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U.S. GEOLOGICAL SURVEY

Earth Science in the Public Service

1994

Touching the Lives of Every Citizen, Every Day

U.S. Geological Survey Yearbook Fiscal Year 1994

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, *Director*

United States Geological Survey Yearbook Fiscal Year 1994
ISSN 0892-3442

UNITED STATES GOVERNMENT PRINTING OFFICE: 1995

For sale by U.S. Geological Survey, Map Distribution Box 25286,
Federal Center, Denver, CO 80225

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A New Look, A New Vision

In this, my first year as Director of the U.S. Geological Survey, I felt it was important to set a visionary course, one that ensures that the USGS is recognized for its excellence in science. By this I mean not just the most objective science but science that can be used, science that is relevant, science that is trusted by all users. I am, justifiably I think, proud of the good science—the practical science—that we provide to the Nation.

But I believe that we can do even better. As a bureau of the Federal Government, we are determined that the American taxpayers will realize full value for their investment of tax dollars and for the trust they have placed in both the science and the management of the USGS. I have made both a personal and a professional commitment to developing a dynamic work environment that emphasizes some basic parameters, which I call the 3 C's—cooperation, coordination, and communication—and the 2 R's—relevance and responsiveness. With these key ideas as our watchwords, I am convinced that the USGS can be an even more vital, more viable, and more valued organization to the broad public that it serves.

What you will see in the pages of this Yearbook is a reflection of that new vision and a new look. We have arranged articles according to four principal public policy theme areas—Hazards, Resources, Environment, and Information. In identifying these themes, we seek to communicate more effectively how USGS earth science information contributes to public policy issues, to cooperate and coordinate more efficiently among the many scientific disciplines within the bureau, and to provide a melting pot for the incredible diversity of earth science expertise that we embody. Additionally, these themes require us to focus some of our efforts on ensuring that USGS products are relevant and responsive to public concerns.

In the same way that the disciplines within the earth sciences overlap and are interconnected, so, too, are the public policy themes that we have selected. They are not mutually exclusive but rather are linked in their inherent need for sound, reliable, and impartial earth science information. As John Muir once said, "When you try to separate anything in nature, you find it is connected to everything else." Although the themes can in some ways stand on their own, they are all dependent on one another. As you will see in the articles in each theme section, many could easily be included in other themes as well. We hope that presenting the ongoing work of the USGS in this new way will help our constituents better understand the rich diversity of the Earth that we study and the challenging task of responding to critical earth science questions that require answers.

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One of the public's most basic and persistent questions is, "How safe am I from the effects of natural hazards?" Answering that question is one of the paramount functions of the USGS mission. Whether it is the threat of earthquakes, flooding, landslides, drought, or volcanic eruptions, the USGS is the Nation's primary source of information in addressing the impact of these hazards. We have been working hard through our various natural hazards programs to reduce the huge indirect tax that every citizen must pay to repair and rebuild after the occurrence of natural disasters. This "disaster tax" burden imposed by earthquakes, floods, droughts, landslides, and other such natural events now costs the Nation more than $55 billion dollars each year. We are determined to reduce that tax burden even as it threatens to climb higher as more and more people move into disaster-prone areas and use more of our finite water supply.

An excellent example of our efforts to reduce the disaster tax is the Northridge, Calif., earthquake of January 1994 (see p. 3). The Northridge earthquake, which rocked much of Los Angeles, was comparable in size to the earthquake that devastated Kobe, Japan, just a few months ago. Although significant losses did result in Los Angeles, they were far below the 5,100 deaths and $100 billion in damages suffered in Kobe. The lower losses in the United States came, in part, because of improved building design incorporating knowledge gained directly from USGS earthquake studies.

We are usually the source of primary data behind the flood predictions that you hear on TV. The USGS operates a water data network across the Nation that provides flood information to the National Weather Service and other management and disaster agencies. This network and followup studies, such as the Scientific Assessment and Strategy Team (SAST), were vital to monitoring the extensive flooding on the Mississippi River in 1993 and coping with the aftermath (see p. 8, 12). A single example will suffice to show the value of the work perfomed by the SAST—the town of Valmeyer, Ill., was relocated from the floodplain to the uplands. Our partner in these hazard mitigation efforts, the Federal Emergency Management Agency, reports that the flood-related information provided by the USGS saved many millions of dollars in rehabilitation efforts and will save millions of dollars more in future disaster payments.

Another question that needs to be answered is "Do we have enough resources—and of good enough quality—to meet current and projected needs?" In the area of energy, we need as a Nation to be looking at the broadest spectrum of potential resources, as the article on the future of energy gases attests (see p. 29). The use of natural resources can lead to additional concerns, such as the recent collapse of a New York salt mine (see p. 38) shows. The same water network that we use to provide streamflow information is also used to make many of the water-quality determinations used by local and State governments. As the Nation's largest collector of water information, the USGS documents the improvement or degradation of water quality over time. Our National Water-Quality Assessment is the only ongoing and truly national analysis of the quality of the Nation's water.

Questions of quality and issues of resource degradation lead us into the realm of the environment and what both natural and human activities are doing to alter the natural environment. From a long-term study of contaminants in the Mississippi River (see p. 52) to establishing a database of mine sites in the U.S.-Mexico border region (see p. 47), the USGS is actively engaged in understanding the conditions and functions of environmental systems and determining the factors that are changing those systems. With this type of understanding, we can often identify effective, cost-efficient methods to clean up or prevent environmental contamination while still developing resource potential. Such an approach is needed to protect not only plants and animals but also, ultimately, human health.

The data and information that the USGS provides are the cornerstone of countless decisions that are made every day by policymakers, land planners, and resource managers.

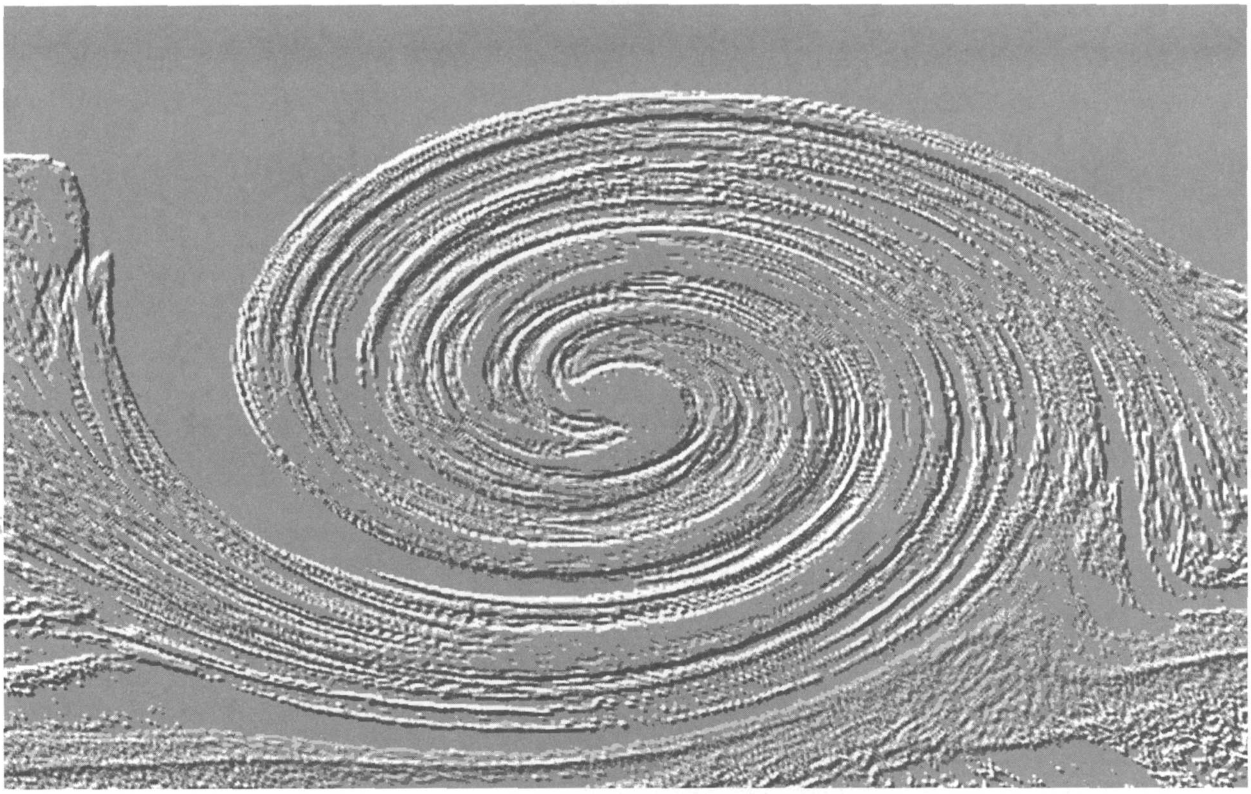
At the core of all USGS work and its value to the public is the vast holding of information about the Earth, for which we are the Nation's foremost collector and archivist. As the many articles in the information section of this Yearbook demonstrate, earth science data are essential to an incredible range of resource and environmental issues and concerns. We are on the cutting edge of many new technologies and innovations in how to gather, process, display, and disseminate earth science information, from a multi-resolution land characterization database designed to monitor changes in land cover (see p. 61) to a coastal circulation computer model that uses parallel processing to help with site characterization for a new sewage-treatment plant for the city of Boston (see p. 70). The data and information that the USGS provides are the cornerstone of countless decisions that are made every day by policymakers, land planners, and resource managers.

Much of the work that we do is in partnership with others. We are at work with more than 1,200 State, local, and other Federal agencies in all 50 States to provide the earth science information that touches and serves the lives of every citizen every day. These partnerships produce savings to the taxpayer by avoiding duplicate efforts and by providing consistent science that can be reused tomorrow. Many of these partners have been with us for many years and share with us in the funding of programs and investigations that benefit State and local interest as well as adding to the national interest by providing information for the public good, as our mission mandates. These partnerships allow us constantly to test our science in the real world.

Our work is also international in scope, reaching out to many nations with whom we share common concerns and similar geology and hydrology. International cooperation is more than just being a good neighbor. As scientists, we benefit immeasurably from the exchange of information with colleagues in other countries and learn more in the process about the resources, hazards, and environmental issues of our own country. Little is known, for example, about the transport and release of mercury or about the processes that control its fate in the environment. Cooperative mineral resource studies with the U.S. Forest Service in Venezuela are providing USGS scientists with information that will help in developing remediation efforts worldwide (see p. 88).

I hope that you will find the new look of the Yearbook and the new vision of the U.S. Geological Survey to be positive changes that ensure we are continuing our commitment to provide "Earth Science in the Public Service."

Gordon P. Eaton
Director, U.S. Geological Survey



Hazards

Understanding natural hazards such as earthquakes, volcanic eruptions, landslides, floods, subsidence, and naturally occurring toxic materials is a critical public issue facing the Nation and the world. Part of the mission of the USGS is to help reduce the "disaster tax" that every citizen pays, regardless of where a hazard occurs. Each year for the past several years, natural disasters have cost the Nation about $50 billion—from the devastation of Hurricane Andrew to the long months of flooding in the Midwest to the renewed anxiety caused by the Northridge, Calif., earthquake. The USGS has a particular charge to help the Nation understand, prepare for, and respond to these natural disasters. Our ability to assist the country in coping with natural disasters comes from our unique combination of earth science expertise, as the articles in this section show. By better understanding the mechanisms of natural hazards, public policymakers can plan and manage in ways that will mitigate the severity of these hazards. Through scientific research, societal planning and preparedness, and proper emergency response, the damaging effects of natural hazards will be lessened, and economic and social losses can be reduced.

The Northridge Earthquake

On the morning of January 17, 1994, at 04:30 (PST) a magnitude 6.7 earthquake severely shook the San Fernando Valley and other regions in and around Los Angeles in southern California. The Northridge earthquake was the most costly earthquake in U.S. history, causing estimated losses of $20 billion. Fifty-seven deaths and more than 9,000 injuries to people in the region were attributed to the earthquake, and 20,000 people were displaced from their homes. The earthquake was moderate in size, but, because it occurred directly under the populated San Fernando Valley, its impact on the people and structures of the Los Angeles area was immense. Thousands of buildings experienced significant damage, and more than 1,600 were "red tagged" as unsafe to enter. Another 7,300 buildings were "yellow tagged" (restricted to limited entry), and minor damage was incurred in many thousands of other structures. The 10 to 20 seconds of strong shaking collapsed buildings, brought down freeway interchanges, and ruptured gas lines that exploded into fires. But the early-morning occurrence was a fortuitous life saver, because there were only a few people in many of the large buildings and parking structures that collapsed, and traffic was very light on the freeway overpasses that fell.

But the early-morning occurrence was a fortuitous life saver...

U.S. Geological Survey (USGS) scientists responded quickly to the Northridge earthquake, investigating and reporting on both geological and societal effects. In the month following the earthquake, USGS personnel focused on:

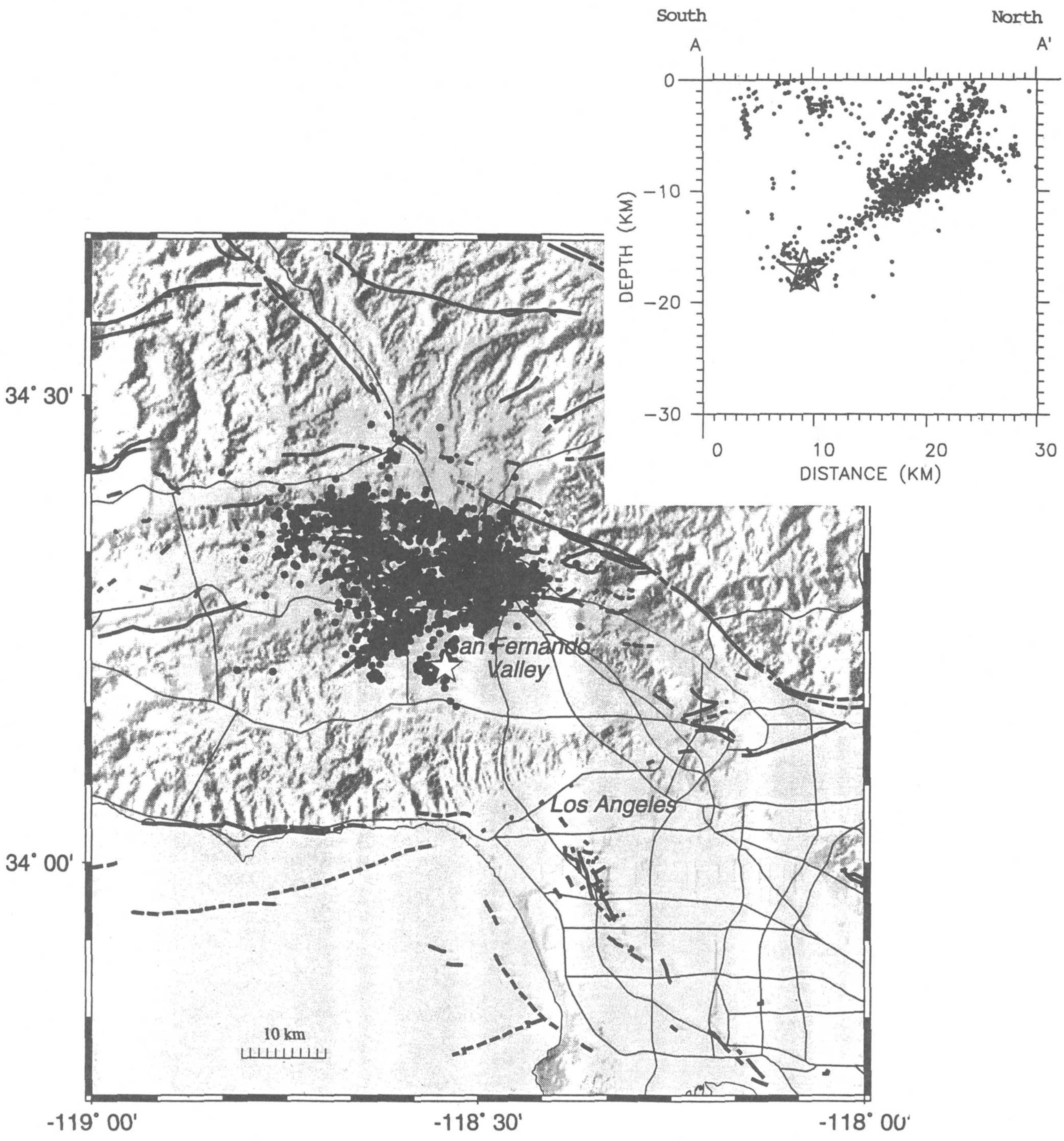
- Monitoring the current seismic activity and providing information about seismic hazards to local government, media, and the public.
- Collecting data on seismic hazards in southern California to help mitigate damage from future earthquakes.

