Vernalis, were very low. Only diazinon was detected in the water samples at concentrations just higher than the detection limit of 10 nanograms per liter.

Alfalfa Pesticides.—The primary pesticides applied to alfalfa fields are dissolved compounds (carbofuran, diazinon, malathion, and diuron) and particle-bound compounds (chlorpyrifos, endosulfan, and trifluralin). The alfalfa pesticides reach the delta in March and April from different locations along the San Joaquin River as well as from local deltaic sources. A pulse of diazinon at a maximum concentration of 84 nanograms per liter was detected in the San Joaquin River from March 14 through 27. During this time, concentrations of carbofuran also increased to a maximum of 100 nanograms per liter and traces of chlorpyrifos were detected.

Figure 2. Pesticide application on almonds, alfalfa, and rice in the Sacramento-San Joaquin Delta, Calif. ***A****, geographic extent of pesticide application.* ***B****, monthly (1988) application rates and average monthly (1956–85) stream discharge past Chipps Island (see fig. 1).*



Other fixed sampling sites included Freeport on the Sacramento River, two sites along Old and Middle Rivers within the delta, and at Chipps Island, the boundary between the delta and San Francisco Bay (fig. 1). Concentrations of diazinon were at the detection limit (10 nanograms per liter) during the sampling period (end of March through mid-May) at these riverine and delta sites and were slightly higher at Chipps Island.

In contrast, concentrations of carbofuran reached a maximum value at all sites on April 5 and decreased thereafter. Carbofuran concentrations increased seaward; maximum levels ranged from 70 nanograms per liter at Freeport on the Sacramento River to 250 nanograms per liter at Chipps Island. For alfalfa and other important delta crops, the information gained from the sampling period shows that pesticide loading to the bay should be measured at the delta-bay boundary at Chipps Island so both riverine and delta sources will be included.

"...high concentrations are detected for only a few weeks at a time."

Rice Pesticides.—Rice pesticides enter the delta primarily from the Sacramento River, which is tidal downstream from Freeport. A concentrated load of dissolved pesticides (carbofuran, methyl parathion, molinate, and thiobencarb) from rice fields enters the Sacramento River in May and June from agricultural drains, such as the Colusa Basin Drain (fig. 1). The presence of these compounds during spawning season and the results of toxicity tests by personnel of State and Federal agencies suggest that the larval stages of striped bass are adversely affected by the pesticides in the river.

The concentrations of the rice pesticides and their degradation products were measured during a 4-day period, beginning June 3, as they were transported downriver from Sacramento to Rio Vista (fig. 1). Three of the four pesticides were detected at all sampling sites: molinate, in concentrations from 7,000 to 12,000 nanograms per liter; thiobencarb, from 40 to 60 nanograms per liter; and carbofuran, from 125 to 350 nanograms per liter. The concentrations of these three pesticides changed little over time as they were transported downstream. Methyl parathion was not detected in any of the river water samples. Samples taken at Chipps Island (fig. 1) also contained measurable concentrations of the three rice pesticides that were detected in the delta water, which suggests that these pesticides are being transported into San Francisco Bay.

Summary

There is much uncertainty about the long-term biological effects of pesticides in the environment; therefore, the standards for concentrations of pesticides in surface waters are not well established. Whereas some of the dissolved-pesticide concentrations measured during this study are not of concern, concentrations of diazinon in samples taken at Vernalis in 1991, after this pesticide was used on almond orchards and alfalfa fields, were considerably above the U.S. Environmental Protection Agency recommended maximum criterion for aquatic life of 9 nanograms per liter.

The factors that control the sources, transport, and transformation of pesticides in surface waters also are poorly understood. In the Sacramento and San Joaquin Rivers, a striking feature is the pulse effect of pesticide loads; that is, high concentrations are detected for only a few weeks at a time.

The application of pesticides on the fields in the Central Valley of California is regulated and recorded, but the variable lag time between application and detection in the rivers makes it difficult to plan when to take samples. Also, there is little information about the persistence of pesticides in the environment. Therefore, an intensive and continuous sampling effort is needed to adequately define pesticide sources over time and to determine the transport of the pesticides within the delta-bay system. By using this information about the behavior of pesticides in the environment, planners and resource managers, as well as the farmers in the Central Valley, will be able to make informed decisions about the use of pesticides relative to the effects on the environment.

Ground Water Atlas of the United States

By James A. Miller

Ground water is an important national resource. Planners, managers, and personnel from Federal and State agencies, congressional staffs, and the public routinely request information from the USGS about aquifers and ground-water resources. Whereas the USGS and other Federal and State agencies have collected extensive amounts of ground-water data for more than 80 years, there has not been a comprehensive overview of the Nation's ground-water resources on a national scale until now. When complete, the new Ground Water Atlas of the United States will provide in a single publication the most important ground-water information collected by the USGS. The Atlas will also serve as a basic reference that describes the location and the geographic, geologic, and hydrologic characteristics of all of the major aquifers in the Nation.

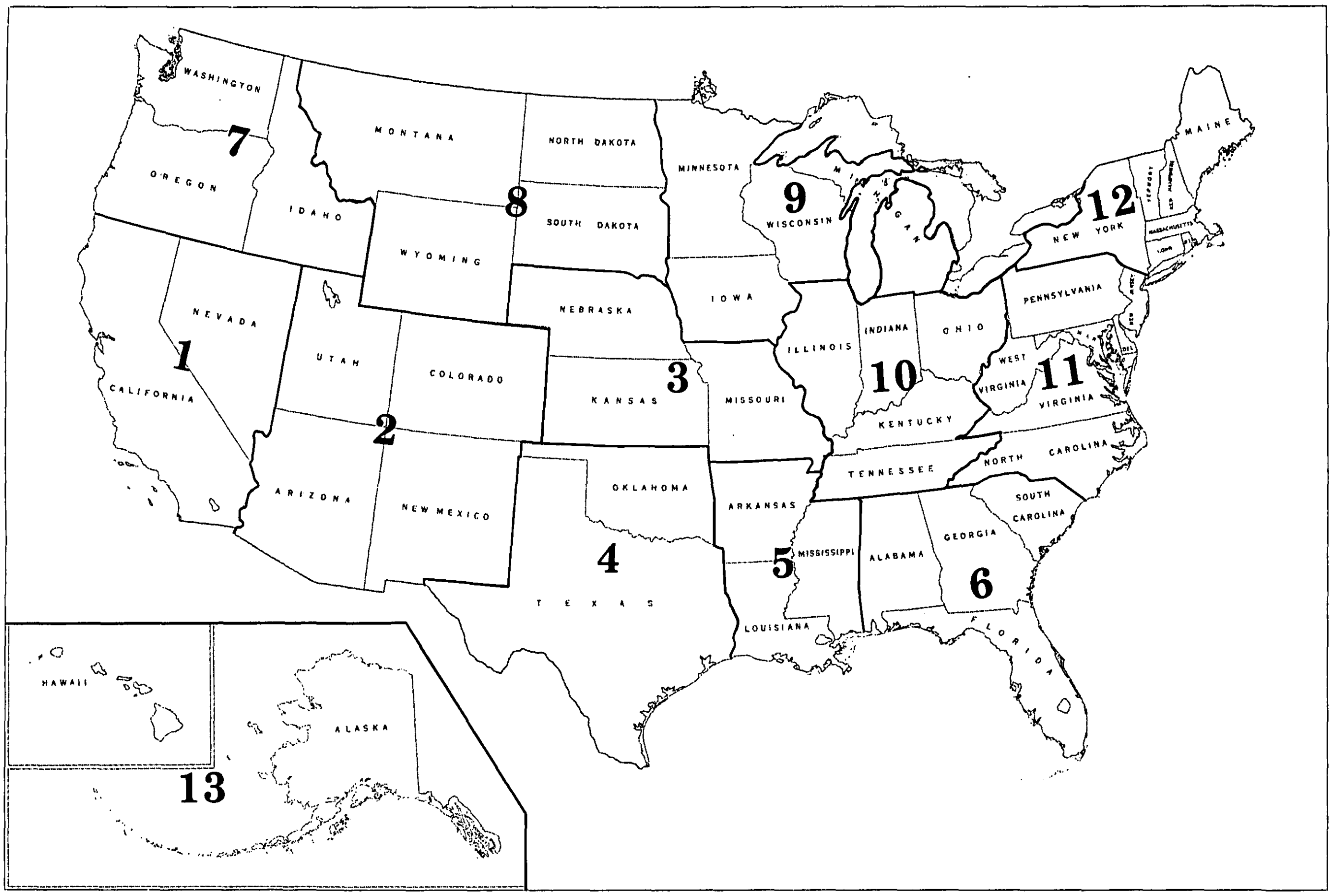


Figure 1. The 50 States, Puerto Rico, and the Virgin Islands have been separated into 13 regional areas. Each area is described in a chapter of the Ground Water Atlas of the United States (Puerto Rico and the Virgin Islands not shown).

The Atlas is written so that it can be readily understood by readers who are not hydrologists. Therefore, it will be useful as a teaching tool in colleges and universities and as an introduction to ground-water hydrology for those in Federal and State agencies, the Congress, and State Legislatures who need to understand ground-water occurrence, movement, and quality.

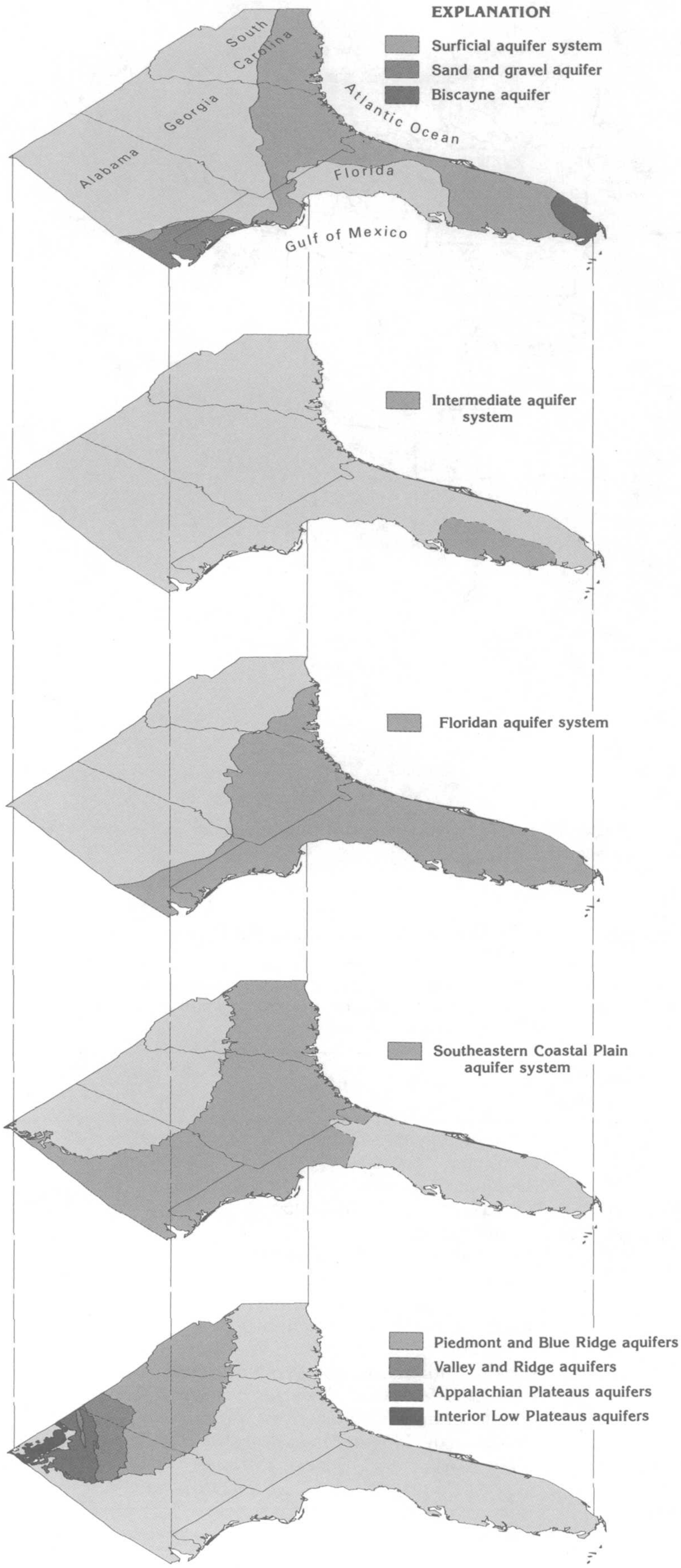
Atlas Design.—The complete color Atlas will have 14 chapters, 13 of which describe regional areas that collectively cover the 50 States, Puerto Rico, and the Virgin Islands (fig. 1). The introductory chapter to the overall publication will be the last chapter written. Two objectives used in delineating the regional areas are (1) to keep each area at a size within which all the principal aquifers can be shown at a reasonable map scale and (2) to contain the most important regional aquifer system or systems entirely within an area. Minor aquifers and minor features of the geology and hydrology of the principal aquifers are not shown because of the scale of the maps.

Maps in the Atlas are supplemented by charts, cross sections, hydrographs, block and

Organization of the Ground Water Atlas of the United States

[The Ground Water Atlas is divided into 14 chapters. Chapter A presents introductory material and nationwide summaries; chapters B through M describe all principal aquifers in a multistate segment of the conterminous United States; and chapter N describes all principal aquifers in Alaska, Hawaii, Puerto Rico, and the Virgin Islands (see fig. 1)]

Number of regional area	Chapter content	Atlas chapter
—	Introductory material and nationwide summaries	730–A
1	California, Nevada	730–B
2	Arizona, Colorado, New Mexico, Utah	730–C
3	Kansas, Missouri, Nebraska	730–D
4	Oklahoma, Texas	730–E
5	Arkansas, Louisiana, Mississippi	730–F
6	Alabama, Florida, Georgia, South Carolina	730–G
7	Idaho, Oregon, Washington	730–H
8	Montana, North Dakota, South Dakota, Wyoming	730–I
9	Iowa, Michigan, Minnesota, Wisconsin	730–J
10	Illinois, Indiana, Kentucky, Ohio, Tennessee	730–K
11	Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia	730–L
12	Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont	730–M
13	Alaska, Hawaii, Puerto Rico, Virgin Islands	730–N



pie diagrams, and photographs that describe the location, geology, and hydrology of the principal aquifers of the United States. The scales of the maps vary from nationwide-sized maps that illustrate problems, such as salt-water encroachment or land subsidence caused by ground-water pumping, to maps of specific aquifers, such as the Biscayne aquifer that extends over only a three-county area in southeastern Florida. Figure captions describe in simple language the principal features of each illustration. Also, pertinent references are listed for each described aquifer for readers who need detailed information.

Each of the 13 descriptive chapters will be published as a separate Hydrologic Investigations Atlas (HA). The first chapter of the Atlas to be published, "Hydrologic Investigations Atlas 730–G," was issued in 1991 and includes aquifers in Alabama, Florida, Georgia, and South Carolina. After all 13 reports are published, the introductory chapter will be written and the 14 chapters will be published as a single book. The introductory chapter will present an overview of ground-water conditions nationwide and discuss the effects of human activities on ground water.

Each descriptive chapter of the Atlas begins with an overview of geologic and hydrologic conditions throughout the regional area covered by that chapter. Regional maps that show amounts of precipitation, runoff, physiography, geology, and ground-water withdrawals by county are included in this overview. Each chapter contains block diagrams, cross sections, and isometric diagrams, such as the one shown in figure 2, that show the relation of each aquifer or aquifer system to underlying and overlying hydrogeologic units. Figure 2 shows aquifers in semiconsolidated and consolidated deposits; some chapters also have a regional map that shows aquifers in unconsolidated deposits.

Discussions of each principal aquifer within a regional area are accompanied by maps that show the location and extent of the aquifer, the thickness of the aquifer, the potentiometric surface of the aquifer, and the quality of the water in the aquifer. Stratigraphic

Figure 2. *All or parts of nine principal aquifers, shown here from shallowest to deepest, are exposed at land surface in the four States (Alabama, Florida, Georgia, and South Carolina) described in area 6 (modified from map HA 730–G) of the Ground Water Atlas of the United States. A tenth aquifer, the Intermediate aquifer system in Florida, is completely buried.*

charts list the geologic units that compose the aquifer. Cross sections detail the relation of the aquifer to the geology of the area, and flow-direction arrows superimposed on the cross sections show the movement of water in the aquifer. Representative hydrographs illustrate the response of water levels in the aquifer to changes in the amount of precipitation or ground-water pumping.

Where data are available, the maps depict the change in water levels over time as the aquifer is developed. Pie diagrams portray the amount of water withdrawn for specific categories of water use. Special conditions caused by ground-water use, such as sinkholes that form in response to ground-water pumping, waterlogging caused by irrigation, and large water-level declines or intrusions of saltwater caused by excessive ground-water withdrawals, are discussed and illustrated.

Color is used in the Atlas to emphasize the information presented in each illustration and for consistency among chapters. A set of five uniform map scales has been chosen so that the maps can be directly compared within and among chapters. Photographs illustrate special features or conditions.

Because USGS ground-water data are so extensive, no new data are being collected for the Atlas; illustrations and interpretations already published are merged, joined, modified, and simplified as necessary. Data bases and interpretive results of the studies conducted as part of the USGS Regional Aquifer-System Analysis (RASA) program are major sources of information for the compilation of the Atlas. Some of the results of these studies are combined into nationwide summaries in the Atlas. The regional syntheses of the RASA studies are supplemented where necessary by material from smaller scale studies. If appropriate illustrations are not available, maps and illustrations are constructed from data files.

Summary.—The Ground Water Atlas of the United States is designed for a varied readership. Accordingly, the level of writing is aimed at readers who have some technical knowledge but are not hydrologists. Technical jargon is kept to a minimum, and technical terms are defined in simple language. The Atlas does not present a comprehensive description of all that is known about each aquifer or aquifer system; rather, it presents, within a single book, the most important aspects of the geohydrology, ground-water flow system, water quality, and use of water withdrawn from the Nation's principal aquifers.

Water Movement Through Soil at a Low-Level Radioactive-Waste Site in the Amargosa Desert

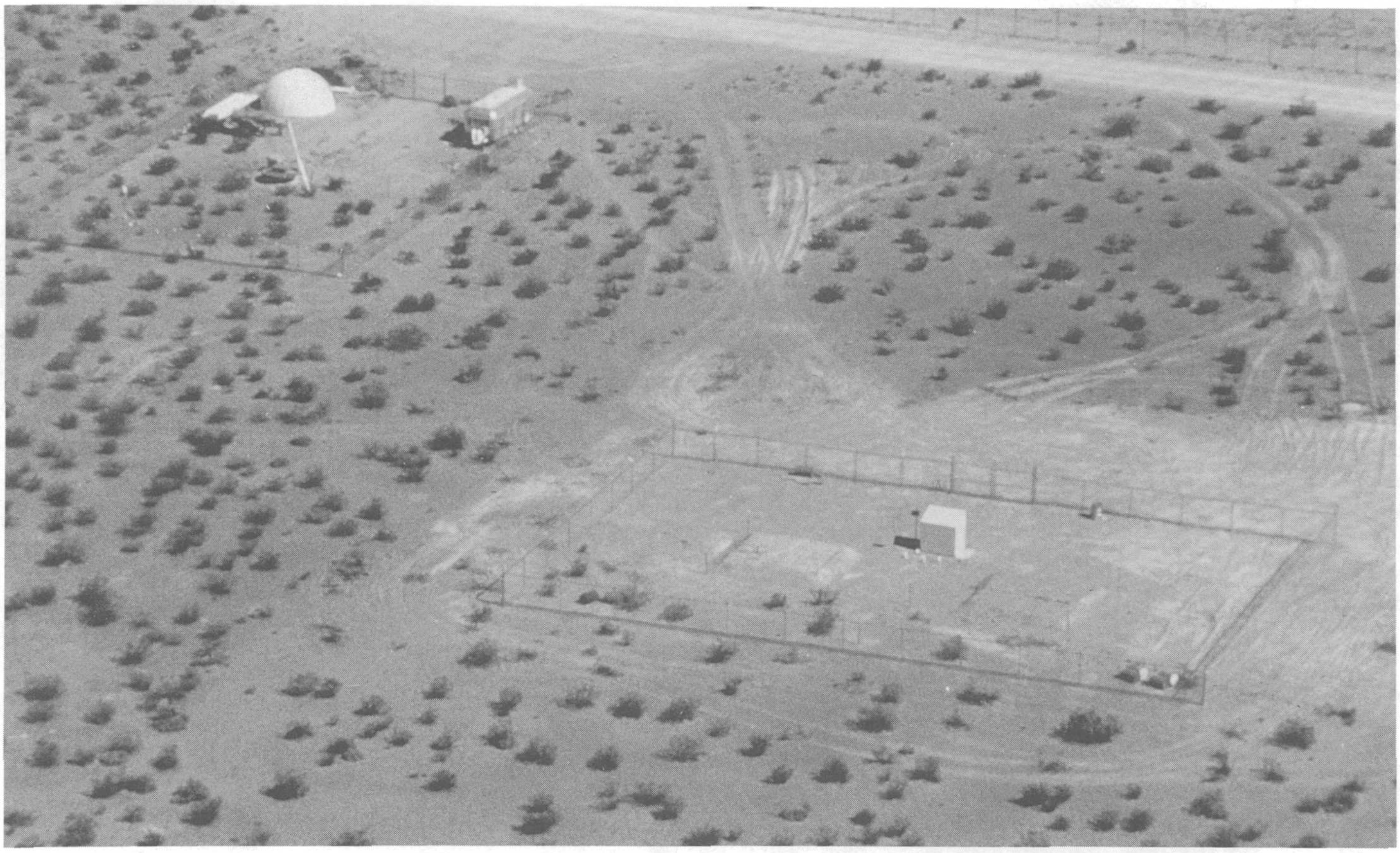
By Brian J. Andraski

About 1.5 million cubic feet of filters, equipment, clothing, and other waste contaminated by radioactive nuclides are generated every year in the United States by electric utilities, universities, hospitals, and industrial facilities. These wastes are called low-level radioactive wastes because the hazard from radiation is both relatively low and short-lived (from 100 to 500 years). At present, low-level radioactive wastes are disposed of in shallow land burial trenches at three locations (Barnwell, S.C.; Beatty, Nev.; and Richland, Wash.) in the United States. Beginning in 1993, two of these three sites (Barnwell and Beatty) will be closed, so several new facilities for the disposal of such wastes will have to be sited and built in the late 1990's.

Arid regions appear to be the ideal choice for shallow land burial of these wastes because low precipitation and high evapotranspiration, which are typical of arid regions, can reduce the potential for contact between water and buried waste. Also, thick, unsaturated zones may provide a natural barrier to the migration of radionuclides to the water table. The processes affecting movement of water through soil at arid sites are not well understood, however, because only recently has there been a need to understand the soil-water regime and the movement of water through soil in arid, nonirrigated sites. This need has been underscored by the ongoing proposals to use arid sites for the disposal of several types of waste. Currently, little information is available about the natural soil-water flow systems at arid sites, and even less is known about how the construction of a waste-disposal facility alters the natural environment of the site.

"Arid regions appear to be the ideal choice for shallow level burial of these wastes. . . ."

Beatty Study Site.—Detailed field investigations at the site in the Amargosa Desert near Beatty, Nev., are part of the USGS program of research on low-level radioactive-waste disposal. Through this program, the USGS assesses the suitability of existing burial sites and develops site-selection and facility-design criteria for use by the U.S. Nuclear Regulatory Commission (NRC) in their selection of future burial sites. The Beatty facility, which is in one of the most arid parts of the



US ECOLOGY, INC.

Aerial view of the undisturbed (fenced, upper left) and disturbed (fenced, center) study sites, which are adjacent to the low-level radioactive-waste facility (behind the fence across the road at the upper right of photo) in the Amargosa Desert near Beatty, Nev.

United States, opened in 1962 and was the first commercially operated, low-level radioactive-waste facility in the country. From 1981 through 1990, precipitation at the site averaged about 4.2 inches annually and ranged from as little as 0.5 inch during 1989 to as much as 9 inches during 1983. Depth to the water table is about 345 feet. The site is underlain by coarse-grained to fine-grained alluvium. Vegetation is sparse, and creosote bush (Larrea tridentata) is the predominant species.

Preliminary evaluation of conditions in the vicinity of the Beatty waste-disposal facility suggested that low average annual precipitation and high average annual evapotranspiration would prevent water from reaching the buried waste. Results from initial studies by USGS personnel, however, indicate that this assumption is invalid. Under the right climatic and soil-moisture conditions, the potential for water to infiltrate at depth at the burial facility does exist, in spite of high evaporation.

Detailed investigations by USGS scientists have been conducted to better define the directions and rates of movement of water through soil under natural conditions and to determine how the removal of vegetation and construction of burial trenches disturbed the natural environment. Undisturbed and disturbed study sites were established adjacent to the low-level waste-disposal facility (see figure). At the undisturbed site, a vertical shaft provides access for installation and retrieval of instruments in the upper 45 feet of the vegetated soil. At the disturbed site, two small-scale test trenches (each about 14 feet in length, depth, and width) were constructed in the same manner as those of the burial facility. The trench covers and the undisturbed soil between the trenches are kept free of vegetation.

At the undisturbed site, near-surface soil is usually dry; however, the amount of water in the soil fluctuates in response to precipitation and evapotranspiration and ranges from about 1 to 12 percent moisture. Below a depth of 3 feet, the amount of water in the soil depends in part on differences in soil texture, and the moisture content ranges from about 4 to 14 percent. Measurements of soil-water-potential and vapor-density gradients in the upper 30 feet of soil indicate that the direction of water movement varies; below the 30-foot depth, however, the measurements indicate that the direction of water movement is generally upward. Estimates of the volume of water flow, in either liquid or vapor form, are typically less than 10^{-3} inches over the area per year.

At the disturbed site, construction of the test trenches produced a backfill material that was generally drier (3 to 4 percent moisture) and significantly more homogeneous than the undisturbed soil. During the first year after the test trenches were built (September 1987 to September 1988), precipitation at the site totaled 6.2 inches (152 percent of the 10-year average). By the end of the first year, the amount of water stored in the near-surface soil of the unvegetated trenches and in the unvegetated soil between the trenches showed a net increase of as much as 64 percent over initial amounts, whereas no net increase occurred in vegetated soil at the undisturbed site.

Precipitation at the site totaled 1.5 inches during the next 2 years. In spite of these extremely dry conditions, the amount of water stored in the near-surface soil of the unvegetated trenches and in the unvegetated soil between the trenches still showed a net increase of from 5 to 15 percent over initial amounts. In contrast, the amount of water stored in the vegetated soil at the undisturbed site was 15 percent less than the initial amount. By the end of the third year (1990), water that infiltrated the trench covers and water from the undisturbed soils adjacent to and beneath the trenches still had not come in contact with the simulated waste.

Results of Investigation.—Results to date (1991) from these ongoing studies have clearly demonstrated that the natural system impedes water permeation at depth at this arid site. In addition to the natural climatic regime (that is, precipitation and evaporation), soil and vegetation are extremely important factors influencing the soil-water regime at the Beatty site. The stratified alluvial soils provide natural barriers to water movement. Because vertical flow of water is impeded, plants can extract and transpire water that accumulates in the root zone. Creosote bush, an evergreen shrub that is extremely drought tolerant, can deplete the soil of what little water is available. The limits on the downward movement of water through the soil caused by these near-surface conditions are reflected in the consistently low soil-water content that is measured at depth. The amount of water or vapor moving through the soil is quite low, and the moisture moves upward or downward in response to soil-water-potential and soil-temperature gradients.

The construction of the burial trenches and removal of the native vegetation significantly altered the natural environment of the site. Trench construction eliminated the natural barriers to water movement originally present in these alluvial desert soils. Two points should be considered regarding the absence or presence of natural barriers to water flow: (1) the lack of such barriers in the trench backfill could increase the potential for deep percolation of water and (2) the presence of these barriers in the soil adjacent to a trench could result in lateral flow of water from the soil into the trench. Lack of vegetation increases the potential for water to percolate toward the buried waste.

Application of Findings to Waste Sites in Arid Regions.—Regulations of the NRC require that near-surface, low-level radioactive-waste sites "shall be capable of being characterized, modeled, analyzed, and monitored." The 1 year of preoperational monitoring required by the regulations for purposes of characterization and subsequent modeling of any proposed commercial low-level radioactive-waste site is generally limited to natural site conditions. Results from the studies near Beatty, Nev., demonstrate that the installation of a disposal facility markedly alters the natural environment. These changes must be considered when a disposal facility is designed and the effectiveness of a proposed site and facility for long-term isolation of waste is studied.

". . .installation of a disposal facility markedly alters the natural environment."

Based on the predominantly low soil-water potential measured to date at both the undisturbed and disturbed study sites, the movement of moisture in the vapor phase is likely to be an important transport mechanism. Transport of radioactive constituents in the vapor phase, such as tritium and carbon-14, may be a major pathway for the migration of contaminants at arid sites. Unsaturated-zone monitoring programs, which are designed for arid disposal sites, need to include monitoring of both liquid and vapor-phase transport mechanisms as potential pathways for the release of radionuclides.

Summary.—The movement of water through soil at arid sites is extremely complex and is influenced by several interacting factors and physical processes. Factors such as climate, vegetation, and soil properties significantly affect the processes that control the movement of water through soil. Depending on specific but often transient conditions, water movement at arid sites may be predominantly either liquid or vapor flow and may occur in response to soil-water-potential and temperature gradients. Results from ongoing studies near Beatty, Nev., are being used to better define the mechanisms and soil properties that control the movement of water through the soil at that arid site. Additional studies of the processes that control directions and rates of water moving through the soil throughout the unsaturated zone are needed. Such studies are critical to evaluating the importance of potential contaminant-release pathways at arid, low-level radioactive-waste disposal facilities and to obtaining a better understanding of the overall hydrologic cycle in arid regions.

Distribution of Atrazine and Similar Nitrogen-Containing Herbicides, Lower Kansas River Basin

By John K. Stamer and Ronald B. Zelt

Nonpoint-source contamination of surface and ground water from agricultural activities is a national issue. Contaminants include pesticides, sediment, nutrients (nitrogen and phosphorus), and fecal bacteria. Of these contaminants, pesticides receive the most attention because they are toxic to aquatic life and are therefore potentially toxic to humans through consumption of contaminated water supplies or fish. Farmers depend on pesticides, including herbicides, to increase crop yields. Herbicides prevent or inhibit the growth of weeds that remove nutrients and moisture needed by the crops. If weeds are harvested with the crop, the value of the harvested crop is less than that of a weed-free crop. Herbicides are applied before planting, or as pre- and post-emergent compounds during or some time after planting. Herbicides often are used in urban areas and in large quantities for nonselective weed control in industrial applications, such as along railroad rights-of-way.

"Atrazine... had the highest concentration of any pesticide measured in surface water during low flow."