Early on January 17, the USGS/Caltech offices in Pasadena, Calif., became the center for seismic information collection and dissemination. The large seismic network that monitors earthquakes in southern California is operated from this location, and, within minutes of the Northridge earthquake, scientists began analyzing data from the network and broadcasting the location and magnitude to the public. USGS and Caltech scientists kept up a steady flow of information to the public over the next few days as details about the earthquake and its damaging effects were inferred from seismic data and observed by field crews. To maintain good communications with emergency response groups, a USGS liaison was stationed at the headquarters of the Federal Emergency Management Agency a few miles away in Pasadena, and a California Office of Emergency Services liaison was detailed to the USGS operations center in Pasadena. These efforts to provide information about earthquakes continued throughout the next few months as the Los Angeles area was rocked by hundreds of felt aftershocks.

Throughout the mainshock and aftershock sequence, real-time earthquake information was relayed to members of the Caltech-USGS Broadcast of Earthquakes (CUBE) program. This project is a cooperative effort to develop a system of rapid earthquake information dissemination in southern California. Earthquake locations and magnitudes are sent to pagers worn by scientists and emergency personnel and to computer displays throughout southern California and other parts of the country within about 5 minutes of an earthquake occurrence. Governmental emergency response agencies, water and power utilities, railroads, and telephone companies all make immediate use of this vital information.

Seismological Observations

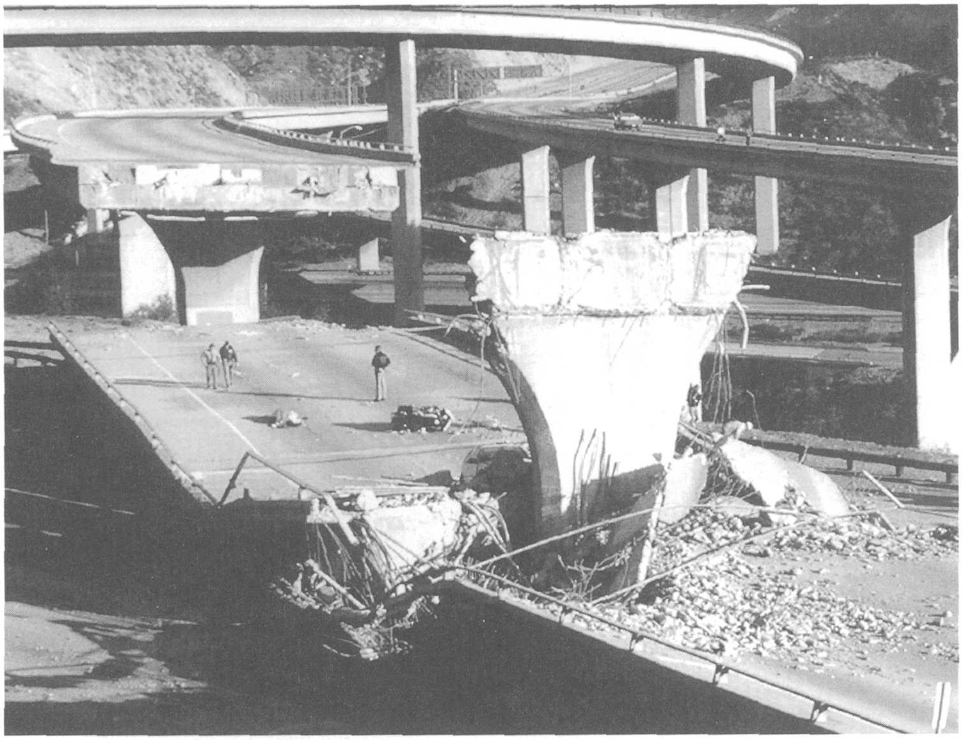
Following the mainshock, there were thousands of aftershocks, including 7 magnitude 5 events, 38 magnitude 4 events, and over 300 magnitude 3 events during the subsequent 4 months. The locations of the aftershocks are distributed across an area of about 30X20 kilometers and map out the extent and orientation of the fault plane. These locations clearly show a plane dipping toward the southwest, which is interpreted to be the rupture surface of the thrust fault that



The locations of several thousand aftershocks of the Northridge earthquake are shown on this map by solid circles. The area covered by the aftershocks roughly indicates the fault that ruptured under the northern San Fernando Valley. The star is the epicenter of the mainshock, where the rupture began. The depth cross section (upper right) shows how the aftershocks outline a fault plane that extends from a depth of 18 kilometers in the south up to 7 kilometers in the north.

produced the earthquake. This plane extends upward from the mainshock hypocenter at 18 kilometers toward (but not reaching) the surface. Preliminary inversions of seismic waveform data indicate slips of as much as 4 meters on the fault plane at depths below 5 kilometers; little slip occurs on the shallow portions of the fault.

The location of the fault plane as inferred from the aftershock distribution does



PHOTOGRAPH COURTESY OF *THE LOS ANGELES TIMES*

The body of a Los Angeles Police Department officer lies near his motorcycle after plunging off the Antelope Valley Freeway overpass, which collapsed onto the Golden State Freeway during the Northridge earthquake.

not correspond to any mapped geologic fault. The earthquake occurred, however, within a system of known thrust faults that extends along the northern edge of the San Fernando Valley. Like the fault that produced the Northridge earthquake, many of these faults are "blind thrusts," which do not extend to the surface and therefore are difficult to recognize prior to large earthquakes.

The extensive damage caused by the earthquakes was mainly a result of intense shaking. The large-amplitude motions were recorded on many strong-motion instruments within the Los Angeles area, producing one of the best data sets of strong ground motions. The recordings showed peak accelerations of 0.5 to 1.0 *g* in the aftershock area and decreasing to 0.1 *g* at distances of about 50 km. Several sites close to the epicenter area recorded accelerations over 1 *g*. These high levels of ground motion and the resultant widespread damage emphasized the need for a better understanding of how local geology affects the levels of ground shaking. A coordinated effort by USGS and university seismologists deployed more than 75 portable seismographs for recording aftershocks to study the complicated wave propagation and local site effects. Instruments were placed in many severely damaged areas of Northridge, Sherman Oaks, and Santa Monica, as well as the

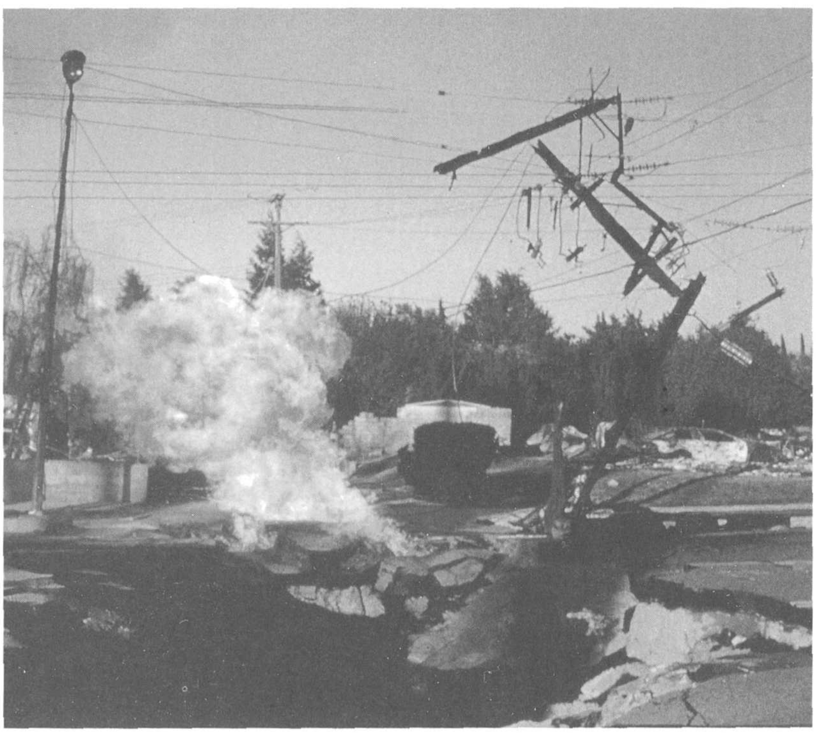
Like the fault that produced the Northridge earthquake, many of these faults are "blind thrusts," which do not extend to the surface and therefore are difficult to recognize prior to large earthquakes.

A *g* of acceleration is equivalent to the force of gravity. A few sites near the Northridge earthquake recorded more than 1 *g* of vertical acceleration. These ground movements would have been capable of throwing objects (of any mass) into the air.

Support for the Southern California Earthquake Center

As a practical example of how its national earthquake research expertise can be applied locally, the U.S. Geological Survey (USGS) has added $1.2 million to a cooperative agreement with the University of Southern California (USC) for the operation of the Southern California Earthquake Center. Since 1991, the USGS has obligated over $6 million in funds in support of this vital local center, which has been charged with educating the public about earthquake activity in southern California. Through activities such as a public real-time seismic data center, an educational outreach program for high school and elementary school pupils, and workshops for professors of engineering and seismology, USC and USGS scientists carry out comprehensive data collection and public outreach efforts in support of the national earthquake research effort.

Strong shaking from the Northridge earthquake collapsed this parking structure on the campus of the California State University at Northridge. Because the earthquake occurred at 4:30 a.m., no people were in the structure.



A ruptured gas main along Balboa Boulevard in Granada Hills caused this fire. Several homes in the area burned down, but, because there was no wind, most fires were easily contained.

collapsed freeway sites at the interchange of Interstate 5 and Highway 14, Highway 118 near Woodley, and Interstate 10 near La Cienega.

Geodetic Observations

Benchmarks resurveyed by using the Global Positioning System (GPS) showed significant permanent ground deformation caused by the earthquake. Vertical uplifts of 40 to 50 centimeters and horizontal movements of 2 to 20 centimeters occurred in the aftershock region. These movements are consistent with the fault geometry derived from seismological observations. Preliminary modeling of the data indicates that slip of 2.5 to 3.5 meters occurred on a 10×10-kilometer patch of the fault. The motion was primarily thrust faulting, and most of the slip occurred at depths greater than 6 kilometers. Following the Northridge earthquake, a number of GPS receivers were permanently installed to provide continuous monitoring of deformations in the San Fernando Valley and Los Angeles basin.

Geological Observations

The lack of evidence of tectonic surface ruptures suggests that the Northridge fault did not extend to the surface. This observation is consistent with seismologic and geodetic data, which show that all slip occurred at depths below 5 kilometers. However, there were observed regions of surface cracking and deformations, which were thought to be the result of strong shaking rather than direct fault ruptures. The most extensive area of ground deformation was in Portrero Canyon on the northern side of the Santa Susana Mountains, where a series of discontinuous tension cracks and normal faults had displacements of as much as 60 centimeters. None of the deformation was associated with any previously mapped surface fault. Another system of small cracks was studied in Granada Hills, where ground deformations caused numerous water- and gas-main ruptures. These features were also caused by ground shaking rather than tectonic faulting.

Extensive landslides occurred in the younger sediments of the western Santa Susana Mountains, Oak Ridge, and Big Mountain areas. There were thousands of landslides, rock falls, and soil failures that occurred as far as 70 kilometers from the epicenter. Fortunately, most of these were in relatively unpopulated areas. Rock falls that choked the ravine bottoms of many canyons in the Santa Susana Mountains presented postearthquake hazards. Had heavy rains fallen, the rock falls could have been saturated and mobilized into debris flows that would have threatened structures near the mouths of the canyons.

The extent of liquefaction caused by this earthquake was much less than what would have been expected, given the historical ground-water levels and the strong levels of shaking that occurred. The reason was probably the lower-than-average water-table levels in the San Fernando Valley. Localized liquefaction and lateral spreading took place in the San Fernando Valley (primarily settling basins along the Los Angeles River) and other areas in Simi Valley, Santa Monica, and Redondo Beach.

Building Safety Net(work)s for Earthquakes

Continuing its work to characterize the regions of the Nation where earthquakes are a public safety risk, the U.S. Geological Survey (USGS) awarded 163 grants, valued at $10 million, to colleges and universities to continue building the critically needed information base for applications such as standards for issuing earthquake forecasts, criteria for building codes and seismic safety standards, and national and regional seismic networks. The USGS also signed 15 cooperative agreements, valued at $2.8 million, with universities to support the U.S. National Seismic Network, one of the key components in understanding earthquake risks from a national perspective. Pilot projects are underway with several regional networks to develop a common model for integrating regional and national networks. Such cooperative research under the USGS-administered National Earthquake Hazards Reduction Program underscores the value of a national program to help identify earthquake hazards, assess earthquake risks, and monitor seismic activity across the United States. The close tie-in through State colleges and universities ensures that the USGS can work effectively with State and local governments and industry to inform them of seismic risks in their areas and to develop building codes and seismic safety standards that protect lives and property.

Conclusions

Scientists have issued frequent warnings about seismic hazards in the Western United States, and this earthquake tested the level of southern California's preparedness. Some successful strategies were the result of past experiences, and failures pointed out areas where more work was needed. On the positive side, information gained from scientific efforts of the National Earthquake Hazard Reduction Program, combined with some of the better seismic building practices in the United States, helped to limit the loss of life. In other parts of the world where these types of programs do not exist, similar-sized earthquakes (for example, India in 1993 and Armenia in 1988) have caused thousands of deaths. On the negative side, building construction was not adequate to prevent widespread structural failures in many communities, such as Northridge, Simi Valley, Sherman Oaks, North Hollywood, and Santa Monica. The Los Angeles freeways collapsed at 7 sites, and another 170 bridges suffered varying amounts of observable damage. Repair work on the bridges caused traffic problems for many months following the earthquake.

The large amount of damage caused by the Northridge earthquake is a consequence of an active geologic structure existing within an urban environment. The type of fault that produced the Northridge earthquake is not unique to the San Fernando Valley. Similar structures exist throughout the area, and there is geologic evidence for several blind thrusts in the Los Angeles basin that are capable of producing events even larger than Northridge. Large earthquakes on these faults could present serious problems for densely populated areas, including downtown Los Angeles, which contains many high-rise buildings. However, the problem of populated areas in close proximity to earthquakes is not limited to Los Angeles. Portions of the San Andreas fault are adjacent to San Bernardino and San Francisco. The Hayward fault passes through densely populated areas of Oakland and East Bay communities. Portland, Oreg., Seattle, Wash., and Memphis, Tenn., all are located in earthquake-prone areas. The lessons learned from the Northridge earthquake about the levels of strong ground shaking produced by a moderate earthquake and the subsequent damage to populated areas should be applied to building construction and earthquake preparedness in all of these cities.

This report was compiled from information gathered by many scientists from the USGS, the California Institute of Technology,

Liquefaction is the process by which wet, loosely compacted soils are transformed by earthquake shaking to a liquid state.

For more information on the Northridge earthquake, contact Jim Mori at:

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Earthquakes similar in size to the one that occurred in Northridge are relatively common around the world. For example, in 1993, there were 141 earthquakes of magnitude 6.0 to 6.9 worldwide. Fortunately, most of these events were not near populated areas.

Earthquakes in 1993
(from the USGS National Earthquake Information Center)
1 M 8.0 to 8.9
13 M 7.0 to 7.9
141 M 6.0 to 6.9

the Southern California Earthquake Center, and the Jet Propulsion Laboratory.

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Lisa Wald
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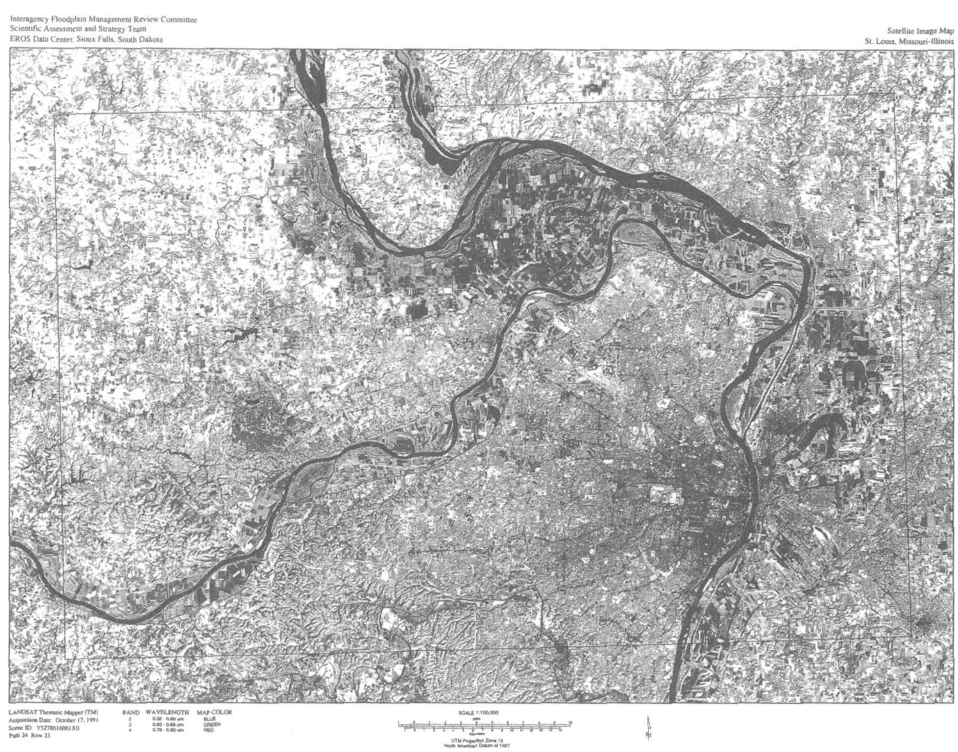
After the Flood of 1993: The Scientific Assessment and Strategy Team

In late summer 1992, after several years of drought, significant precipitation returned to much of the upper Mississippi River basin. Rain and snow continued over the eastern portions of the basin for the remainder of the year and saturated the soils. By late spring of 1993, runoff of tremendous proportions flowed into the floodplains. Throughout July and August 1993, devastating floods hit the lower Missouri River, the upper Mississippi River, the Illinois River, and many of their tributaries. Thirty-eight lives were lost, and estimated damages were between $10 billion and $16 billion.

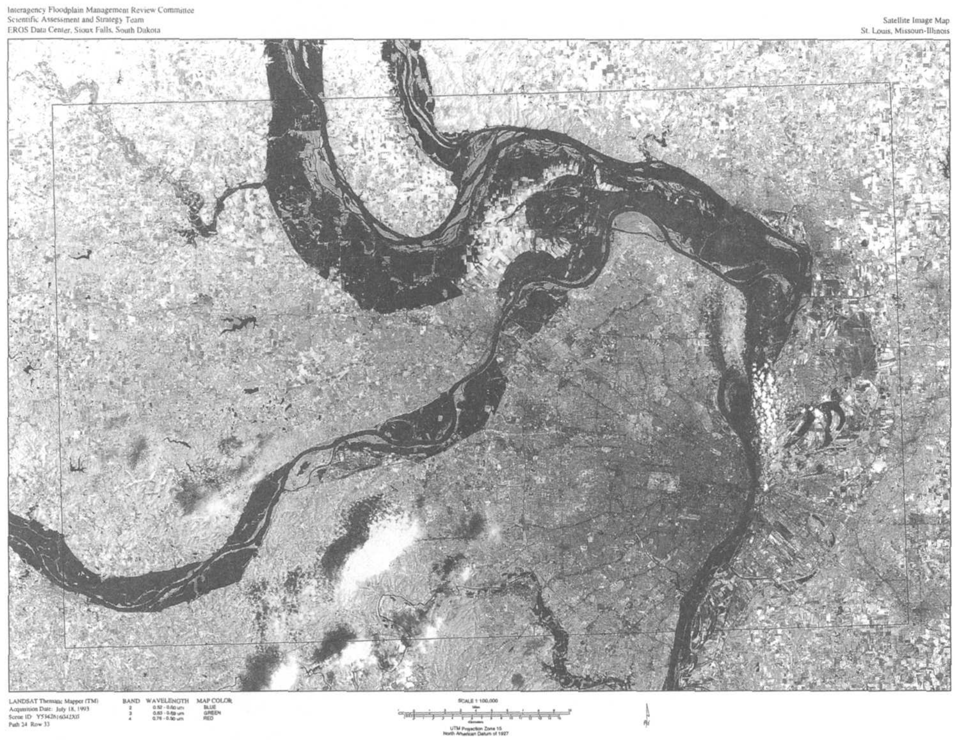
The Scientific Assessment and Strategy Team

The Administration, recognizing the high cost of repairing levees and other infrastructures, rebuilding and floodproofing homes, reclaiming agricultural lands, and reestablishing the economic system, decided to reexamine the use of floodplains in the upper Mississippi River basin.

On November 24, 1993, the Scientific Assessment and Strategy Team (SAST) was established by the Assistant to the President for Science and Technology Policy, the Associate Director of the Office of Management and Budget, and the Director of the Office of Environmental Policy. The team was made up of members from the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency (USEPA), the Federal Emergency Management Agency, the U.S. Fish and Wildlife Service, the National Biological Service, the Soil Conservation Service, and the U.S. Geological Survey (USGS). The USGS was directed to lead this interdisciplinary, interagency group.



Landsat Thematic Mapper image (from October 17, 1991) of river conditions at St. Louis, Mo., prior to the 1993 floods showing where the lower Missouri River and upper Mississippi River meet.



Landsat Thematic Mapper image (from July 18, 1993) showing the near-maximum stage of the July 1993 flood peak at St. Louis, Mo.

The SAST mission is to provide scientific advice and assistance to Federal officials responsible for decisions about flood recovery in the upper Mississippi River basin and to develop information on river-basin management. The formal objectives of the SAST are to:

- Develop a database for mapping, scientific analysis, and decisionmaking.
- Produce maps showing base information and vulnerability to flooding.
- Prepare reports documenting the products of the SAST and the methodologies used to produce them and identify the monitoring, research, modeling, data management, and distribution requirements needed to support integrated river-basin management.

The Interagency Floodplain Management Review Committee

Shortly after the establishment of the SAST, another group known as the Interagency Floodplain Management Review Committee (IFMRC) was formed to determine the major causes and consequences of the flood of 1993, to evaluate the performance of existing floodplain management and related watershed management programs, to recommend changes in policies and programs, and to achieve risk reduction, economic efficiency, and environmental enhancement in the floodplain and related watersheds. The IFMRC also identified legislative initiatives that might be proposed by the Administration. As the scientific arm of the IFMRC, the SAST provided more than 150 maps and analyses for IFMRC use. The IFMRC has completed its tasks and been dissolved, but the SAST continues to conduct analyses and to gather and distribute scientific data.

Data and Analysis

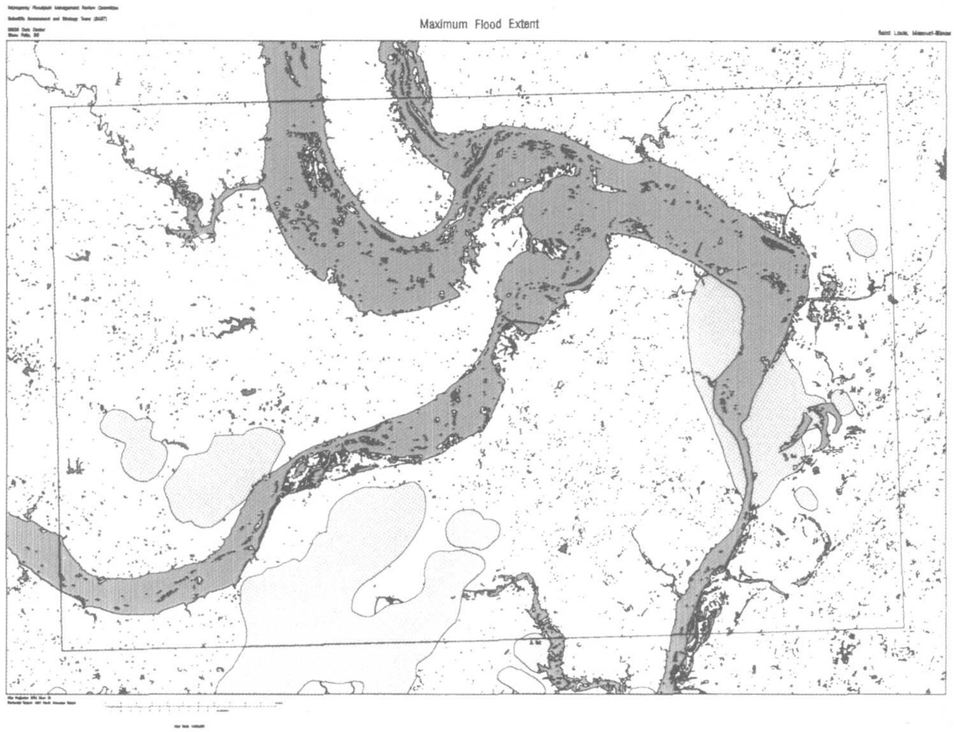
The SAST's first task was to identify and integrate existing data and information. Because management of the upper Mississippi River basin is inherently spatial, geographic information systems (GIS) and digital image-processing technologies were used. Where possible, existing data were integrated. The SAST used readily available digital data and also digitized current and historical maps. New data were created from field information and remote sensing. Hydraulic models were run, analyses were

SAST data are being made available as they are checked for quality. An interagency clearinghouse is being established to ensure that the most current digital data are distributed as soon as possible. The data will be made available online, nearline, or offline, depending on the size or type of data. Already, some of the data are available on the Internet by using World Wide Web with an X-Mosaic front end.

SAST data can be accessed by opening the Uniform Resource Locator (URL) and entering:

http://edcwww.cr.usgs.gov/sast-home.html

The clearinghouse is being used as a prototype for the Federal Geographic Data Committee (FGDC), which is responsible for planning the National Spatial Data Infrastructure, and is testing some FGDC concepts. As such, it is part of the national information infrastructure and the information superhighway.



Computer-generated map showing the maximum flood extent at St. Louis, Mo., during the floods of 1993. Darker shades represent flooded areas and streams; lighter areas are probably clouds.

conducted in the field and by using remote sensing, literature was reviewed, results were reported, maps were produced, and a digital-data clearinghouse was established.

Database

The SAST built a database of some 240 gigabytes of digital data, including readily available agency data such as 1:100,000-scale digital line graph files, the USEPA's toxins release inventory, and Thematic Mapper (TM) data for the entire upper Mississippi River basin as well as TM data for the area hardest hit by the floods. It also contains less commonly available data, such as interpretations of sedimentation and scour, and spatial and attribute information on all major levees on the main stems of the upper Mississippi, lower Missouri, and lower Illinois Rivers.

Hydraulic Models

Upland models.–The SAST ran hydraulic and hydrologic models to estimate the effects of various land-treatment practices in the uplands. Four distinct watersheds were tested in different physiographic regions. The results clearly showed that the effects of land treatment varied in regions of different physical characteristics.

Floodplain model.–A modeling effort was conducted to gain a better understanding of the effects of levees and different land uses on the floodplains. The UNET model, available through the U.S. Army Corps of Engineers, is a one-dimensional, steady-state hydraulic model that treats areas affected by levees as storage cells. This model was run for the main stem of the Mississippi River from Cairo, Ill., to Hannibal, Mo., along the Missouri River from its mouth to Hermann, Mo., along the Illinois River from its mouth to Meredosia, Ill., and along the Salt, Meramec, and Kaskaskia Rivers from their mouths to the first gaging station. Results of running various scenarios after calibrating the model to the 1993 floods as well as two earlier, less intensive floods showed that removing the levees

...removing the levees would have lowered the stage of the floods....

would have lowered the stage of the floods, but the amount depended on the use to which the overbank lands were put. However, the flood stage would have been reduced only a few feet in most places in a flood the size of the 1993 flood. In addition, for overbank conditions that significantly reduced conveyance, the flood stage could actually rise. For example, if dense forest covered the floodplain, the study showed that the flood would have been higher in some locations.

Analysis

The problem of flooding includes both upland and floodplain issues. Five current studies are described here.

Regionalization scheme.–The SAST drafted a regionalization scheme for the uplands based on slope variance, which was compared to variables such as topography, soil type, soil moisture holding capacity, and surface-water ponding. Further refinement of this scheme will be useful in determining appropriate upland land-treatment practices for different places.

Dynamic geomorphology.–The flood of 1993 provided a unique opportunity to examine the effects of floods on sedimentation and scour. "Nature's experiment" left a temporary record useful for determining the effect of energy variations within the flood on both the engineered environment and the natural floodplain.

Levees.–The location of levees on the floodplain clearly affects their effectiveness and durability. The sections of levees that are predictably at risk are now known to include areas occupied by coarse surficial materials deposited by one or more channels active in the past, areas along downstream channel banks between the bends of meanders, areas along tributary channels subject to significant crossflow conditions during flooding, and areas along narrow passages of water between islands and the mainland.

Habitat restoration.–Understanding the dynamics of the geomorphology on the floodplain improves the chances of finding suitable habitat restoration sites. Areas where changes in channel and sand bar locations take place are sites where new plant growth takes hold. These sites are necessary for aquatic species that form an important part of the natural food web. As these growths mature, new places must be created naturally for additional new growth.

Geomorphology and surficial geology.–SAST scientists examined satellite images, aerial photographs, and historical maps augmented by field observations to determine the location of high-, medium-, and low-energy floodplain terraces at an initial level. These areas are being mapped as the analyses are refined. Information thus gathered will help identify locations suitable for different land uses, including agriculture, habitat restoration, industry, and commerce.

Reporting

The SAST contributed significantly to parts I through IV of the IFMRC report and wrote a scientific document that was published as part V of the report. The report is the first in a series that will include the database report; proceedings of the hydraulic, hydrologic, and ecologic modeling workshop; background reports; and numerous articles in scientific journals.

Maps

Part of the SAST's responsibility is to make data available. A number of maps were produced for the IFMRC for its analysis and for use by appropriate agencies. The base maps portrayed roads and watercourses. Mylar overlays showed levees and their ownership, extent of flooding, historical changes in stream channels, floodplains having 1 and 0.2 percent chances of flood occurrence, existing habitat locations, and other information. A more detailed set of maps under consideration will show the above information plus historical and current land-use and land-cover data, floodplain geomorphology, surficial geology, and other variables necessary for making decisions on the floodplain. Prototypes will be published in the USGS's Miscellaneous Investigation series of maps and will be put on compact disc-read only memory (CD-ROM) for distribution.

Some of these data and others have already been incorporated into a computerized demonstration capable of answering questions such as:

- Where are all of the toxics-release inventory sites that were affected by the 1993 floods? Are any of them in the floodplains?

- What general locations, according to the geomorphic criteria, are most suitable for aquatic habitat restoration?
- What levees were overtopped, topped, or breached during the 1993 floods?

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Conclusion

The upper Mississippi River basin system is complex, and its various aspects are interrelated. Actions taken on one part of the system can affect other parts of the system to a greater or lesser degree. Therefore, the system must be treated as a whole when making decisions on how best to serve the needs of different areas within the system. The SAST is conducting a customer-driven activity based on a specific regional and national need. The team's experience results in lessons not only for science but also for science management and for the interaction between science and the decisionmaking process. It is advancing science both by research in floodplain dynamics and by applied research in floodplain and upland management. The team is investigating and testing various data sets as well as developing new ones according to need. It is a model for improving our understanding of data and information integration, management, and dissemination and is a proving ground for data networking.

Both Government and private organizations are already basing restoration and pilot field study decisions on SAST data. The SAST has proven to be an excellent example of a temporary, high-performance interagency organization, the results of which will be valuable for years to come.

John Kelmelis
is the Director of the Scientific Assessment and Strategy Team and was a member of the IFMRC.

Missouri River Basin Earth Resources Mapping Group

In addition to flood-related problems, a variety of other earth-science-related issues also affect land-, mineral-, and water-use decisions throughout the Missouri River basin. To identify and study these issues, the U.S. Geological Survey and the geological surveys of Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Wyoming have formed the Missouri River Basin Earth Resources Mapping Group. A major function of the group is to encourage collaboration among Federal, State, and local agencies on the collection, interpretation, and use of natural resource information within the basin. This multidisciplinary effort focuses on interactions between human activities and the natural systems of the region. The group has identified four regionally important categories of human activity that relate closely to a variety of earth-science issues: urbanization, agriculture, mineral or energy extraction, and human-induced changes to natural systems. Issues associated with urbanization include flooding, ground failure, shrinking and swelling soils, subsidence, earthquakes, and extraction of construction materials. Issues related to agricultural activities include ground- and surface-water consumption, land and water contamination from agricultural chemicals, depletion of soil nutrients, salinization, wetland loss, and accelerated soil erosion, sedimentation, and runoff from cultivated or overgrazed lands. Issues related to mineral and energy extraction include mine drainage, leaching of waste materials, land subsidence, and accelerated erosion and sedimentation from disturbed lands. Issues associated with changes to natural systems include accelerated erosion and sedimentation and the resulting impacts on wetlands and associated habitats. These issues, although resulting from activities within the basin, may have far-reaching effects outside the basin as well.