The USGS began a surface-water-quality assessment of the 15,300-square-mile lower Kansas River basin in southeastern Nebraska and northeastern Kansas (fig. 1) in 1986 as part of the National Water-Quality Assessment (NAWQA) program. About 85 percent of the study unit area is agricultural land typical of the midwestern United States; principal crops are corn, sorghum, soybeans, and wheat. The study unit includes the Big Blue and Delaware River basins and smaller tributaries to the 170-mile reach of the Kansas River from Junction City, Kans., to its confluence with the Missouri River at Kansas City, Kans. Three large Federal reservoirs (Tuttle Creek, Perry, and Clinton Lakes) lie within the Kansas part of the study unit. These reservoirs are used for flood control, low-flow augmentation, public-water supplies, and recreation. Most of the surface-water storage in the lower Kansas River basin is held in these three reservoirs, which have a substantial effect on streamflow and water quality in the Kansas River. In the study unit, surface runoff provides much of the water used for public supply, and surface water is the principal source of public supply in the Kansas part of the study unit.

The areal and temporal distribution in surface water of atrazine and similar nitrogen-containing herbicides, such as alachlor, cyanazine, metolachlor, and simazine, are being defined in this study of the lower Kansas River basin. As a group, these compounds are used extensively throughout the study unit; atrazine is used the most. In 1989, an estimated 4.3 million pounds of the active ingredient atrazine were applied to corn and sorghum cropland in the study unit. This amount is about 5 percent of the total amount of atrazine used in the United States during that year.

Analyses by USGS personnel of available data on 458 water samples collected at 20 surface-water sites from 1978 to 1986 by personnel of the Kansas Department of Health and Environment indicated that atrazine, metolachlor, and alachlor were the herbicides most frequently detected in water from the Kansas part of the study unit; the highest concentrations were for atrazine.

Atrazine, unlike metolachlor or alachlor, was detected during each month of the year. Median concentrations of atrazine in water samples collected during June, July, and August of each year from 1978 to 1986 exceeded the Maximum Contaminant Level (MCL) of 3.0 micrograms per liter established by the U.S. Environmental Protection Agency for finished public-water supplies under the Safe Drinking Water Act of 1986.

After the available data were analyzed, USGS personnel measured concentrations of nitrogen-containing herbicides in samples of stream water that were collected during low-flow conditions from summer 1988 to spring 1989 at 61 synoptic-sampling sites in the study unit (fig. 1). During low flow, shallow ground water is the source of most of the flow in unregulated streams. Analyses of these samples indicated that atrazine was the most frequently detected herbicide and had the highest concentration of any pesticide measured in surface water during low flow. In general, the highest concentrations of atrazine were measured in the Big Blue River basin upstream of Tuttle Creek Lake where the largest amounts of atrazine were applied to the land (fig. 1). In July 1988, the median concentration of atrazine in samples from the 61 sites was 2.6 micrograms per liter; 38 percent of the samples had concentrations of atrazine higher than the established MCL of 3.0 micrograms per liter.

Concentrations of atrazine during low flow also fluctuated seasonally; the highest median concentrations occurred in spring and summer and the lowest in fall and winter. Of the 61 sites sampled during low flow, only one site—the outflow of Perry Lake on the Delaware River—had atrazine concentrations

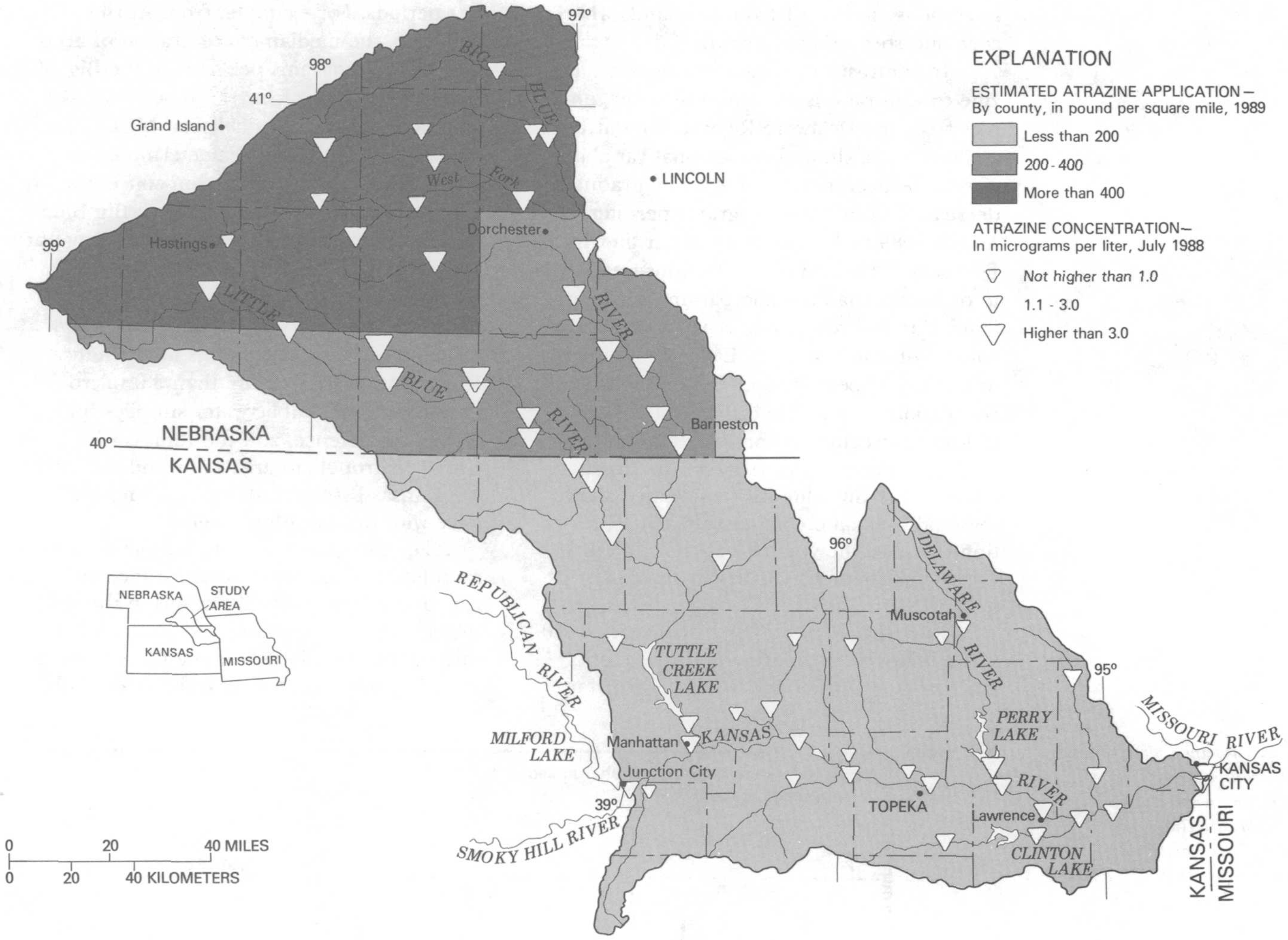


Figure 1. Areal distribution of atrazine concentrations during low-flow sampling in July 1988 relative to estimated atrazine use by county (1989) in the lower Kansas River basin. (Figure produced by using a geographic information system.)

higher than the established MCL of 3.0 micrograms per liter during each of the four seasons. Following atrazine, in order of decreasing median concentrations, were the herbicides metolachlor, cyanazine, and simazine; median concentrations of these compounds during low flow ranged from 0.1 to 0.3 microgram per liter.

To define the temporal variability of concentrations of herbicides in the principal streams in the study unit, water samples were collected monthly or more frequently from 12 fixed stations from March 1989 to February 1990 to provide samples that covered the range of expected streamflows. Analyses of these water samples indicate that atrazine was the herbicide most frequently detected in water (95 percent of 178 samples) and that atrazine concentrations fluctuated seasonally from March 1989 to February 1990. The highest concentrations occurred during June and July 1989 when median concentrations exceeded the established MCL of 3.0 micrograms per liter. In August 1989, more than 25 percent of the samples contained atrazine concentrations that exceeded the established MCL. The lowest median concentrations occurred in February 1990, followed closely by January 1990 and November 1989. Median concentrations ranged from 0.2 to 0.3 microgram per liter during those 3 months.

A markedly different pattern emerged when seasonal fluctuations of atrazine concentrations between unregulated and regulated streams from March 1989 to February 1990 were compared (fig. 2). Atrazine concentrations in the Delaware River, which is unregulated above Perry Lake, near Muscotah, Kans., were lowest in March and April before the herbicide was applied and highest in May, June, and July in response to herbicide application, precipitation, and subsequent surface runoff into the streams. The highest concentrations of atrazine were 22 micrograms per liter in June 1989 and 9.4 micrograms per liter in July. Thereafter, regardless of the rates of streamflow, atrazine concentrations began to decline, decreasing to 0.2 microgram per liter by February 1990 (fig. 2). Patterns were similar in the unregulated streams West Fork Big Blue River near Dorchester, Nebr., and Big Blue River at Barneston, Nebr., where concentrations of atrazine ranging from 10 to 20 micrograms per liter occurred in response to runoff from croplands where corn and sorghum are grown.

In contrast to unregulated streams, atrazine concentrations measured in water samples from the Delaware River at the outflow of Perry Lake showed no seasonal variability (fig. 2). Concentrations of atrazine gradually decreased from 4.0 micrograms per liter in March 1989 to 1.7 micrograms per liter in February 1990, and concentrations were equal to or higher than 3.0 micrograms per liter from March through mid-August 1989. The volume of water in Perry Lake in relation to its outflow appeared to moderate the seasonal fluctuations in atrazine concentrations from inflowing streams. In contrast, analyses of outflow-water samples from Tuttle Creek Lake on the Big Blue River indicated some seasonal fluctuations in atrazine concentrations because the volume of water in Tuttle Creek Lake is much smaller in relation to its outflow.

Note that March 1989 to February 1990 was a relatively dry period and that higher atrazine concentrations could occur during wet periods. For example, from April to October 1986, the median concentration of atrazine, 4.4 micrograms per liter, in the Big Blue River downstream from Tuttle Creek Lake was higher than the established MCL. This median concentration was determined from 10 samples, and the maximum concentration was 8.3 micrograms per liter. The Big Blue River often contributes a large percentage of the streamflow in the Kansas River during summer months; therefore, high concentrations of atrazine in the Big Blue River can cause atrazine concentrations in the Kansas River to increase to more than 3.0 micrograms per liter. Public-water supplies for Topeka, Lawrence, and the Kansas City, Kans., metropolitan area are withdrawn from the Kansas River downstream from its confluence with the Big Blue River.

For the March 1989 to February 1990 sampling period, mean concentrations of atrazine at 3 of the 12 fixed stations in the study unit exceeded the established MCL of 3.0 micrograms per liter. One station is on West Fork Big Blue River near Dorchester, Nebr.,

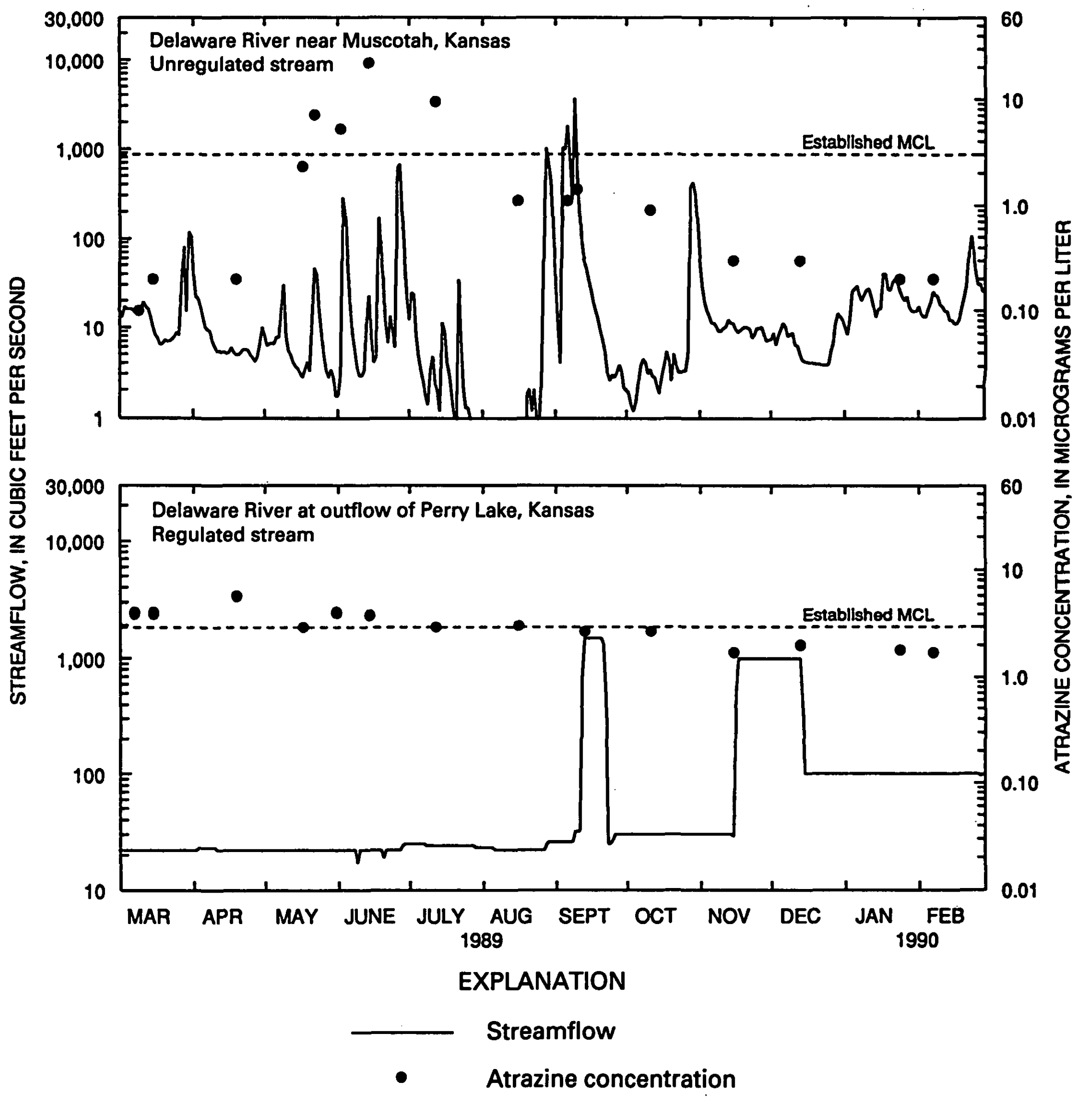
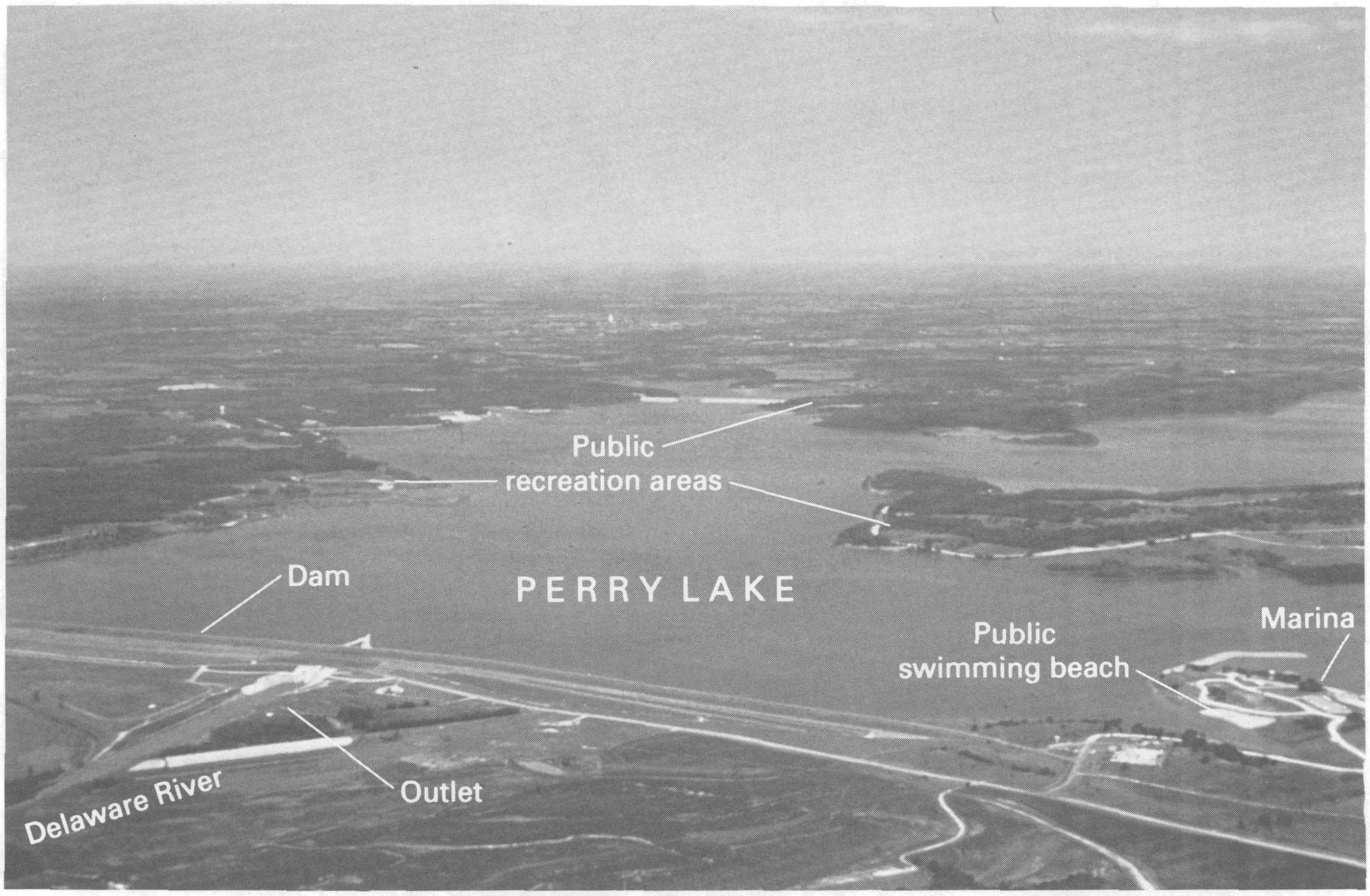


Figure 2. Atrazine concentrations in water relative to rates of streamflow in an unregulated stream, Delaware River near Muscotah, Kans., and in a regulated stream, Delaware River at the outflow of Perry Lake, Kans., March 1989 to February 1990. MCL, Maximum Contaminant Level.



U.S. ARMY CORPS OF ENGINEERS

Aerial photograph of Perry Lake, Kans., showing the dam, outlet of the lake, beach area for swimmers, and recreational areas.

and two stations are on the Delaware River, the drainage area of which lies entirely in Kansas. All three stations are downstream from areas that are predominantly cropland. Upstream of Perry Lake, the sampling station on the Delaware River near Muscotah, Kans., is downstream from two public surface-water-supply intakes and upstream from one intake.

Atrazine concentrations in samples from the outflow of Perry Lake are representative of atrazine concentrations within the lake. Public-water supplies are withdrawn from Perry Lake for two rural water districts and several Federal- and State-owned recreational areas. Water withdrawn from the Delaware River and Perry Lake receives no special treatment to remove atrazine from the finished water, and there is the potential for concentrations of atrazine in these public-water supplies to exceed the MCL at different times of the year.

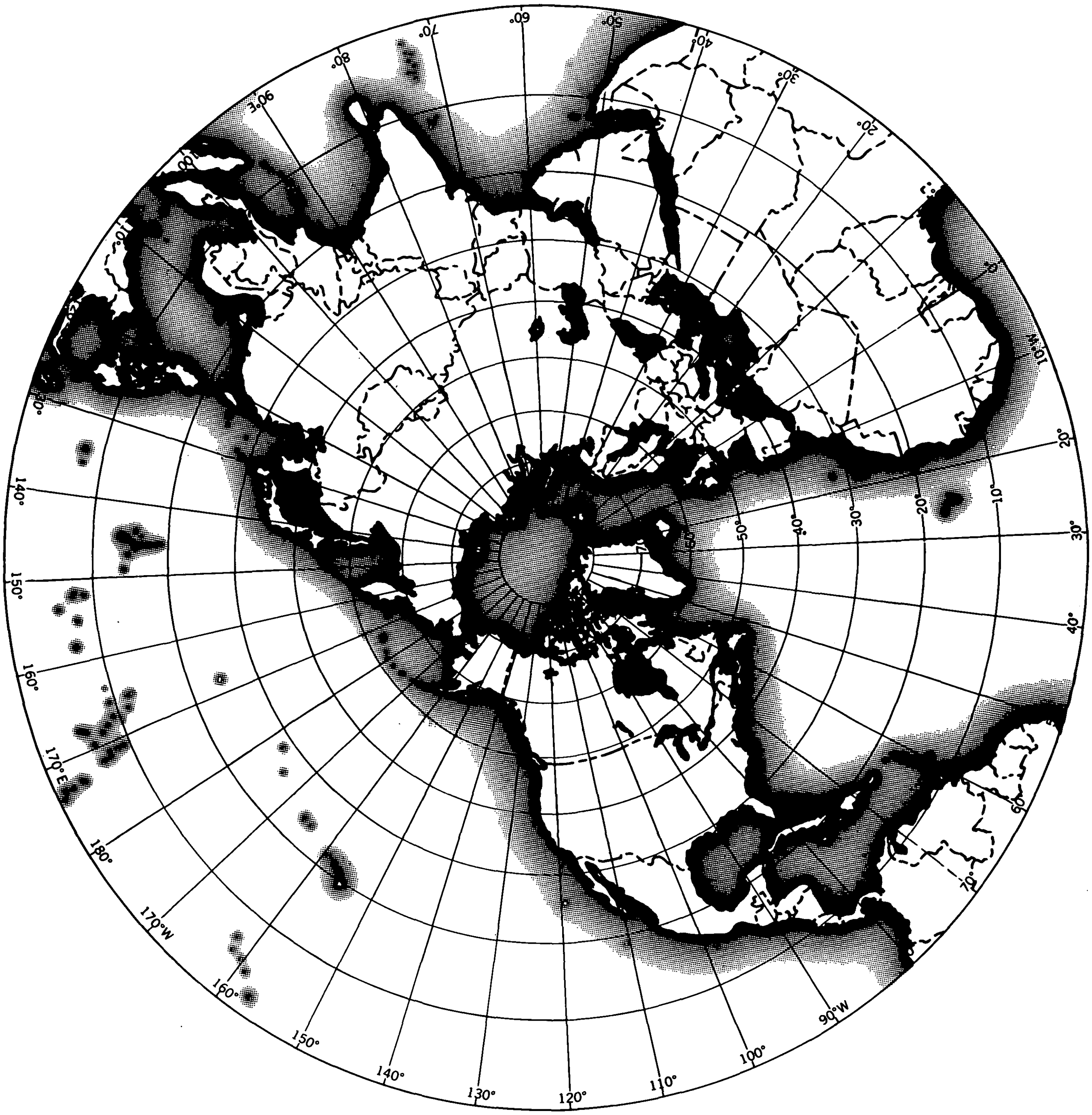
Atrazine and similar nitrogen-containing herbicides pose a special problem in public-water supplies because these compounds are relatively water soluble. Several studies in different States have shown that conventional water treatment is ineffective for removal of atrazine, alachlor, or similar compounds from the finished water.

The USGS has begun to implement the NAWQA program with 20 additional study units. Results from the assessment were used by the Kansas State Board of Agriculture Technical Advisory Committee (TAC) as the basis for establishing the Delaware River basin in northeastern Kansas as a pesticide management area pesticide management area. This pesticide management area is the first in the Nation that targets reducing the amount of atrazine in runoff that enters inland surface waters. Administration of the pesticide management area includes components of management and conservation practices, education, monitoring, research, enforcement, and evaluation. The USGS is involved with the research and monitoring components of the pesticide management area through the Federal-State cooperative program and will continue to provide information that may be used by the TAC as it considers the establishment of additional pesticide management areas in Kansas.

Mission

U.S. Geological Survey cooperative science and technology studies with foreign nations are authorized under the Organic Act, as revised, and the Foreign Assistance Act and related legislation when the activities are determined by the Departments of State and the Interior to be in the best interest of the U.S. Government. Objectives of the investigations include:

- Liaison will be established and maintained with foreign counterpart organizations, scientists, and technicians. The technology transfer and data exchange will be facilitated through cooperation, goodwill, and harmony.
- Comparative international studies will expand the range and contribute to the attainment of domestic research objectives through testing and application of scientific concepts and techniques in favorable areas abroad.
- Worldwide data bases will be established into which information about known and potential foreign resources of interest to the United States will be incorporated. These data bases will be available worldwide to all interested parties.
- Worldwide cooperative studies in the earth sciences will broaden the expertise of both USGS and foreign-counterpart scientists and technicians.
- Earth science and natural resource programs of other Federal agencies, international organizations, academia, and the private sector that share mutual interest with USGS efforts will be supported; the Department of State, in particular, will be provided with information from which to formulate objectives and decisions on matters of foreign policy.



Introduction

USGS international studies in science and technology continued as essential activities to complement the domestic scientific program during fiscal year 1991. The studies are conducted under U.S. Government approved, bilateral or multilateral agreements with foreign counterpart organizations. USGS technical assistance programs in foreign countries provide for the transfer of technology by advice, training, and demonstrations and are commonly done under the auspices of other U.S. Federal agencies, international scientific organizations or financial institutions, or foreign governments. USGS scientific cooperative programs with foreign nations include almost any activity from informal contacts between individual scientists about topics of mutual interest to formally organized, jointly staffed and funded, coordinated research on scientific phenomena.

USGS scientists often serve as officers, committee members, or participants in international organizations, commissions, and associations. Many USGS employees were involved in providing information, particularly to the Departments of Defense and State, about the Middle Eastern region as a USGS contribution to the U.S. Operations Desert Shield and Desert Storm (see p. 44). Several hundred copies of regional and quadrangle Landsat image base maps for the Middle eastern countries were supplied in answer to requests. In addition, many geologic, hydrologic, and terrain-analysis reports were furnished.

In spite of international crises in several areas of the world during the past year, USGS ongoing programs continued, although most were at a reduced pace. New and expanding programs in the geological, hydrological, and mapping sciences and technologies are under discussion for the nations of Eastern Europe (see p. 86), the former Soviet Union, and Latin America, all of which have demonstrated a renewed interest in cooperation, and also in several Middle Eastern countries, where reconstruction will require a knowledge of geological and hydrological sciences.

International efforts highlighted this year include those at Mount Pinatubo, in Central and Eastern Europe, and in Canada.

The 1991 Eruption of Mount Pinatubo Volcano

By John W. Ewert and Christopher G. Newhall

The June 12–15, 1991, eruption of Mount Pinatubo volcano, located 100 kilometers northwest of Manila in the Philippines (fig. 1), was the largest eruption in the past 5 decades and led to the largest known evacuation of people due to a volcanic threat. Quick deployment of monitoring instruments and preparation of a volcanic hazards map by scientists from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and the USGS helped scientists to better understand the precursors of volcanic activity and provided the basis for accurate warnings of impending eruptions. These warnings were widely disseminated and led to the evacuation of more than 58,000 residents near the volcano, including 14,500 U.S. military personnel from Clark Air Base prior to June 12. Before the climactic eruption of June 15, more than 100,000 people had left the area.

USGS monitoring instrumentation used at Pinatubo was drawn principally from a permanent supply of specialized equipment kept ready for volcano crises under the auspices of the USGS Volcano Hazards Program and the joint USGS–Office of Foreign Disaster Assistance (OFDA) Volcano Disaster Assistance Program. OFDA is an office of the Agency for International Development (AID) and is responsible for administering the AID overseas disaster assistance program. By the end of fiscal year 1991, more than 23 USGS geologists, seismologists, hydrologists, and electronics and computer specialists had each spent between 3 and 8 weeks at Pinatubo and helped PHIVOLCS advise community and national leaders and those at risk.

April 2, 1991.—The eruptive cycle began, with a series of small explosions of steam and mud from an east-northeast-trending, 1.5-kilometer-long chain of vents on the north side of the volcano. Vigorous steam emissions continued from vents on the north side of the summit dome through the end of May.

April 5.—PHIVOLCS installed four non-telemetered seismographs on the northwest side of Pinatubo, 10 to 15 kilometers from the summit. During the next several weeks, these stations recorded between 40 and 140 seismic

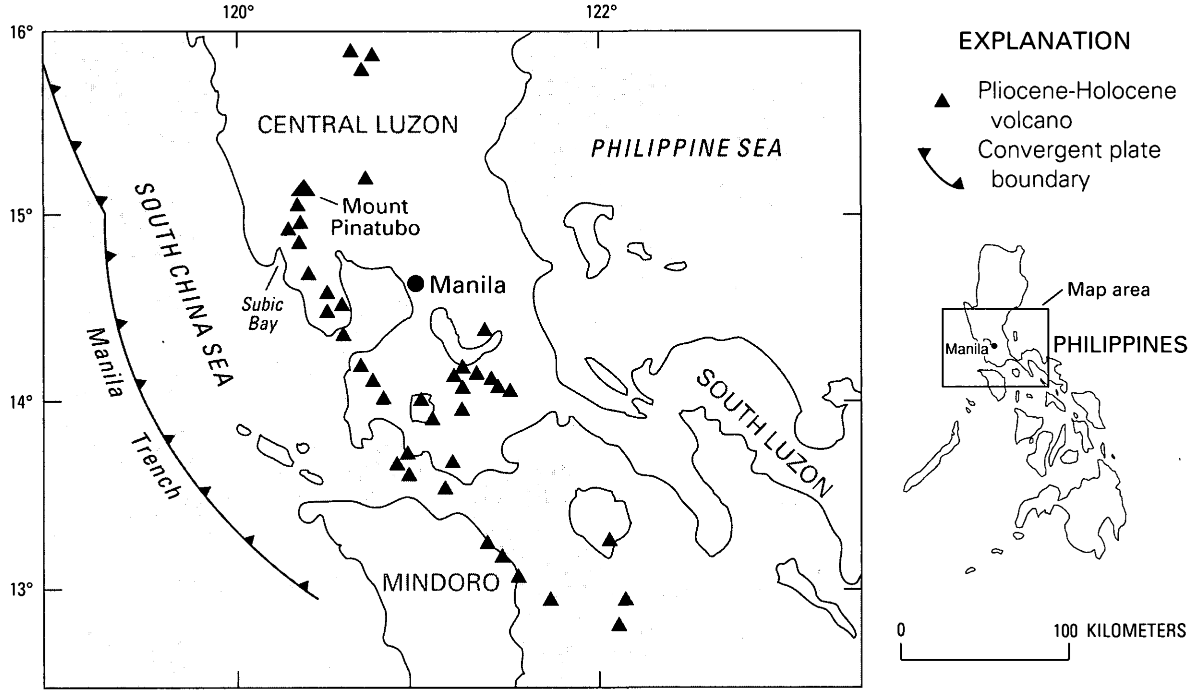


Figure 1. Location of Mount Pinatubo in the Philippines and the convergent plate boundary that causes the volcanic activity in the Philippines.

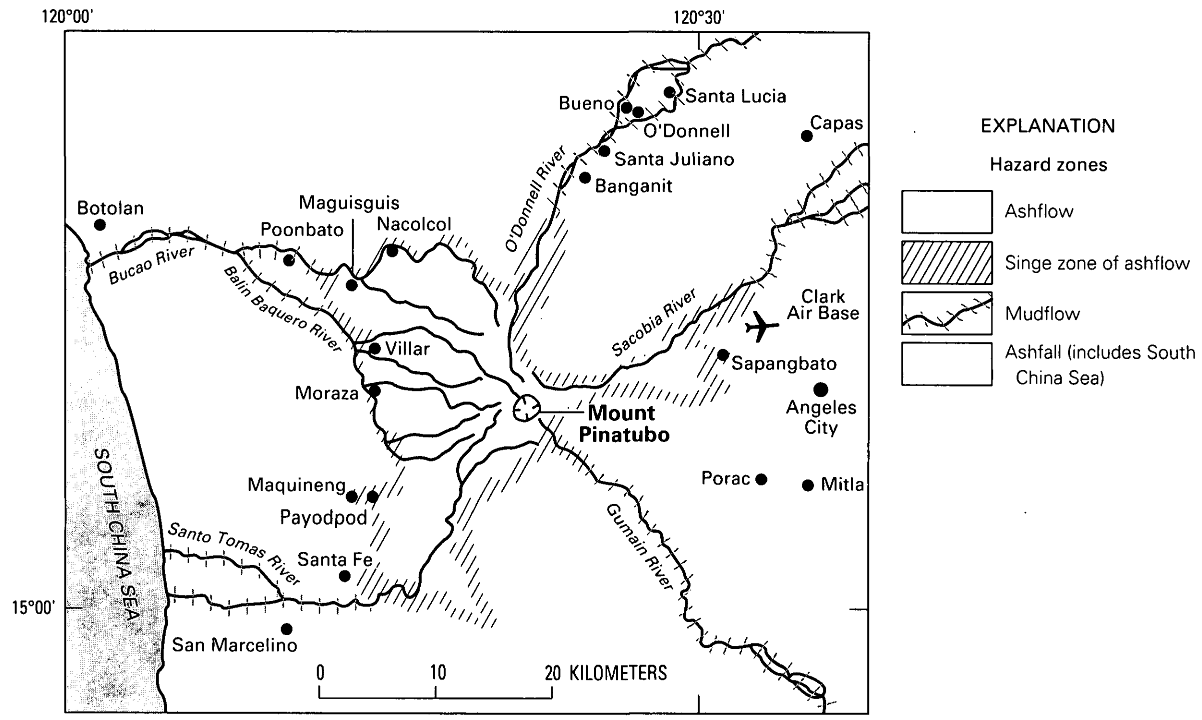


Figure 2. Volcanic hazards map of Mount Pinatubo.

events per day, most of which were less than magnitude 1.

April 22.—In response to a request from the Government of the Philippines and the U.S. Air Force at Clark Air Base, an initial three-person USGS team was dispatched to Pinatubo with telemetered seismic instrumentation, a computer-based seismic-data collection and analysis system, telemetered tilt meters, and a COSPEC (correlation spectrometry) instrument for measuring the emission of sulfur dioxide (SO_2) gas. A seven-station telemetered seismic net, installed by a PHIVOLCS–USGS team, was fully operational by mid-May; the central recording site was located on Clark Air Base.

A 5-level alert system (see table) was developed by PHIVOLCS and the USGS to provide communication about the status of Mount Pinatubo to public officials and to provide a framework against which to make contingency plans.

May 13.—The alert system (1 is low alert and 5 is high alert) was adopted and distributed to civil defense and local officials beginning when the volcano was at level 2.

Only limited geologic information was available before April 2, 1991. The volcano was known to be a 3-kilometer-diameter dacite dome complex surrounded by voluminous fans of geologically young (600–8,000 years before the present) ashflow deposits. No historic eruptions had occurred at Mount Pinatubo, but the volcano was known to be thermally active and had been explored as a potential geothermal energy source by the Philippine National Oil Company. Although there was no volcanic hazards map of the volcano, one was quickly compiled by the PHIVOLCS–USGS team to show areas most susceptible to ashflows, mudflows, and ashfall. The map was based on the maximum known extent of each type of deposit from past eruptions and was intended to show a worst-case scenario.

May 23.—The map was first distributed to Philippine civil defense officials, local governments, and the U.S. military. The map proved to forecast closely the areas that were impacted on June 15. Figure 2 is a redrafted version of this map.

Late May.—The number of seismic events fluctuated from day to day. Trends in rate and character of seismicity, earthquake hypocenter locations, or other measured parameters were insufficiently conclusive to allow forecasting of an eruption.

End May to beginning June.—Subtle changes in seismic activity (a single long-period earthquake, periods of tremor, and hypocenters began to concentrate beneath the steam vents) heralded a trend of accelerating precursory activity. SO_2 gas emissions, which had increased tenfold from May 13 to May 28, suddenly decreased as if magma had sealed its conduit so that gas could not escape.

June 6–12.—A swarm of progressively shallower volcano-tectonic earthquakes accompanied by inflationary tilt on the upper east flank culminated in the extrusion of a small lava dome, near the most vigorous steam vent, and in continuous low-level ash emission.

An alert level 4 was announced on June 7, and residents of Zambales, Tarlac, and Pampanga Provinces within 20 kilometers of the volcano were evacuated. Early on June 10, in the face of a growing dome, increasing ash emission, and worrisome seismicity, 14,500 nonessential personnel and dependents were evacuated by road from Clark Air Base to Subic Bay Naval Station. Almost all aircraft had already been removed from Clark when this action was taken.

From June 7 to 12, periods of tremor became more frequent and had lower frequency, and SO_2 emissions dropped to low levels. Although magma continued to move beneath the volcano, the tremor fluctuations and SO_2 emissions suggested that the vent had been sealed by a cap of degassed magma.

Hazard-alert levels established for volcanic hazard communication at Mount Pinatubo

Alert level	Criteria	Interpretation
0	Background; quiet	No eruption in foreseeable future.
1	Low-level seismic, fumarolic, other unrest.	Magmatic, tectonic, or hydrothermal disturbance; no eruption imminent.
2	Moderate level of seismic, other unrest, with positive evidence for involvement of magma.	Probable magmatic intrusion; could eventually lead to an eruption.
3	Relatively high and increasing unrest including numerous shallow, volcanic earthquakes; accelerating ground deformation; increased vigor of fumaroles, gas emission.	If trend of increasing unrest continues, eruption possible within 2 weeks.
4	Intense unrest, including harmonic tremor and (or) many long-period (low-frequency) earthquakes.	Eruption possible within 24 hours.
5	Eruption in progress	Eruption in progress.

Stand-down procedures

In order to protect against lull-before-the-storm phenomena, alert levels will be maintained for the following periods after activity decreases to the next lower level:

From level 4 to level 3: Wait 1 week.
From level 3 to level 2: Wait 72 hours.

June 12–14.—At 08:51 on June 12, a powerful explosion sent an ash column 19,000 meters above sea level (m asl), as measured by weather radar at Clark Air Base (fig. 3). Additional explosions occurred on the night of June 12 and in the morning of June 13. Explosions destroyed part of the dome and formed a small crater adjacent to the dome. Seismic activity during this period became intense. Recognizable seismic buildup, as much as several hours prior to the explosions from June 12 to 14, permitted short-term notification of impending eruptions to Philippine civil authorities and Philippine and U.S. military authorities.

June 14–15.—On June 14 an 8-hour episode of vigorous seismic activity, more vigorous than any observed before at Pinatubo, lasted until 13:09 when the first explosion of what became the climactic eruptive phase began. Explosive eruptions became more frequent into the night and following morning when, at 05:55, a lateral blast spread southwest, north, northwest, and west from the volcano and sent a broad column of ash to at least 12,000 m asl. Six additional eruptive pulses followed the blast, and by early afternoon the eruption was essentially continuous, lasting approximately through June 15.

At this time, Typhoon Yunya was nearing Pinatubo. The extreme vigor of the eruption, loss of telemetered seismic stations between the summit and the observatory, and uncertainty about the effect of Yunya on immediate mudflow hazards precipitated the

Figure 3 (left). The June 12 eruption column from Mount Pinatubo taken from the east side of Clark Air Base.

Figure 4 (right). Mount Pinatubo on June 29 showing the crater, surrounding topography inundated by ashflows, and minor continuous ash venting.

RICK HOBLITT

ED WOLFE

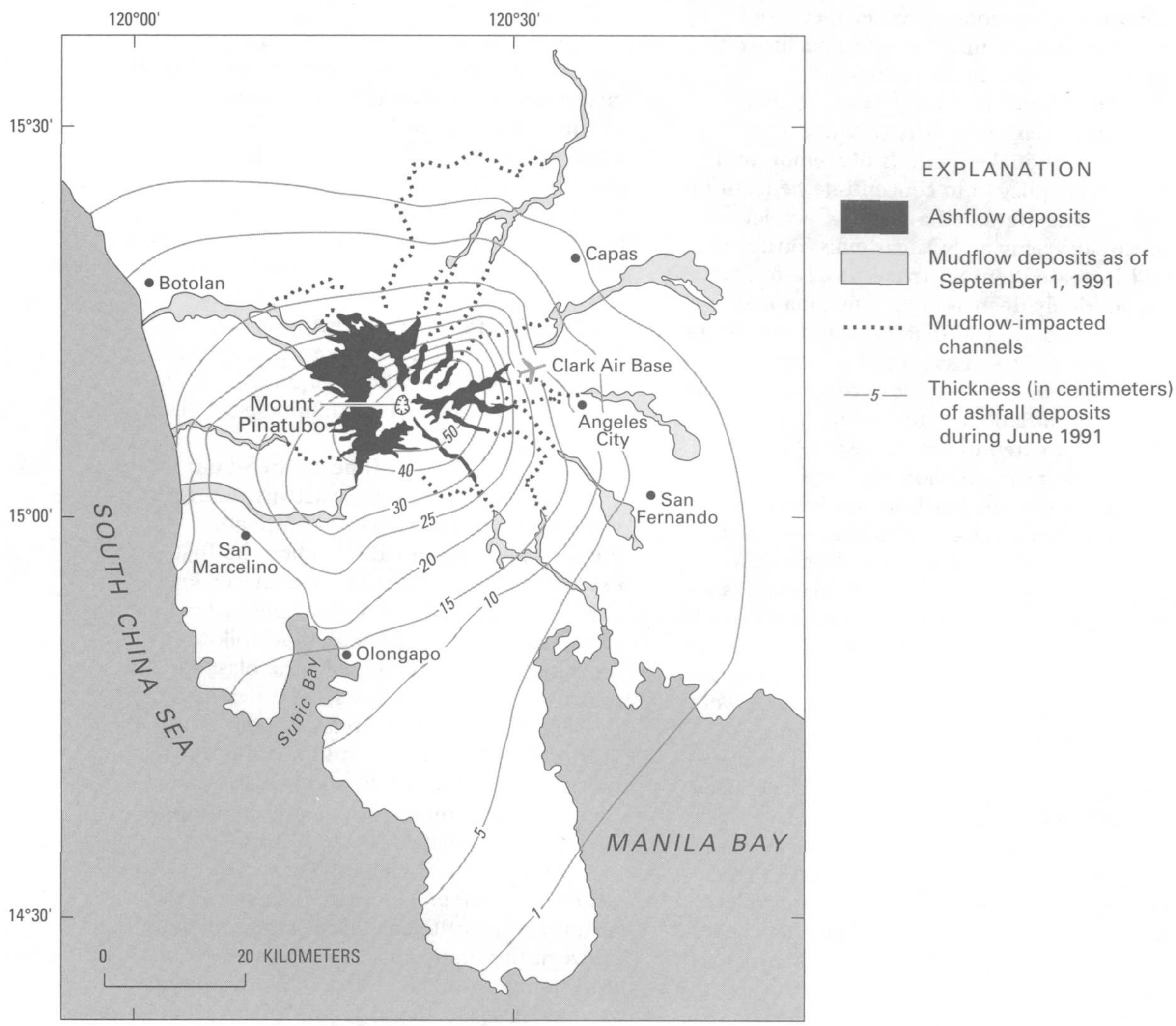


Figure 5. Distribution of ash and ashflows from the June 1991 eruptions.

evacuation of the remaining Air Force, USGS, and PHIVOLCS personnel from Clark Air Base at 14:30 June 15. Personnel returned to Clark the following morning. Seismicity began to decline late on June 15, but the volcano continued to erupt a 10,000-meter-high column of ash for the next several weeks. The various explosions of June 12 to 15 destroyed six of the seven seismic field stations and both telemetered tiltmeters. By June 18 the USGS had dispatched replacement equipment and additional personnel to reinstall the seismic net and to replace the USGS group on site.

The effects of the June 15 climactic eruption were impressive. A crater 2 kilometers in diameter was formed on the north side of the summit dome, and ashflow deposits covered approximately 100 square kilometers of the area around the volcano. These voluminous ashflow deposits filled in the deeply dissected landscape on the north, west, and south flanks of the volcano to such a degree that these areas are now broad featureless plains (fig. 4). Preliminary estimates of bulk volume of ejecta range from 7 to 11 cubic kilometers.

Airfall and mudflow hazards accompanying the eruption were exacerbated by typhoon Yunya during the peak eruptive activity. Cyclonic winds spread tephra over a circular area more than 200 kilometers in diameter, covering at least 20,000 square kilometers with enough ash to damage crops, infrastructure, and buildings (fig. 5). Most of the deaths (more than 330 people) and injuries from this eruption were from the June 15 collapse of roofs under wet heavy ash; many of these roof failures would not have occurred if there had been no rainfall. Heavy rain from the typhoon remobilized ashflow deposits into mudflows on all sides of the volcano. These flows destroyed homes, bridges, and irrigation-canal dikes and buried cropland beyond the volcano.

The onset of the wet season in July brought continued hazards as the ashflow and airfall deposits were remobilized into secondary mudflows. Damage to bridges, irrigation-canal systems, roads, cropland, and urban areas occurred in the wake of each significant rainfall. In early July, a system of telemetered rain gages and a demonstration system of flow monitors was installed to measure precipitation rates and track mudflows in specific drainages. These data allowed the PHIVOLCS–USGS group to provide Philippine civil and U.S. military authorities with real-time mudflow-hazard information.

By August of this year, more than 100,000 people were still displaced by the eruption and continuing mudflow hazard. The main transportation corridors connecting Manila to Angeles City and Olongapo were subject to disruption with each heavy rain. Areas near the volcano will undoubtedly be subject to inundation by mudflows for several more years.

Effects of the eruption on global weather patterns remain to be seen. The mass of SO_2 erupted on June 15 to 16 has been estimated by the National Aeronautics and Space Administration at approximately 18 million tons—about double what was erupted by the 1982 eruptions of El Chichon in Mexico. On the basis of data from other large eruptions in the historical past, some climatic cooling can be anticipated. Plans are that the USGS will continue support to PHIVOLCS in fiscal year 1992 and will assist, as requested, in the continued monitoring of Pinatubo.

Cooperative Investigations

The USGS currently has 51 agreements with counterpart agencies in 36 individual countries under which cooperative research may be undertaken; another 25 agreements are pending in various stages of negotiations, which will bring the total number of cooperating countries to 44. In addition, 13 other agreements are multinational, regional, or worldwide in scope. The agreements authorize the following types of cooperative investigations in fiscal year 1991:

Remote Sensing, Surveying, and Mapping
- Data collection from AVHRR (advanced very high resolution radiometer), Landsat, and SPOT (Satellite Pour l'Observation de la Terre) imagery,
- Production of base, topographic, geologic, and other thematic maps,
- Assessment of changes in glaciers, ice sheets, and climate in polar regions.

Mineral Resources Assessments
- A worldwide International Strategic Minerals Inventory,
- Research and modeling of deposits in individual countries.

Energy Resources Assessments
- Worldwide estimates for oil and gas by the World Energy Resources Program,
- Research and modeling of petroleum, coal, and peat and geothermal potential in individual countries.

Water Resources Assessments
- Research and modeling of surface and ground water in individual countries and regional basins.

Natural Disaster Assessments
- Research and modeling of methods to mitigate geologic and hydrologic hazards,
- Predictive investigations and monitoring for volcanic eruptions,
- Global research on seismicity, earthquakes, and geophysics.

Oceanography
- Research and modeling in marine geology,
- Research and modeling of deltaic and coastal sedimentary and erosional processes.

Climate Change and Atmospheric Deposition
- Research, assessment, and modeling of global warming and acid rain.

Central and Eastern Europe—Opportunity for Cooperation in Science

By Richard D. Krushensky

With the opening of Central and Eastern Europe to a market economy and to western influences, the western scientific community has an unparalleled opportunity to assist in the development and advancement of all scientific disciplines in this region. Federal agencies concerned with science and the U.S. Department of State have begun cooperative work under bilateral Science and Technology Agreements with Hungary, Poland, and Yugoslavia, and cooperative work with science agencies of Czechoslovakia is slated to begin in the spring of 1992.

A prime objective of the Science and Technology Program is to revitalize the sciences in the region after 40 years of isolation from the West. The program is funded by the governments involved. A second major regional objective is the mitigation of environmental degradation that accompanied the industrial recovery of the region after the Second World War. The need to raise the standard of living of the populace and the implementation of a market economy will lead to increased pressures on the environment.

"A prime objective of the Science and Technology Program is to revitalize the sciences in the region after 40 years of isolation from the West."

Cooperative science and technology programs between the USGS and geoscience organizations in the region are directed to the characterization and assessment of mineral and energy resources and natural hazards and to the assessment of geology-related environmental degradation and its mitigation or avoidance. The application of results from ongoing USGS domestic programs to problems in Central and Eastern Europe have led to insights that in turn have been applied to geology-related problems in the United States.

Hungary.—Cooperative science and technology projects between the USGS and Hungarian geological organizations have been approved only recently and studies have just begun. Late Miocene (5- to 10-million-year-old) sediments in the Pannonian basin will be studied to gain a better understanding of the Earth's polarity reversals during that time. This sedimentary record is proving to be a paleomagnetic Rosetta Stone for an understanding of the Earth's geomagnetic behavior during the late Miocene. This new understanding will allow the development of a greatly improved and detailed polarity time scale, as well as an improved understanding of global magnetic polarity reversals during the late Miocene.

Because contamination of ground water is widespread in Hungary, and the basins in which ground water lies are geologically well known, the USGS, in cooperation with the Hungarian Research Center for Water Resources, will test the hypothesis that the change in oxygen-18 and tritium composition of ground water recharge during the last glacial-interglacial transition (10,000 to 12,000 years before the present) can be used as a marker for ground-water dating and that this technique can replace the carbon-14 dating technique, which is both expensive and in some geologic situations not usable. Ground water that is determined to be very old (for example, 10,000 years old) probably has had little or no dilution with water since that date. If it is used or has the potential to be used as a source of potable water, its contamination should be avoided. On the other hand, if it is never to be used as a source of potable water, it might be an acceptable repository for toxic or nuclear wastes. The USGS has the lead in cooperation with other bureaus in the Interior Department and the government of Hungary to set up national laws and regulations related to use and regulation of public lands, including mineral and energy resources, resource leasing, royalties, and environmental protection related to land use.

Poland.—Emphasis in one of the USGS and Polish Institute of Geology cooperative studies is directed to the development of an understanding of the way in which formation and deposition have affected the quality of lignite and coal and in turn influence environmental, technological, and economic aspects of lignite and coal use in Poland and the United States. A related project, concerning the origin and habitat of coal gases in Polish and United States coal basins, is designed to study the origin, accumulation, and migration of coal gases. This study is of particular importance because of the potential use of coal gases as an energy source and because of the relationship of these gases to hazardous rock and gas outbursts and methane explosions in coal mines worldwide. USGS and Polish scientific teams will also study geochemical and geophysical means of prospecting for mineral deposits in areas where the deposits are covered by tens to hundreds of feet of sedimentary rock.

Economic applications are also of major importance in a study of the comparative anatomy of large marine evaporite basins such as the Zechstein basin of central and western Poland and the Delaware and Paradox basins in the United States. Because the occurrence of sulfur and petroleum with evaporite sequences is poorly understood, resolution of the mode of origin of these salt basins may have far-reaching economic implications for the United States, Poland, and other countries.

Yugoslavia.—Overuse of fertilizers, selenium deficiency, or excess amounts of cadmium, zinc, or lead from soils or coal deposits were previously thought to be the causes of endemic kidney disease throughout the Balkans. However, cooperative studies with Yugoslav geoscience scientists suggest a tie between endemic kidney disease and the outcrop or the subsurface existence of very young coal deposits. One or more organic compounds from these immature low-rank coal deposits or coal mine spoils appears to be the causative agent.

Basic research studies conducted in the United States are applied to the study of the petrology and geochemistry of magmatic and metamorphic complexes in the southern part of the Pannonian Basin and the northernmost Dinaric Alps in western Yugoslavia. This cooperative study will evaluate the metallic mineral resource potential of the area. Results of geochemical studies of ground water in the cavernous limestone terrane of western Yugoslavia and the incidence of toxic metals such as mercury, uranium, zinc, and lead in the ground water as it moves to its natural outlets on the Adriatic coast are of immediate and direct application to the mining districts of Tennessee and Missouri.

As in Poland, lignite in southern Yugoslavia is the major fuel for the production of electrical energy. Cooperative studies between USGS scientists and scientists of the Institut za Naučna Istraživanja I Rrazvoj Institute address the geochemical composition of lignite and the enclosing rocks. The study includes determination of the optimum analytical method and the analysis for trace elements in the coal and its byproducts, such as ash. Basic research is also conducted on soil profiles and soil geochemistry of soils developed on alluvial terraces of the Sava River in Slovenia and the relationship of these soils to the tectonic and climatic history of the region.

Civil war in Yugoslavia has curtailed cooperative projects. Yugoslav counterparts continue project work without the on-site participation of U.S. scientists.

Outlook.—Cooperative studies between the USGS and Czechoslovak geoscience organizations have not yet begun under the recently signed Science and Technology Agreement. Other Balkan countries such as Bulgaria, Greece, and Romania are affected by the same or similar geological and environmental problems as those in Hungary, Poland, and Yugoslavia and would profit by similar cooperative programs.

27TH INTERNATIONAL GEOGRAPHICAL CONGRESS

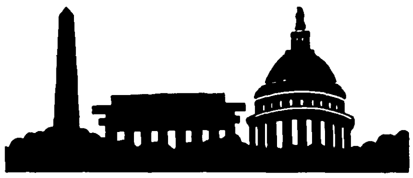
GEOGRAPHY IS DISCOVERY

More than 10,000 earth scientists representing 85 countries will gather in Washington, D.C., from August 2–14, 1992, for the joint congress of the 17th International Society for Photogrammetry and Remote Sensing (ISPRS) and the 27th International Geographical Congress (IGC). It will have been 40 years since either meeting was last hosted on North American soil. More than 143 technical and professional sessions are to be presented at these meetings. A combined scientific, technical, and commercial exhibition will span both weeks, August 4–13, 1992.

The ISPRS is a scientific and educational organization consisting of 85 member nations and 5 regional societies focusing on photogrammetry, remote sensing, mapping, and geographic information systems and their application in such areas as monitoring global change. The ISPRS Congress will have more than 115 technical sessions in which an international exchange of ideas, experiences, and research will take place.

The IGC is held in collaboration with and under the sponsorship of the International Geographical Union, which has 88 member countries or territories and 10 associate members. Twenty-one commissions and seven study groups concerned with geographic themes will be represented at the conferences. The 27th IGC, under the theme, "Geography is Discovery," will feature plenary sessions and symposia, as well as paper and poster sessions concerning virtually every aspect of basic and applied geographical research.

The joint sessions will also offer workshops and short courses. The USGS is one of several Federal mapping science agencies that are principal supporters of the congress.



AUGUST 2-14, 1992
XVII ISPRS CONGRESS - WASHINGTON, D. C.

ISPRS

The Geological Survey of Canada Celebrates its Sesquicentennial

By Bruce F. Molnia

In April 1992, the Geological Survey of Canada (GSC), the premier geoscientific agency in Canada, turns 150 years old. The GSC was established in 1842, 37 years before the founding of the USGS, and is the oldest geological survey in North America. The GSC's original mandate was to accurately map and evaluate the mineral and natural geologic resources of what was then called Upper and Lower Canada. A long and productive tradition of USGS–GSC cooperation dates from the last decades of the 19th century, and the USGS joins in celebration of this historic event in the life of the GSC.

"A long and productive tradition of USGS–GSC cooperation dates from the last decades of the 19th century. . . ."

The GSC's current mission is to provide Canada with a comprehensive geoscience knowledge base contributing to economic development, public safety, environmental protection, and national sovereignty by acquiring, interpreting, and disseminating geoscience information concerning Canada's landmass, including the offshore and by providing logistical support for polar science.

Because the United States and Canada share a common border, the USGS and the GSC share a number of interests related to the geology of this common border and to the earth sciences in general. Currently, there are more than a dozen cooperative activities involving personnel from both the USGS and the GSC. These activities range from essentially completed interactions in which final maps and reports are published or are in varying degrees of completion (Quebec-Maine Transect Project and GLIMPCE Program), to activities that are in full flower (Metallogenesis and Tectonics of the Russian Far East, Alaska, and Canadian Cordillera Project, North American Mississippi Valley Type Deposits Project, and Late Cenozoic Climates of Alaska and Yukon Project), to new activities that have just sprung from the planning phase or are beginning a cooperative field phase (Interior Alaska Metamorphic and Tectonics Project). The following are descriptions of these cooperative activities.

Quebec-Maine Transect Project.—Seismic reflection and refraction profiles across Maine and in southern Quebec were collected jointly by the USGS and the GSC from 1983 to 1985. The results of these geophysical experiments were digitally merged with geological and potential field data of Quebec and Maine in a geographic information system to produce a complex transect in the format of the Global Geoscience Transects Project of the International Lithosphere Program. A CD-ROM (compact disc, read-only memory) of the digitized transect accompanied by gridded gravity, magnetics, and seismic reflection and refraction data will be produced in fiscal year 1992. The transect, first assembled in 1989 for the International Geological Congress, was released as a USGS Open-File Report in August 1991 and will soon be released as part of the USGS Miscellaneous Investigations Map series.

GLIMPCE Program.—The Great Lakes International Multidisciplinary Program on Crustal Evolution (GLIMPCE), organized by the USGS and the GSC, is an international cooperative program to study the Earth's crust beneath the Great Lakes. Seismic surveys of more than 1,000 kilometers in Lake Superior, Lake Michigan, and Lake Huron, as well as aeromagnetic surveys of Lake Huron and Lake Superior, were accomplished in 1986 and 1987. New gravity data were collected in Lake Huron in 1988. Another GLIMPCE activity was an experiment to collect seismic refraction data of the crust below the Great Lakes to depths greater than 50 kilometers.

A geological feature that received considerable attention as a result of the refraction experiment was the Midcontinent Rift, a 1.1-billion-year-old continental-scale structure that curves in a broad arc from Kansas through Lake Superior and into southern Michigan. Joint USGS–GSC analysis of the GLIMPCE seismic and aeromagnetic data is revolutionizing our understanding of the geologic history of the Lake Superior region and of continental rifts in general. GLIMPCE products include annotated crustal transects and potential field geophysical maps incorporating both GLIMPCE data and older regional data. The USGS will publish 1:1,000,000-scale aeromagnetic and gravity maps of Lake Superior. Similar maps of Lake Huron are being prepared by the GSC.

Metallogenesis and Tectonics of the Russian Far East, Alaska, and Canadian Cordillera Project.—This project has two major collaborative efforts involving USGS and GSC personnel. The first, the compilation of a 1:5,000,000-scale terrane map of the North Pacific, depicting tectonostratigraphic terranes, plutonic rocks, and overlap assemblages, will be completed in 1992. The map will be accompanied by a text describing each of the terranes, including details of terrane stratigraphy. When published, this map will serve as the base for the compilation of a second 1:5,000,000-scale metallogenic map set of the Russian Far East, Alaska, and Canadian Cordillera, including (1) map sheets depicting the locations of approximately 1,000 significant load deposits, 150 placer districts, and the metallogenic belts of the region,

(2) detailed tables describing significant lode deposits and placer districts, and (3) a text describing the tectonic origin of the metallogenic belts. Publication is expected in the Spring of 1993.

North American Mississippi Valley Type (MVT) Deposits Project.—Since 1987, the USGS and the GSC have cooperated in sampling and examining every MVT lead-zinc deposit in North America and in preparing a review paper summarizing information on MVT districts throughout the world. Exploration guidelines, and critical data on grade and tonnage are included in the report. The GSC has funded and published three studies of paleomagnetic dating of U.S. midcontinent MVT deposits. The USGS is conducting a reconnaissance chemical study of fluid inclusions from Canadian MVT deposits. Both the USGS and the GSC are cooperating in the study of lead-zinc deposits in Poland, and the GSC will provide paleomagnetic dating of the deposits from Poland.

Late Cenozoic Climates of Alaska and Yukon Project.—This project aims to improve our understanding of the history of climate and environmental change in northwest North America during the past 17 million years. The project involves the participation of 20 scientists having a variety of research specialties from the USGS, the GSC, Agriculture Canada, and several academic institutions in the United States and Canada. Phase one of the project involves interdisciplinary investigations of natural exposures of late Cenozoic rock and unconsolidated deposits containing fossil assemblages useful for determining ancient climate conditions and paleoenvironmental reconstruction.

Field work in 1990 and 1991 involved the study and sampling of fossil-rich deposits along the Porcupine River and at other locations in Alaska and the Yukon. Planned work for 1992 includes field investigations aimed at improving our understanding of the timing and development of the Alaska Range. The rise of these high mountains in the late Cenozoic caused a dramatic climate change in the Alaskan interior and in adjacent parts of Canada. Phase two of the project, scheduled for 1993, involves scientific drilling to recover a 350-meter-long sediment core from Yukon Flats, Alaska. The core may provide a nearly continuous high-latitude record of climate and environmental change spanning the past 10 million years or more.

Interior Alaska Metamorphic and Tectonics Project.—Present activities of this project are in east-central Alaska along the northern Yukon border, of which USGS and GSC geologists have identified a series of questions of mutual concern and potential cooperation. The study area is a region where existing mapping studies and basic geologic information are sparse, are of a reconnaissance quality, or are largely outdated. Topics of mutual interest include (1) the origin and age of granitic plutons in the border region and their history relative to regional depositional, metamorphic, and deformational events and (2) understanding the basic stratigraphic and structural patterns of this border region. Uranium-lead dating and isotopic studies of samples collected from the Bear Mountain pluton during USGS field investigations in 1991 will be performed by the GSC. Cooperative field studies are being considered for 1993.