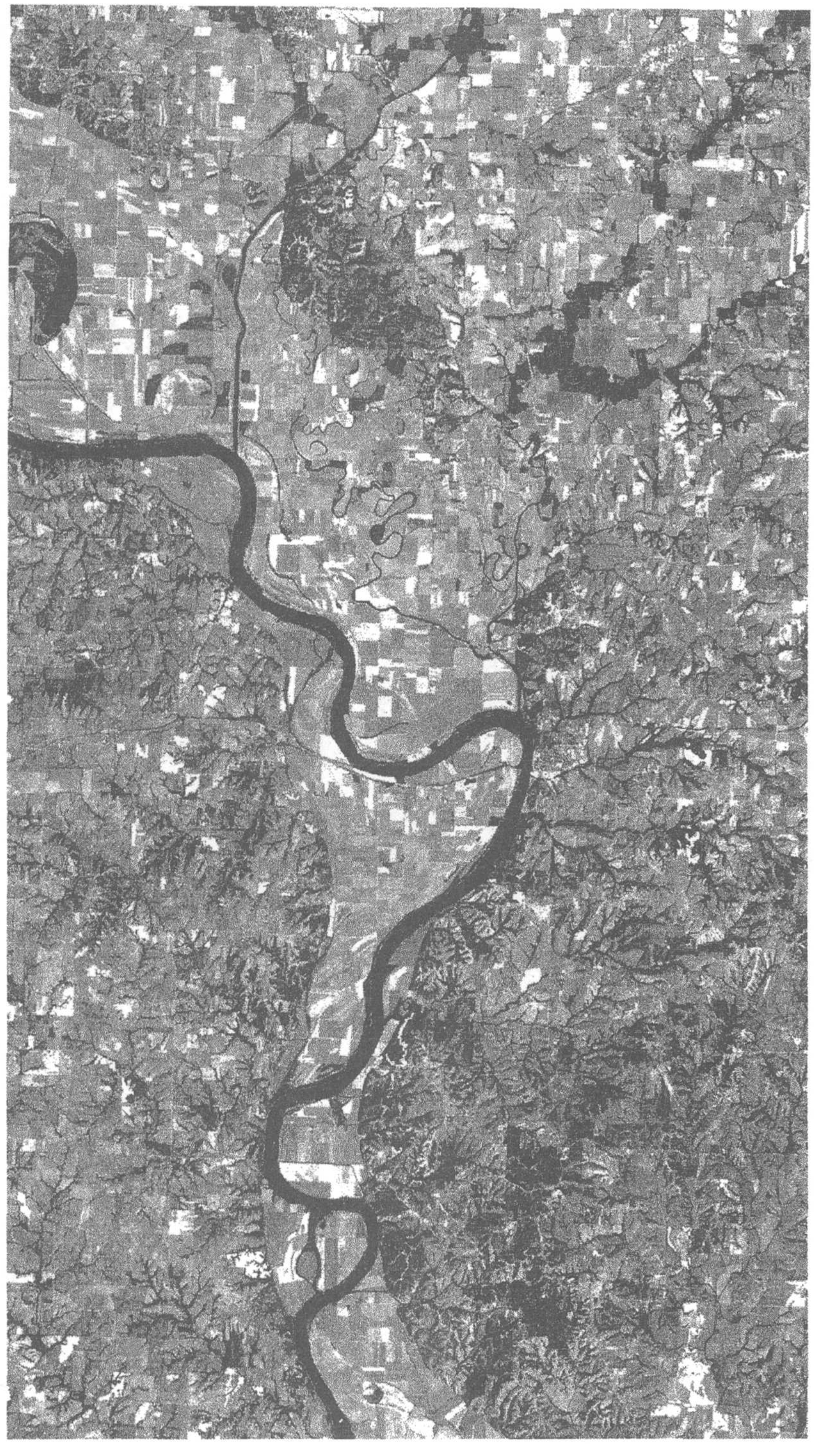
W.H. Langer
is USGS coordinator of the Missouri River Basin Resources Mapping Group and an expert in regional geologic mapping and analysis.

Impact of the 1993 Floods in the Upper Mississippi River Basin

The 1993 floods in the upper Mississippi River basin were without precedent in modern North America. As measured by precipitation amounts, river levels, flood duration and extent, and economic losses, they surpassed any previous flood in the history of the United States. Seasonal rainfall records were broken in 9 Midwestern States, 95 National Weather Service forecast points experienced record flooding, and 45 U.S. Geological Survey (USGS) gaging stations recorded peak discharges exceeding the 100-year-flood value; many of these stations remained above flood stage for weeks.

These floods clearly showed that people and property throughout the Midwest remain at risk to the hazard of riverine flooding; as the Nation's population continues to increase, this risk is also increasing. Average annual riverine flood damages have exceeded $3 billion

The upper Mississippi River basin is one of several ecosystems targeted by the Department of the Interior for intensive investigations and coordination activity. The U.S. Geological Survey and other agencies are contributing scientific expertise as one of the cornerstones in resource decisionmaking. Enhanced scientific understanding will improve ecosystem management and help resource-management agencies generate solutions that successfully resolve environmental problems.



Landsat Thematic Mapper satellite image showing pre-1993 flood conditions near Glasgow, Mo. (September 24, 1992). As the distribution of agricultural fields clearly shows, nearly all of the floodplain in this area was under cultivation before the 1993 floods; wetland areas were primarily limited to the active channel of the Missouri River, tributary channels, and immediately adjacent areas. Only one large oxbow lake (upper left) remained viable.

Among the principal–and not surprising–findings of postflood analysis is that flooding cannot be fully controlled; therefore, the risk of flooding cannot be wholly avoided. Moreover, the costs of flooding have become so high that they cannot be fairly or adequately shared without an aggressive program of damage avoidance and mitigation. Thus, the conceptual foundation of floodplain management needs to be redefined. Informed floodplain management requires a new scientific focus, one that considers not only where and how often but also precisely how it will flood. How energetically? With what concentration of force? With what potential for structural damage or for extensive scour and deposition and where? Detailed geologic, geomorphic, and hydrologic assessments of floodplains are required to fully answer these questions and thus to provide timely and relevant information to support a coordinated program of floodplain management by Federal, tribal, State, and local government agencies.

To learn the answers to these vital questions, USGS scientists are studying the lower Missouri River floodplain between Kansas City and St. Louis, Mo. Mapping and analytical activities include:

- Mapping the geomorphology and surficial geology of the floodplain.

Landsat Thematic Mapper satellite image of the area near Glasgow, Mo., showing flood conditions on August 1, 1993, 3 days after the main flood crest in this area. River flow at this time was approximately 60 to 80 percent of peak flood flow. Even at this time, flood waters (shown in black) covered the entire floodplain from bluff to bluff in most areas. One small cloud obscures a small area of the floodplain in the left-central part of this image.

- Compiling an archive of historical channel and floodplain change.
- Analyzing regional patterns of flood-induced erosion and sedimentation.
- Developing conceptual models for predicting levee-failure risks and impacts.

Informed floodplain management requires a new scientific focus, one that considers not only where and how often but also precisely how it will flood.

These activities are being conducted as part of the Scientific Assessment and Strategy Team effort collaboratively with researchers from several Federal agencies, including the National Biological Service, the U.S. Army Corps of Engineers, the Soil Conservation Service, and the National Aeronautics and Space Administration. The results will be communicated to policymakers and other interested groups through a coordinated series of printed maps and digital map products.

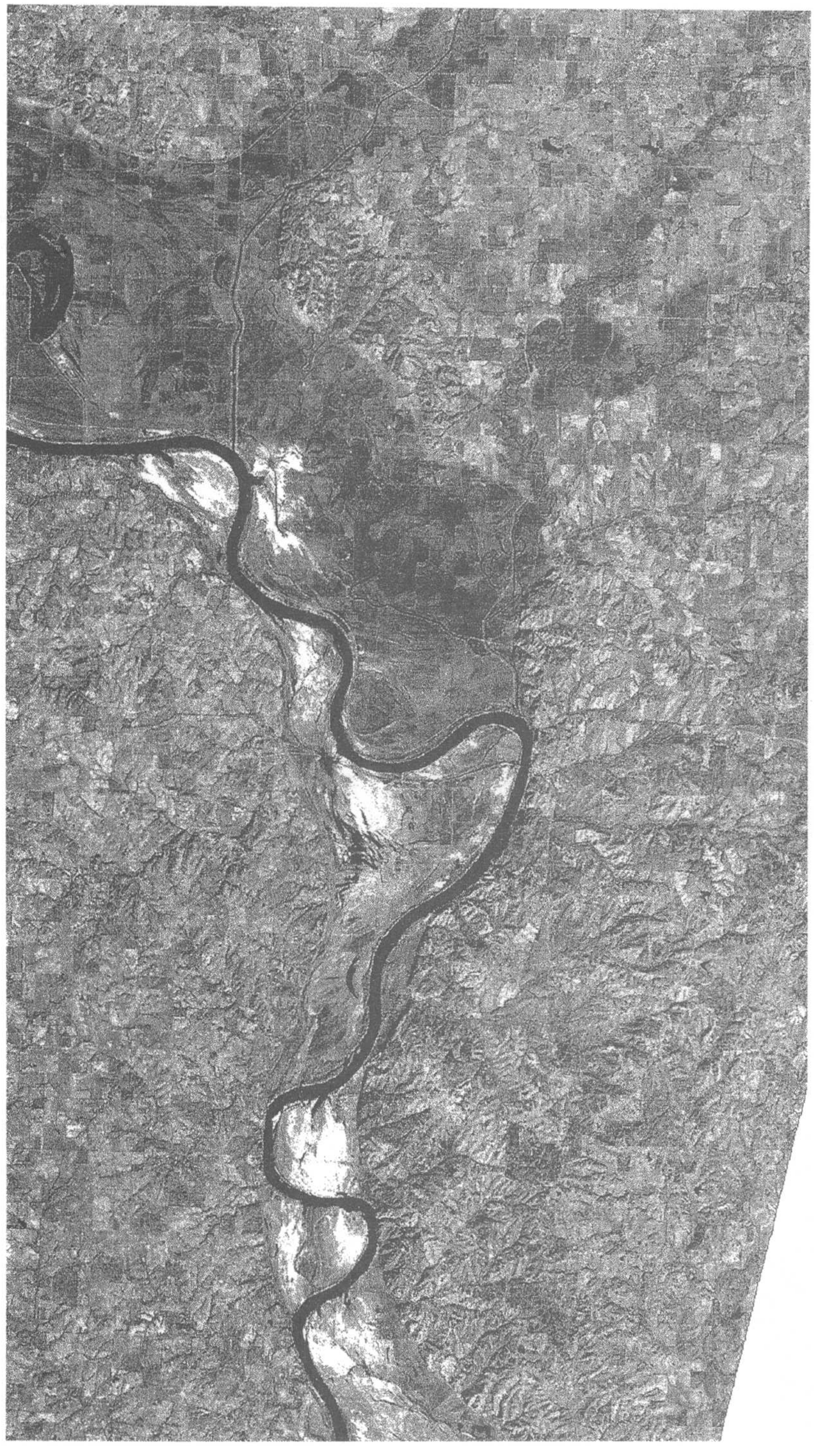
Different Rivers+Different Reaches=Different Flood Impacts

Comparison of the effects of the 1993 floods on the upper Mississippi and lower Missouri Rivers shows that river reaches in similar physiographic regions may respond very differently during floods. Although these rivers and their larger tributaries share a number of common features, significant differences in river discharge and slope, floodplain width, and sediment load strongly affect flood response. For example, the floodplain of the lower Missouri River is, on average, about twice as steep and half as wide as the floodplain of the middle Mississippi. Consequently, impacts of the 1993 flood were very different along these two rivers. Levee breaches along the lower Missouri River commonly resulted in high-velocity flows across its relatively narrow and relatively steep floodplain. These high-energy flows caused extensive deep scour and thick sand deposition across prime agricultural bottomlands. In contrast, levee breaches along the middle Mississippi River produced fewer areas of intense erosion and sedimentation, and impacts were largely limited to passive inundation of large bottomland tracts.

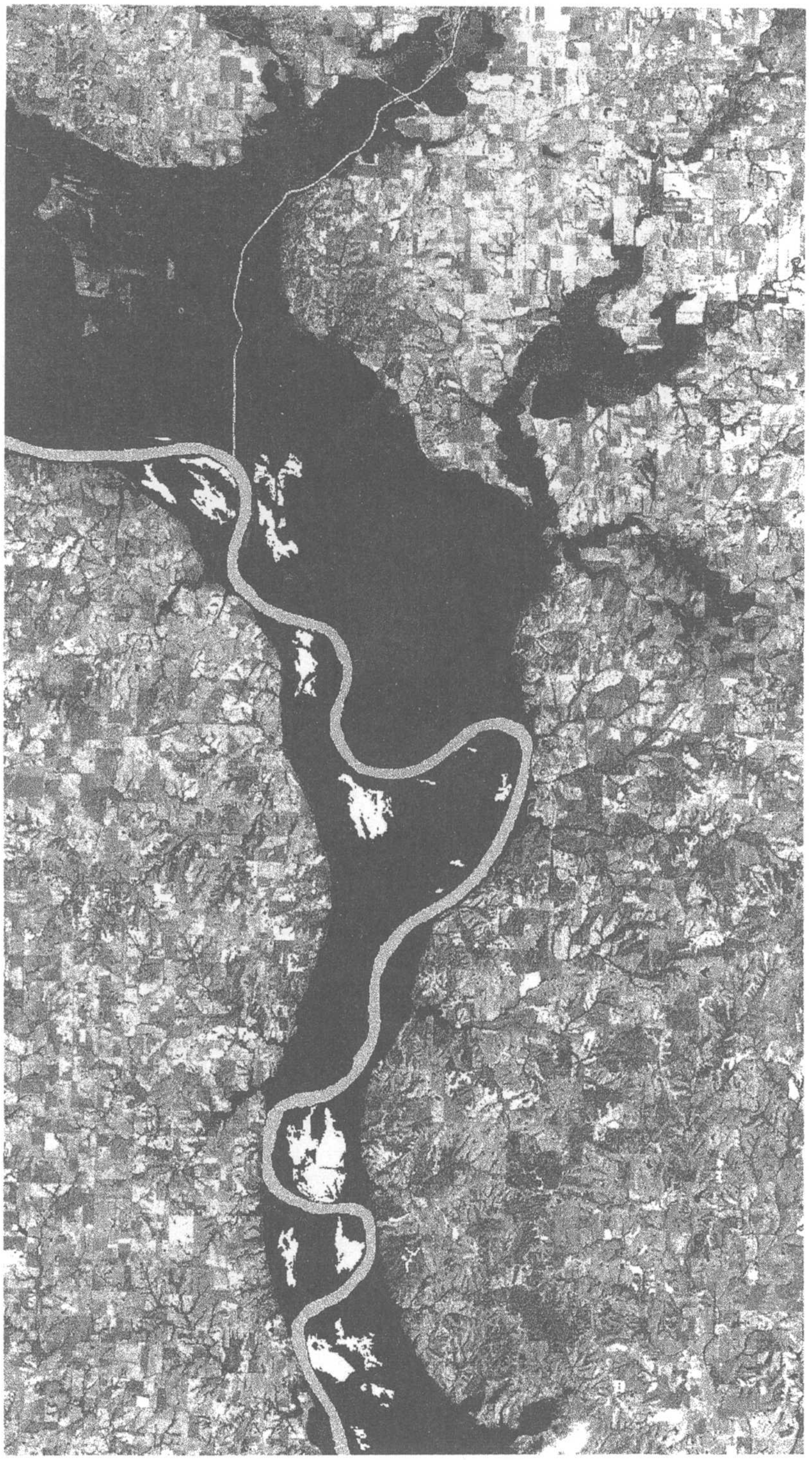
Where the floodplain is narrow, the meandering river channel partitions the floodplain surface into distinct segments, each almost completely bounded by the river channel and the valley sides. These areas, locally termed "bottoms," occur as two distinct morphologic types: the loop bottom, a relatively small, roughly symmetrical bottomland area bounded by a single, continuously curving meander loop, and the long bottom, a larger, roughly rectilinear segment bounded by a straight channel reach that typically runs along the valley wall. Of the two, the loop bottom is much more prone to severe and extensive flood-induced scour and deposition.

An important characteristic of the Missouri River, like all meandering rivers, is the migration of its meandering channel and the associated reworking of its floodplain surface. Areas reworked during the past two centuries are underlain primarily by channel sand and gravel that are capped by only minor amounts of overbank silt and clay. Thus, they provide relatively poor foundations for agricultural levees, and levees located in these areas are more prone to catastrophic failure. On average, areas reworked during this time form approximately one-third of the floodplain; however, most loop bottoms have been almost completely reworked.

The downstream gradients of most loop bottoms are significantly steeper than the average downstream gradient of the floodplain. These steeper gradients are produced when fast-moving water overflows the upstream margins of meander loops, building thick sand deposits. In contrast, the downstream positions of loop bottoms are usually flooded much more passively. Where the overflows have been concentrated by levee failures, the more energetic of them also cause extensive scour; if they are channeled along existing depressions, these sediment-laden high-energy flows can transport large quantities of coarse sand and gravel more than 1.6 kilometers from the river channel. In contrast, the downstream portions of loop



Landsat Thematic Mapper satellite image showing post-1993 flood conditions near Glasgow, Mo. River flow at this time was approximately 8 percent of the flow during peak flood conditions. Nine large levee failures occurred in the area of this scene during the 1993 floods. Associated areas of thick to moderately thick sand deposits (generally greater than 15 centimeters thick) are shown as white areas on this image. Date of acquisition December 7, 1993.