Scientific Exchange and Training

USGS international programs seek to strengthen earth science institutions in foreign countries by providing training in the United States for foreign nationals and by exchanging scientists. During fiscal year 1991, 95 scientists and technicians from 43 foreign countries received training in the United States, and 42 visiting scientists from 16 countries conducted research at either the USGS or other facilities as arranged by the USGS. In fiscal year 1991, the total of USGS employees permanently assigned overseas was 30, and 585 USGS employees made 710 project-related overseas trips. The number of personnel involved in training and project-related travel is considerably less than in past years, probably as a result of restricted travel imposed during the Middle East crisis.

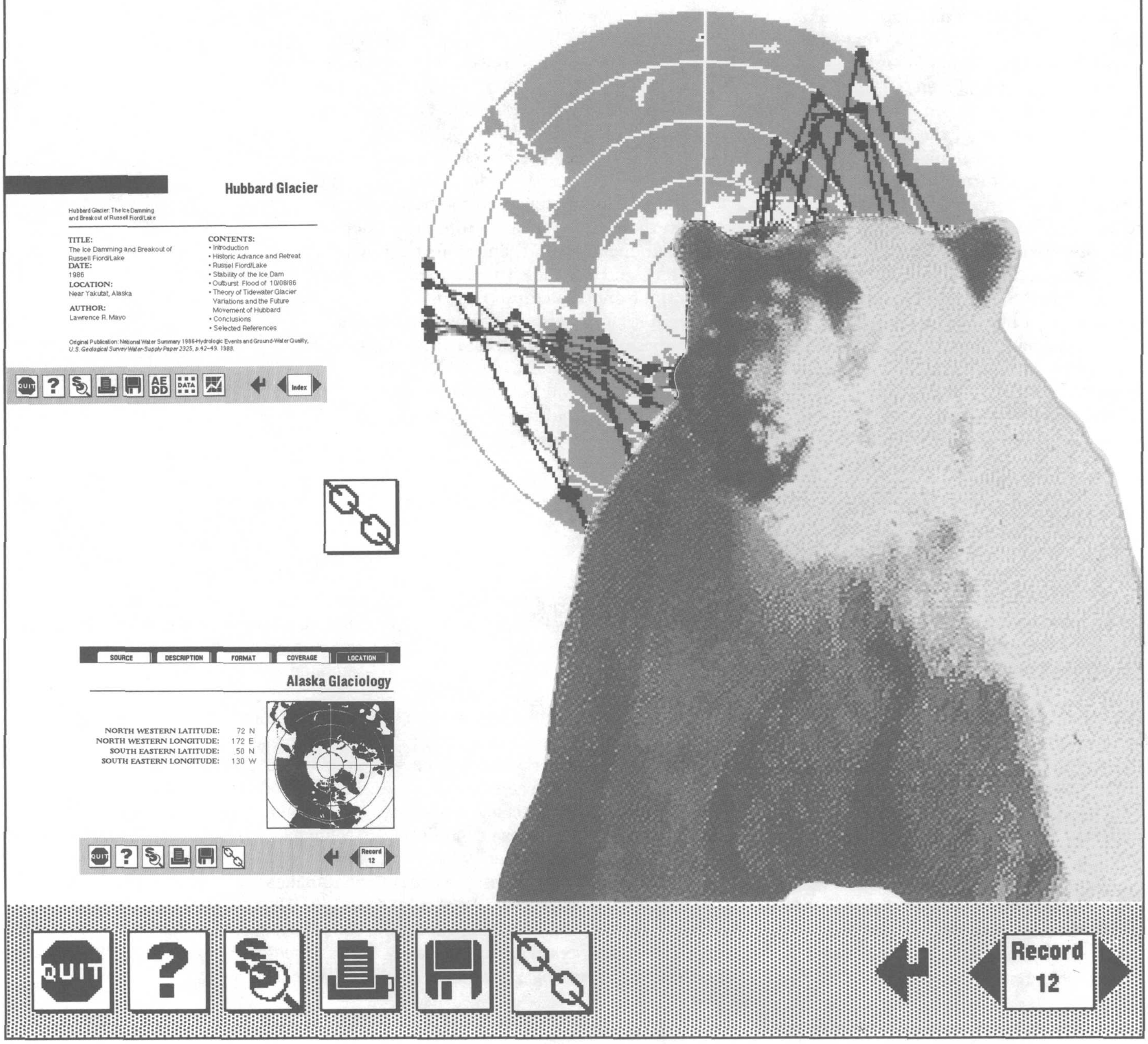
At least 485 scientists and technicians from other countries received instruction and training by USGS specialists within their respective countries, either one-on-one or in workshops and short courses. This overseas training was concentrated in, but not restricted to, those countries where the USGS has permanently assigned personnel or long-term projects, as in Saudi Arabia, Abu Dhabi, Pakistan, Venezuela, Bolivia, Fiji, and Bangladesh. Short courses and workshops focused on mineral resources, geologic hazards, remote sensing, computer processing of satellite imagery, field geologic mapping, and techniques of water and geochemical sampling and analysis.

Formally scheduled USGS training courses presented in the United States for worldwide participation during fiscal year 1991 included Understanding Earthquakes and Mitigating Their Effects and Techniques of Hydrologic Investigations in Denver, Colo.; Marine Geology—Research and Applications Techniques in Hilo and Honolulu, Hawaii; and Remote Sensing Applications for Environmental Assessment and Monitoring in Sioux Falls, S. Dak.

Mission

The Information Systems Division provides support and services to the Director of the U.S. Geological Survey, to major programs in each division of the USGS, the U.S. Department of the Interior, and to other government agencies on information technology and automated data processing (ADP). The Division operates the USGS mainframe computer located in Reston, Va., and Technology Information Centers and minicomputers in four ADP service centers nationwide.

The Division assists users in acquiring ADP and telecommunications hardware, software, and services; coordinates and improves information systems through systems analysis and design; provides user education and assistance; and conducts research into better ways to use computer technology to solve mission-related problems. The Division coordinates, manages, and operates voice, data, and radio communications for the USGS, including GEONET, the data communications network of the Interior Department, from which gateways provide access to other national networks and supercomputer systems.



Message from the Assistant Director for Information Systems

During the last 4 decades, computing has become one of the most pervasive and powerful technologies for information management and scientific progress. High-performance computing technology is now essential in science and engineering. Computers empower individuals to improve their work and the organization to better accomplish its mission. Examples of this in the USGS cut across the entire spectrum of our scientific research activities and include preparing three-dimensional models of solute transport, using geographic information systems, locating earthquake epicenters, preparing digital elevation models, and tracking financial resources through the Federal Financial System.

We are committed to meeting the continuing challenge of rapidly changing computer technology and helping the USGS make the best and most effective use of these tools. The articles in this chapter briefly describe a few of the challenges—mainframe computing, telecommunications, and scientific visualization. Computer networking is another challenge that will impact all USGS employees. As more USGS personnel have powerful workstations on their desks, the need to link the Survey computers in a fast, dependable, and inexpensive network will become increasingly essential. A recent example is how we have integrated the diverse USGS electronic mail systems. Networking will allow scientists and administrators to actively share applications and data. We are committed to meeting these challenges.

J.E. Biesecker

The Changing Role of USGS Mainframe Computing

By Tod Huffman, Larry Harms, and Mark Kutsko

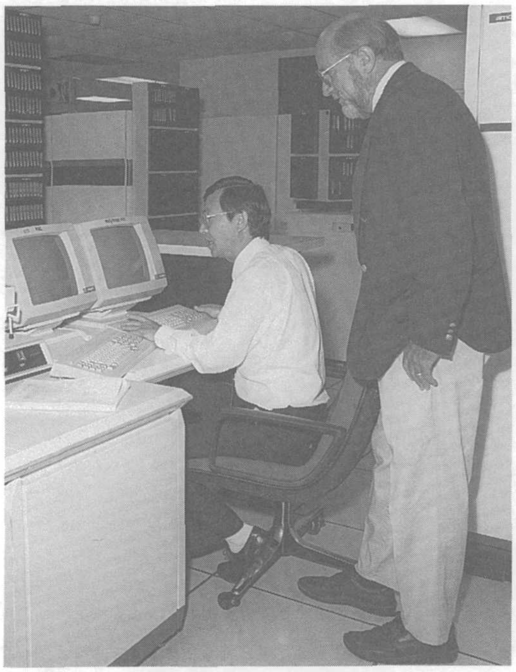
Today's modern computing data center usually contains at least one mainframe computer. Mainframe computers typically possess very fast central processor units and large main memories and provide access to a variety of high-performance and high-capacity data storage devices. During the past 25 years, mainframe computing has continued to serve the data collection, processing, analysis, and storage requirements of USGS scientists and administrators.

During the last 10 years, due to the rapid development, availability, and low cost of smaller types of computers, many USGS computing activities have downsized their mainframe-based applications to networked minicomputers, personal computers, or the new client-to-server architectures. These downsizing transitions have been accomplished at a slow, measured pace, and in many cases the mainframe continues to serve these relocated applications by providing supportive remote batch processing, data storage, and archival services. The role of the mainframe is being redefined within the networked computing infrastructure of the USGS, but the mainframe still provides unique services required by the very large, distributed collections of scientific and administrative data.

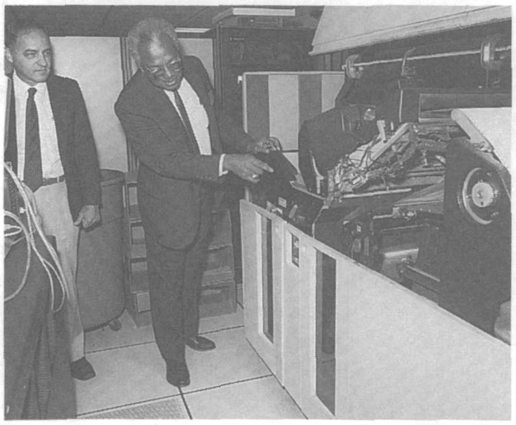
The USGS Amdahl 5890 mainframe is a dual processor, 45-million-instruction-per-second computer located in the USGS National Center in Reston, Va. Associated central processor resources include 256 megabytes of main memory and 40 input/output channels accessing more than 160 billion bytes of magnetic disk storage. The Amdahl Multiple Domain Feature permits concurrent operation of as many as four physically separate operating domains. Each domain represents an isolated segment of the computer that provides data integrity and processing security.

Running under the control of the IBM Multiple Virtual Storage/Extended Architecture (MVS/XA) operating system, five major production subsystems provide online transaction processing for large, distributed administrative systems, powerful editing and programming languages, data base management, and extensive batch processing. The mainframe data center is open around-the-clock, including Saturday, and the mainframe runs unattended on Sunday. Mainframe services can be accessed from anywhere in the Nation by using existing USGS GEONET network services or local area network telecommunication links such as Internet. Currently, 6,500 registered users process about 800,000 jobs annually.

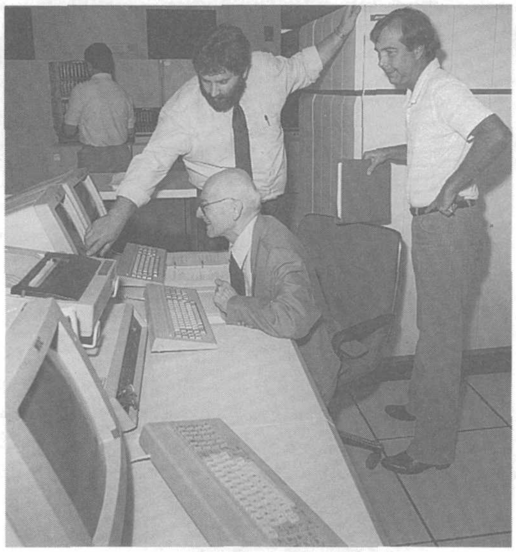
As a partner in the nationwide network of USGS computers, the mainframe is the central computing facility of the Department



The console is the focal point for mainframe monitoring.



The mainframe laser printer can create hard-copy output at the rate of 215 pages per minute.



The mainframe console also services UNIX.

of the Interior (DOI) Federal Financial System (FFS) and of other large personnel and administrative systems serving the USGS and other Federal and DOI agencies nationwide. The mainframe continues to serve the distributed system of minicomputers through batch processing and archival services for the USGS National Water Information System and serves as postprocessor and data base archiver for the USGS National Digital Cartographic Data Base.

The mainframe also supports very large data base activities of the DOI Office of Surface Mining Reclamation and Enforcement and Bureau of Mines and provides various processing services for the Minerals Management Service, the U.S. Fish and Wildlife Service, and the DOI Office of the Secretary. Communication facilities connect the mainframe and Bureau of Reclamation and Bureau of Indian Affairs computers in Denver, Colo., and Albuquerque, N. Mex., and support data transfer and interactive processing sessions.

Among the large application systems residing on the mainframe is the DOI standard automated accounting and payment system, the FFS, managed by the Washington Administrative Service Center in Reston (see p. 101). Five client agencies, the USGS, National Park Service, Bureau of Indian Affairs, U.S. Courts, and Patent and Trademark Office, use the mainframe. Continuing DOI progress toward departmentwide financial systems standardization, FFS processing on both the USGS and the Bureau of Reclamation Administrative Service Center computers represented approximately 70 percent of the Department's total accounting transactions during fiscal year 1991.

Another large system supported by the mainframe is the automated Standard Form 52 (SF 52) system. The SF 52 system is a paperless system that encompasses the automation of all phases of processing personnel actions, including creating and approving requests for personnel action by management, processing actions by the Personnel Office, and transmitting information to update master personnel files. Actions can be electronically routed to all appropriate individuals in management and personnel offices nationwide. Courtesy copies, concurrence routing, browsing, deleting, or canceling actions are also supported.

The Automated Vacancy Announcement System (AVADS) also runs on the mainframe and is another large system that supports USGS personnel activities. AVADS is an interactive system designed to create, edit, distribute, and print the full text of all vacancy announcements of the USGS. As requests to fill positions are received for advertisement, USGS personnel offices enter vacancy announcement information into the AVADS data base. AVADS transmits all pertinent information that is unique to a specific vacancy to USGS distribution points nationwide. At each distribution point, vacancy announcements are printed and posted where employees have access to and can obtain printed copies.

The public can also browse microcomputer AVADS information when visiting USGS personnel offices. AVADS is currently being expanded to become the DOI vacancy announcement system. All bureaus will enter their announcement information, which will then be electronically distributed departmentwide. A microcomputer-based bulletin board of all vacancy information will also be available to the public for nationwide access.

The USGS National Digital Cartographic Data Base (NDCDB) has been resident on the mainframe since the late 1970's and is still very actively used. NDCDB is being redesigned to take advantage of a large, more powerful relational data base management system associated with the mainframe. The NDCDB is an automated, interactive index providing up-to-date information about digital cartographic data available for distribution and sale throughout the USGS. The index is used by USGS Earth Science Information Centers, NDCDB data base managers, and others desiring access to digital cartographic information. The index can be queried to answer questions about the data held in the digital archive. The bulk of the digital data archive is now contained on magnetic cartridge tape. Because the archive will be transferred to an automated robot tape cartridge device, accessing this data will soon take less time.

The USGS mainframe supports several large data base applications for other Bureaus within DOI. One of the principal functions of the Office of Surface Mining Reclamation and Enforcement (OSMRE) is to administer the Surface Mining and Reclamation Act of 1977 (Public Law 95–87). The basic functions of enforcing this act are inspecting mines and assessing and collecting penalties. The Collection Management Information System (CMIS), located on the mainframe, was developed to manage and support these functions. CMIS stores, tracks, and reports information on citations for mining violations reported by field inspectors. This interactive system provides online data entry and retrieval for OSMRE headquarters and regional office staff nationwide. The retrieval function provides online query and batch reporting, which summarize and categorize OSMRE activities.

The Applicant Violator System (AVS) is another highly visible system maintained by the OSMRE on the mainframe. AVS contains information on all surface coal mining operations and companies in the Nation. The primary function of the AVS is to check whether an applicant for a surface mining permit is in any way related to, or is itself, a violator of mining regulations. For violators, AVS blocks issuance of new mining permits. The system is used by State regulatory authorities, Federal permitting units, OSMRE headquarters, field and area offices, technical centers, and other parties designated by the courts.

During fiscal year 1992, the USGS will start new mainframe services that will enhance the ability of the data center to provide unique services within the USGS computing network:

- A mass storage system for USGS earth science data, using a UNIX-like gateway into the mainframe, includes simple, straightforward mechanisms for storing and retrieving very large files and is accessible to any local area subnetwork via GEONET or Internet. A large, automated tape cartridge device for storing 1.2 trillion bytes (expandable to 20 trillion bytes) of data will be one of the components of data storage supporting this new service. This mass storage system will also be available to users of the MVS/XA operating system.
- The Soft*Switch electronic mail (Email) software will use the mainframe to connect all of the diverse and disparate USGS Email systems into a unified USGS system. This service will allow the existing Email systems of the USGS, as well as other mail systems within the scientific community, to exchange messages easily.
- Network access to the mainframe will be improved by upgrading the Transmission Control Protocol/Internet Protocol (TCP/IP) network connection. TCP/IP network access to the MVS/XA operating system will be available. New software allowing direct access to transaction processing, time sharing, text editing, Model 204 data base management system, and batch subsystems will permit local area network access to production mainframe services from personal computers (PC's) and workstations nationwide. Using this TCP/IP network link to the mainframe, remote computer environments, such as PC's and workstations, can route and submit batch jobs to the mainframe and have output from these jobs automatically returned to the point of submittal.
- Several new software subsystems will automate data center operations, data processing help-desk services, and computer console monitoring. These systems will improve the efficiency, reliability, and ease of use of data

"The USGS mainframe supports several large data base applications for other Bureaus within DOI."

center services and should help in reducing costs associated with operating the center.

By improving the ease of access to the mainframe and adding mainframe data center services that supplement and enhance applications resident in other USGS nonmainframe computing environments, the mainframe is moving into a new era of service to the USGS computing community. In the future, the mainframe will continue to provide unique data processing facilities and services that effectively respond to ever-changing USGS and DOI computing needs nationwide.

Emerging Telecommunications Technologies

By Elaine Stout

From the early days of using Arpanet—a Department of Defense computer network—to the present use of the USGS GEONET and the massive Internet networks, USGS scientists have implemented and used wide-area telecommunications technology. In the past, especially with networks such as GEONET, extensive and expensive error checking and correcting were relegated to the network. The USGS end user devices, often inexpensive terminals, could not correct errors or perform the most rudimentary error checking. In essence, the network did all the time-consuming work.

The networking and computing environment is evolving from slow terminal-based systems to high-speed distributed systems. Newly developed communications networking technologies reflect this evolution. Three reasons driving the move to new telecommunication technology are (1) end users, such as USGS scientists, require far higher transmission rates for transport of images and visualization, (2) end-user devices have significantly improved intelligence and processing power, and (3) extremely high-quality transmission circuits are available and affordable.

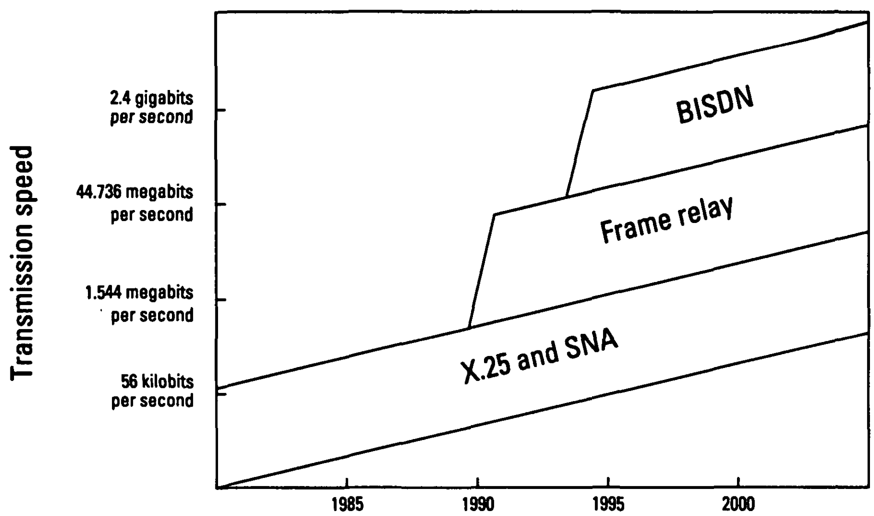
In the USGS, higher transmission speed is found in the new Distributed Information System (DIS–II) workstations and powerful graphics devices that generate extensive local area network (LAN) to LAN traffic. These workstations and devices use new computing interfaces (for example, X Windows) such that a remote computer actually appears to be local. Even the personal computer can now support error detection and retransmission. The USGS move to higher speed computing applications has paralleled the telecommunications industry distribution of very high speed, all-digital circuitry throughout the country.

Optical fiber now is pervasive; all major telecommunications carriers have fiber running east and west, north and south. To date, the continental United States has more than 2 million miles of optical fiber. Historically, data networks such as GEONET were designed to cope with errors resulting from analog communications circuits and equipment. The new fiber and new computing devices have substantially increased the reliability of the network.

Telecommunications networking of the 1990's will include words and acronyms such as frame relay, cell relay, BISDN (Broadband Integrated Services Digital Network), SMDS (Switched Multimegabit Data Service), ATM (Asynchronous Transfer Mode), and SONET (Synchronous Optical NETwork). Some of these new technologies (including frame relay, cell relay, BISDN, and ATM) are streamlined by fast packet switching. Fast packet combines the advantages of the older circuit switching approach—high throughput and low delay—with the advantages of statistical multiplexing techniques that allow for efficient use of the transmission circuitry by shared bandwidth. Frame relay is the only commercially available network technology now being distributed; the other technologies will be introduced in the mid- and late 1990's. However, the direction of telecommunications technology is defined: high-speed fast packets and, when appropriate, shared bandwidth for voice and video services.

The USGS is currently testing and distributing one of these newer technologies. Since February 1991, frame relay technology has been tested between Reston, Va., and Menlo Park, Calif.; Lakewood, Colo., was added in July 1991. Performance gains, as measured by bits per second transferred, have been significant. More than 2,000 individual tests were run between Reston and Menlo

Communications services, BISDN (Broadband Integrated Services Digital Network), frame relay, and X.25 (international packet switching standard) and SNA (Systems Network Architecture), the time frame in which they were introduced, and the associated transmission speeds.

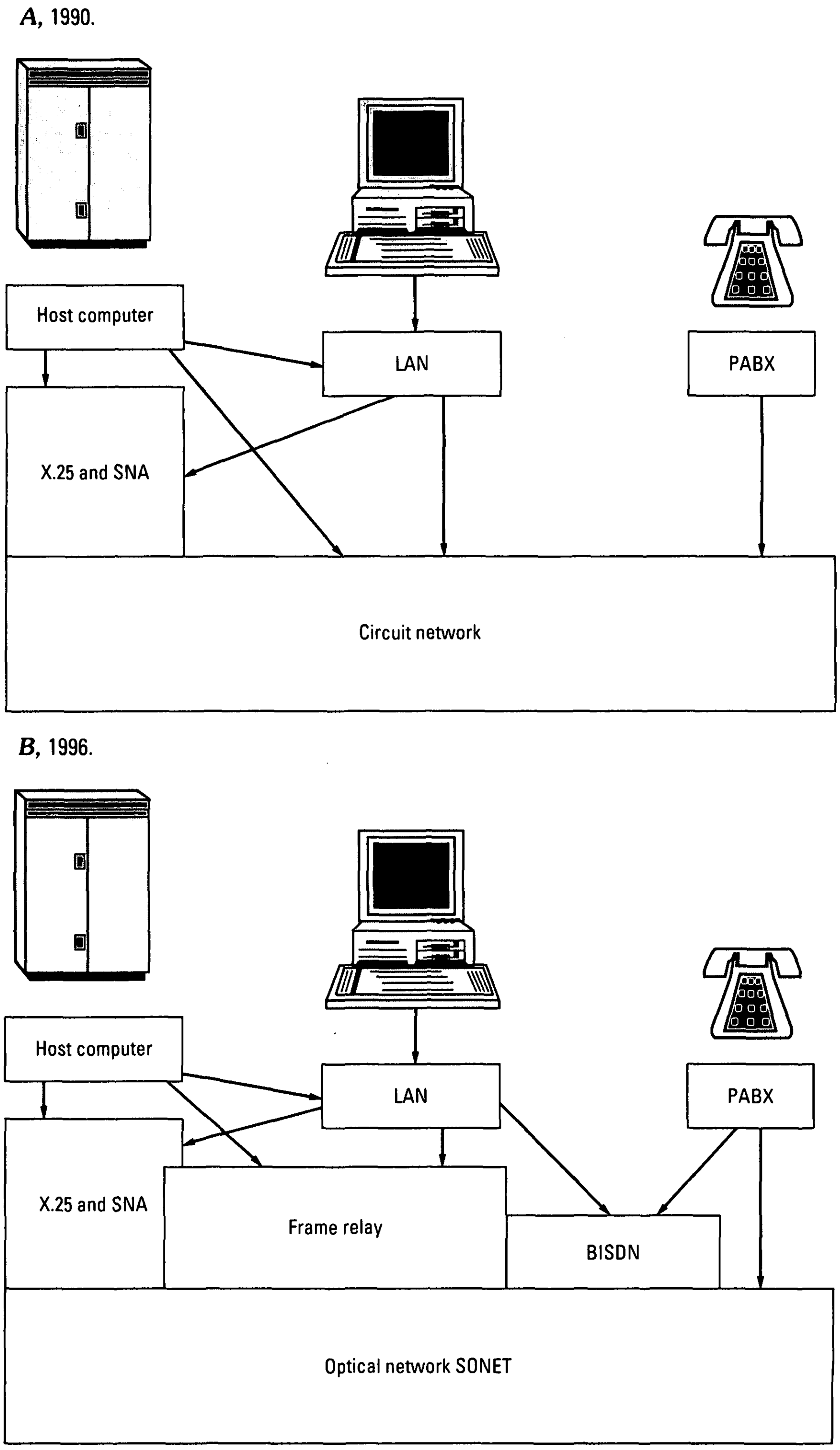


Park, and frame relay throughput performance was 19 times greater than that of the USGS GEONET network. When compared to Internet, frame relay performance gains were about sixfold. Two types of tests were run: one test was machine oriented; the other, user oriented. For the machine test, computers transmitted large files back and forth all day by using the Transmission Control Protocol/ Internet Protocol—the predominant protocol in the USGS. For the user test, individual X Windows sessions were established for transmission of a graphics image from Menlo Park to Reston; this test was performed randomly throughout the day.

Results from the throughput testing and the random X Windows tests were compared and were within 2 percent of one another. In other words, the performance predicted for the user actually happened. Frame relay performance to date has been impressive and could make the usual bottleneck—the slow wide-area network—more tolerable. Frame relay technology has immediate benefits for the USGS. Also, a frame relay network supporting high transmission rates can be installed with relatively small capital investment.

The USGS was the first Federal agency to test frame relay and continues to assess new fast packet technologies. Also, the USGS is using a newly developed backbone network for more than just frame relay. On the same transmission circuit, several simultaneous voice calls are routinely transmitted with video conferences. While frame relay is an interface standard from LAN to a wide-area network, the wide-area networking switching approach, called cell relay, increases the performance and lowers the ultimate cost of the network by integrating voice, data, and video. Consequently, via the same optical fiber telecommunications circuitry, all the above services are available at the Reston, Menlo Park, and Lakewood sites.

Another advance at the USGS is compressed video conferencing. Compressed video is dramatically different from full broadcast video. For instance, to broadcast 1 second of the evening network news requires about 90 million bits; using the USGS compressed video conferencing, that same video second requires as few as 56,000 bits, a tiny portion of the full broadcast mode. Amazingly, even though substantial compression occurs, the overall picture and audio quality is good and, more importantly, affordable. Compressed video conferencing services have dropped in price significantly during the last few years. Also, as recently as 3 years ago, a full T1 circuit (capacity of 1.544 megabits) was needed for this type of video presentation. Now, due to enhanced video algorithms



The expansion and evolution from the 1990 networking architecture to the 1996 networking architecture. **A**, *1990, host computer, LAN (local area network), and PABX (Private Automatic Branch eXchange) connected to X.25 (international packet switching standard) and SNA (Systems Network Architecture) and a slow-speed circuit network.* **B**, *1996, this environment will evolve to host computer, LAN, and PABX connections to high-speed services, X.25 and SNA, frame relay, and BISDN over optical networks, such as SONET.*

(those routines that convert and compress the picture), compressed video may be transmitted in just 4 percent of the old T1 requirement.

Telecommunications continue to change and evolve at an ever increasing rate. By the time new technologies are developed, they may be obsolete. The USGS has consistently balanced the costs with the benefits of new technologies; further, decisions are tempered with the knowledge that, as the Greek philosopher Heraclitus (540–480 B.C.) stated, "Nothing endures but change." In the telecommunications arena, this is the rule.

Scientific Visualization for Scientific Research

By Carmelo Ferrigno, Richard A. MacDonald, and Brian Schachte

Scientists must constantly find new methods to quickly and effectively analyze increasing quantities of data that are collected and generated in their research. The traditional manual methods of reviewing large tables of printed data and plotting results are no longer effective. By using a process called scientific visualization, scientists can now use computers to review their data and generate the diverse charts and graphs needed to illustrate research results. The visualization of data goes beyond just generating pie charts and line charts (fig. 1). The latest techniques use three-dimensional graphics (fig. 2) and computer-generated animation and videos to analyze data.

Scientific visualization techniques are important to many USGS research projects. Research in such areas as earthquake and volcano simulations and water-quality studies generates massive amounts of data that cannot be properly analyzed without the use of computer-generated graphics. Another example of visualization is the work being done by USGS employees who are using cameras and video cassette recorders to record such events as excavating and collecting within a geological fault zone. These recordings are later used to study the structure and composition of the fault area.

The USGS has developed a video that describes some of the visualization techniques (fig. 3) that can be used to analyze scientific data. Other videos are being developed by using desktop computer systems. It is anticipated that several videos will be produced that simulate geologic events such as earthquakes.

Other new visualization products range from simple graphics printed on paper or viewed on a computer terminal to videos describing the results of earth science

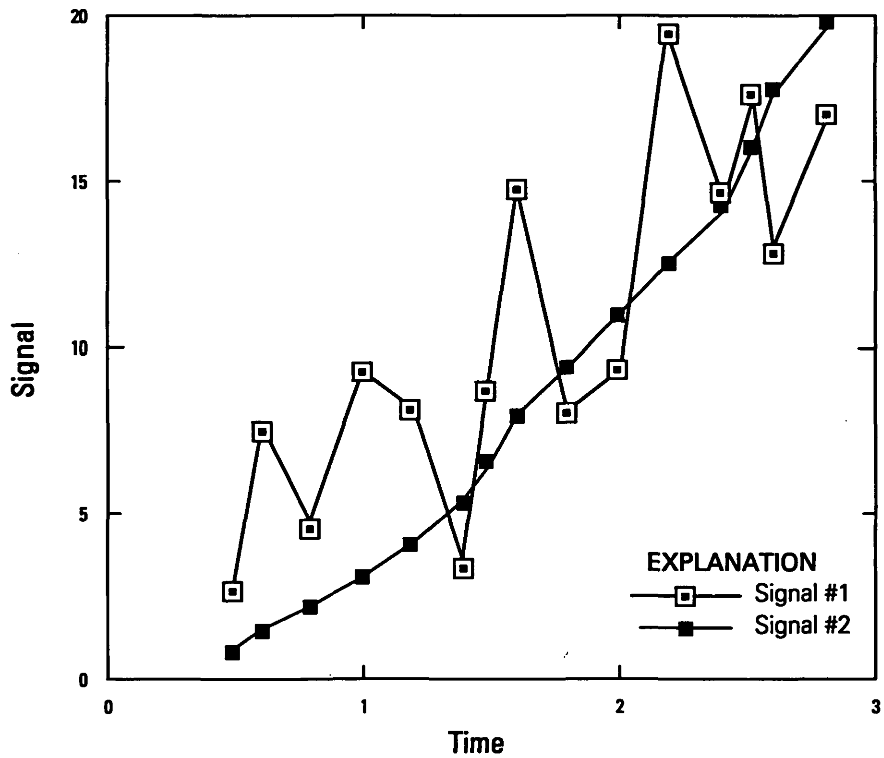


***Figure 1.** Example of typical graph used to portray data in a geological report as created by using scientific visualization.*

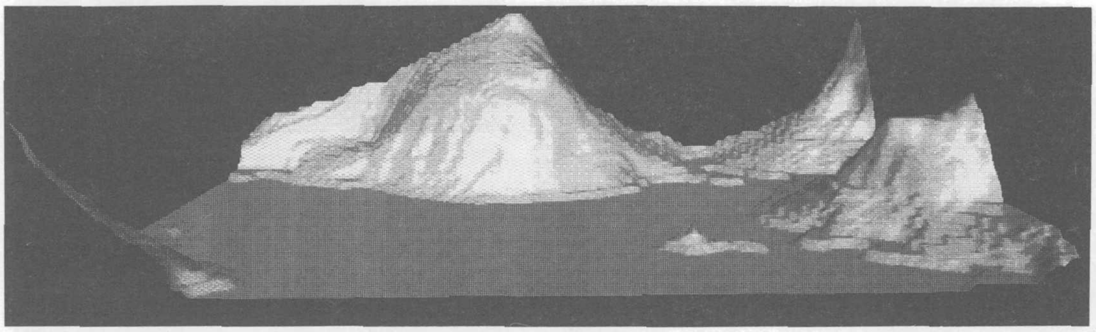


Figure 2. Example of elevation data portrayed in a three-dimensional perspective view.

research. Current production projects include one video depicting monthly streamflow conditions from 1929–91 and another video showing the results of a three-dimensional model of Pamlico Sound in North Carolina.

Another scientific visualization tool is the CD-ROM, which can be used to disseminate earth science information within an interactive and visual format. Using a microcomputer, a person can access the information on a CD-ROM randomly. A recent product, the Arctic Data Interactive, is now available and contains extensive graphical and textual information on the Arctic region of Alaska. Currently, a second CD-ROM is being developed as an aid in teaching elementary school children about such topics as the making of maps at the USGS.

It is clear that the use of scientific visualization techniques will increase within the USGS. The complexity of the research activities will increase partially due to the use of more sophisticated and powerful supercomputers. This increase will lead to the generation of more complex data that will require the use of visualization techniques for analysis. At the same time, the visualization techniques will keep pace with the requirement with the help of Federal Government national laboratories.

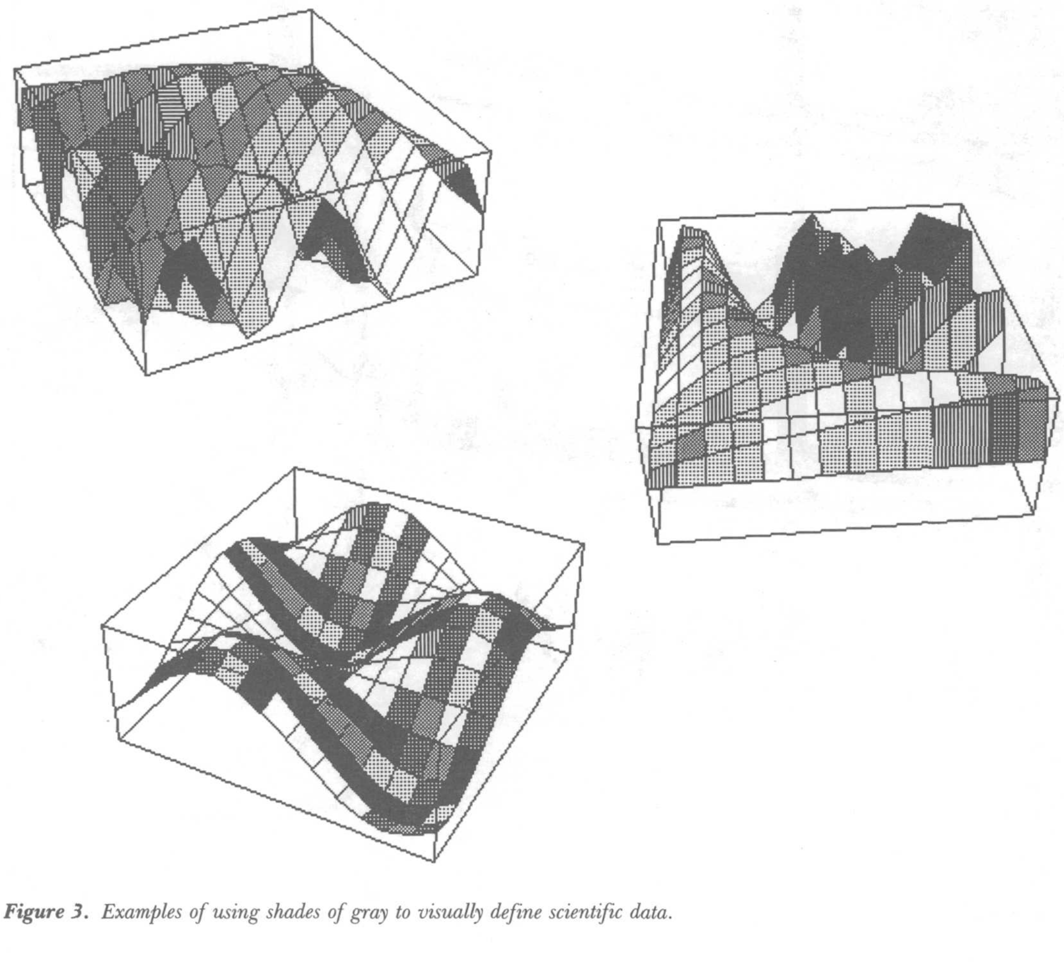
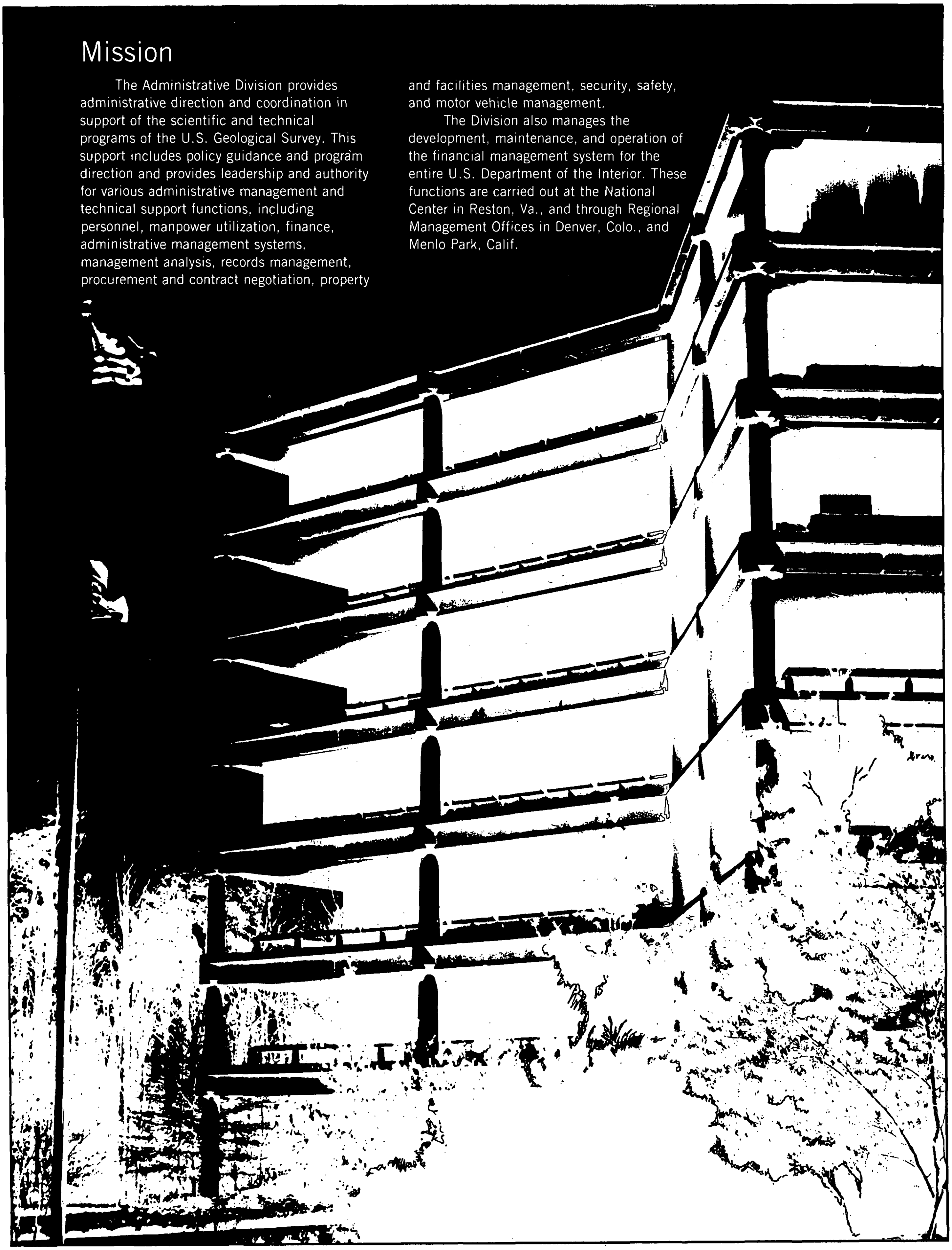


Figure 3. Examples of using shades of gray to visually define scientific data.

Mission

The Administrative Division provides administrative direction and coordination in support of the scientific and technical programs of the U.S. Geological Survey. This support includes policy guidance and program direction and provides leadership and authority for various administrative management and technical support functions, including personnel, manpower utilization, finance, administrative management systems, management analysis, records management, procurement and contract negotiation, property and facilities management, security, safety, and motor vehicle management.

The Division also manages the development, maintenance, and operation of the financial management system for the entire U.S. Department of the Interior. These functions are carried out at the National Center in Reston, Va., and through Regional Management Offices in Denver, Colo., and Menlo Park, Calif.



Message from the Assistant Director for Administration

To accomplish its stated mission, the Administrative Division has established goals to make the most cost-effective balanced use of administrative support resources while maintaining or increasing the quality of service and to improve responsiveness to our service clientele. The division is also actively increasing the professionalism of administrative support services and proactive administrative partnerships at both the bureau and departmental levels.

We are aggressively pursuing the Secretary of the Interior's human resources initiatives through strong support of our Volunteer for Science Program and furthering the employment of women, minorities, and persons with disabilities. During 1991, we established a USGS Public Service Award to recognize employee accomplishments as public servants to the American people. We initiated employee support groups and workshops to deal with concerns such as family and friends participating in Operation Desert Storm, elder care, and latchkey children. We continue to support child care centers in Northern Virginia and in Menlo Park, Calif., and began developmental work for a new center in Flagstaff, Ariz., scheduled to open in fiscal year 1992.

In the area of facilities management, we transferred land and facilities at the USGS Western Region Center in Menlo Park, Calif., to the General Services Administration. This action consolidates the ownership of these holdings and improves management of these facilities. Successful negotiations with the National Archives and Records Service enable the USGS to save space and record-holding costs by now being able to archive invaluable scientific records on CD-ROM (compact disc, read-only memory).

Many financial management improvements and changes in administrative support that have been undertaken recently are explained in the following pages. Through these improvements and streamlining of systems, we are able to provide the most cost-effective administrative support for the scientific, research, and technical programs of the USGS.

For the future, we will continue to streamline administrative operations and look at new technologies to reduce paper-intensive activities and to economize and expedite procedures wherever possible. In addition, we will be conducting a Total Quality Management pilot project to further improve service to our customers—the scientific staff and programs of the USGS.

Jack J. Stassi

Streamlining with Automation

By Kory K. Lee

During 1991, the USGS automated several administrative operations that support the scientific mission of the bureau. To enhance administrative information management and to comply with federally mandated regulations, the USGS put into operation new automated systems in the areas of personnel, general services, and facilities. Specific new automated systems implemented bureauwide are the Performance Management Tracking System, the Space Management System, the Inventory Control System, and the Motor Vehicle Management System.

Performance Management Tracking System.—Following a 1990 management control review of bureau performance management practices, the USGS began to use an automated performance management tracking system (PMTS) that aids managers and personnel offices in tracking annual performance standards and appraisal paperwork. Now used bureauwide, the PMTS provides managers and personnel offices with more timely and accurate information regarding the status of performance management documentation at all organizational levels.

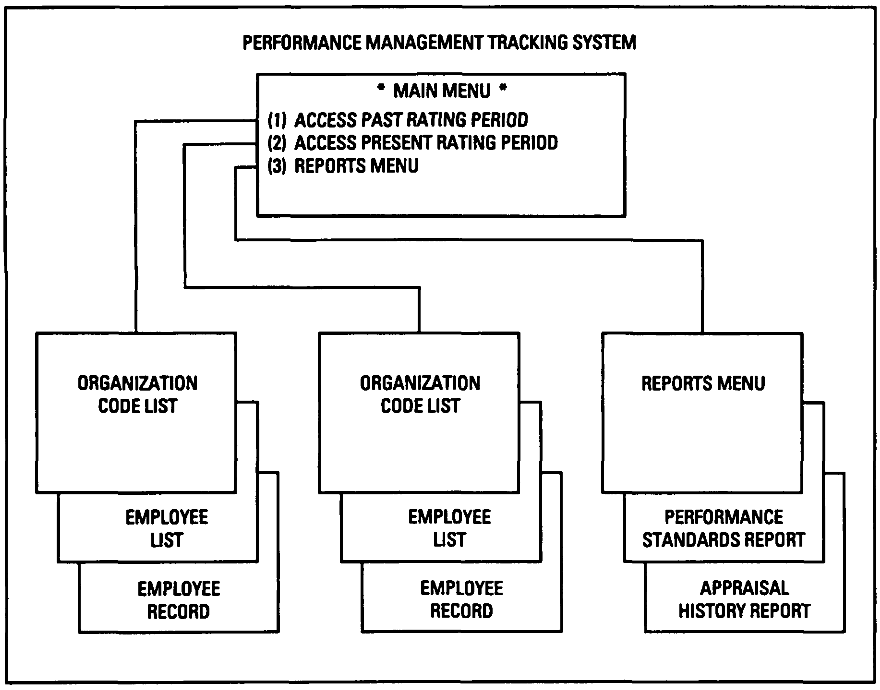
The PMTS consists of interactive screens for updating or querying the data base. Depending on security profiles maintained by the system, users can enter and track the date performance standards were developed, the date the annual appraisal was prepared, and the annual rating for employees in a specific organization. The system also provides performance management due dates and performance appraisal history for each employee. PMTS provides reports, such as the Performance Standards Report and the Annual

Appraisal History Report, which give more timely information on the organization's compliance with performance management requirements.

Space Management System.—In 1991, the USGS completed the initial phase of the Space Management System (SMS). The new SMS replaces manual and personal-computer-based processes for allocating space costs and tracking space holdings for the entire bureau. Developed on an IBM System/38 minicomputer, the SMS improves the monitoring, analyzing, and reporting of the use and cost of USGS workspace leased from the General Services Administration (GSA).

The first phase of SMS accepts electronic input of quarterly billing data from the GSA, tracks the allocation of space, and distributes costs of the assigned space to each USGS division based on actual usage. Data on GSA- and USGS-owned space assignments can be accessed through standard inquiries such as the building inquiry that reports location and statistics. One SMS design feature, an interface to the Federal Financial System, replaces a labor-intensive process for distributing costs for GSA leased space back to the divisions. To provide SMS data for users at the microcomputer level, an optional feature of the System/38 enables users to query and transfer data to a personal computer; once transferred, the data are available for word processing or spread-sheet documents. Enhancements such as a budget and forecasting module are planned for the next phase.

Inventory Control System.—To improve customer service and inventory management, the USGS acquired an off-the-shelf inventory control and point-of-sale system. The new system, now incorporated in all Administrative Division supply management offices, replaces manual procedures and obsolete technology that had become increasingly costly to maintain.

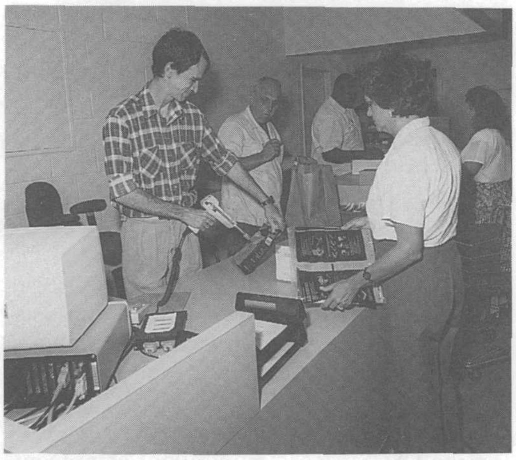


The new control system operates on a microcomputer local area network in each of the regional locations of Reston, Va.; Denver, Colo.; and Menlo Park, Calif. The system maintains a complete data base of office supplies, field equipment, and special order items. As these supplies are purchased by USGS offices, the system uses bar-code reading technology to post sales transactions against the inventory at the time of purchase. An interface with the Federal Financial System allocates the costs of the supplies to the proper account. The system automatically determines cost-effective reorder points for inventory items using Economic Order Quantity (EOQ) techniques. EOQ determines the stock level to which a particular item should diminish before reordering is needed and the optimum reorder quantity to minimize total costs. Once the EOQ is determined, the inventory control system provides information for ordering stock from the GSA and open market vendors.

Motor Vehicle Management System.—The Motor Vehicle Management System (MVMS) is used to collect bureauwide motor vehicle usage information in a more timely and accurate manner and to transmit vehicle data to the Departmental Fleet Management System. The MVMS is used primarily by regional and field offices in the Geologic, Water Resources and National Mapping Divisions. The information, collected to monitor vehicle usage and satisfy departmental and bureau reporting requirements, includes mileage, fuel consumption, and vehicle maintenance costs for more than 1,500 USGS-owned vehicles.

As late as 1990, this information was recorded and processed on outdated punch cards. The MVMS provides system users with three ways of entering data: a personal-computer-based data base application that has automated transmission to the bureau mainframe computer, an online mainframe system, or an interface with existing systems that gather motor vehicle information. In subsequent processing, the data are used to update the bureau Property Management System and provide reports required by the Interior Department. The personal computer and online functions have built-in edits that improve the accuracy of vehicle-use data.

The DOI AVADS Study.—During 1991, the Department of the Interior (DOI) initiated a study to explore the feasibility of a departmentwide automated vacancy announcement and distribution system (AVADS). Designed for departmental and nondepartmental



Inventory control system: Use of the bar-code reader speeds checkout and immediately updates the system data base.

users, AVADS will electronically distribute announcements, make them available as quickly as possible, reduce the amount of paper handled, and consolidate redundant distributions. The study, led by the USGS and involving personnel from many Interior bureaus, examined the AVADS currently in use at the USGS, as well as existing automated and manual processes from four other DOI bureaus: the Bureau of Indian Affairs, Bureau of Land Management, U.S. Fish and Wildlife Service, and Minerals Management Service.

Requirements for an announcement system were determined by representatives from each bureau. On the basis of selection criteria such as cost and ease of implementation and maintenance, the study recommended a modified version of the USGS AVADS. Enhancements to the existing system will allow distribution of the job announcements using a wide-area network and electronic bulletin board service. Initial implementation of the system is planned for 1992.

Washington Administrative Service Center

By Anthony B. Queern

During this fiscal year, the USGS Washington Administrative Service Center (WASC) provided ongoing leadership in the implementation and enhancement of the Department of the Interior (DOI) standard automated accounting and payment system, the Federal Financial System (FFS). The WASC handles departmental administrative systems development at client DOI bureaus and Federal agencies, such as the Administrative Office of the U.S. Courts. The WASC also provides management assistance, planning, contractor services, computer center services, and technical services to its customers.

The FFS is managed by the WASC in Reston, Va. FFS computer services are also provided by the Department's Denver, Colo., Administrative Service Center. To date, the USGS, Bureau of Reclamation, Bureau of Mines, U.S. Fish and Wildlife Service, Bureau of Land Management, National Park Service, and Administrative Office of the U.S. Courts use the system.

In addition to FFS support efforts, the WASC began work on two additional department administrative systems to improve and standardize administrative systems throughout the DOI. These new initiatives are the Interior Department Electronic Acquisition System and an upgrade of the Interior Procurement Data System. Also this year, a working capital fund was authorized by Congress to improve the administrative efficiency of the WASC.

Federal Financial System.—At the beginning of fiscal year 1991, the USGS, Bureau of Reclamation, Bureau of Mines, and U.S. Fish and Wildlife Service continued operations under the FFS. Continuing DOI progress toward departmentwide standardization, the Bureau of Land Management and the National Park Service became the latest bureaus to successfully convert their financial operations to the FFS and began processing accounting transactions during the fiscal year. The addition of these bureaus increased the number of FFS-processed transactions to approximately 70 percent of the Department total.

The Administrative Office of the U.S. Courts, the first client agency outside the DOI, carried out its 1990 annual financial closing activities under the FFS and continued operations for 1991 using computer services and support of the WASC. In 1991, WASC stabilized the recently added bureaus and began extensive conversion work for the fiscal year 1992 addition of the Bureau of Indian Affairs and Department of Commerce Patent and Trademark Office. A new and enhanced FFS software release was successfully tested and installed at both administrative service centers. The new release offers more flexibility and increases the number of options for FFS users.

Interior Department Electronic Acquisition System.—In August 1990, the Assistant Secretary for Policy, Management, and Budget and the DOI Management Committee decided to proceed with the analysis and design of a standardized departmentwide automated

"To date, the USGS, Bureau of Reclamation, Bureau of Mines, U.S. Fish and Wildlife Service, Bureau of Land Management, National Park Service, and Administrative Office of the U.S. Courts use the system."

procurement system. This decision was the culmination of a study conducted by department staff and an intrabureau study team and included technical support provided by the WASC. After analyzing the state of procurement automation in the 11 bureaus and offices within the DOI, the study team recommended the acquisition of a procurement system that would automate small purchases and contracts. Features of the proposed Interior Department Electronic Acquisition System (IDEAS) span the procurement cycle from advanced acquisition planning and electronic requisitioning to contract administration and close-out.

Another interbureau working group, composed of experienced procurement specialists and technical staff from the various bureaus, completed documentation describing the functional requirements of the system and prepared recommendations for departmentwide standards for data, processes, reports, and interfaces to other administrative systems such as the FFS. From these requirements, the WASC developed a conceptual model that defines the core requirements for the IDEAS.

". . .the WASC was awarded a Public Service Excellence Award for fiscal year 1991. . . ."

The WASC conducted a market search to identify bureau, other agency, or commercial software meeting DOI requirements. The WASC is also conducting a detailed cost-benefit analysis in accordance with Federal Information Processing Standards guidelines. The analysis will evaluate the various alternatives to determine the most cost-effective approach to installing a system for the Department. The collection of baseline cost data for the analysis is complete. The analysis will result in a strategy for procuring or adapting a standard system that meets departmentwide specifications.

Interior Procurement Data System.—During 1991, the WASC completed work to standardize procurement reporting systems in the DOI. The work consisted of upgrading software, hardware, and system documentation on the Interior Procurement Data System (IPDS). The DOI is required to report socioeconomic and contract award information regarding Federal funds obligated during the procurement process to the GSA Federal Procurement Data System (FPDS). The IPDS collects information for each Bureau and Purchasing Office in the Department and provides data for the FPDS. The IPDS also tracks and reports additional information to meet specific reporting needs in the Department. The IPDS has been targeted to serve as the first module of IDEAS.

The upgrade consisted of developing new software to take advantage of superior processing capabilities of the USGS Amdahl mainframe computer. The USGS computer provides a central location for the bureaus to report their procurement data and offers the flexibility of entering data directly or submitting data remotely from existing procurement reporting systems. IPDS began operating in October.

Working Capital Fund.—To improve administrative support for the Department, the WASC modified its organizational and funding structure to operate under a working capital fund. Authorized by Congress to begin operations in fiscal year 1991, the fund assists in the management of support activities that the USGS provides for department and government customers. Such activities include the WASC, a general purpose computer center, and the USGS telecommunications equipment replacement fund. The working capital fund is financed by customer fees generated as work is performed for WASC and computer center customers. A team was formed within the USGS to oversee management of the fund and carry out the many organizational tasks associated with its implementation. The project was completed at the end of fiscal year 1991.

Recognition.—At the DOI Financial Management Conference, the WASC was awarded a Public Service Excellence Award for fiscal year 1991 by the Public Employees Roundtable Awards Committee. The award noted the WASC contribution to improvements in financial management that ultimately benefit the public through unique efforts to upgrade the financial management operations of the Department of the Interior. WASC contributions go beyond the successful implementation of the FFS in the DOI and other agencies; they include the development of an innovative approach to the procurement of off-the-shelf software, the incorporation of government requirements into the DOI system to make it more useful to other agencies, and leadership in the Federal Government user group for the FFS software as well as in efforts to award a governmentwide contract for commercially available software and related services.

USGS Office Supply Service Center

By Bert Simon

Since 1974, the USGS National Center self-service supply store has provided a convenient, cost-effective source of office supplies for employees in Reston, Va. The store currently carries nearly 1,000 items and averages about $500,000 in annual sales to 226 customer accounts, including other Federal agencies in the Reston and Herndon area. The store is a centralized source of supplies and materials that would otherwise have to be obtained less efficiently and at higher cost by individual offices. Consolidated purchasing and stocking saves an estimated $250,000 annually in procurement processing, order receiving and delivery, and storage.

In 1991, the store was transformed into a service center by the addition of new products and the consolidation of services previously available from other sources. Major process, layout, and environmental improvements combined to enhance customer service and management quality.

The year-long transformation began with the consolidation and pruning of inventory. Obsolete, slow-moving, and zero-demand items were removed from inventory and reported to the General Services Administration (GSA) for redistribution. The GSA accepted transfer and credited the USGS with nearly $10,000 of the merchandise, and the Department of Defense accepted the remaining excess inventory, having a book value of $184,000. Remaining bulk stock was moved from an off-site storage location to the Service Center. The installation of new bulk-storage shelving permits most of the supply stock to be placed on the sales room floor. These actions eliminated multiple stock locations, reduced internal movement of stock, saved storage space, and provided a ready supply of merchandise to the customer.

Service Center efficiency was improved significantly by the new Inventory Control System (ICS), which is off-the-shelf software customized to meet USGS requirements. Highlights of the system are point-of-sale inventory accounting, data entry through barcode scanning, itemized sales receipt preparation, and extensive management reporting. ICS was brought online in May 1991 and is now the supply manager's principal tool for controlling supply operations. ICS maintains perpetual inventory control, and a point-of-sale feature decreases stock balances as sales are transacted. ICS also eliminates manual price changing because current prices are maintained in the data base.

This pricing feature and the use of product bar codes allow new stock to be placed on the sales floor upon receipt and eliminates delays due to manual price marking. Efficiency is further improved through the ability of the system to compute economic order quantity (EOQ), which determines when and how much to order. EOQ helps the manager maintain stock at the minimum level necessary to meet customer demand. The system adjusts to fluctuations in demand and modifies stock levels accordingly.

Customer service was the driving force behind improvements in store layout, stock arrangement, and the addition of convenience features. Highly functional display racks provide maximum flexibility for displaying and rearranging supply stock. Improved aisle and bin signs aid customers in locating items. Carts and tote baskets are available, and a literature rack at the check-out area displays pamphlets and brochures on a variety of administrative subjects requested by customers.

The Service Center is primarily a supply center, but it also provides additional services to customers. Personnel at the customer service counter respond to inquiries and process orders for recycled laser printer cartridges, gas cylinders, field equipment, bulk items such as copier paper, and special order supplies. The center houses and provides training and operator assistance for the only color copier at the National Center.

The Service Center is close to other in-house service elements. A customer service representative assists employees in obtaining requested support. Print requisition assistance, mail operations support, messenger service, passenger shuttle assistance, personal property reutilization, and transportation services are provided to walk-in customers and by telephone. The Transportation Office, conveniently located near the Service Center, provides services such as overnight express mail, freight shipments, shipment claims assistance, and household goods shipments.

To ensure that supplies and services keep pace with the changing requirements of USGS programs, Service Center staff meet regularly with a committee of customer representatives. The committee investigates improving services, promoting effective communication, evaluating the services provided, and ensuring that customer concerns are satisfactorily resolved. Feedback from individual customers and from the committee helps the Service Center continually improve customer service.

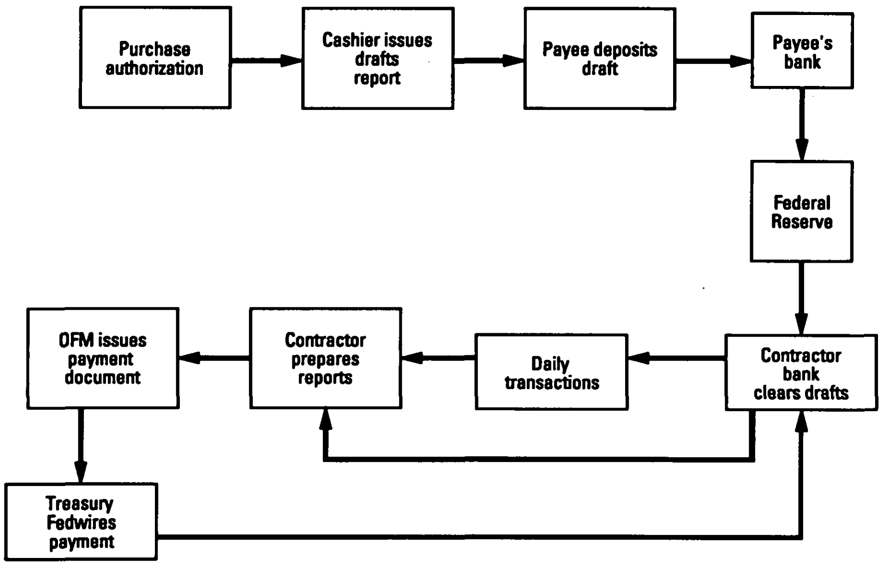
". . .a centralized source of supplies and materials that would otherwise have to be obtained less efficiently and at higher cost. . . ."