Annotated Landsat Thematic Mapper satellite image summarizing the principal impacts of the 1993 floods in the area near Glasgow, Mo. Areas buried by significant thicknesses of sand are shown in white, the main stem channel of the Missouri River is shown in gray, and other areas of flooding are shown in black.

bottoms are usually flooded much more passively. Where they are unprotected by levees, these downstream areas (being lower than the average level of the floodplain) are flooded first by backwater overflow. This relatively passive backwater flooding does not transport bedload efficiently; thus, deposits from this flooding are generally thin and widely dispersed.

Floodplain Flow-Energy Zones

The floodplains of the lower Missouri and middle Mississippi Rivers can be divided into at least four flow-energy zones: (1) the active river channel (artificially constrained into a relatively deep, narrow channel by the engineered structures of the present navigation channel system), (2) the active high-energy floodplain (the land surface adjacent to the existing river channel constructed primarily by the river in both its natural and structurally controlled regimes), (3) the low-energy floodplain (one or more river terraces marginal to the active floodplain area that represent older, higher levels of the river valley), and (4) the highest river terraces (not inundated by the 1993 floods and at least 10,000 years old). Where the floodplain is narrow, the active channel and high-energy zones occupy most of the floodplain surface; where the floodplain is wide, the low-energy zones typically predominate. These natural floodplain zones were impacted differently by the 1993 floods, when the high-energy floodplain was actively flooded to depths of 3 to 6 meters, and extensive areas of deep scour and of thick sand deposition were created by local concentration of the rapidly flowing flood water. All other areas were much less significantly affected.

Levee-Induced Scour and Sedimentation Effects

Experience from the 1993 flooding suggests that the present system of levee protection along the lower Missouri River is not working. During the 1993 flood, levee breaks in agricultural areas focused flood-flow energy at hundreds of sites and caused extraordinary levee damage, deep scour, and extensive sand deposition on the floodplain. Locally, breaches through railway embankments and flow diversions around railroad and highway bridges also acted to focus flood-flow energy and thereby added to the scour and deposition problem. On average, approximately 5 to 7 percent of the floodplain (5,000 to 7,000 hectares) between Glasgow and St. Louis, Mo., was seriously affected by these processes.

More than 90 percent of this damage was directly related to levee breaches in the high-energy zone. Scour holes, locally known as "blow holes" or "blew holes," were eroded into the floodplain by the high-intensity flood scour associated with these levee breaches. The larger holes are as much as 500 meters wide and 1,000 meters long. These holes typically attain their greatest depths (as much as 16 meters) just at the levee break. Stripped zones, locally cutting completely through the tilled zones of these rich agricultural lands, formed immediately downstream of the deep scour holes. Within these zones, which locally extend as far as 1.6 kilometers downstream from the largest breaches, shallow parallel channels and grooves as much as 1.5 meters deep and scattered scour holes as much as 4 meters deep and 60 meters long mark the locations of major flow paths.

Extensive thick deposits resulting from the 1993 flood are generally located downstream from large levee breaches within the high-energy floodplain zone. Moderately thick to thick sand deposits locally cover more than 30 percent of the floodplain in some bottomland areas. In contrast, moderate to thick flood deposits cover less than 5 percent of the floodplain along most other reaches. Deposits related to levee breaches are thick enough to conceal preexisting features of the floodplain surface. At the downstream margins of the scour zones associated with these breaches, lobe- to crescent-shaped sand sheets as much as 1 to 3 meters thick formed where the flood flow fanned out from the levee break. In some areas, these deposits locally extend as much as several hundred meters downstream from the scour zone margin. Less extensive deposits of thick sand were laid down in the lee of trees and buildings, in borrow pits adjacent to levees, and within the channel's riparian fringe.

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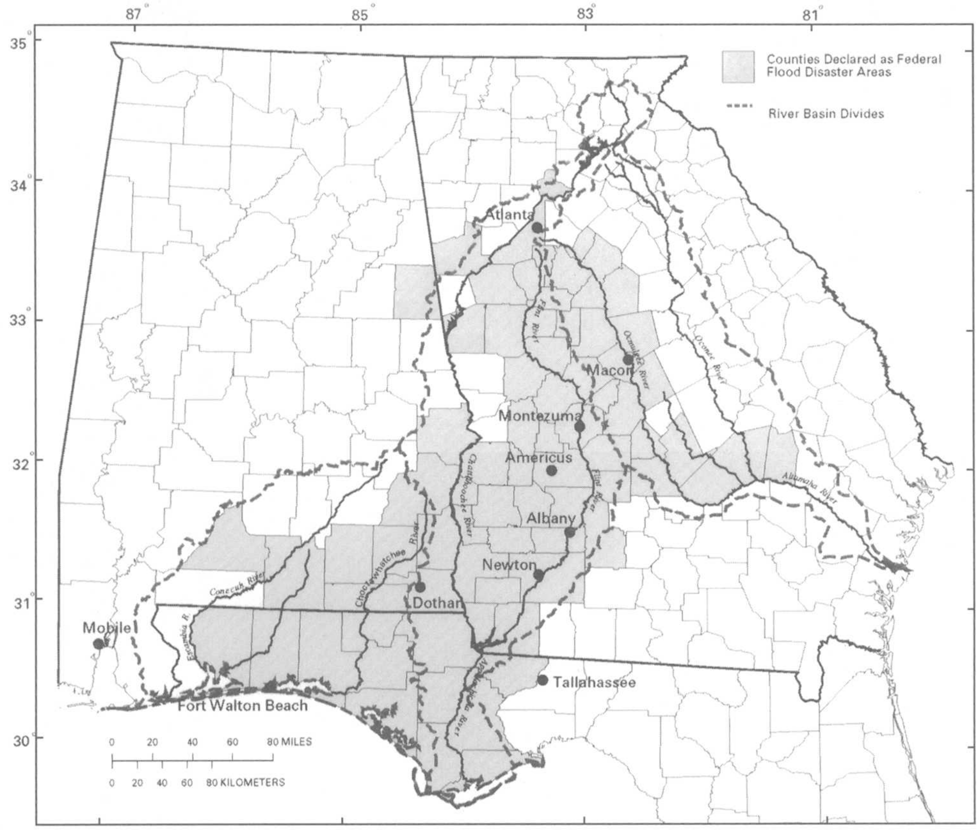
The Independence Day Flood of 1994

In July 1994, parts of Alabama, Florida, and Georgia were devastated by floods that resulted from rains produced by Tropical Storm Alberto. The storm took 33 lives and caused property damages of nearly $1 billion. Ultimately, a total of 78 counties in the three States were declared Federal flood disaster areas. Whole communities were inundated by floodwaters as numerous streams reached peak stages and discharges far greater than those of previous known floods. Montezuma and Newton, Ga., were almost entirely encompassed by floodwater from the Flint River. Many municipal, industrial, and private water systems were inundated and rendered unserviceable for several days. In Macon, Ga., the municipal water-treatment plant was flooded, and about 150,000 people were without water for 3 weeks. Highway traffic was disrupted as hundreds of bridges and culverts were overtopped and, in many cases, washed out. Roughly 1,000 bridges were closed during the flooding, and about 500 remained closed for several more days while temporary repairs were made. Stretches of Interstates 75 and 16 were closed for several days, and preliminary estimates of road and bridge damage in Georgia were about $130 million. Numerous dams failed, emptying recreational lakes and farm ponds. In Albany, Ga., sinkholes formed in some areas underlain by cavernous limestone, resulting in the destruction or condemnation of numerous homes. Thousands of acres of crops



Counties declared Federal flood disaster areas and streams affected by severe flooding in Alabama, Florida, and Georgia.

Subdivision north of Albany, Ga., in floodwater from Kinchafoonee Creek on July 9, 1994.

were damaged or destroyed by rain and floodwater. About 471,000 acres of farmland in Georgia were affected by the flood; estimated damages were about $100 million.

The death and suffering caused by this storm serve to emphasize once again the high cost exacted in life and property by flood disasters and the attendant importance of preparing for, monitoring, and documenting such occurrences.

Tropical Storm Alberto grew from a tropical depression that formed off the western coast of Cuba in the Gulf of Mexico on June 30. Alberto first came over land on the morning of July 3 near Fort Walton Beach, Fla. Once ashore, the storm rapidly lost energy and was downgraded to a tropical depression by that afternoon. The remnants of Alberto drifted north to just west of Atlanta, Ga., early on July 5, changed course, and moved slowly in a southwesterly direction before dissipating on July 7. Slow movement of the storm and abundant tropical moisture combined to help produce historical rainfalls. Storm rainfall totals greater than 13 inches were common in areas of Florida, Alabama, and Georgia. The highest total rainfall of 27.6 inches (July 3–7) and the highest 24-hour rainfall of 21.1 inches (24-hour period that ended at 7 a.m. on July 6) were recorded in Americus, Ga. The total rainfall for Americus was about 0.6 percent of the area's mean annual rainfall, and the 24-hour high was nearly 2.5 times greater than the area's estimated 100-year recurrence-interval unit for 24-hour rainfall.

The floods that resulted from Tropical Storm Alberto were no less remarkable than the rainfall that caused them. On the night of July 4 and the morning of July 5, damaging flash floods ranged from the southern suburbs of Atlanta to Macon. The peak discharge at the streamflow-gaging station on Line Creek near Senoia, Ga., which has its headwaters near Atlanta, was 2.4 times the 100-year recurrence-interval flood discharge. The maximum stage at the Senoia gage was 5.2 feet higher than any other recorded during its 30 years of operation. As the rains moved south on the night of July 5 and the morning of July 6, more destructive flash flooding occurred in the Americus area. Muckalee Creek at Americus, which probably had been affected by undetermined amounts of water released as a result of local dam failures, peaked on July 6 at a discharge about 4.0 times larger than the 100-year flood discharge. About 20 miles south of Americus, a peak discharge 1.4 times larger than the 100-year flood discharge was recorded on July 7 at the streamflow-gaging station on Kinchafoonee Creek near Dawson, Ga.

As the floodwaters on small streams merged and moved downstream, larger streams, such as the Flint and the Ocmulgee Rivers in Georgia and the Choctawhatchee River in Alabama and Florida, surpassed the 100-year recurrence-interval flood discharges. The most widespread flooding was in the Flint and the Ocmulgee River basins in Georgia; floods equaled or were greater than the 100-year recurrence-interval discharge along almost their entire lengths. Floods equal to or greater than 100-year recurrence-interval discharges were recorded at all Flint River streamflow-gaging stations from Lovejoy, Ga., about 20 miles south of Atlanta, to Bainbridge, Ga., about 2.9 miles upstream of its confluence with the Chattahoochee River at the southwestern corner of the State. At the streamflow-gaging station at Montezuma, the Flint River peaked on July 8 at a stage 6.7 feet higher than the 1929 flood, which had been the largest flood of this century. Floods on the Ocmulgee River were greater than the 100-year recurrence-interval discharge from Juliette, Ga., which is about 20 miles north of Macon, to Jacksonville, Ga., which is about 50 miles upstream from its confluence with the Oconee River.

Sinkhole that formed in an Albany, Ga., cemetery in the aftermath of flooding from Tropical Storm Alberto.

Dwelling in Albany, Ga., in floodwaters from the Flint River on July 14, 1994.

U.S. Geological Survey (USGS) personnel monitored and reported stream conditions from the onset of the storm until floodwaters receded. Stream-stage and flow information was gathered and reported to the U.S. Army Corps of Engineers, the National Weather Service, the Federal Emergency

A 100-year recurrence interval means that an event has a 1 percent chance of occurring in any given year.

Dwellings in Albany, Ga., damaged by floodwater from the Flint River.

Management Agency, the Federal Highway Administration, various State natural-resource and highway departments, electrical power companies, and numerous county and city officials as they worked to minimize loss of life and property. The flooding was so severe and widespread that 17 streamflow-gaging stations were heavily damaged or destroyed; thus, much of the necessary data had to be gathered manually and reported by cellular telephone. At the height of the flooding, nearly 40 USGS personnel were working in the field to provide hydrologic information vital to protecting lives and property.

Even with the superb effort to collect current hydrologic information during the flood, it was impossible to visit every site where data were needed. In some instances, bridges and roadways were inundated, and floodwaters were too dangerous to risk working from boats. In other cases, personnel simply could not get to the point of interest before the floodwater receded. Immediately following the flood, field crews were dispatched to flag high-water marks along major rivers and many of their tributaries so that flood profiles could be determined and indirect determinations of peak discharge at key locations could be computed. Reconstruction of gaging stations and followup fieldwork continued well into the fall of 1994. The hydrologic information collected and analyzed in the aftermath of the flood will be valuable in guiding wise land use and minimizing the effects of future floods.

Timothy W. Hale
has extensive experience in the collection and analysis of surface-water data.

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is a surface-water specialist who has 22 years of experience in the collection of surface-water data and the hydraulic analysis of stream systems.

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Debris-Flow Hazards at Mount Rainier

Debris flows pose significant hydrologic hazards on and near volcanoes in the Pacific Northwest. Debris flows are destructive, churning masses of water, rock, and mud that travel rapidly down river valleys. They typically contain as much as 65 to 70 percent rock and soil by volume and have the appearance of wet concrete. Assessment of debris-flow hazards has been a key activity for U.S. Geological Survey (USGS) hydrologists. Debris-flow hazards near Mount Rainier, Wash., have been of particular concern because of the volcano's proximity to the densely populated Puget Sound region. The volcano also lies at the heart of frequently visited Mount Rainier National Park, so visitor safety is of further concern.

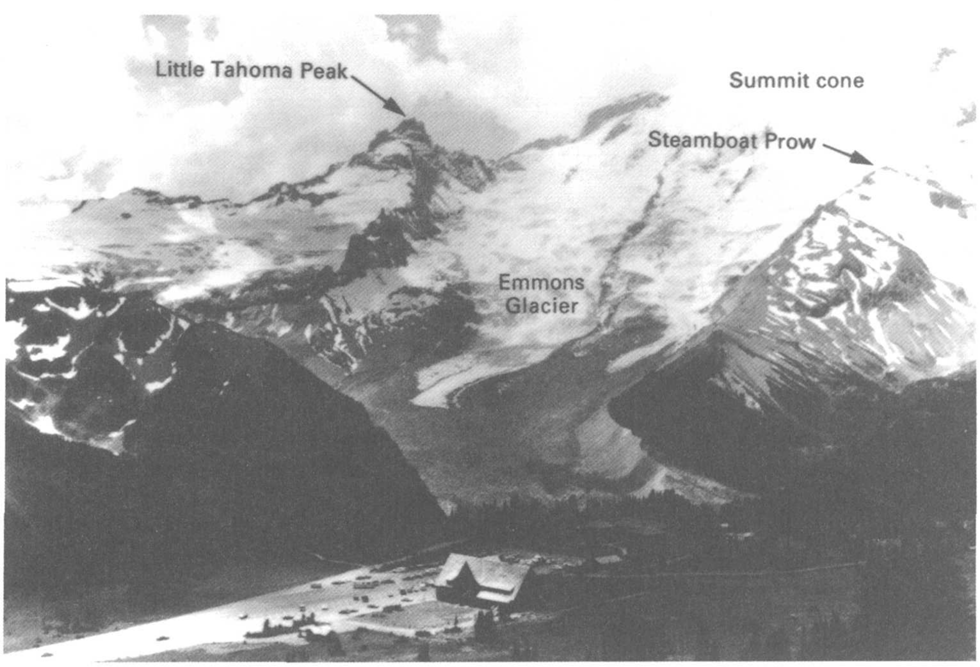
USGS investigations of giant debris flows originating at Mount Rainier have provided key natural-hazards information to public officials charged with developing comprehensive, long-term land-use plans. A preliminary report that can be consulted is Open-File Report 90–385, *Sedimentology, Behavior, and Hazards of Debris Flows at Mount Rainier.* A source of more information about glacier-generated debris flows at Mount Rainier is Water-Resources Investigations Report 93–4093, *Geomorphic Change Caused by Outburst Floods and Debris Flows at Mount Rainier, Washington, with Emphasis on Tahoma Creek Valley.*

Debris flows at Mount Rainier vary tremendously in size and may form by various processes. The smallest but most frequent ones begin as glacial outburst floods. Outburst floods originate when water stored at the base of glaciers or within pockets in glacier ice is suddenly released. Outburst floods have been recorded from four glaciers on Mount Rainier–the Nisqually, Kautz, South Tahoma, and Winthrop Glaciers. By far the most prolific producer of outburst floods, the South Tahoma Glacier released 15 between 1986 and 1992. Outburst floods from the South Tahoma Glacier occur during periods of unusually hot or rainy weather in summer or early autumn and are apparently caused by rapid input of meltwater or rainwater to the base of the glacier. The exact timing of such outburst floods is unpredictable, however.

Outburst floods become debris flows by incorporating large quantities of sediment from valley floors and walls, usually by triggering small landslides that mix with the floodwaters. Glacier-generated debris flows at Mount Rainier travel downstream at speeds of 10 to 20 miles per hour and have steep, bouldery snouts (30–60 feet high in the most constricted parts of a stream valley) followed by a churning mass of mud, rock, and vegetation. Their deafening noise is often accompanied by strong local wind, thick dust clouds, and violent ground shaking. These debris flows usually follow stream channels, but their exact paths are unpredictable. The flow's bouldery snout commonly clogs the stream channel; the moving mass behind the snout then overtops the stream banks and cuts a new channel, perhaps through forest or across trails and roads. Debris flows that originate as outburst floods have repeatedly destroyed or damaged roads and facilities in Mount Rainier National Park. Out of concern for visitors' safety and guided by the results of USGS investigations, park managers have restricted access to certain areas.

Two sorts of giant but infrequent debris flows originating from Mount Rainier pose hazards well beyond the National Park boundaries. USGS investigations of these

Partially buried table at the picnic ground alongside Tahoma Creek at Mount Rainier after debris flow in the fall of 1986. All traces of the picnic ground have since been obliterated.



View of the eastern side of Mount Rainier showing the source area of the Osceola Mudflow. The crater left by the removal of 0.7 cubic mile of the volcanic edifice was later filled by volcanic deposits that form the present-day summit cone. The Osceola Mudflow overran Steamboat Prow as it flowed. Rock debris on the lower Emmons Glacier came from a 1963 landslide from Little Tahoma Peak.

Because Mount Rainier poses a significant hazard to life and property in the surrounding heavily populated areas (particularly in the Seattle/Tacoma metropolitan area), the volcano has been designated as a Decade Volcano as part of the International Decade for Natural Hazard Reduction. The USGS has begun a multidisciplinary assessment of natural hazards associated with the volcano for use in developing effective mitigation actions.

giant debris flows have focused on estimating their frequency and determining the areas likely to be inundated when such flows occur. The largest of these debris flows begin as enormous landslides. Hot, chemical-laden ground water that circulates through a volcano's interior alters the rock to a weak, clay-rich form. Such weakened rock may break away from the rest of the volcano, particularly during a volcanic eruption. The landslide that produced the enormous Osceola Mudflow 5,700 years ago removed 0.7 cubic mile of rock from the summit of Mount Rainier. Events of this sort have occurred, on average, about once every 500 to 1,000 years and produced debris flows that reached the lowland around Puget Sound, inundating now-populated areas near Tacoma and Seattle.

Giant debris flows also form during volcanic eruptions when hot rock avalanches move down the volcano's flanks and incorporate snow and glacier ice. Debris flows formed in this way occur on average about once every 100 to 500 years at Mount Rainier. Although not all are mobile enough to reach the Puget Sound lowland, they do inundate presently populated areas in river valleys radiating from Mount Rainier.

Along with carrying out scientific studies of potential volcanic debris-flow hazards in the Cascade Range of Washington, Oregon, and California, a key goal of USGS investigators is to prepare hazards assessments that can be used by public officials who are concerned with land-use planning and emergency services. Concise summary reports aimed at nonspecialist audiences, along with maps that delineate types and frequency of debris-flow hazards, are being prepared. Spatial data will be made available in forms readily accessible to users of geographic information systems.

Joseph S. Walder
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Comet Collision With Jupiter

Discovery of Periodic Comet Shoemaker-Levy 9, which collided with Jupiter in July 1994, was one of the more spectacular results of a detailed, long-term, telescopic survey of the night sky by U.S. Geological Survey (USGS) geologist Eugene M. Shoemaker and two USGS volunteers, Carolyn S. Shoemaker and David H. Levy, at Palomar Observatory in California.

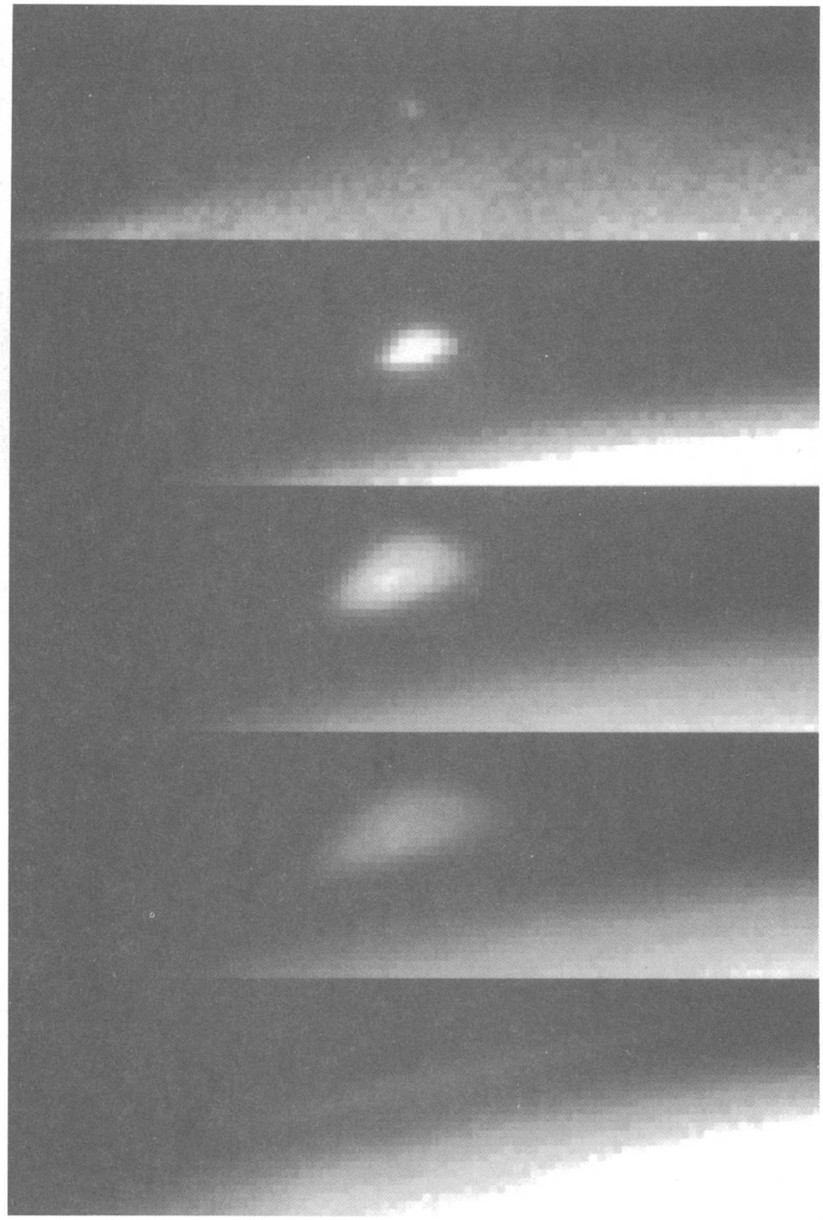
The Palomar Asteroid and Comet Survey was begun in 1983 to improve the statistical base for the study of planet-crossing asteroids, particularly Earth crossers, and comets. Gene had long been involved in research concerning impact craters on Earth, the other terrestrial planets, and the satellites of the solar system, but little was known about the populations of the planet-crossing asteroids and comets that produced these craters. He had begun his research on impact and crater formation by working on nuclear craters at the Nevada Test Site, followed by geologic mapping at Meteor Crater in Arizona. In succeeding years, he extended his work to lunar cratering problems and lunar geology in the Ranger, Surveyor, and Apollo missions and then studied cratering on the moons of the outer planets during the Voyager missions. To evaluate the ages of geologic units on these distant bodies, it was necessary to estimate the flux of asteroids and comets in their neighborhoods and the rate at which these cosmic bullets produce craters.

An ideal instrument to use in searching for these objects is the Palomar 18-inch Schmidt telescope. This photographic instrument is capable of covering 60 square degrees of sky in a single exposure. The USGS team spends 7 nights a month, 11 months of the year, observing with the 18-inch Schmidt. Over the years, techniques for searching the sky have improved steadily. Four-minute exposures evolved to 6 and then 8 as new, finer grained films were used. At first, on a long winter's night, as many as 96 exposures were taken. In recent years, that pace has slowed to about 60 somewhat longer exposures. The number of planet-crossing asteroids and comets discovered has gradually increased.

After each observing run at Palomar, the team returns to Flagstaff, where the films are scanned with a stereomicroscope, and the positions on the sky of objects of interest are measured. The orbits of discovered objects are used to calculate the probability that they will collide with the planets and satellites, and populations and impact cratering rates are estimated from the number of objects discovered per unit area of sky photographed.

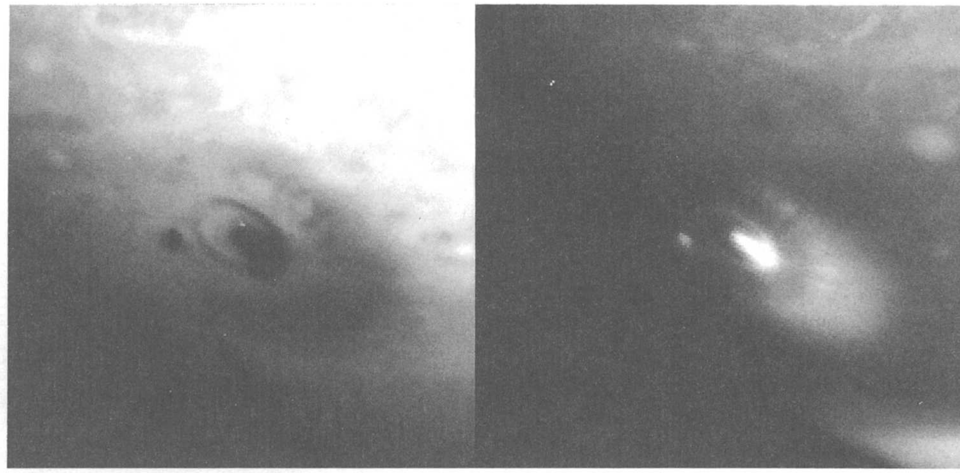
By the winter of 1993, 29 comets and 44 Earth-approaching asteroids had been discovered in the project; at present, the total number of newly discovered comets found by the Palomar Asteroid and Comet Survey stands at 33.

The winter of 1993 was a difficult one at Palomar. Stormy weather occurred throughout the world, and Palomar was not exempt. In January and February, very few films were taken because of rain and clouds. March proved no exception and, after the first clear night, promised to be almost a "wipeout." The Shoemakers, Levy, and a visiting astronomer from France, Philippe Bendjoya, were more than a little discouraged the second night when a storm approached after observations had barely started. Because films are taken in sets of four fields that are then repeated to give pairs suitable for stereoscopic examination, a set must be completed for anything to be discovered. Two sets were down, and a third was started as clouds began to cover the sky. Persistence paid off when the observers shot through the "holes" in the clouds and finished the last half of the third set. To take that set, they had used marginal film, which was partially light struck as a result of the film storage box having been opened accidentally in Flagstaff. Had the film not been damaged, it would not have been "wasted" on a dubious sky. Two days later in late afternoon, after scanning all the other films, Carolyn started looking at the pairs from the damaged film. While scanning a field with Jupiter on it, she came across a most unusual-looking comet, which was bar shaped and had a coma, tail, and wings, unlike the usual round comet, which has a coma and tail. The team telephoned Jim Scotti, who was observing on the Spacewatch



Time sequence of plume rising above the limb of Jupiter from the impact of fragment G, the largest fragment of Comet Shoemaker-Levy 9. The impact occurred on July 18, 1994, at 7:28 UT; minutes later, the first hint of the fireball of superheated gases appeared above the shadow of Jupiter (shown as the dark band separating it from the limb of the planet). It rose to a height of almost 3,000 kilometers before it collapsed into a thin stratospheric pancake. The top image was taken at 7:33 UT in the methane band, the second at 7:38 UT in the red, the third at 7:41 UT in the green, the fourth at 7:44 UT in the blue, and the last at 7:51 UT in the violet.

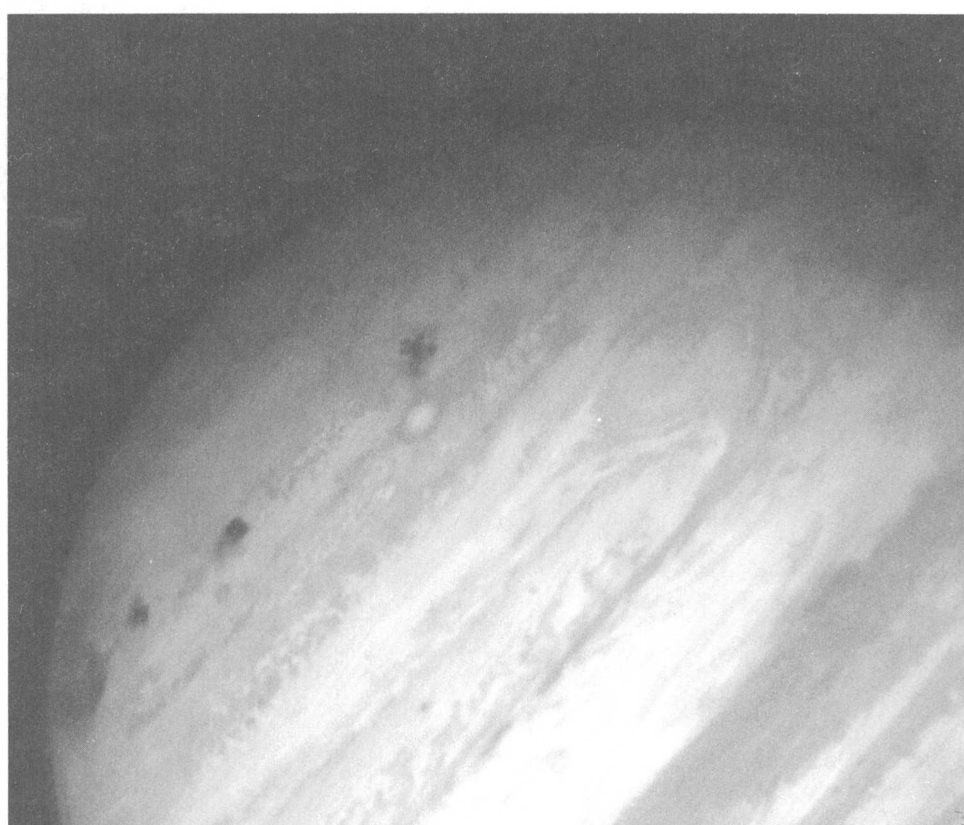
USGS volunteer **Carolyn Shoemaker** discovered her first comet in the fall of 1983. With her discovery of five more comets in 1984, she established a new record for the rate of comet discovery from a ground-based telescope. In 1987, retired USGS geologist **Henry Holt** joined the project as a volunteer. In the following years, he discovered numerous asteroids, including one that passed extremely close to Earth. In 1989, author and amateur astronomer **David Levy** became a volunteer in the project. The comet project would not have been able to continue without the time and effort of these dedicated Volunteers for Science.



PHOTOGRAPH COURTESY OF HEIDI HAMMEL, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, NASA HUBBLE SPACE TELESCOPE

Two views of the impact zone on Jupiter of fragment G of Comet Shoemaker-Levy 9. The image on the left was made in green light with the Planetary Camera channel of the Wide Field Planetary Camera 2 (WFPC2). The image on the right is the same field taken through the WFPC2 methane filter. Data for the images were obtained in the early morning hours of July 18, 1994. The impact site is visible as a complex pattern of circles seen in the lower left of the partial planet image. The small, dark feature to the left of the pattern of circles is the impact site of fragment D. The dark, sharp ring at the site of the fragment G impact is 80 percent of the size of the Earth. The comet broke up into 21 fragments during a close passage by Jupiter in July 1992. Fragment G was one of the brightest and likely the largest of the 21 fragments. The remaining fragments continued to impact Jupiter through July 22, 1994. Scientists estimate that the combined energy from all the impacts approached the equivalent of 40 million megatons of TNT. Jupiter was approximately 477 million miles from Earth when the image was taken.

Jupiter as photographed by the Hubble Space Telescope's Planetary Camera. Eight impact sites are visible. From left to right are the E/F complex (barely visible on the edge of the planet), the star-shaped H site, the impact sites for tiny N, Q1, small Q2, and R, and, on the far right limb, the D/G complex. The D/G complex also shows extended haze at the edge of the planet. The features evolved rapidly on time scales of days. The smallest features in this image are less than 200 kilometers across. This image is a color composite from three filters at 9530, 5550, and 4100 angstroms.