Third Party Drafts

By Judith A. Gunnells

To reduce the amount of cash being held in imprest funds, the USGS Office of Financial Management (OFM) implemented a third party draft payment system as an alternative payment mechanism for imprest fund transactions. A third party draft is a checklike instrument drawn against a contractor's bank account. The chart (p. 104) shows the document flow for the drafts. The contractor supplies the USGS with the drafts, which are issued by a USGS cashier in lieu of cash for

Third party drafts



"The use of the drafts proved to be highly successful and has since been expanded to 61 locations bureauwide."

the same types of transactions processed through an imprest fund, with the exception of travel advances. The payee of the draft cashes or deposits the draft, which is processed through the banking system and presented to the contractor's bank for payment. The contractor then bills the USGS for reimbursement of all items paid by the contractor. Subsequently, the USGS reimburses the contractor with a wire transfer of funds. It takes about 10 days from the time a draft is issued to the time it clears the contractor's account.

In cooperation with OFM, the Water Resources Division Northeast Region conducted a pilot of the third party draft program at 18 locations having imprest funds and at 4 locations having no imprest funds. The use of the drafts proved to be highly successful and has since been expanded to 61 locations bureauwide. Drafts are widely accepted by vendors since payment is being made at the time of the purchase, rather than having the vendor bill the USGS. Although the drafts may be used for many types of transactions, they have proven to be most advantageous for payment for services provided by gage readers, for registration fees, for publications and subscriptions, and for software updates. To date, the USGS has processed 14,901 drafts having a total dollar amount of $1,354,775.

Third party drafts can be used to supplement an imprest fund or even eliminate cash in the imprest fund. Drafts offer better cash management procedures, flexibility, and internal control. Audit trails are provided, and there are fewer security problems. The cashier does not need to replenish the fund since no cash is actually being disbursed. Although cashiers must account for all drafts issued, they are not personally liable as they are with cash. In those participating locations having no imprest funds, the program streamlines the purchasing process since it provides a mechanism for purchasing goods and services that was not available previously without issuing a purchase order or blanket purchase agreement. Future uses of the drafts are for On-the-Spot Awards and for ordering merchandise by the c.o.d. (cash on delivery) method.

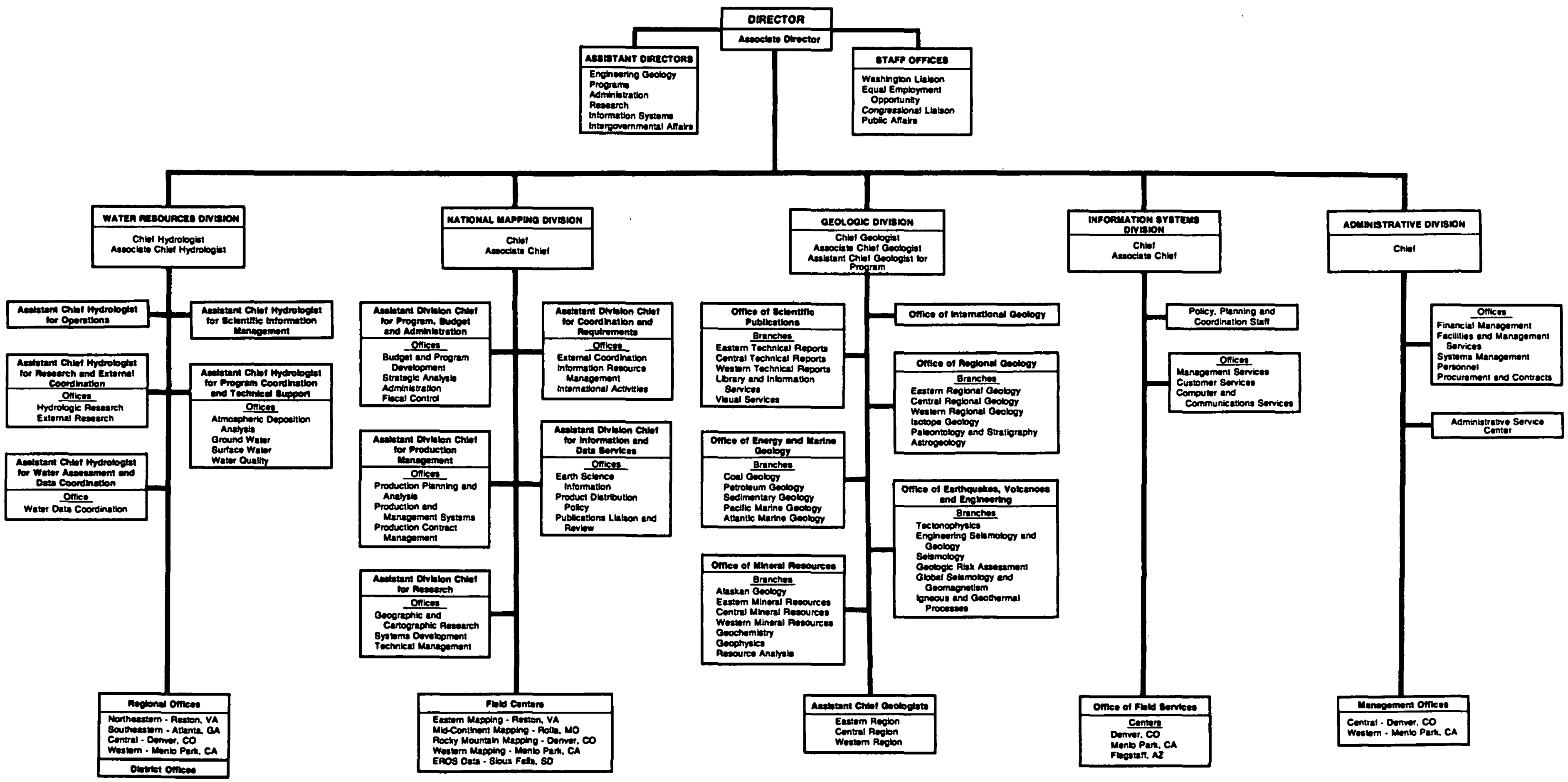
Child Care

After 1 year of operation, the Federal Children's Center of Northern Virginia, established by the USGS and five other Federal agencies, is almost fully enrolled. The first year was eventful, beginning with a formal dedication ceremony attended by Congressman Frank Wolf and other local dignitaries. Parents were added to the board of directors, and an emergency drop-in program was started to allow parents to use the center when other child care arrangements fall through. A tuition assistance program was begun, and a before-and-after-school program was planned to begin in December 1991. The year ended with formal evaluations of the center by parents and staff members; these evaluations confirm that the center is a great success.

The GeoKids Center in Menlo Park is making plans to build a modern child care facility to be completed in late 1992, with the assistance of the San Francisco Region of the General Services Administration (GSA). GeoKids continues to be cited as a model parent-cooperative program and was awarded a 1991 Recognition Award for Program Excellence by the California Association for the Education of Young Children.

Start-up funds were committed for a child care program in Flagstaff, Ariz., and employees there are working with GSA officials to obtain updated needs assessment information to guide them in the development of a program for children of Federal employees in Flagstaff.

ORGANIZATION OF THE U.S. GEOLOGICAL SURVEY
U.S. Department of the Interior



Budget Information

USGS budget authority for fiscal year 1991, by appropriation, for surveys, investigations, and research (SIR)
[Dollars in thousands]

Activity/Subactivity/Program element	Fiscal year 1991 enacted
National Mapping, Geography, and Surveys	**$132,396**
National Map and Digital Data Production	47,954
Cartographic Data and Map Revision	41,838
Thematic and Special Data	4,624
SLAR	1,492
Information and Data Systems	19,165
National Data Base Management	7,937
Information Dissemination Services	4,156
Global Change Data Systems	7,072
Research and Technology	17,959
Cartographic and Geographic Research	8,333
National Cartographic Requirement Coordination and Standards	3,946
Geographic and Spatial Information Analysis	5,680
Advanced Cartographic Systems	47,318
Geologic and Mineral Resource Surveys and Mapping	**221,391**
Geologic Hazards Surveys	68,906
Earthquake Hazards Reduction	50,475
Volcano Hazards	16,190
Landslide Hazards	2,241
Geologic Framework and Processes	35,917
National Geologic Mapping	21,273
Deep Continental Studies	3,106
Geomagnetism	1,785
Coastal and Wetlands Processes	9,753
Global Change Research	10,409
Global Change and Climate History	10,409
Offshore Geologic Surveys	27,302
Offshore Geologic Framework	27,302
Mineral Resource Surveys	48,677
National Mineral Resource Assessment Program	25,118
Strategic and Critical Minerals	9,974
Development of Assessment Techniques	13,585
Energy Geologic Surveys	30,180
Evolution of Sedimentary Basins	6,725
Coal Investigations	8,212
Oil and Gas Investigations	5,817
Oil Shale Investigations	593
Uranium and Radon Investigations	1,917
Geothermal Investigations	6,094
World Energy Resource Assessment	822

Activity/Subactivity/Program element	Fiscal year 1991 enacted
Water Resources Investigations	**$177,399**
National Water Resources Research and Information System—Federal Program	100,860
Data Collection and Analysis	22,753
National Water Information Clearinghouse	3,730
Coordination of National Water Data Activities	1,022
Regional Aquifer System Analysis	10,703
Core Program Hydrologic Research	10,133
Improved Instrumentation	1,696
Water Resources Assessment	1,619
Toxic Substances Hydrology	14,628
Nuclear Waste Hydrology	3,925
Acid Rain	3,138
Scientific and Technical Publications	2,300
National Water-Quality Assessment Program	18,219
Global Change Hydrology	6,994
National Water Resources Research and Information System—Federal-State Cooperative Program	65,763
Data Collection and Analysis, Areal Appraisals, and Special Studies	61,776
Water Use	3,987
National Water Resources Research and Information System—State Research Institutes and Research Grants Program	10,776
State Water Resources Research Institutes	5,647
National Water Resources Research Grants Program	4,358
Program Administration	771
General Administration	**21,205**
Executive Direction	6,668
Administrative Operations	12,004
Reimbursements to the Department of Labor	2,533
Facilities	**18,299**
National Center—Rental Payments to GSA	15,452
National Center—Facilities Management	2,847
Total, SIR	**$570,690**

USGS budget for fiscal years 1988 to 1991, by activity and sources of funds[1]

[Dollars in thousands; totals may not add because of rounding]

Budget activity	1988	1989	1990	1991
Total	**$662,101**	**$670,897**	**$ 723,137**	**$802,538**
Direct program	448,233	451,988	[1]501,510	575,044
Reimbursable program	213,868	218,909	221,628	227,494
States, counties, and municipalities	68,609	69,577	74,113	87,415
Miscellaneous non-Federal sources	12,775	14,194	15,151	13,499
Other Federal agencies	132,484	135,138	132,363	126,580
National Mapping, Geography, and Surveys	**120,845**	**126,457**	**141,069**	**162,421**
Direct program	90,541	94,235	111,528	132,395
Reimbursable program	30,304	32,222	29,542	30,026
States, counties, and municipalities	1,579	1,520	2,132	2,366
Miscellaneous non-Federal sources	10,021	10,804	10,278	9,722
Other Federal agencies	18,705	19,898	17,131	17,938
Geologic and Mineral Resource Surveys and Mapping	**224,028**	**215,882**	**241,739**	**261,513**
Direct program	177,278	178,329	200,472	225,112
Reimbursable program	46,750	37,553	41,267	36,401
States, counties, and municipalities	1,138	961	1,917	2,661
Miscellaneous non-Federal sources	368	682	2,022	1,260
Other Federal agencies	45,244	35,910	37,328	32,480
Water Resources Investigations	**278,380**	**287,154**	**295,128**	**333,238**
Direct program	149,471	145,635	152,904	177,969
Reimbursable program	128,910	141,520	142,224	155,269
States, counties, and municipalities	65,893	67,095	70,064	82,388
Miscellaneous non-Federal sources	2,354	2,700	2,839	2,503
Other Federal agencies	60,662	71,725	69,321	70,378
General Administration	**17,746**	**19,059**	**21,493**	**21,528**
Direct program	14,684	16,330	18,081	21,206
Reimbursable program (Federal)	3,062	2,729	3,412	322
Miscellaneous non-Federal sources	3	0	1	1
Other Federal agencies	3,060	2,729	3,411	321
Facilities	**16,252**	**17,450**	**18,502**	**18,314**
Direct program	16,214	17,421	18,502	18,314
Reimbursable program	38	29	0	0
Computer and administrative services to other accounts	**4,804**	**4,856**	**5,183**	**5,476**
Reimbursable program	4,804	4,856	5,183	5,476
Miscellaneous non-Federal sources	29	7	11	13
Other Federal agencies	4,775	4,849	5,172	5,463
Operation and maintenance of quarters	**45**	**38**	**23**	**48**
Direct program	45	38	23	48

[1] Direct program includes $570,472 for current year, $4,361 for no year, $163 for Contributed Funds, and $48 for Operation and Maintenance of Quarters.

USGS reimbursable funds from other Federal agencies for fiscal years 1988 to 1991, by agency

[Dollars in thousands; figures in parentheses are included in Department of the Interior totals]

Budget activity	1988	1989	1990	1991
Department of Agriculture	$ 3,392	$ 3,638	$ 3,379	$ 3,464
Department of Commerce	50	0	281	323
National Oceanic and Atmospheric Administration	6,138	5,327	1,448	2,258
Department of Defense	39,462	40,478	41,257	42,002
Department of Energy	26,800	31,630	29,574	28,521
Bonneville Power Administration	258	311	358	159
Department of the Interior	17,166	14,076	12,728	12,533
Bureau of Indian Affairs	(4,664)	(2,190)	(2,018)	(1,834)
Bureau of Land Management	(1,773)	(1,317)	(1,239)	(1,256)
Bureau of Mines	(29)	(0)	(24)	(0)
Bureau of Reclamation	(6,715)	(5,926)	(6,119)	(6,259)
Minerals Management Service	(291)	(222)	(32)	(76)
National Park Service	(1,069)	(1,304)	(883)	(1,036)
Office of the Secretary	(1,983)	(2,206)	(1,343)	(1,549)
Office of Surface Mining	(352)	(264)	(106)	(67)
U.S. Fish and Wildlife Service	(290)	(648)	(964)	(456)
Department of State	9,896	10,082	8,144	8,279
Department of Transportation	794	1,479	362	299
Environmental Protection Agency	3,591	3,096	5,279	4,302
National Aeronautics and Space Administration	4,877	4,952	5,607	6,270
National Science Foundation	535	630	2,328	625
Nuclear Regulatory Commission	1,589	1,797	1,917	1,441
Tennessee Valley Authority	269	170	217	200
Miscellaneous Federal agencies	18,146	17,472	19,484	15,904
Total	**$132,963**	**$135,139**	**$132,363**	**$126,580**

Guide to Information and Publications

Earth Science Information Centers

To obtain information on cartographic data and on earth science programs, publications, and services, or to obtain copies of reports and maps, write or visit U.S. Geological Survey Earth Science Information Centers at the following addresses:

Alaska:
Room 101
4230 University Dr.
Anchorage, AK 99508–4664

Room G–84
605 West 4th Ave.
Anchorage, AK 99501

New Federal Building, Box 12
101 12th Avenue
Fairbanks, AK 99701

California:
Room 3128
532 Bldg. 3
345 Middlefield Rd.
Menlo Park, CA 94025–3591

Colorado:
Room 1813
504 Denver Federal Center, Bldg. 25
Box 25046
Denver, CO 80225–0046

District of Columbia:
Main Interior Bldg., Room 2650
1849 C St., NW.
Washington, DC 20240
(When visiting, use E St. entrance.)

Mississippi:
Bldg. 3101
Stennis Space Center
Bay St. Louis, MS 39529

Missouri:
Room 231
1400 Independence Rd.
Rolla, MO 65401–2602

South Dakota:
EROS Data Center
Sioux Falls, SD 57198–0001

Utah:
8105 Federal Bldg.
125 S. State St.
Salt Lake City, UT 84138–1177

Virginia:
Room 1C–402
507 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Washington:
678 U.S. Courthouse
W. 920 Riverside Ave.
Spokane, WA 99201

Water Information

Water-Source Data

To obtain assistance in locating sources of water data, identifying sites at which data have been collected, and obtaining specific information, write:

U.S. Geological Survey
National Water Data Exchange
421 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Water-Data Aquisition Activities

To obtain information on ongoing and planned water-data acquisition activities of all Federal agencies and many non-Federal organizations, write:

U.S. Geological Survey
Office of Water Data Coordination
417 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Water Resources of Specific Areas

To obtain information on water resources in general and about the water resources of specific areas of the United States, write:

U.S. Geological Survey
Hydrologic Information Unit
419 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Geologic Information

General Geology

To obtain information on geologic topics such as earthquakes and volcanoes, energy and mineral resources, the geology of specific areas, and geologic maps and mapping, write:

U.S. Geological Survey
Geologic Inquiries Group
907 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Mineral Resources

To obtain information on mineral resources, write or visit:

Minerals Information Office*
Main Interior Bldg., Room 2647
1849 C St., NW.
Washington, DC 20240

*Joint venture of the USGS and the U.S. Bureau of Mines.

Minerals Information Office, USGS
340 N. 6th Ave.
Tucson, AZ 85705

Minerals Information Office, USGS
c/o Mackay School of Mines
University of Nevada, Reno
Reno, NV 89557–0047

Minerals Information Office, USGS
U.S. Courthouse, Room 656
W. 920 Riverside Dr.
Spokane, WA 99201

Maps

Topographic and Thematic

To buy maps of all areas of the United States and to request USGS catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Map Distribution
Building 810
Denver Federal Center, Box 25286
Denver, CO 80225

To buy Alaska maps, residents of Alaska may write or visit:

Earth Science Information Center
New Federal Building, Box 12
101 12th Avenue
Fairbanks, AK 99701

Aerial Photographs and Satellite Images

To obtain information on aerial photographs and satellite and space images, write or visit:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198

Books and Reports

To buy USGS book publications, to request USGS circulars, or to obtain information on the availability of microfiche or paper-duplicate copies of open-file reports, write:

U.S. Geological Survey
Book and Open-File Report Sales
Federal Center, Box 25286
Denver, CO 80225

Periodicals

New Publications

To get on the mailing list for the monthly list of *New Publications of the U.S. Geological Survey* (free), write:

U.S. Geological Survey
Distribution Support Section
582 National Center
12201 Sunrise Valley Drive
Reston, VA 22092

Earthquakes & Volcanoes

To subscribe to *Earthquakes & Volcanoes*, a bi-monthly, nontechnical digest that provides up-to-date information on earthquakes, volcanoes, and related natural hazards around the world, write:

Superintendent of Documents
Government Printing Office
Washington, DC 20402

U.S. Geological Survey Offices

[Information current as of April 1992]

Headquarters Offices	Central Region	Western Region
National Center **12201 Sunrise Valley Drive** **Reston, VA 22092**	**Denver Federal Center** **Box 25046** **Denver, CO 80225**	**345 Middlefield Rd.** **Menlo Park, CA 94025**

Office of the Director

Director	Dallas L. Peck	(703) 648–7411	101 National Center
Associate Director	Doyle G. Frederick	(703) 648–7412	102 National Center
Special Assistant (Washington Liaison) and Deputy Ethics Counselor	Jane H. Wallace	(202) 343–3888	Rm. 2648, Interior Bldg. Washington, DC 20240
Assistant Director for Research	Stephen E. Ragone	(703) 648–4450	104 National Center
Assistant Director for Engineering Geology	James F. Devine	(703) 648–4423	106 National Center
Assistant Director for Administration	Jack J. Stassi	(703) 648–7200	201 National Center
Assistant Director for Programs	Peter F. Bermel	(703) 648–4430	105 National Center
Assistant Director for Intergovernmental Affairs	John J. Dragonetti	(703) 648–4427	109 National Center
Assistant Director for Information Systems	James E. Biesecker	(703) 648–7108	801 National Center
Congressional Liaison Officer	Talmadge W. Reed	(703) 648–4457	112 National Center
Chief, Public Affairs Office	Donovan B. Kelly	(703) 648–4460	119 National Center
Equal Employment Opportunity Officer	Bruce D. Palmer	(703) 648–4417	116 National Center
Director's Representative—Central Region	Harry Tourtelot	(303) 236–5438	406 Denver Federal Center
Director's Representative—Western Region	George Gryc	(415) 329–4002	Western Region, Stop 144
Special Assistant to the Director for Alaska	Philip J. Carpenter	(907) 271–4138	4230 University Drive, Suite 201 Anchorage, AK 99508

Administrative Division

Chief	Jack J. Stassi	(703) 648–7200	201 National Center
Administrative Officer	Louie Pectol	(703) 648–7204	203 National Center
Office of Personnel, Chief	Maxine C. Millard	(703) 648–7442	215 National Center
Office of Procurement and Contracts, Chief	John K. Peterson	(703) 648–7373	205 National Center
Office of Financial Management, Chief	Vacant	(703) 648–7604	270 National Center
Office of Facilities and Management Services, Chief	William F. Gossman, Jr.	(703) 648–7338	207 National Center
Office of Systems Management, Chief	Phillip L. McKinney	(703) 648–7256	206 National Center
Washington Administrative Service Center, Chief	Phillip L. McKinney	(703) 648–7256	206 National Center
Central Regional Management Officer	F.B. Sower	(303) 236–5900	201 Denver Federal Center
Western Regional Management Officer	George F. Hargrove, Jr.	(415) 329–4150	Western Region, Stop 211

Information Systems Division

Chief	James E. Biesecker	(703) 648–7108	801 National Center
Deputy Chief	Wendy A. Budd	(703) 648–7103	801 National Center
Office of Customer Services, Chief	Virginia L. Ross	(703) 648–7178	805 National Center
Office of Computer and Communications Services, Chief	Charles D. Nethaway	(703) 648–7077	807 National Center
Office of Management Services, Chief	Eliot Christian	(703) 648–7245	802 National Center
Office of Field Services, Chief	Doug R. Posson	(303) 236–4944	801 Denver Federal Center

National Mapping Division

Chief	Allen H. Watkins	(703) 648–5748	516 National Center
Associate Chief	Roy R. Mullen	(703) 648–5745	516 National Center
Assistant Division Chief for Research	Joel L. Morrison	(703) 648–4640	519 National Center
Assistant Division Chief for Program, Budget and Administration	Richard E. Witmer	(703) 648–4611	514 National Center
Assistant Division Chief for Information and Data Services	Gary W. North	(703) 648–5780	508 National Center
Assistant Division Chief for Coordination and Requirements	Gene A. Thorley	(703) 648–5742	590 National Center
Assistant Division Chief for Production Management	James R. Plasker	(703) 648–4146	511 National Center
Eastern Mapping Center, Chief	K. Eric Anderson	(703) 648–6002	567 National Center
Mid-Continent Mapping Center, Chief	Merle E. Southern	(314) 341–0880	1400 Independence Rd., Rolla, MO 65401

National Mapping Division—Continued

Rocky Mountain Mapping Center, Chief	Randle W. Olsen	(303) 236–5825	510 Denver Federal Center
Western Mapping Center, Chief	John R. Swinnerton	(415) 329–4254	Western Region, Stop 531
Earth Resources Observation Systems Data Center, Chief	Vacant	(605) 594–6123	EROS Data Center, Sioux Falls, SD 57198

Geologic Division

Chief Geologist	Benjamin A. Morgan	(703) 648–6600	911 National Center
Associate Chief Geologist	William R. Greenwood	(703) 648–6601	911 National Center
Assistant Chief Geologist for Program	David P. Russ	(703) 648–6640	910 National Center
Administrative Officer	Elwood H. Like	(703) 648–6611	912 National Center
Human Resources Officer	John D. McGurk	(703) 648–6628	911 National Center
Office of Scientific Publications, Chief	John M. Aaron	(703) 648–6077	904 National Center
Office of Regional Geology, Chief	Mitchell W. Reynolds	(703) 648–6959	908 National Center
Office of Earthquakes, Volcanoes, and Engineering, Chief	Robert L. Wesson	(703) 648–6714	905 National Center
Office of Energy and Marine Geology, Chief	Gary W. Hill	(703) 648–6470	915 National Center
Office of Mineral Resources, Chief	Glenn H. Allcott	(703) 648–6100	913 National Center
Office of International Geology, Chief	A. Thomas Ovenshine	(703) 648–6047	917 National Center
Assistant Chief Geologist, Eastern Region	Nancy Milton	(703) 648–6660	953 National Center
Assistant Chief Geologist, Central Region	Harry A. Tourtelot	(303) 236–5438	911 Denver Federal Center
Assistant Chief Geologist, Western Region	William R. Normark	(415) 329–5101	Western Region, Stop 19

Water Resources Division

Chief Hydrologist	Philip Cohen	(703) 648–5215	409 National Center
Associate Chief Hydrologist	John N. Fischer	(703) 648–5216	408 National Center
Assistant Chief Hydrologist for Scientific Information Management	James F. Daniel	(703) 648–5699	440 National Center
Assistant Chief Hydrologist for Operations	William B. Mann IV	(703) 648–5031	441 National Center
Assistant Chief Hydrologist for Research and External Coordination	Robert M. Hirsch	(703) 648–5041	436 National Center
Office of Hydrologic Research, Chief	Roger G. Wolff	(703) 648–5043	436 National Center
Office of External Research, Chief	John E. Schefter	(703) 648–6800	424 National Center
Assistant Chief Hydrologist for Program Coordination and Technical Support	Verne R. Schneider	(703) 648–5229	414 National Center
Office of Atmospheric Deposition Analysis, Chief	Ranard J. Pickering	(703) 648–6874	416 National Center
Office of Ground Water, Chief, Acting	Thomas E. Reilly	(703) 648–5001	411 National Center
Office of Surface Water, Chief	Charles W. Boning	(703) 648–5301	415 National Center
Office of Water Quality, Chief	David A. Rickert	(703) 648–6862	412 National Center
Assistant Chief Hydrologist for Water Assessment and Data Coordination	David W. Moody	(703) 648–6856	407 National Center
Office of Water Data Coordination, Chief	Nancy C. Lopez	(703) 648–5019	417 National Center
Northeastern Region, Chief	Stanley P. Sauer	(703) 648–5817	433 National Center
New England Programs, Chief	Ivan C. James II	(617) 565–6866	10 Causeway St., Rm. 926 Boston, MA 02222
Mid-Atlantic Programs, Chief	Herbert J. Freiberger	(301) 838–1535	208 Carroll Bldg. 8600 La Salle Rd. Towson, MD 21204
Mid-East Programs, Chief	Donald E. Vaupel	(609) 771–3902	Suite 206 Mountain View Office Park 810 Bear Tavern Rd. West Trenton, NJ 08628
Ohio Valley Programs, Chief	Catherine L. Hill	(317) 290–3333	5957 Lakeside Blvd. Indianapolis, IN 46278
Western Great Lakes Programs, Chief	Daniel P. Bauer	(608) 276–3801	6417 Normandy Ln. Madison, WI 53719
Southeastern Region, Chief	James L. Cook	(404) 409–7700	Suite 160 Spalding Woods Office Park Norcross, GA 30092
Southeast Programs, Chief	Michael W. Gaydos	(404) 409–7700	Suite 160 Spalding Woods Office Park Norcross, GA 30092
Lower Mississippi Programs, Chief	Wanda C. Meeks	(501) 324–6391	2301 Federal Office Bldg. 700 W. Capitol Ave. Little Rock, AR 72201

Water Resources Division—Continued

Central Region, Chief	James F. Blakey	(303) 236–5920	406 Denver Federal Center
Midwest Programs, Chief	James E. Kircher	(913) 842–9909	4821 Quail Crest Pl. Lawrence, KS 66049
North Central Programs, Chief	William J. Herb	(612) 229–2607	702 Post Office Bldg. 108 E. Kellogg Blvd. St. Paul, MN 55101
Rocky Mountain Programs, Chief	Charles A. Pascale	(303) 236–4882	415 Denver Federal Center Box 25046 Denver, CO 80225
Southwest Programs, Chief	Charles R. Burchett	(512) 832–5791	8011 Cameron Rd., Bldg. 1 Austin, TX 78753
Western Region, Chief	T. John Conomos	(415) 329–4403	Western Region, Stop 470
Pacific Northwest Programs, Chief	Garald G. Parker, Jr.	(206) 593–6510	1201 Pacific Ave., Suite 600 Tacoma, WA 98402
Great Basin Programs, Chief	William J. Carswell, Jr.	(702) 887–7600	Rm. 114 Federal Bldg. 705 N. Plaza St. Carson City, NV 89701

District Offices

Alabama	Hillary H. Jeffcoat	(205) 752–8104	520 19th Ave. Tuscaloosa, AL 35401
Alaska	Philip J. Carpenter	(907) 786–7100	4230 University Dr., Suite 201 Anchorage, AK 99508
Arizona	Robert D. MacNish	(602) 670–6671	375 S. Euclid Ave. Tucson, AZ 85719
Arkansas	Ector E. Gann	(501) 324–6391	2301 Federal Office Bldg. 700 W. Capitol Ave. Little Rock, AR 72201
California	John M. Klein	(916) 978–4633	Rm. W–2234 Federal Bldg. 2800 Cottage Way Sacramento, CA 95825
Colorado	David J. Lystrom	(303) 236–4882	415 Denver Federal Center Box 25046 Denver, CO 80225
Connecticut	Chester E. Thomas, Jr.	(203) 240–3060	Rm. 525 Abraham A. Ribicoff Federal Bldg. 450 Main St. Hartford, CT 06103
Delaware (See Maryland)			
District of Columbia (See Maryland)			
Florida	Irwin H. Kantrowitz	(904) 681–7631	227 N. Bronough St., Suite 3015 Tallahassee, FL 32301
Georgia	Timothy W. Hale	(404) 986–6860	6481–B Peachtree Industrial Blvd. Doraville, GA 30360
Hawaii	William Meyer	(808) 541–2653	677 Ala Moana Blvd., Suite 415 Honolulu, HI 96813
Idaho	Jerry L. Hughes	(208) 334–1750	230 Collins Rd. Boise, ID 83702
Illinois	Stephen F. Blanchard	(217) 398–5353	102 E. Main St., 4th Floor Urbana, IL 61801
Indiana	Jo Ann Macy	(317) 290–3333	5957 Lakeside Blvd. Indianapolis, IN 46278
Iowa	Norwood B. Melcher	(319) 337–4191	P.O. Box 1230 Rm. 269 Federal Bldg. 400 S. Clinton St. Iowa City, IA 52244
Kansas	Richard A. Herbert	(913) 842–9909	4821 Quail Crest Pl. Lawrence, KS 66049
Kentucky	Alfred L. Knight	(502) 582–5241	2301 Bradley Ave. Louisville, KY 40217
Louisiana	Darwin D. Knochenmus	(504) 389–0281	P.O. Box 66492 6554 Florida Blvd. Baton Rouge, LA 70806
Maine	Derrill J. Cowing	(207) 622–8201	26 Ganneston Dr. Augusta, ME 04330