PHOTOGRAPH COURTESY OF THE HUBBLE SPACE TELESCOPE COMET TEAM AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION telescope at Kitt Peak in Arizona. By that time, snow was beginning to fall on Palomar, but Scotti was not yet clouded out. With his more powerful telescope, he was able to confirm the comet and said that he could see five separate comets lined up in a bar with wings of dust. This comet was 19 9 3e, to become known as Periodic Comet Shoemaker-Levy 9, for it was the ninth periodic (orbit less than 200 years) comet discovered by the team of the Shoemakers and Levy.

Comet Shoemaker-Levy 9 held three surprises for its discoverers and the rest of the world: (1) it was completely disrupted, its 21 visible fragments lined up like "a string of pearls," as David Jewitt noted in Hawaii; (2) it was captured in orbit about Jupiter; and (3) it was to impact Jupiter a little more than a year after its discovery. Never before had a comet been seen so completely disrupted as this one. It had been broken up by tidal forces during a passage very near Jupiter on July 7, 1992. In addition, never before had any comet been seen in orbit about a planet, although two comets had been found shortly after escape from temporary orbit about Jupiter. More important, never before had any asteroid or comet been predicted to impact a planet. Not only the team but also scientists from many different fields and much of the lay world were elated at the possibility of observing and learning from this collision.

More important, never before had any asteroid or comet been predicted to impact a planet.

The "Great Crash of 1994" commenced on July 16 and ended on July 22 as large fragments of Shoemaker-Levy impacted Jupiter about every 7 to 9 hours. The size of the original comet and the sizes of the individual fragments were not known with any degree of certainty because of telescopic limitations. A major assist came from the Hubble Space Telescope, which was trained on the comet during July 1993 in hopes of being able to determine the sizes of the nuclei. Preliminary estimates of the sizes of the brightest nuclei were made, but uncertainties remained because of the dust cloud surrounding each one. Further observations were made with the space telescope after its repair in December, and improved images of the train of nuclei and of individual nuclei were taken up to a few hours before impact. Nevertheless, the exact sizes remained uncertain. Several scientific teams interested in the dynamics of impact modeled the impact of various-sized fragments on the basis of a variety of assumptions. One of those groups involving Gene and USGS geologist David Roddy worked with Paul Hassig of the Titan Corporation to carry out numerical modeling of the explosions. They obtained a prediction for a plume produced by a 1-kilometer body having the density of ice.

Time was reserved on telescopes worldwide so that the impacts could be observed at different longitudes depending on impact times. Jupiter was observed ahead of time to provide a basis for recognizing possible changes in the Jovian atmosphere. Amateur astronomers were prepared to look for any new features large enough to be detected by small telescopes. Never before had so many eyes been trained on one planet in the same week.

Because the comet fragments were to impact on the far side of Jupiter just beyond the limb, it was uncertain whether any explosion forming a fireball plume rising above the limb would be seen. Such an event was thought to require at least a 1-kilometer fragment breaking up fairly high in the atmosphere and releasing more energy than the world's total arsenal of nuclear weapons. The plume from fragment A exceeded expectations, and impacts of the brighter, larger nuclei produced even larger plumes, some rising nearly 3,000 kilometers above the visible cloudtops. To everyone's surprise, each plume produced a huge cloud of dark particles that was readily detectable against the bright face of Jupiter. Throughout the week, as more collisions occurred and Jupiter rotated to reveal the impact sites, the Hubble Space Telescope imaged the events along with other major telescopes, including the South Pole Infrared Explorer, which, weather permitting, could observe Jupiter continuously. Reports and images flowed worldwide over the Internet computer network; by July 27, about 2 million images had been taken off the Internet by private viewers. Shoemaker-Levy 9 had become everyone's comet.

The comet collision occurred at a time in the world's history when instrumentation and communication were capable of recording and extracting a huge amount of

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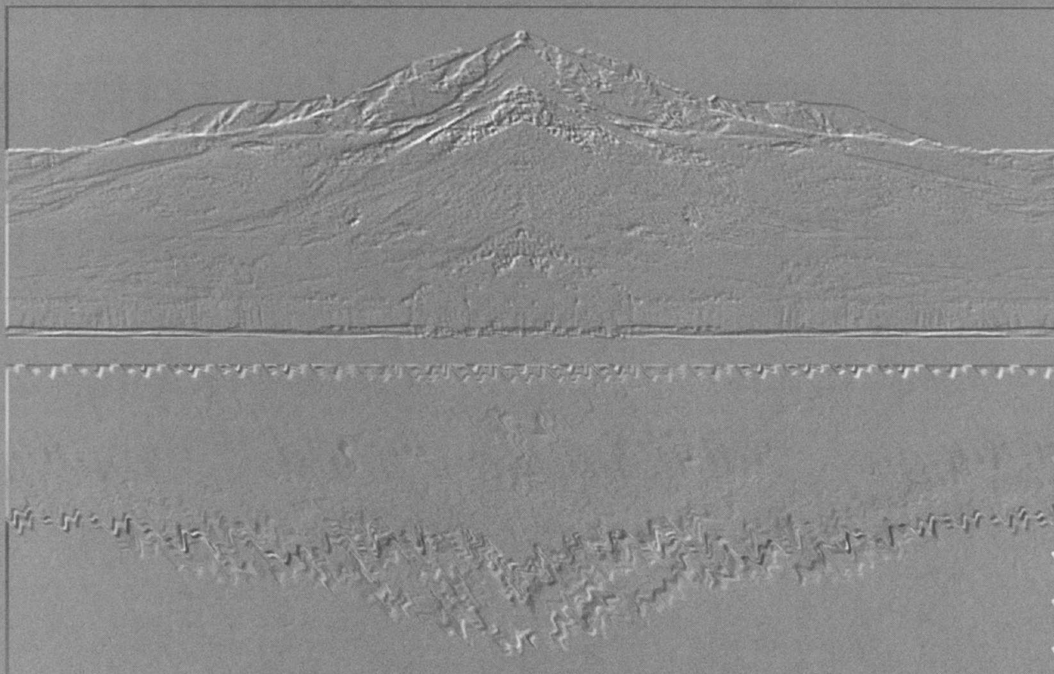
information. Moreover, the impacts occurred when Jupiter was high in the sky and had not disappeared in the Sun's glare. In addition, although it was on the far side of Jupiter, the impact longitude was close to the limb, where the fireballs could be seen to rise above the atmosphere. Since that week in July, astronomers and other scientists have been studying the results of that once-in-a-millennium event. Those interested in the chemistry of the comet as well as the chemistry of Jupiter's atmosphere have been hard at work. A surge in radio emissions during the impacts and a brightening of the auroras at the poles are being studied. Computer modeling of the impact dynamics continues. Winds in Jupiter's atmosphere are spreading out and merging the dark material from the various plumes, and the evolution of the dark clouds is being monitored closely. The long-term history of this dark material is especially relevant to predicting the effects of comet impact on Earth. The dark marks in the Jovian atmosphere have persisted well into October.

Meanwhile, the USGS team continued the search at Palomar and discovered three more comets. For Gene and Carolyn Shoemaker, Periodic Comet Shoemaker-Levy 9 was the fulfillment of Gene's dream to observe an impact and Carolyn's to discover the comet of the century. The project at Palomar drew to a close at the end of 1994, but new work with other telescopes will begin in Flagstaff, Ariz. Much remains to be learned about asteroids and comets, cratering in our solar system, and the Earth's future.

Carolyn Shoemaker
is a USGS volunteer who discovered her first comet in the fall of 1983.



Resources

USGS

Population growth and expansion place ever-increasing demands on the Nation's renewable and nonrenewable resources, including energy, minerals, water, and land. As growth continues, competing needs for land and water are heightened. Population expansion into the suburbs, for example, has excluded more and more land from resource development, particularly for locally derived resources like aggregate, which is used for road building. The need for resources competes with other important needs, such as conservation and environmental protection. The task of identifying areas that are favorable for the discovery and development of renewable and nonrenewable resources is more critical now than ever before. In addition, the quality of available resources is an ever-increasing concern, whether the resource is energy, minerals, or water. The USGS provides fundamental scientific knowledge on the abundance of natural resources and the environmental consequences of their extraction and use. USGS resource studies are commonly integrated with studies on hazards and the environment. The articles in this section show some of the various aspects of USGS work in resources, from monitoring changes in ground-water levels to looking at the environmental effects of resource development. USGS resource studies are also a large component of comparative studies in other countries that aid in improved understanding of domestic resources.

The Future of Energy Gases

Over the course of human history, the energy sources that people have used have become more efficient and cleaner, from biomass (wood or peat) to coal to oil. The continuation of that trend can be seen in the increased global use of gas, a fuel with environmental and economic benefits, although coal and oil will almost certainly continue to be major sources of energy well into the 21st century. The trend will probably continue with the development of nonpolluting, renewable energy sources, such as solar energy, and various forms of nuclear energy. Before societies can achieve the goal of developing cleaner, more efficient sources of energy, however, it is likely that the role of natural gas in the energy mix will increase.

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Natural Gas as a Bridge to Future Energy Systems

Increased use of natural gas could help to create the infrastructure necessary for the use of gaseous fuels. Gaseous fuels may be the energy of the future, whether as a natural gas or as an energy carrier for a gas such as hydrogen. Increasing the use of natural gas today could begin development of the infrastructure necessary to carry, store, and use gaseous fuels. This use might pave the way for the ultimate conversion of the present liquid- and solid-based fuel system to a gas-based fuel system. Although many people are optimistic about future supplies of natural gas, the amount of that supply is still uncertain. The current production supply of natural gas is running low; in order to maintain production, there must be a significant increase in the number of exploratory and development wells drilled. Such an increase will produce a dilemma, however.

Increased drilling will increase reserves and could therefore satisfy demand, but drilling will not increase significantly until the price of gas goes up; higher prices could then diminish demand. Also, use of natural gas is intended to reduce the effects of environmental damage caused by fuel use, but numerous wells, many in environmentally sensitive areas, will need to be drilled to get adequate supplies of natural gas.

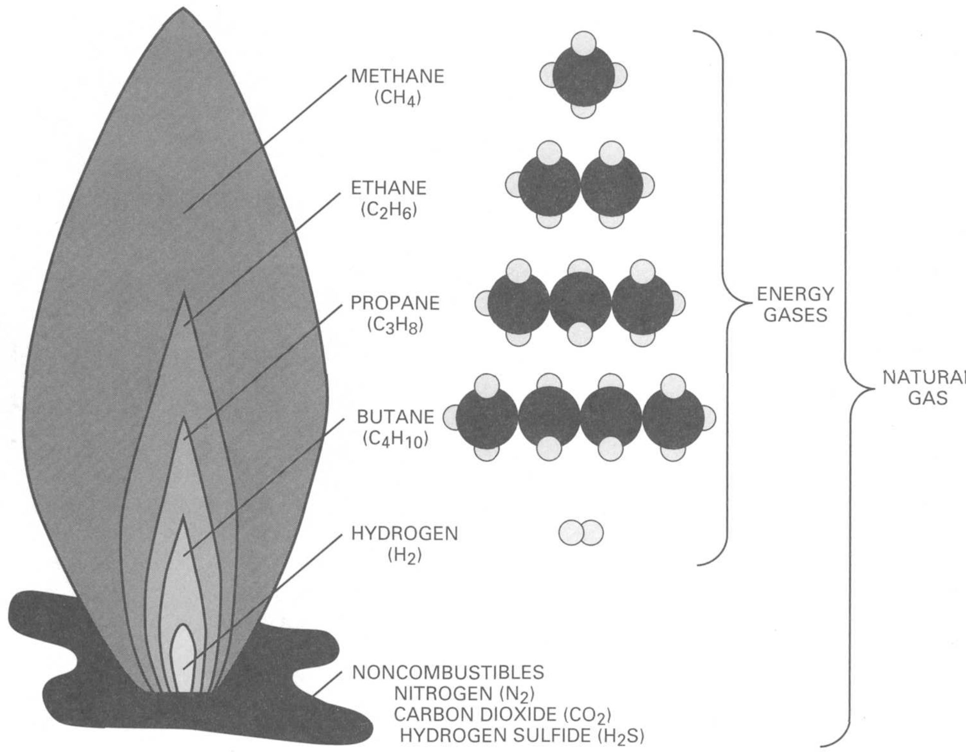
Understanding the nature and occurrence of energy gases, therefore, is important for two critical issues facing our Nation–the economy and the environment. The U.S. Geological Survey (USGS) is actively involved in research on the origin, abundance, and availability of energy gases. This research is pertinent to discussions of the future energy mix, global warming, the dependence of the Nation on imported fossil fuels, and the size of gas reserves, all of which are concerns faced daily at local, State, and national levels.

What Is Natural Gas?

Natural gas usually refers to methane, although small amounts of other hydrocarbon gases such as ethane, propane, and butane are also present in natural gas mixtures. Methane is the simplest of the hydrocarbon molecules–one carbon atom surrounded by four hydrogen atoms–and exists in variable amounts in the Earth's atmosphere, water, and rock layers.

Natural processes create methane in three different ways. Biogenic gas is expelled from microorganisms during the digestion of organic compounds; thermogenic gas results from the decomposition of organic matter when heat and pressure are applied; abiogenic gas is created deep within the Earth's crust when crustal gases react with minerals or when hydrogen- and carbon-rich primordial gases seep from the Earth's interior. Most of the methane that is extracted from large natural-gas accumulations found in the Earth's crust is believed to be either biogenic or thermogenic in origin, although abiogenic methane may also be present.

Naturally occurring gases in the Earth's crust are collectively referred to as natural gas. Some of these gases are combustible and give off heat energy when burned; they are collectively called energy gases. Energy gases typically make up more than 75 percent of all natural gas and are mostly hydrocarbon gases, which are compounds composed of hydrogen and carbon atoms only. The flame represents the typical proportions of energy gases found in natural gas, shown in order of abundance. Methane constitutes 80 to 100 percent of the volume of energy gases. A household flame contains nearly 100 percent methane.



Energy Gas Resources

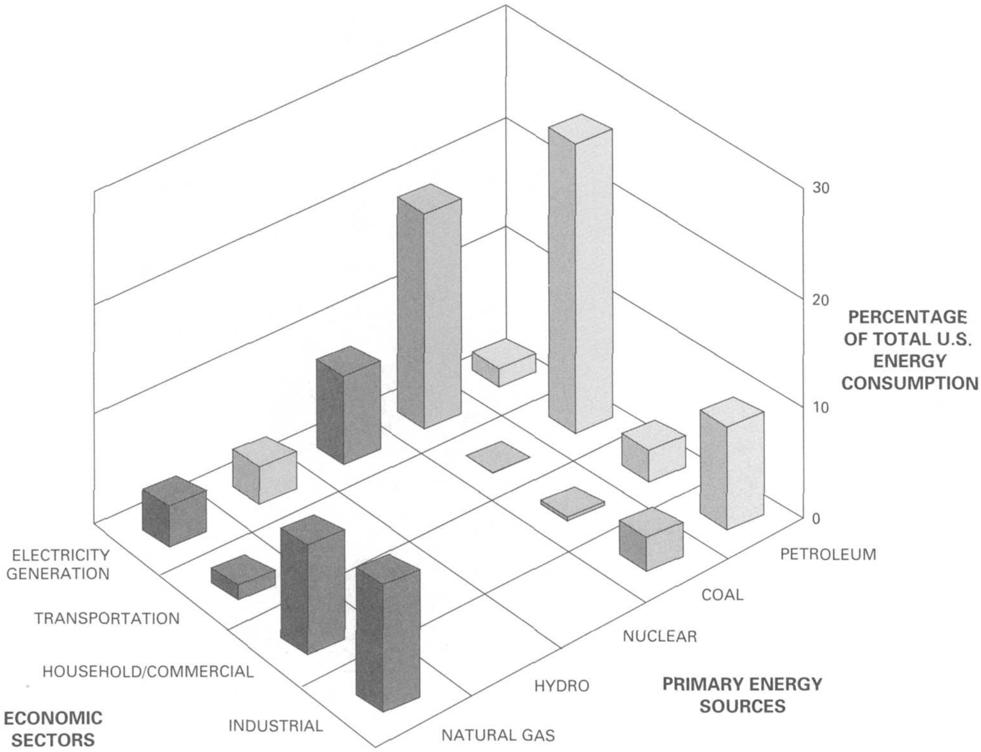
The contribution of natural gas to meeting the world's primary energy requirements will depend ultimately on the availability and cost of sufficient supplies to meet growing demand. Yet uncertainty and disagreement prevail concerning global natural gas resources.