Water Resources Division—Continued

District Offices—Continued

Maryland	Dave Grason	(301) 828–1535	208 Carroll Bldg. 8600 La Salle Rd. Towson, MD 21204
Massachusetts	Michael C. Yurewicz	(508) 485–6360	28 Lord Rd., Suite 280 Marlborough, MA 01752
Michigan	Cynthia Barton	(517) 377–1608	6520 Mercantile Way, Suite 5 Lansing, MI 48911
Minnesota	George Garklavs	(612) 229–2607	702 Post Office Bldg. 180 E. Kellogg Blvd. St. Paul, MN 55101
Mississippi	Gerald L. Ryan	(601) 965–4600	Suite 710 Federal Bldg. 100 W. Capitol St. Jackson, MS 39269
Missouri	Marvin G. Sherrill	(314) 341–0824	1400 Independence Rd., Stop 200 Rolla, MO 65401
Montana	Joe A. Moreland	(406) 449–5302	Drawer 10076, Rm. 428 Federal Bldg. 301 S. Park Ave. Helena, MT 59626
Nebraska	Michael V. Shulters	(402) 437–5082	Rm. 406 Federal Bldg. 100 Centennial Mall, North Lincoln, NE 68508
Nevada	Jon O. Nowlin	(702) 887–7600	Rm. 114 Federal Bldg. 705 N. Plaza St. Carson City, NV 89701
New Hampshire	Brian Mrazik	(603) 225–4681	525 Clinton St. Bow, NH 03304
New Jersey	Janice R. Ward	(609) 771–3902	Suite 206, Mountain View Office Park 810 Bear Tavern Rd. West Trenton, NJ 08628
New Mexico	Russell K. Livingston	(505) 262–5301	Pinetree Office Park, Suite 200 4501 Indian School Rd., NE. Albuquerque, NM 87110
New York	L. Grady Moore	(518) 472–3107	P.O. Box 1669 343 U.S. Post Office and Courthouse Albany, NY 12201
North Carolina	James F. Turner	(919) 571–4000	3916 Sunset Rd. Raleigh, NC 27606
North Dakota	William F. Horak, Jr.	(701) 250–4601	821 E. Interstate Ave. Bismarck, ND 58501
Ohio	Steven M. Hindall	(614) 469–5553	975 W. Third Ave. Columbus, OH 43212
Oklahoma	Kathy D. Peter	(405) 231–4256	220 N.W. 66th, Bldg. 7 Oklahoma City, OK 73116
Oregon	Marvin O. Fretwell	(503) 231–2008	10615 S.E. Cherry Blossom Dr. Portland, OR 97216
Pennsylvania	David E. Click	(717) 730–6900	840 Market St. Lemoyne, PA 17043
Puerto Rico	Allen L. Zack	(809) 749–4346	P.O. Box 364424 GSA Center, Bldg. 652 Hwy 28, Km. 7.2, Pueblo Viejo San Juan, PR 00936
Rhode Island (See Massachusetts)			
South Carolina	Glenn G. Patterson	(803) 750–6100	Stephenson Center, Suite 129 720 Gracern Rd. Columbia, SC 29210
South Dakota	Richard E. Fidler	(605) 353–7176	Rm. 408 Federal Bldg. 200 4th St., SW. Huron, SD 57350
Tennessee	Ferdinand Quinones-Marquez	(615) 736–5424	810 Broadway, Suite 500 Nashville, TN 37203
Texas	Richard O. Hawkinson	(512) 832–5791	8011 Cameron Rd., Bldg. 1 Austin, TX 78753
Utah	Harvey L. Case III	(801) 524–5663	Rm. 1016 Administration Bldg. 1745 W. 1700 South Salt Lake City, UT 84104

Water Resources Division—Continued

District Offices—Continued

Vermont (See New Hampshire)			
Virginia	Gary S. Anderson	(804) 771–2427	3600 W. Broad St., Rm. 606 Richmond, VA 23230
Washington	Garald G. Parker, Jr.	(206) 593–6510	1201 Pacific Ave., Suite 600 Tacoma, WA 98402
West Virginia	David P. Brown	(304) 347–5130	603 Morris St. Charleston, WV 25301
Wisconsin	Warren A. Gebert	(608) 276–3801	6417 Normandy Ln. Madison, WI 53719
Wyoming	Barney D. Lewis	(307) 772–2728	2617 E. Lincolnway, Suite B Cheyenne, WY 82001

Cooperators and Other Financial Contributors

Cooperators listed are those with whom the USGS had a written agreement cosigned by USGS officials and officials of the cooperating agency for financial cooperation in fiscal year 1991. Parent agencies are listed separately from their subdivisions whenever there are separate cooperative agreements for different projects with a parent agency and with a subdivision of it. Agencies are listed in alphabetical order under the State or territory where they have cooperative agreements with the USGS. Agencies with whom the USGS has research contracts and to whom it supplied research funds are not listed.

Cooperating office of the U.S. Geological Survey
g—Geologic Division
n—National Mapping Division
w—Water Resources Division

Alabama
Alabama Department of—
Economic and Community Affairs (w),
Environmental Management (w),
Highways, Departments No. 1, 2, and 6 (w);
Anniston, City of (w);
Birmingham, City of (w);
Butler, County of (w);
Coffee County Commission (w);
Fayette County Commission (w);
Florida Department of Environmental Regulation (w);
Geological Survey of Alabama (n,w);
Greenville, City of (w);
Huntsville, City of (w);
Jefferson County Commission (w);
Mobile, City of (w);
Montgomery, City of (w);
North Sumter Water Authority (w);
Prattville, City of (w);
Sumter, County of (w);
Sylacauga, City of (w);
Tuscaloosa, City of (w);
University of Alabama—Tuscaloosa (w)

Alaska
Alaska Department of—
Fish and Game (w),
Natural Resources, Division of Geological and Geophysical Surveys (w),
Transportation (w);
Alaska Energy Authority (w);
Alaska Industrial Development and Export Authority (w);
Anchorage, Municipality of (w);
Annette Islands Reserve Tribal Government (g);
Fairbanks North Star Borough (w);
Juneau, City and Borough of (w);
Kenai Peninsula Borough (w);
Kenai Soil and Water Conservation District (w);
Kodiak, Borough of (w);
Matanuska Susitna Borough (w);
Sitka, City and Borough of (w);
University of Alaska, Fairbanks (g)

American Samoa
American Samoa, Government of (w)

Arizona
Arizona Department of—
Environmental Quality (w),
Health Services (w),
Water Resources (w);
Arizona Municipal Water Users Association (w);
Arizona State Land Department (w);
Arizona State University (g);
Colorado Department of Highways (w);
Franklin Irrigation District (w);
Gila Valley Irrigation District (w);
Gila Water Commissioner, Office of (w);
Hualapai Indian Tribe (g);
Maricopa County—
Flood Control District (w),
Water District (w);
Metropolitan Water District of Southern California (w);
Navajo Nation (w);
Pima County Department of Transportation (w);
Prescott, City of (w);
Safford, City of, Water, Gas, and Sewer Department (w);
Salt River Project (w);
San Carlos Apache Tribe (g);
San Carlos Irrigation District (w);
Scottsdale, City of, Water Resources Department (w);
Show Low Irrigation Company (w);
Tohono Oldham Nation (w);
Tucson, City of (w);
Yuma, City of (w)

Arkansas
Arkansas Department of—
Parks and Tourism (w),
Pollution Control and Ecology (w),
Health (w);
Arkansas Game and Fish Commission, Fisheries Division (w);
Arkansas Geological Commission (n,w);
Arkansas Soil and Water Conservation Commission (w);
Arkansas State Highway and Transportation Department (w);
Arkansas-Oklahoma: Arkansas River Compact Commission (w);
Beebe, City of (w);
Independence, County of (w);
Little Rock—
Municipal Water Works (w),
Public Works Department (w);
Rogers, City of, Water Utilities Department (w);
University of Arkansas—
at Fayetteville (w),
at Little Rock (w)

California
Alameda County—
Flood Control and Water Conservation District (Hayward) (w),
Water District (w);
Antelope Valley-East Kern Water Agency (w);
California Department of—
Boating and Waterways (w),
Conservation (g),
Food and Agriculture (w),
Parks and Recreation (g,w),
Transportation (w),
Water Resources (w);
California Water Control Board (w);
Carpinteria County Water District (w);
Casitas Municipal Water District (w);
Coachella Valley Water District (w);
Contra Costa County Flood Control and Water Conservation District (w);
Crestline-Lake Arrowhead Water Agency (w);
Desert Water Agency (w);
East Bay Municipal Utility District (w);
East Valley Water District (w);
Eastern Municipal Water District (w);
Georgetown Divide Public Utility District (w);
Humboldt Bay Municipal Water District (w);
Imperial County Department of Public Works (w);
Imperial Irrigation District (w);
Indian Wells Valley Water District (w);
Los Angeles, County of (w);
Los Angeles County Sanitation Districts (g);
Los Angeles Department of City Planning (g);
Madera Irrigation District (w);
Marin Municipal Water District (w);
Mendocino County Water Agency (w);
Merced, City of (w);
Merced Irrigation District (w);
Metropolitan Water District (w);
Mojave Water Agency (w);
Mono, County of (w);
Montecito Water District (w);
Monterey County Water Resources Agency (w);
Monterey Peninsula Water Management District (w);
North Kern Water Storage District (w);
Orange County Water District (w);
Pala Band of the Mission Indians (w);
Palo Alto, City of (w);
Panoche Water and Drainage District (w);
Pechanga Indian Reservation (w);
Rancho California Water District (w);
Riverside County Flood Control and Water Conservation District (w);
Sacramento Municipal Utility District (w);
Sacramento County Department of Public Works (w);
San Benito County Water District (w);
San Bernardino County Flood Control District (w);
San Bernardino Valley Municipal Water District (w);
San Diego, City of (w);
San Diego, County Department of Public Works (w);
San Francisco, City and County of (w);
San Francisco Water Department (w);
San Luis Obispo County Engineering Department (w);
San Mateo County Department of Public Works (w);
Santa Barbara, City of, Department of Public Works (w);
Santa Barbara County—
Flood Control and Water Conservation District (w),
Water Agency (w);
Santa Clara Valley Water District (w);
Santa Cruz, City of (w);
Santa Cruz County Flood Control and Water Conservation District (w);
Santa Maria Valley Water Conservation District (w);
Santa Ynez River Water Conservation District (w);
Scotts Valley Water District (w);
Sonoma County—
Planning Department (w),
Water Agency (w);
Tahoe Regional Planning Agency (w);
Tulare County Flood Control District (w);
Turlock Irrigation District (w);
United Water Conservation District (w);
University of California—
at Berkeley (g),
Lawrence Livermore National Laboratory (g);
Water Resources Control Board (w);
Woodbridge Irrigation District (w);
Yolo County Flood Control and Water Conservation District (w);
Yuba County Water Agency (w)

Colorado
Arapahoe County Water and Wastewater (w);
Arkansas River Compact Administration (w);
Arvada, City of (w);

Aspen, City of (w);
Aurora, City of (w);
Bent, County of (w);
Boulder, City of (w);
Boulder, County of (w);
Breckenridge, Town of (w);
Centennial Water and Sanitation District (w);
Cherokee Water and Sanitation District (w);
Colorado Department of—
Health (w),
Natural Resources, Oil and Gas Conservation Commission (w),
Transportation (w);
Colorado Division of—
Water Resources, Office of the State Engineer (w),
Wildlife (w);
Colorado River Water Conservation District (w);
Colorado Springs, City of—
Department of Public Utilities (w),
Engineering Division (w);
Colorado Water Conservation Board (w);
Delta County Board of Commissioners (w);
Denver, City and County, Board of Water Commissioners (w);
Eagle County Board of Commissioners (w);
East Grand County Water Quality Board (w);
Englewood, City of (w);
Evergreen Metropolitan District (w);
Fort Collins, City of, Water and Wastewater (w);
Fountain Valley Authority (w);
Fremont Sanitation District (w);
Garfield, County of (w);
Glendale, City of (w);
Glenwood Springs, City of (w);
Golden, City of (w);
Jefferson County Board of County Commissioners (w);
Lakewood, City of (w);
Lamar, City of (w);
La Plata, County of (w);
Las Animas, City of (w);
Longmont, City of (w);
Loveland, City of (w);
Lower Fountain Water-Quality Management Association (w);
Metropolitan Wastewater Reclamation District (w);
Moffat, County of (w);
Northern Colorado Water Conservation District (w);
Northglenn, City of (w);
Pueblo Board of Water Works (w);
Pueblo, City of, Department of Utilities (w);
Pueblo County Commissioners (w);
Pueblo West Metropolitan District (w);
Rio Blanco, County of (w);
Rio Grande Water Conservation District (w);
Rocky Ford, City of (w);
St. Charles Mesa Water District (w);
Southern Ute Indian Tribe (w);
Southwestern Colorado Water Conservation District (w);
Steamboat Springs, City of, Public Works Department (w);
Thornton, City of (w);
Trinchera Water Conservation District (w);
Uncompahgre Valley Water Users Association (w);
University of Colorado (g);
Upper Arkansas Council of Governments (w);
Upper Arkansas River Water Conservation District (w);
Upper Eagle Regional Water Authority (w);
Upper Yampa Water Conservancy District (w);
Urban Drainage and Flood Control District (w);
Ute Mountain Indian Tribe (w);
Ute Mountain Reservation (g);
Vail Valley Conservation Water District (w);
Westminster, City of (w);
Yellow Jacket Water Conservancy District (w)

Connecticut
Connecticut Department of—
Environmental Protection (g,n,w),
Transportation (w);
Fairfield, Town of, Conservation Department (w);
New Britain, City of, Board of Water Commissioners (w);
Norwich Sewer Authority (w);
South Central Connecticut Regional Water Authority (w);
Torrington, City of (w)

Delaware
Geological Survey (n,w)

District of Columbia
Department of Public Works (w);
Metropolitan Washington Council of Governments (w)

Florida
Bay County Utilities (w);
Boca Raton, City of (w);
Bradenton, City of (w);
Broward County Office of Natural Resources Protection (w);
Cape Coral, City of (w);
Cocoa, City of (w);
Collier, County of (w);
Daytona Beach, City of (w);
Florida Department of—
Environmental Regulation (w),
Natural Resources (w)—
Division of Survey and Mapping (n),
Transportation (n,w);
Florida Institute—
Food and Agricultural Sciences (w),
Phosphate Research (w);
Florida Keys Aqueduct Authority (w);
Fort Lauderdale, City of (w);
Game and Freshwater Fish Commission (w);
Hallandale, City of (w);
Highland Beach, Town of (w);
Hillsborough, County of (w);
Hollywood, City of (w);
Jacksonville, City of (w);
Jacksonville Electric Authority (w);
Lake, County of (w);
Lake Mary, City of (w);
Lee, County of (w);
Madison, City of (w);
Manatee County—
Board of County Commissioners (w),
Environmental Action Commission (w);
Marion, County of (w);
Martin, County of (w);
Metropolitan Dade County (w);
Miami-Dade Water and Sewer Authority (w);
North Port, City of (w);
Northwest Florida Water Management District (w);
Ocala, City of (w);
Palm Beach, County of (w);
Perry, City of (w);
Pinellas, County of (w);
Polk, County of (w);
Pompano Beach, City of (w);
Port Orange, City of (w);
Reedy Creek Improvement District (w);
Sarasota, City of (w);
Sarasota, County of (w);
South Florida Water Management District (w);
South Indian River Water Control District (w);
Southwest Florida Water Management District (w);
St. Johns, County of (w);
St. Johns River Water Management District (w);
St. Lucie, County of (w);
St. Petersburg, City of (w);
Stuart, City of (w);
Suwannee River Water Management District (Live Oak) (w);
Tallahassee, City of—
Electric Department (w),
Water Quality Laboratory (w);
Tampa, City of (w);
Tampa Bay Regional Planning Council (w);
Tampa Port Authority (w);
University of Miami (g);
University of South Florida (g);
Volusia, County of (w);
Walton, County of (w);
West Coast Regional Water Supply Authority (w);
Winter Park, City of (w)

Georgia
Albany, City of (w);
Albany Water, Gas, and Light Commission (w);
Bibb, County of (w);
Blairsville, Town of (w);
Brunswick, City of (w);
California Air Resources Board (w);
Chatham County-Savannah Metropolitan Planning Commission (w);
Chestatee-Chattahoochee Resource Conservation and Development (w);
Clayton County Water Authority (w);
Covington, City of (w);
De Kalb County Public Works Department (w);
Georgia Department of—
Natural Resources (g)—
Water Quality Support Program (w),
Geologic Survey (n,w),
Transportation (w)—
at Atlanta (w),
at Forest Park (w);
Georgia Mountain Regional Development Center (w);
Georgia State University, Center for Hydrology (w);
Gwinnett, County of, Preconstruction Division (w);
Helena, City of (w);
Macon-Bibb County Water and Sewage Authority (w);
Moultrie, City of (w);
Springfield, City of (w);
Thomaston, City of (w);
Thomasville, City of (w);
Tifton, City of (w);
Tifton County Commission (w);
Valdosta, City of (w);
Zebulon, City of (w)

Guam
Guam, Government of, Environmental Protection Agency (w)

Hawaii
Hawaii, County of, Department of Water Supply (w);
Hawaii Department of—
Agriculture, Division of Agriculture Resource Management (w),
Land and Natural Resources (g)—
Division of—
Forestry and Wildlife (n),
Water Resource Management (w),
Transportation (w);
Honolulu Board of Water Supply (w);
Honolulu, City and County of, Department of Public Works (g,w);
Kauai, County of, Department of Water Supply (w);
Maui, County of, Department of Water Supply (w);
Office of State Planning (n)

Idaho
Bonner County Commissioners (w);
Coeur d'Alene Tribe of Idaho (w);
College of Southern Idaho (w);
Idaho Department of—
Health and Welfare (w),
Water Resources (w);
Nampa, City of (w);

Nez Percé Tribe (w);
Shoshone, County of (w);
Shoshone-Bannock Tribes, (w);
Southwest Irrigation District (w);
Teton, County of (w);
University of Idaho (g);
Water District No. 01 (Idaho Falls) (w);
Water District No. 32D (Dubois) (w)

Illinois

Bloomington and Normal Sanitary District (w);
Cook County Forest Preserve District (w);
Decatur, City of (w);
DeKalb, City of, Public Works Department (w);
DuPage County Forest Preserve, Planning and Development Section (w);
DuPage County Department of Environmental Concerns (w);
Illinois Department of—
  Energy and Natural Resources—
    Geological Survey Division (n,w),
    State Water Survey (w),
  Transportation—
    Division of Highways (n),
    Division of Water Resources (w);
Illinois Environmental Protection Agency (w);
Lake County Department of Planning, Zoning, and Environmental Quality (w);
Metropolitan Sanitary District of Greater Chicago (w);
Northern Illinois University (g);
Springfield, City of (w)

Indiana

Carmel, Town of, Utilities (w);
Elkhart, City of, Water Works (w);
Indiana Department of—
  Environmental Management (w),
  Natural Resources (n), Bureau of Land, Forest, and Wildlife (w),
  Transportation (w);
Indianapolis, City of, Department of Public Works (w)

Iowa

Ames, City of (w);
Carroll County Auditor (w);
Carroll County Health Department (w);
Carroll County Soil and Water (w);
Cedar Rapids, City of (w);
Davenport, City of (w);
Des Moines, City of (w), Water Works (w);
Fort Dodge, City of (w);
Guthrie County Health Department (w);
Iowa Department of—
  Transportation, Highway Division (w),
  Natural Resources, Geological Survey Bureau (n,w);
Iowa State University (w);
University of Iowa—
  Institute of Hydraulic Research (w),
  Hygienic Laboratory (w)

Kansas

Arkansas River Compact Administration (w);
Clay County Board of Commissioners (w);
Emporia, City of, Department of Public Works (w);
Geary County Board of Commissioners (w);
Harvey, County of (w);
Hays, City of (w);
Iowa Tribe of Kansas and Nebraska (w);
Kansas City-Wyandotte County Health Department (w);
Kansas Department of—
  Health and Environment (w),
  Transportation (w);
Kansas Geological Survey (n,w);
Kansas State Board of Agriculture, Division of Water Resources (w);
Kansas State University Department of Agronomy (w);
Kansas University Center for Research, Inc. (w);
Kansas Water Office (w);
Kickapoo Tribe of Kansas (w);
Linn, County of (w);
McPherson, County of (w);
Olathe, City of (w);
Prairie Band of Potawatomi Tribe (w);
Reno, County of (w);
Sac and Fox Tribe of Missouri (w);
Sumner, County of (w);
University of Kansas, Kansas Geological Survey (g);
Western Kansas Ground Water Management District #1 (w);
Wichita, City of (w)

Kentucky

Campbellsville Municipal Water (w);
Elizabethtown, City of (w);
Fulton, City of (w);
Glasgow Water Company (w);
Jefferson, County of, Department of Public Works and Transportation (w);
Kentucky Department of Natural Resources and Environmental Protection Cabinet (w);
Kentucky State University (w);
Lewisburg, City of (w);
Metropolitan Sewer District (w);
Owensboro, City of (w);
Purchase Area Development District (w);
University of Kentucky, Kentucky Geological Survey (n,w);
University of Louisville (w)

Louisiana

Alexandria, City of (w);
Capital-Area Groundwater Conservation Commission (w);
East Baton Rouge Parish (w);
Jefferson Parish Department of Public Utilities (w);
Louisiana Department of—
  Health and Hospitals, Office of Public Health (w),
  Transportation and Development (w), Office of Public Works (n),
  Wildlife and Fisheries (w);
Louisiana Geological Survey (w);
Louisiana Office of Emergency Preparedness (w);
Louisiana State University and A&M College (w);
Plaquemines Parish (w);
Sabine River Compact Administration (w);
St. John the Baptist Parish (w);
St. John the Baptist Water Works, District 3 (w);
Terrebonne Parish (w)

Maine

Androscoggin Valley Council of Governments (w);
Cobbossee Watershed District (w);
Greater Portland Council of Governments (w);
Maine Department of—
  Conservation, Geological Survey (n,w),
  Transportation (n);
Maine Low Level Radioactive Waste Authority (w);
North Kennebec Valley Regional Planning Commission (w);
Northern Maine Regional Planning Commission (w);
Penobscot Valley Council of Governments (w);
University of Maine (w)

Maryland

Anne Arundel County Planning and Zoning Office (w);
Baltimore City of, Water Quality Management (w);
Delaware Geological Survey (w);
Delaware Department of Natural Resources and Environmental Control (w);
Delaware River Basin Commission (w);
Hyndman, Borough of (w);
Maryland Department of—
  Environment (w),
  Natural Resources (g,w),
    Energy Administration (w);
Maryland Geological Survey (n,w);
Salisbury, City of (w)

Massachusetts

Cape Cod Commission (w);
Executive Office of Environmental Affairs (n);
Mashpee Water District (w);
Massachusetts Department of—
  Environmental Management, Division of Resources Conservation (w),
  Environmental Protection, Division of Water Pollution Control (w),
  Fisheries, Wildlife, and Environmental Law Enforcement, Division of Fisheries and Wildlife (w),
  Public Works (w);
Massachusetts Water Resources Authority (g);
Metropolitan District Commission—
  Parks, Engineering and Construction Division (w),
  Watershed Management Division (w);
Norway, City of (w);
Ostego County Road Commission (w);
Tri-County Regional Planning Commission (w);
Wayne, County of (w);
Woods Hole Oceanographic Institute (g)

Michigan

Adrian, City of (w);
Ann Arbor, City of (w);
Battle Creek, City of—
  Board of—
    Public Utilities (w),
    Water and Light (w);
Cadillac, City of, Wastewater Treatment Plant (w);
Clare, City of (w);
Consumers Power Company (w);
Elsie, Village of, Department of Public Works (w);
Flint, City of, Water Plant (w);
Huron-Clinton Metropolitan Authority (w);
Imlay, City of (w);
Kalamazoo, City of, Department of Public Works (w);
Keweenaw Bay Indian Community (w):
Lansing, City of, Board of Water and Light, Water and Stream Division (w);
Macomb, County of (w);
Mason, City of (w);
Michigan Department of—
  Natural Resources—
    Office of Budget and Federal Aid (w),
    Sanitary Sewers and Engineering (w),
  Transportation, Design Division (w);
Michigan Power Company (w);
Monroe County Health Department, Environmental Health Division (w);
Negaunee, City of, Water and Wastewater Treatment Plant (w);
Norway, City of (w);
Oakland County Drainage Commission (w);
Otsego County Road Commission (w);
Portage, City of (w);
Portland, City of (w);
Tri-County Regional Planning Commission (w);
Wayne, County of, Division of Environmental Health (w);
Ypsilanti Community Utility Authority (w)

Minnesota

Beltrami County SWCD (w);
Dakota County SWCD (w);
Elm Creek Conservation Management and Planning Commission (w);
Fond Du Lac Reservation Business Committee (w);
Hennepin County Conservation District (w);

Leech Lake Reservation, Division of Resource Management (w);
Lower Red River Watershed Management Board (w);
Metropolitan Waste Control Commission (w);
Mille Lacs Reservation Business Committee (w);
Minneapolis Water Works (w);
Minnesota Department of—
  Natural Resources (g,w),
  Transportation (w);
Minnesota Pollution Control Agency (w);
Minnesota State Planning Agency (n);
Northwest Minnesota Ground Water Steering Committee (w);
Red Lake Reservation Business Committee (w);
Red Lake Watershed District (w);
Rochester Public Utilities (w);
St. Paul, City of, Board of Water Commissioners (w);
University of Minnesota, Minnesota Geological Survey (g);
Vadnais Lake Area Watershed (w);
White Earth Reservation Business Commission (w);
Whitewater Joint Powers Board (w)

Mississippi

Harrison County Development Commission (w);
Jackson, City of (w);
Jackson County Port Authority (w);
Mississippi Department of—
  Agriculture and Commerce (w),
  Environmental Quality—
    Office of Geology (w),
    Office of Land and Water Resources (w),
    Office of Pollution Control (w),
  Highways (w);
Pat Harrison Waterway District (w);
Pearl River Basin Development District (w);
Pearl River Valley Water Supply District (w);
Sabine River Compact Administration (w);
Yazoo Mississippi Delta (w)

Missouri

Branson, City of (w);
Cape Girardeau, City of (w);
Independence, City of (w);
Jackson County Parks and Recreation (w);
Metropolitan St. Louis Sewer District (w);
Mid-America Regional Council (w);
Missouri Department of—
  Conservation (w),
  Health (w),
  Natural Resources—
    Division of Environmental Quality (w),
    Division of Geology and Land Survey (n,w),
    Land Reclamation Commission (w);
Missouri Highway and Transportation Commission (n,w);
Rolla, City of (w);
Rolla Municipal Utilities (w);
Springfield, City of, City Utilities (w);
St. Francis County Environmental Corporation (w);
Sullivan, City of (w);
Watershed Commission of the Ozarks (w);
University of Missouri-Columbia, Department of Geology (w)

Montana

Blackfeet Nation (w);
Chippewa Creek Tribe of Rocky Boy's Reservation (g);
Fort Belknap Community Council (w);
Fort Peck Reservation (w);
Helena, City of (w);
Lewis and Clark City-County Health Department (w);
Montana Bureau of Mines and Geology (w);
Montana Department of—
  Agriculture (w),
  Fish, Wildlife, and Parks (w),
  Health and Environmental Sciences (w),
  Highways (w),
  Natural Resources and Conservation (w);
Salish and Kootenai Tribes of Flathead Reservation (w);
Santee-Sioux Tribal Office (w);
Wyoming State Engineer (w)

Nebraska

Central Platte Natural Resources District (w);
Kansas-Nebraska Big Blue River Compact Administration (w);
Lincoln, City of (w);
Little Blue Natural Resources District (w);
Lower Loup Natural Resources District (w);
Lower Platte South Natural Resources District (w);
Lower Republican Natural Resources District (w);
Middle Niobrara Natural Resources District (w);
Middle Republican Natural Resources District (w);
Nebraska Department of—
  Environmental Control (w),
  Roads (w),
  Water Resources (w);
Nebraska Natural Resources Commission (w);
Nemaha Natural Resources District (w);
North Platte Natural Resources District (w);
Omaha Tribe of Nebraska (w);
Panhandle Resource and Development Project (w);
Papio-Missouri River Natural Resources District (w);
Santee-Sioux Tribal Office (w);
South Platte Natural Resources District (w);
Twin Platte Natural Resources District (w);
University of Nebraska, Conservation and Survey Division (w);
Upper Elkhorn Natural Resources District (w);
Upper Loup Natural Resources District (w);
Upper Niobrara White Natural Resources District (w);
Upper Republican Natural Resources District (w);
Water Resources Center (w)

Nevada

California Department of Water Resources (w);
Carson City/County Department of Public Works (w);
Carson Water Subconservancy District (w);
Clark County Regional Flood Control District (w);
Clark County Sanitation District (w);
Douglas, County of (w);
Duck Valley Reservation (w);
Elko, County of (w);
Henderson, City of (w);
Interim Finance Commission, Legislative Counsel Bureau (w);
Las Vegas, City of (w);
Las Vegas Valley Water District (g);
Mackay School of Mines (w);
Nevada Bureau of Mines and Geology (g,n,w);
Nevada Department of—
  Conservation and Natural Resources—
    Division of Environmental Protection (w),
    Division of Water Resources (w),
  Human Resources, Division of Health, Consumer Health Protection Service (w),
  Transportation (w);
  Wildlife (w);
Nye, County of (w);
Pyramid Lake Indian Tribe (w);
Regional Water Planning and Advisory Board of Washoe County/Cities of Reno and Sparks (w);
South Lake Tahoe, City of (w);
South Lake Tahoe Public Utility District (w);
Summit Lake Paiute Indian Tribe (w);
Tahoe Regional Planning Agency (w);
Washoe County Planning Department (n)

New Hampshire

New Hampshire Department of—
  Environmental Services (g,w),
  Transportation (n)

New Jersey

Bergen, County of (w);
Brick Township Municipal Utility Authority (w);
Gloucester County Planning Commission (w);
Morris County Municipal Utilities Authority (w);
New Brunswick, City of (w);
New Jersey Department of Environmental Protection (n,w)—
  Division of Science and Research (n);
North Jersey District Water Supply Commission (w);
Passaic Valley Water Commission (w);
Pinelands Commission (w);
Rutgers State University (w);
Somerset County Board of Chosen Freeholders (w);
Washington Township Municipal Utility Authority (w);
West Windsor, Township of (w)

New Mexico

Albuquerque, City of—
  Hydrology Division (w),
  Waste Water Utility (w);
Albuquerque Metropolitan Arroyo Flood Control Authority (w);
Bernalillo, County of (w);
Canadian River Municipal Water Authority (w);
Costilla Creek Compact Commission (w);
Elephant Butte Irrigation District (w);
Highlands University, School of Science and Technology (w);
La Cienega Acequia Association (w);
Las Cruces, City of (w);
Las Vegas, City of (w);
Navajo Indian Nation, Department of Environmental Protection (w);
New Mexico Bureau of Mines and Mineral Resources, Division of Mining and Technology (w);
New Mexico Environment Department (w);
New Mexico Department of Highways (w);
New Mexico State University Agricultural Experiment Station (w);
Office of the State Engineer (w);
Pecos River Commission (w);
Pueblo of Zuni (w);
Raton, City of (w);
Rio Grande Compact Commission (w);
Rio San Jose Flood Control District (w);
Ruidoso, Village of (w);
Santa Fe Metropolitan Water Board (w);
Santa Rosa, City of (w);
University of New Mexico (n)

New York

Academy of Natural Sciences (w);
Amherst, Town of, Engineering Department (w);
Auburn, City of (w);
Chautauqua, County of, Department of Planning and Development (w);
Cheektowaga, Town of (w);
Chenango, County of (w);
Cornell University, Electric Power Research Institute (w);
Cortland, County of (w);
Essex, County of, Planning Department (w);
Hudson-Black River Regulating District (w);
Kiryas Joel, Village of (w);
Long Island Regional Planning Board (w);
Monroe, County of, Department of Environmental Health (w);
Nassau, County of—
  Department of Health (w),
  Department of Public Works (w);
New York City Department of Environmental Protection—
  Bureau of Water Supply (w),
  Division of Water Quality Planning (w);

New York State Department of—
Environmental Conservation, Division of Water (w),
Transportation (w);
New York State Power Authority (w);
Nyack, Village of, Board of Water Commissioners (w);
Onondaga, County of—
Department of Drainage and Sanitation (w),
Water Authority (w);
Orange County Water Authority (w);
Putnam, County of, Department of Planning (w);
Rockland, Town of (w);
Schuyler County Department of Planning and Economic Development (w);
State University of New York, Syracuse (n,w);
Suffolk, County of—
Department of Health Services (w),
Water Authority (w);
Tompkins, County of, Department of Planning (w);
Ulster, County of (w)

North Carolina

Asheville, City of (w);
Bethel, Town of (w);
Brevard, City of (w);
Chapel Hill, Town of (w);
Charlotte, City of (w);
Durham, City of (w);
Forsyth, County of (w);
Greensboro, City of (w);
Guilford County S.W.C.D. (w);
Highpoint, City of (w);
Lexington, City of (w);
Mecklenburg, County of (w);
North Carolina Agricultural Extension Service (w);
North Carolina State Department of—
Environment, Health, and Natural Resources (w),
Transportation (w);
North Carolina Wildlife Resources Commission (w);
Raleigh, City of (w);
Rocky Mount, City of (w);
Triangle Area Water Supply Monitoring, Project Steering Committee (w)

North Dakota

Dickinson, City of (w);
Lower Heart Water Resources District (w);
Minot, City of (w);
North Dakota Department of—
Game and Fish (w),
Health, Water Supply, and Pollution Control (w),
Parks and Recreation (w),
Transportation (w);
North Dakota Forest Service (n);
North Dakota Geological Survey (w);
Oliver County Board of Commissioners (w);
Public Service Commission (w);
Standing Rock Sioux Tribe (g,w);
State Water Commission (w);
Three Affiliated Tribes Natural Resources Department (w)

Ohio

Akron, City of (w);
Canton, City of, Water Department (w);
Columbus, City of (w);
Eastgate Development Company (w);
Fremont, City of (w);
Lima, City of (w);
Miami Conservancy District (w);
Ohio Department of—
Natural Resources (w),
Transportation (n,w);
Ohio State University (g), Department of Agronomy (w);
Ross, County of (w);
Seneca Soil and Water District (w);
Sumit County Engineers (w);
Toledo Metropolitan Area Council of Governments (w);
University of Cincinnati (w);
University of Toledo (w)

Oklahoma

Ada, City of (w);
Association of Central Oklahoma Governments (w);
Enid, City of (w);
McGee Creek Authority (w);
Oklahoma City, City of (w);
Oklahoma Conservation Commission (w);
Oklahoma Department of Transportation (n,w);
Oklahoma Geological Survey (g);
Oklahoma State Health Department (w);
Oklahoma Water Resources Board (w);
Sac and Fox Nation (w)

Oregon

Ashland, City of (w);
Clark County, Washington—
Intergovernmental Resources Center (w),
Public Services Department (w);
Coos Bay-North Bend Water Board (w);
Douglas, County of (w);
Eugene, City of, Water and Electric Board (w);
Jackson, County of (w);
Klamath Tribe (w);
Lane Council of Governments (w);
McMinnville, City of, Water and Light Department (w);
Oregon Department of—
Fish and Wildlife (w),
Human Resources, State Health Division (w),
Natural Resources, Analysis and Planning Management Services Division (w),
Transportation (w),
Water Resources (w);
Portland, City of—
Bureau of—
Environmental Services (w),
Water Works (w);
Puget South Water Quality Authority (w);
Tualatin Valley Irrigation District (w);
Umatilla Tribal Council (w);
United Sewerage Agency (w);
Warm Springs Tribal Council (w);
Washington State Department of Natural Resources (w)

Pennsylvania

Allentown, City of, Engineering Department (w);
Bethlehem, City of (w);
Bucks, County of (w);
Chester, County of, Water Resources Authority (w);
Delaware River Basin Commission (w);
Harrisburg, City of, Department of Public Works (w);
Hazelton City Authority Water Department (w);
Joint Planning Commission of Lehigh-Northampton Counties (w);
Lancaster County Planning Commission (w);
Letort Regional Authority (w);
Media Borough Water Department (w);
New York State Department of Environmental Conservation (w);
North Penn Water Authority (w);
North Wales Water Authority (w);
Philadelphia, City of, Water Department (w);
Pennsylvania Department of—
Environmental Resources—
Bureau of Community Environmental Control (w),
Bureau of Mining and Reclamation (w),
Bureau of Soil and Water Conservation (w),
Bureau of Topographic and Geologic Survey (n,w),
Bureau of Water Quality Management (w),
Bureau of Water Resources Management (w);
Pike County Planning Commission (w);
Somerset Conservation District (w);
Susquehanna River Basin Commission (w);
Tinicum, Township of (w);
University Area Joint Authority (w);
University of Delaware, Geological Survey (w);
West Bradford, Township of (w);
Williamsport, City of, Bureau of Flood Control (w)

Puerto Rico

Puerto Rico Aqueduct and Sewer Authority (w);
Puerto Rico Department of Natural Resources (w);
Puerto Rico Environmental Quality Board (w);
Puerto Rico Industrial Development Company (w);
Puerto Rico Mineral Resources Development Corporation (g);
University of the Virgin Islands (w);
Virgin Islands Water and Power Authority (w)

Rhode Island

New Shoreham, Town of (w);
Office of Housing, Energy, and Intergovernmental Relations (w);
Rhode Island State Department of Environmental Management, Division of Water Resources (w);
State Water Resources Board (w);
University of Rhode Island (n)

South Carolina

Beaufort-Jasper County Water Authority (w);
Charleston Public Works (w);
Land Resources Conservation Commission (n);
Myrtle Beach, City of (w);
Oconee County Sewer Commission (w);
Pageland, Town of (w);
Pickens, County of (w);
South Carolina State—
Department of Health and Environmental Control (w),
Department of Highways and Public Transportation (w),
Public Service Authority (w),
Water Resources Commission (n,w);
South Carolina Sea Grant Consortium (w);
Spartanburg Sanitary Sewer District (w);
Spartanburg Water System (w);
University of South Carolina Department of Environmental and Health Services (w);
Waccamaw Regional Planning and Development Commission (w);
Western Carolina Regional Sewer Authority (w);
York, County of, Planning and Development Service (w)

South Dakota

Area II Minnesota River Basin (w);
Belle Fourche Irrigation District (w);
Cheyenne River Sioux Tribe (w);
East Dakota Water Development District (w);
Lawrence, County of (w);
Mellette/Todd County Conservation (w);
Minnehaha, County of (w);
Oglala Sioux Tribe, Pine Ridge (w);
Rapid City, City of (w);
Rosebud Sioux Tribe (w);
Sioux Falls, City of, Utilities Department (w);
Sisseton-Wahpeton Sioux Tribe(w);
South Dakota Department of—
Environment and Natural Resources—
Geological Survey Division (w),
Water Resource Management Division (w),
Water Quality Division (w),
Water Rights Division (w),
Game, Fish and Parks, Custer State Park Division (w);
Transportation (w);
South Dakota North Central Research Conservation and Development (w);
South Dakota School of Mines and Technology (w);

South Dakota State University (w);
Stanley County Conservation District (w);
Watertown, City of (w);
West Dakota Water Development District (w);
West River Water Development District (w)

Tennessee

Alamo, City of (w);
Alcoa, City of (w);
Alpha Talbott Utility District (w);
Bartlett, City of (w);
Cedar Grove Utility District (w);
Chattanooga, City of, Department of Public Works (w);
Chickasaw Basin Authority (w);
Clarksville-Montgomery, County of (w);
Columbia, City of (w);
Dickson, City of (w);
Eastside Utility District (w);
Erwin, Town of (w);
Fayetteville Water System (w);
Franklin, City of (w);
Germantown, City of (w);
Hixson Utility District (w);
Humphreys, County of (w);
Jackson, City of, Utility Division (w);
Jasper, City of (w);
Johnson City, City of, Public Works Department (w);
Knoxville, City of (w);
Lawrenceburg, City of (w);
Lebanon, City of (w);
Lewisburg, City of, Water Treatment Plant (w);
Lincoln, County of, Board of Public Utilities (w);
Maury City, City of (w);
Memphis, City of—
Division of Public Works (w),
Light, Gas, and Water Division (w);
Memphis State University (w);
Metropolitan Governments, Nashville, City of, and Davidson, County of (w);
Murfreesboro, City of, Water and Sewer Department (w);
Pigeon Forge, City of (w);
Red Boiling Springs, Town of (w);
Rutherford, County of (w);
Savannah Valley Utility District (w);
Sevierville, City of (w);
Shelby County Government (w);
Spring Hill, Town of (w);
Suck Creek Utility District, Office of Planning and Development (w);
Tennessee Department of—
Environment and Conservation—
Division of—
Geology (w),
Groundwater Protection (w),
Recreation Planning (w),
Office of Water Pollution Control (w),
Transportation—
Division of Planning (w),
Division of Structures (w);
Tennessee State Planning Office (w);
Tennessee Wildlife Resources Agency (w);
Townsend, Town of (w);
Union City, City of (w);
University of Tennessee (w);
Upper Duck River Development Agency (w);
Wartrace, City of (w)

Texas

Abilene, City of (w);
Arlington, City of (w);
Austin, City of (w);
Austin, City of, Regulatory Affairs and Quality Control (w);
Bexar-Medina-Atascosa Counties (w);
Brazos River Authority (w);
Coastal Water Authority (w);
Colorado River Municipal Water District (w);
Corpus Christi, City of (w);
Dallas, City of (w);
Dallas, City of, Public Works Department (w);
Edwards Underground Water District (w);
El Paso, City of, Public Service Board (w);
Fort Worth, City of, Water Department, Water Pollution Control (w);
Franklin, County of, Water District (w);
Gainesville, City of (w);
Galveston, County of (w);
Garland, City of (w);
Georgetown, City of (w);
Graham, City of (w);
Greenbelt Municipal and Industrial Water Authority (w);
Guadalupe-Blanco River Authority (w);
Harris, County of, Flood Control District (w);
Harris-Galveston Coastal Subsidence District (w);
Houston, City of (w);
Lavaca-Navidad River Authority (w);
Lower Colorado River Authority (w);
Lower Neches Valley Authority (w);
Lubbock, City of (w);
Nacogdoches, City of (w);
North Central Texas Council of Governments (w);
North Central Texas Municipal Water Authority (w);
North Texas Municipal Water District (w);
Northeast Texas Municipal Water Authority (w);
Orange, County of (w);
Pecos River Commission (w);
Red River Authority (w);
Sabine River Authority of Texas (w);
Sabine River Compact Administration (w);
San Angelo, City of (w);
San Antonio, City of—
Environmental Development Service (w);
Public Service Board (w),
Water Board (w);
San Antonio River Authority (w);
San Jacinto River Authority (w);
Tarrant, County of, Water Control and Improvement District No. 1 (w);
Texas Soil and Water Conservation Board (w);
Texas State Department of Highways and Transportation (w);
Texas Water Development Board (n,w);
Titus, County of, Fresh Water Supply District No. 1 (w);
Trinity River Authority (w);
Upper Guadalupe River Authority (w);
Upper Neches River Municipal Water Authority (w);
West Central Texas Municipal Water District (w);
Wichita, County of, Water Improvement District No. 2 (w);
Wichita Falls, City of (w)

Trust Territory of the Pacific Islands

Federated States of Micronesia, State of Ponape (w);
Northern Mariana Islands, Commonwealth of (g,w),
Department of Public Health and Environmental Services (w),
Utility Commission (w),
Municipality of—
Rota (w),
Luta Soil and Water Conservation (w),
Tinian (w);
Republic of Palau (w);
Samoa, Government of, Department of Public Works (w)

Utah

Bear River Commission (w);
Central Utah Water Conservation District (w);
Five County Association of Government (w);
Goshute Tribal Government (g);
Ogden River Water Users (w);
Salt Lake, County of, Division of Flood Control (w);
Tooele, City of (w);
Tooele, County of (w);
Utah Department of—
Agriculture, Environmental Quality Section (w),
Health, Division of Environmental Health (w),
Natural Resources—
Geological and Mineral Survey (g,n,w),
Oil, Gas, and Mining Division (w),
Water Resources Division (w),
Water Rights Division (w),
Wildlife Resources Division (w);
Washington County Water Conservancy District (w);
Weber Basin Water Conservancy District (w);
Weber River Water Users Association (w)

Vermont

Agency of—
Administration (n),
Natural Resources (g,n);
Department of—
Environmental Conservation (w),
Health, Division of Environmental Health (w)

Virginia

Accomack-Northampton Planning District Commission (w);
Alexandria, City of (w);
Delaware Geological Survey (w);
Hampton Roads Planning District Commission (w);
Henrico, County of, Department of Public Utilities (w);
James City, County of (w);
James City Service Authority (w);
Loudoun, County of (g);
Maryland, Department of—
Environment (w),
State Highway Administration (w);
Metropolitan Washington Council of Governments (w);
Newport News, City of (w);
Northern Virginia Planning District Commission (w);
Prince William Health District (w);
Rappahannock-Rapidan Planning District Commission (w);
Roanoke, City of (w);
Southeastern Public Service Authority of Virginia (w);
University of Virginia, Department of Environmental Sciences (w);
Virginia Department of Mines, Minerals, and Energy, Division of Mineral Resources (n);
Virginia Beach, City of, Water Resources Division (w);
Virginia Institute of Marine Science (w);
Virginia State Water Control Board (w);
Washington, D.C., Department of Public Works (w);
Williamsburg, City of (w);
York, County of (w)

Washington

Aberdeen, City of (w);
Ashland, City of (w);
Bellevue, City of (w);
Chelan, County of, Public Utility District No. 1 (w);
Clark County Intergovernmental Resource Center (w);
Douglas, County of, Public Utility District No. 1 (w);
Eugene Water and Electric Board (w);
Hoh Indian Tribe (w);
King, County of, Department of Public Works (w);
Kitsap, County of, Public Utility District No. 1 (w);
Lewis, County of—
Board of Commissioners (w),
Public Works Department (w);
Nisqually Indian Tribe (w);
Oregon Department of Energy (w);
Oregon Executive Department (w);
Pacific County Commissioners (w);

Pierce, County of, Public Works Department (w);
Portland, City of—
    Bureau of—
        Environmental Services (w),
        Water Works (w);
Puget Sound Water Quality Authority (w);
Quinault Indian Business Committee (w);
Seattle, City of—
    Department of Lighting (w),
    Water Department (w);
Seattle-King County Department of—
    Health (w),
    Public Works (w);
Skagit, County of (w), Department of Public Works (w);
Snohomish, County of—
    Board of Commissioners (w),
    Public Utilities Department (w);
Spokane County Commissioners (n);
Swinomish Tribal Community (w);
Tacoma, City of, Department of—
    Public Utilities (w),
    Public Works (w);
Thurston, County of, Department of—
    Health (w),
    Public Works (w);
Unified Sewerage Agency (w);
University of Washington (g);
Warm Springs Tribal Confederation (w);
Washington Department of—
    Administration, Capitol Buildings and Grounds Facilities (w),
    Community Development (n);
    Ecology (n,w),
    Environmental Quality (w),
    Fisheries (w),
    Human Resources (w),
    Information Services (n),
    Natural Resources (g,n),
    Wildlife (w);
Washington State Community Development (w);
Whatcom, County of (w);
Yakima Tribal Council (w)

West Virginia

Eastern Panhandle Regional Planning and Development Council (w);
Morgantown, City of, Utility Board (w);
New Martinsville, City of (w);
Washington Public Service District (w);
West Virginia Department of—
    Commerce, Tourism and Parks Section (w),
    Health, Office of Environmental Health Services (w),
    Highways (w),
    Natural Resources—
        Division of—
            Water Resources (w),
            Wildlife (w);
West Virginia Geological and Economic Survey (w)

Wisconsin

Bad River Tribal Council (w);
Balsam Lake Protection and Rehabilitation District (w);
Barron, City of (w);
Beaver Dam, City of (w);
Big Muskego Lake District (w);
Brown County Planning Commission (w);
Dane, County of—
    Department of Public Works (w),
    Lakes and Watershed Management (w),
    Regional Planning Commission (w);
Delavan, Town of (w);
Druid Lake Inland Protection and Rehabilitation District (w);
Eagle Springs Lake Sanitary District (w);
Fond Du Lac, City of (w);
Forest County Potawatomi Community (w);
Fowler Lake Management District (w);
Galena, City of (w);
Geological Survey (w);
Green Bay Metropolitan Sewerage District (w);
Green Lake Sanitary District (w);
Hillsboro, City of (w);
Hubbard, Township of (w);
Illinois Department of Transportation (w);
Lac Courte Oreilles Governing Board (w);
Lac Du Flambeau Indians (w);
Lac La Belle Management District (w);
Little Arbor Vitae Protection and Rehabilitation District (w);
Little Green Lake Protection and Rehabilitation District (w);
Little Muskego Lake District (w);
Little St. Germain Lake District (w);
Loon Lake/Wescot Management District (w);
Madison Metropolitan Sewerage District (w);
Marinette County Land Conservation (w);
Mead, Township of (w);
Menominee Indian Tribe of Wisconsin (w);
Merton, Township of (w);
Muskego, City of (w);
Norway, Town of (Wind Lake) (w);
Oconomowoc Lake, Village of (w);
Okauchee Lake Management District (w);
Oneida Tribe of Indians (w);
Peshtigo, City of (w);
Powers Lake Management District (w);
Red Cliff Indians (w);
Rock, County of, Public Works Department (w);
Southeastern Wisconsin Regional Planning Commission (w);
Stockbridge-Munsee Indians (w);
Thorp, City of (w);
University of Wisconsin, Extension, Geological and Natural History Survey (n);
Waukesha Water Utility (w);
Waupun, City of (w);
Whitewater-Rice Lake Management District (w);
Wind Lake Management District (w);
Wisconsin Department of—
    Justice (w),
    Natural Resources (w),
    Transportation (w);
Wisconsin Winnebago Business Committee (w);
Wittenberg, Village of (w)

Wyoming

Attorney General (w);
Cheyenne, City of (w);
Economic Development and Stability Board (w);
Evanston, City of (w);
Evansville, Town of (w);
Freemont, County of (w);
Gillette, City of (w);
Laramie, County of (w);
Medicine Bow Conservation District (w);
Midvale Irrigation District (w);
Northern Arapahoe Tribe (w);
Pinedale, City of (w);
Sheridan Area Water Supply Joint Power Board (w);
Shoshone Tribe (g,w);
Teton, County of (w);
Uinta, County of (w);
Water Development Commission (w);
Wind River Environmental Quality Commission (w);
Wyoming Department of—
    Agriculture (w),
    Environmental Quality (w),
    Game and Fish (w),
    Highways (w);
Wyoming Governor's Office (w);
Wyoming State Engineer (w);
Wyoming Water Research Center (w)

Federal Cooperators

Central Intelligence Agency (g)

Department of Agriculture

Agricultural Research Service (n,w);
Forest Service (g,n,w);
Soil Conservation Service (n,w)

Department of the Air Force (w)

Air Force Academy (w);
Headquarters, AFTAC/AC (g);
Kirtland Air Force Base (w);
MacDill Air Force Base (w);
Occupational and Environmental Health Laboratory (w);
Patrick Air Force Base (g);
Vandenberg Air Force Base (w)

Department of the Army (w)

Aberdeen Proving Ground (w);
Belvoir RD&E Center (g);
Corps of Engineers (g,n,w);
Engineer Topographic Laboratory (g,w);
Fort Bliss Military Reservation (w);
Fort Bragg Military Reservation (w);
Fort Carson Military Reservation (w);
Picatinny Arsenal (w);
Rocky Mountain Arsenal (w);
White Sands Missile Range (w)

Department of Commerce (w)

Bureau of the Census (n);
National Institute of Standards and Technology (g);
National Marine Fish Service (w);
National Ocean Service (n);
National Oceanic and Atmospheric Administration (g,n,w);
National Weather Service (w)

Department of Defense Agencies

Defense Advanced Research Projects Agency (g);
Defense Logistics Agency (w);
Defense Mapping Agency (n);
Defense Nuclear Agency (g);
National Guard Bureau (w)

Department of Energy (g,n,w)

Alaska Power Administration (w);
Bonneville Power Administration (w);
Hanford Project (w);
Health and Environmental Research (g);
Idaho Falls Operations Office (g,w);
Los Alamos National Laboratory (g,w);
Nevada Operations Office (g,w);
Oak Ridge Operations Office (g,w);
Rocky Flats Operations Office (w);
Sandia National Laboratories (g,w);
Savannah River Operations Office (w);
Schenectady Naval Reactors Office (w);
Test Operations Office, Las Vegas, Nevada (g);
Yucca Mountain Project (w)

Department of the Interior

Bureau of Indian Affairs (g,n,w);
Bureau of Land Management (g,n,w);
Bureau of Mines (n,w);
Bureau of Reclamation (g,n,w);
Minerals Management Service (g);
National Park Service (g,n,w);
Office of the Secretary (w);
Office of Surface Mining Reclamation and Enforcement (w);
U.S. Fish and Wildlife Service (n,w)

Department of Justice (w)

Department of the Navy (w)

Naval Facilities Engineering Command (g);
Naval Oceanographic Office (g);
Naval Weapons Center, China Lake (g);
Navy Pacific Division (w);
Office of Naval Research (g);
Pacific Missile Test Center (g);

South Naval Facilities Engineering Command (w);
U.S. Marine Corps (w)

Department of State (g)
Agency for International Development (g,n);
Foreign and Nonforeign Governments (g);
Government of Saudi Arabia (g);
International Boundary and Water Commission, U.S. and Mexico (w);
International Joint Commission, U.S. and Canada (w)

Department of Transportation
Federal Highway Administration (w)

Environmental Protection Agency (g,n,w)
Corvallis Environmental Research Laboratory (w);
Environmental Monitoring Systems Laboratory (g);
Office of Radiation Programs (g);
Office of Water (w)

Federal Emergency Management Agency (g,w)

Federal Energy Regulating Commission Licensees (w)

Library of Congress (n)

National Aeronautics and Space Administration (g,n,w)

National Science Foundation (g,n,w)

Nuclear Regulatory Commission (g)

Tennessee Valley Authority (n,w)

Veterans Administration (w)

Other Cooperators and Contributors

American Society for Photogrammetry and Remote Sensing (n)

Boy Scouts of America (n)

United Arab Emirates (w)

United Nations (g,w)
Inter-America Development Bank (g);
United Nations Development Program (n);
Unesco (w);
World Bank (g)

Yearbook Staff

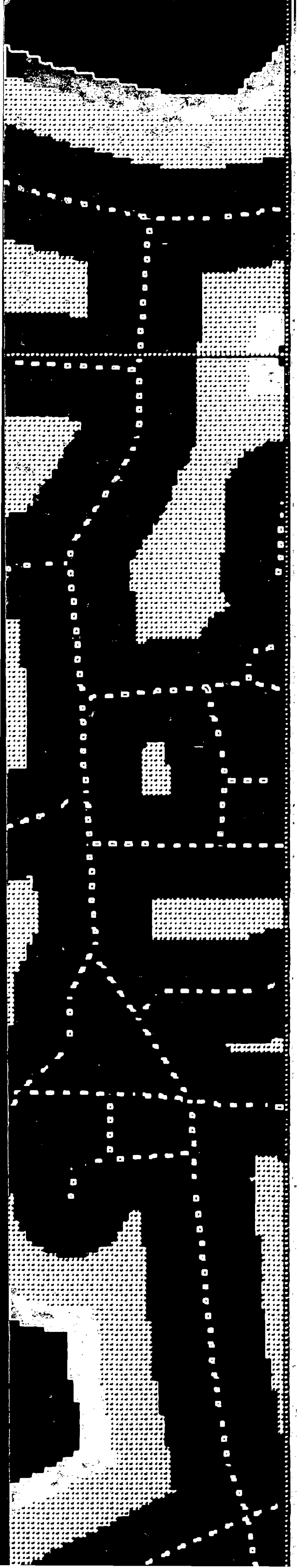
The staff of the USGS Yearbook appreciates comments from readers. If there are features that you particularly enjoy reading or information that you would like to have, but is not included, please let us know. Write to Managing Editor, USGS Yearbook, 119 National Center, Reston, VA 22092.

Annette Kulyk	National Mapping Division	Sunne Rinkus	Graphic Designer
Bonnie D'Agostino	Geologic Division	William A. Dize	Graphics Photographic Specialist
Sandye Holmes	Water Resources Division	Carolyn McQuaig	Typographer
Marti Quigley	Information Systems Division	Linda Jacobsen	Editor
Connie Stephenson	Administrative Division	Gail Wendt	Managing Editor

Please call or write to the following 1991 yearbook authors if you have questions or comments about the information in specific articles. (See the top of page 109 for full regional addresses.)

Gregory J. Allord	(608) 238–9333 ext. 200	505 Science Drive, Madison, WI 53711–1061
Larry L. Amos	(703) 648–4143	514 National Center
Brian J. Andraski	(702) 887–7636	705 North Plaza Street, 114 Federal Bldg., Carson City, NV 89701
Walter J. Bawiec	(703) 648–6148	920 National Center
Kenneth J. Bird	(415) 354–3006	345 Middlefield Rd., Menlo Park, CA 95025
Steven D. Craigg	(703) 648–6981	902 National Center
Robert H. DeAngelis	(703) 648–4539	521 National Center
Michael A. Domaratz	(703) 648–4533	590 National Center
Jay Donnelly	(703) 648–5395	521 National Center
Max M. Ethridge	(703) 648–4650	514 National Center
John W. Ewert	(206) 696–7997	David A. Johnstone Bldg., CVO—Rm. 228, 5400 MacArthur Blvd., Vancouver, WA 98661
Carmelo Ferrigno	(703) 648–7142	804 National Center
Michael E. Field	(415) 354–3088	345 Middlefield Rd., Menlo Park, CA 95025
Stephen R. Gillespie	(703) 648–5705	514 National Center
Kathryn D. Gunderson	(703) 648–7144	802 National Center
Judith A. Gunnells	(703) 648–7612	270 National Center
Larry Harms	(703) 648–7161	804 National Center
Thomas M. Holm	(605) 594–6142	U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198
David G. Howell	(415) 329–5430	345 Middlefield Rd., Menlo Park, CA 95025
Tod Huffman	(703) 648–7128	815 National Center
Mark J. Johnsson	(415) 354–3067	345 Middlefield Rd., Menlo Park, CA 95025
Herman A. Karl	(415) 354–3084	345 Middlefield Rd., Menlo Park, CA 95025
John Michael Kernodle	(505) 262–5310	4501 Indian School Road NE, Suite 200, Albuquerque, NM 87110–3929
Richard D. Krushensky	(703) 648–6060	917 National Center
Kathryn M. Kuivila	(916) 978–4648	Rm. W–2234, Federal Bldg., 2800 Cottage Way, Sacramento, CA 95825
Mark Kutsko	(703) 648–7153	804 National Center
Kory K. Lee	(703) 648–7241	206 National Center
Donald L. Light	(703) 648–5106	511 National Center
Katherine F. Lins	(703) 648–4535	514 National Center
Richard A. MacDonald	(703) 648–7120	804 National Center
Leslie B. Magoon	(415) 354–3010	345 Middlefield Rd., Menlo Park, CA 95025
Robert P. Massé	(303) 236–1510	967 Denver Federal Center
E.J. McFaul	(703) 648–7126	904 National Center
W. David Menzie	(703) 648–6125	920 National Center
James A. Miller	(404) 409–7710	Spalding Woods Office Park, Suite 160, Norcross, GA 30092
Bruce F. Molnia	(703) 648–4120	917 National Center
Wayne L. Newell	(703) 648–6900	926A National Center
Christopher G. Newhall	(703) 648–6747	959 National Center
Richard W. Paulson	(703) 648–6851	407 National Center
Anthony B. Queern	(703) 648–6987	206 National Center
Mitchell W. Reynolds	(703) 648–6960	908 National Center
Brian Schachte	(703) 648–7131	804 National Center
Bert Simon	(703) 648–7283	231 National Center
David R. Soller	(703) 648–6907	926 National Center
John K. Stamer	(913) 842–9909	4821 Quail Crest Place, Lawrence, KS 66049
Elain Stout	(703) 648–7006	809 National Center
Arthur C. Tarr	(303) 236–1605	966 Denver Federal Center
Stephen J. Vandas	(303) 236–4795	414 Denver Federal Center
Nick Van Driel	(703) 648–4185	586 National Center
William H. Wright, Jr.	(703) 648–6514	915 National Center
Ronald B. Zelt	(913) 842–9909	4821 Quail Crest Place, Lawrence, KS 66049

Editor's note: All photographs are by USGS employees unless otherwise noted.



As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.