Commercial quantities of methane are present in many geologic environments, and the modern era of exploration for natural gas has stimulated the development of new technologies and strategies that expand capabilities to find gas accumulations. The most common accumulations of gas are associated with oil. Gas often forms a pocket between the denser oil below and an impermeable cap rock above. Where no natural-gas distribution system is available, gas produced in association with oil is often considered a nuisance. In many countries, if gas cannot be used as a fuel source for field operations, it is often vented or flared. In the United States, gas is almost never flared but is reinjected to maintain reservoir pressure.

Other natural-gas accumulations are termed unconventional, because gas in these accumulations either is more expensive to extract than gas found in conventional settings associated with oil or requires new technologies for extraction. For instance, gas that accumulates where reservoir rock permeability is low is referred to as tight gas. In this type of reservoir, there may be large pore spaces to hold gas, but, because there is little if any connection between the pore spaces, the flow of gas to the well bore is greatly restricted. Because tight gas is widely disseminated, usually without well-defined boundaries, and is difficult to extract, its ultimate resource potential remains uncertain.

Coal-bed gas is another unconventional resource. Coal is carbon-rich, woody terrestrial plant material that has been compressed and transformed. A byproduct of this transformation is methane, and its presence in coal beds is one of the greatest dangers to underground mining–at high concentrations in mines, methane causes explosions. By extracting coal-bed gas before mining, the potential danger is reduced and an energy resource gained.

Another source of unconventional natural gas that has attracted attention is deep gas, which is located in rocks at depths greater than 4,000 meters and may represent a potential supply. Methane remains stable at depth, whereas oil tends to concentrate in more shallow parts of the crust, either because it has been pushed upward by the gas or because it



Total energy consumption in 1991 for the United States by economic sector (left scale) and energy source (right scale). The Nation's largest share of energy is consumed during electricity generation, predominantly by coal-fired steam plants. Transportation, the second largest energy-consuming sector, depends heavily on gasoline, diesel, and aviation fuels, which are refined from crude oil (petroleum). Technological developments that lead to greater efficiency of energy consumption during electricity generation and transportation will substantially lessen the Nation's total energy requirement.

breaks down at the high temperatures found at depths greater than about 5 kilometers. Also, as pressure increases, gas compresses; compression results in more energy per unit volume and, therefore, may enhance the desirability of deep exploration.

Gas is also trapped in media other than rock. In shallow crustal horizons, enormous volumes of gas can be dissolved in brines. Although most scientists think brine gas is uneconomic, like the vast quantities of gold dissolved in sea water, local circumstances and ingenuity may combine to give such gas limited economic potential.

Gas trapped in the atomic lattice of water ice is another unexplored, unconventional resource. These so-called hydrates look like dry ice, but hydrates will burn. Although huge quantities of gas exist in hydrate form, the commercial value of this gas source is yet to be demonstrated. Recent studies suggest that more than 100 million trillion cubic feet of methane exists in gas hydrates worldwide; the potential resource may be as much as 700,000 trillion cubic feet. This amount represents about 10,000 times more gas than the global natural-gas consumption in 1990, a truly immense quantity. There is, therefore, great incentive to learn more about methane in gas hydrates and the technology required to develop it.

Natural Gas and the Environment

At present, approximately 90 percent of all energy consumed in the United States comes from burning fossil fuels. The remainder comes from nuclear and hydroelectric power and small amounts of geothermal, wind, and solar power. When fossil fuels burn, the carbon-hydrogen bonds are broken, and heat is released. Carbon combines with atmospheric oxygen to form carbon dioxide (CO_2), which is released to the atmosphere, while the hydrogen atoms combine with oxygen to form water vapor. Because of its lower carbon content, methane combustion produces roughly one-half the CO_2 emissions of coal and about two-thirds as much CO_2 as oil while delivering the same amount of thermal energy.

Carbon dioxide and water vapor are the two most abundant greenhouse gases. These gases, which also include methane, ozone, nitrogen oxides (NO_x), carbon monoxide, and chlorofluorocarbons (CFC's), linger in the atmosphere, where they can affect the temperature of the Earth's surface as well as cause other effects. Short-wavelength energy from the Sun passes through the atmosphere and reaches the Earth, but the greenhouse

In 1993, the U.S. Geological Survey assembled a team of senior scientists for a major study on the role of energy gases in the Nation's energy mix. The "Energy Gases Team" produced a series of three publications under the umbrella title *The Future of Energy Gases,* describing the origin, distribution, development, and use of natural gases. The series consists of Professional Paper 1570, which is technical in content; the colorfully illustrated Circular 1115, written in nontechnical language; and a 30-minute video appropriate for general audiences. The results of the study are summarized in this article.

gases prevent some of the longer wavelength reradiated energy from escaping back into space. By absorbing some of this outgoing radiation, the greenhouse effect keeps the planet warm and comfortable. Recent concern is focused on manmade changes in the composition and concentration of greenhouse gases that may cause overheating of the planet, or global warming.

Since the industrial revolution, the concentration of CO_2 in the atmosphere has increased by about 25 percent, largely because of the increased output of CO_2 caused by burning fossil fuels. To reduce the human contribution of greenhouse gases to the atmosphere, it has been suggested that we should replace high-carbon fuels with low- or zero-carbon forms of energy. In this respect, natural gas may be a significant improvement over coal and oil, although the relative efficiencies and cleanliness of the technologies consuming the fuels are also important. However, cessation of fossil-fuel burning would not immediately affect the atmosphere. Because the residence time of CO_2 in the atmosphere is estimated to be several hundred years, reducing the CO_2 overload will be a very slow process.

Methane is also a greenhouse gas, roughly 25 times more potent than CO_2. In contrast to CO_2, however, methane has a short residence time in the atmosphere. Like CO_2, the amount of atmospheric methane is increasing at an exponential rate. Its sources are poorly quantified, but about one-third is emitted from natural sources such as wetlands, volcanic regions, termites, and decomposition of methane hydrates. Of the remaining two-thirds, more than half comes from agricultural activities (rice paddies and cattle), and the rest comes from petroleum activities, biomass burning, and landfills.

The geologic factors governing the generation, migration, and entrapment of energy gases are complex and are ongoing research endeavors of the USGS. In addition, the USGS gathers information on the size and nature of these accumulations, which also contributes to a basic understanding of the Nation's energy gas resources. Methane, the most important energy gas, is formed in many ways in nature and is an intrinsic part of the natural environment. However, only under certain conditions is the gas trapped within the Earth's crust in sufficient quantities to allow economic recovery. Moreover, by gathering geologic data on methane emissions and by studying the geologic aspects of global climate, the USGS provides information that can be used in developing national policies on environmental issues.

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Monitoring the High Plains Aquifer

The High Plains aquifer underlies one of the major agricultural areas in the United States. About 20 percent of the irrigated land in the United States is in the High Plains, and nearly 30 percent of the ground water used for irrigation in the United States is pumped from the High Plains aquifer. The aquifer underlies about 174,050 square miles in Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming.

Water levels in some parts of the High Plains aquifer declined as much as 100 feet from the start of widespread irrigated agriculture (about 1940) to 1980. These declines and continued irrigation development in the region led in 1988 to a U.S. Geological Survey (USGS) program to monitor annual water-level changes in the High Plains aquifer. As stated in the Omnibus Water Resources Development Act of 1986 (Public Law 99–662), the USGS in cooperation "...with the States of the High Plains region is authorized and directed to monitor the water levels of the Ogallala [High Plains] aquifer, and report annually to Congress."

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Although this aquifer is known as the Ogallala aquifer, the different geologic units and ages of the deposits that constitute the aquifer necessitated a more inclusive designation. The High Plains aquifer consists mainly of one or more hydraulically connected geologic units of late Tertiary or Quaternary age; the Ogallala Formation generally is the principal unit. The average saturated thickness was about 190 feet in 1980 but exceeded 1,000 feet in north-central Nebraska. About 66 percent of the estimated drainable water in storage by volume in the High Plains aquifer in 1980 (3,250 million acre feet) was in Nebraska.

Water levels in the High Plains aquifer are monitored through an extensive observation-well network. This network comprises many smaller networks of observation wells maintained by Federal, State, and local agencies. Local water and natural-resource conservation districts are responsible for the largest number of the observation wells within these networks. The USGS Water Resource Districts are responsible for compiling water-level data from various local networks and maintaining the water-level database in most of the High Plains States.

The observation wells are, for the most part, privately owned irrigation wells that are well suited for monitoring water-level change because their large diameters and large pumping capacities make them less prone to plugging. Water-level measurements in the High Plains usually are made during winter and early spring when water levels generally have recovered fully from pumping during the previous irrigation season and represent the highest water levels during the year. A small number of specially designed observation wells are equipped with recording devices for continuous monitoring of water levels in critical areas.

The High Plains water-level monitoring network changes from year to year. A small number of wells are lost from the network each year as a result of well failures (collapsing or plugging) and are not replaceable. In some areas, however, additional observation wells are added to better define local water-level changes. Between 1980 and 1993, water-level changes in the High Plains aquifer were based on measurements from 6,206 wells. Observation wells added to the network after 1980 permitted water-level change from 1992 to 1993 to be based on observations from 8,053 wells.

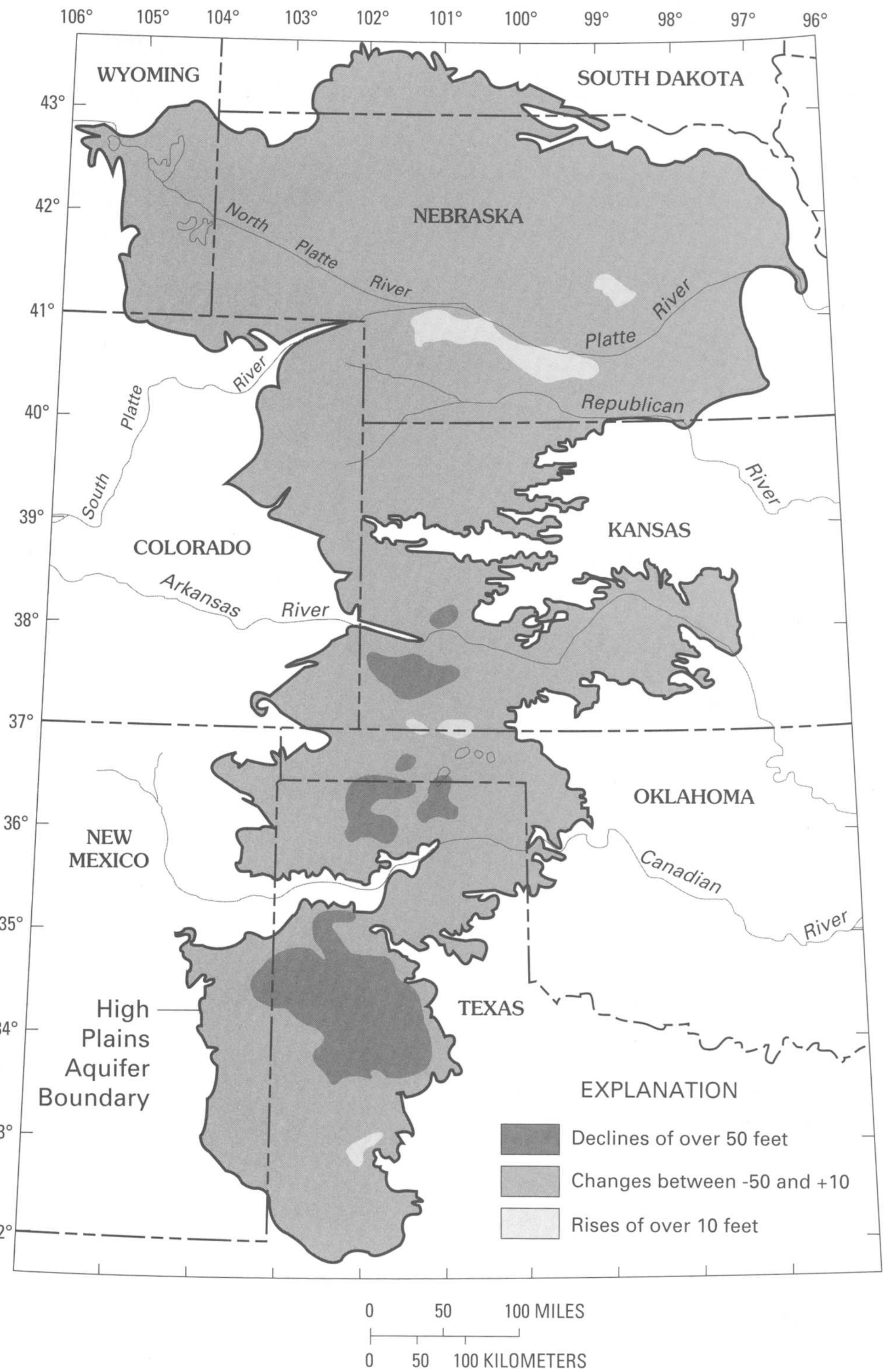
Water-level declines were substantial in several areas of the High Plains before 1980. The estimated average area-weighted water-level decline from predevelopment (1940) to 1980 for the High Plains was 9.9 feet, which represents an average decline of about 0.25 foot per year. In some parts of the Central and Southern High Plains, declines were greater than 100 feet. In the Northern High Plains, declines were much smaller and less extensive largely as a result of later irrigation development.

The geographic patterns of water-level change in the High Plains since 1980 are similar to the pre-1980 patterns of change. Those areas in which water levels declined substantially between 1980 and 1993 tend to be the same areas in which declines were large before 1980. The magnitude of the declines after 1980 in these areas, however, generally is much smaller than that before 1980. The average water level in the High Plains declined 2.09 feet from 1980 to 1993 in comparison with the average decline of 9.9 feet from predevelopment since 1980 (see table). This difference can be attributed partly to the shorter time period from 1980 to 1993 and partly to a slower annual rate of decline since 1980. The average annual rate of decline decreased from 0.25 foot from predevelopment (1940) to 1980 to about 0.16 foot from 1980 to 1993, 64 percent of the pre-1980 rate. The annual rate of decline from predevelopment to 1980 might have been substantially larger if the total area irrigated in the High Plains was comparable to the area irrigated after 1980. In 1959, the approximate

Average area-weighted water-level changes in the High Plains aquifer from predevelopment to 1980 and from 1980 to 1993

State	Area-weighted water-level change (feet)	
	Predevelopment to 1980[1]	1980 to 1993
Colorado	−4.2	−3.25
Kansas	−9.9	−7.26
Nebraska	0	
New Mexico	−9.8	−3.42
Oklahoma	−11.3	−.41
South Dakota	0	−.90
Texas	−33.7	−1.96
Wyoming	0	+.63
High Plains	−9.9	−2.09

[1] From U.S. Geological Survey Professional Paper 1400–B, published in 1984.



Water-level change in the High Plains aquifer from 1980 to 1993.

midpoint of the period from predevelopment to 1980, about 6 million acres were irrigated in the High Plains. Since 1980, about 14 million acres have been irrigated annually in the High Plains.

Several factors appear to have contributed to the smaller average water-level decline after 1980, even though the average area irrigated more than doubled:

- Precipitation in most parts of the High Plains was above normal during 1980 to 1993. Average annual precipitation for the High Plains was 1.81 inches above normal from 1981 to 1992.
- Irrigation development in the High Plains shifted from areas having large potential rates of aquifer depletion to areas where potential rates of depletion were smaller. After 1950, most of the growth in irrigated acreage was in the Northern High Plains, where greater potential recharge and smaller consumptive irrigation requirements resulted in smaller net withdrawals from the aquifer than in the Central and Southern High Plains. More than one-half of the 14 million acres irrigated in the High Plains after 1980 were in the Northern High Plains, largely in Nebraska.
- Advances in irrigation technology, which include center-pivot sprinkler irrigation and light-weight gated pipe designed to apply water more evenly and to minimize conveyance and field losses, have greatly decreased ground-water pumpage requirements. Irrigation from open ditches, which can result in water losses of as much as 50 percent, is no longer common. Recent sprinkler designs, which include the low-energy, precise-application method, minimize wind losses from center-pivot irrigation. Surge irrigation permits more uniform field application by the gravity method and lessens the need to exceed crop requirements in certain parts of the field to assure complete coverage. Although much of the excess water applied by various methods in the past was returned to the underlying aquifer through percolation, substantial volumes of water were lost by runoff and evaporation of ponded water.
- Irrigation management practices that minimize pumpage costs and conserve water have been widely adopted. Agricultural production has been converted to crops or plant varieties that have smaller consumptive irrigation requirements. Irrigation scheduling, which includes monitoring of soil and water conditions, commonly minimizes excess application of irrigation water.
- Large water-level declines in some areas of the High Plains before 1980 prompted local regulations to control irrigation withdrawals. State and local agencies were granted the authority to monitor and regulate pumpage volumes from existing wells, to regulate well spacing, and to limit new well construction. Irrigation runoff also has been limited in many parts of the High Plains since the late 1970's by regulations that require such practices as reuse pits.

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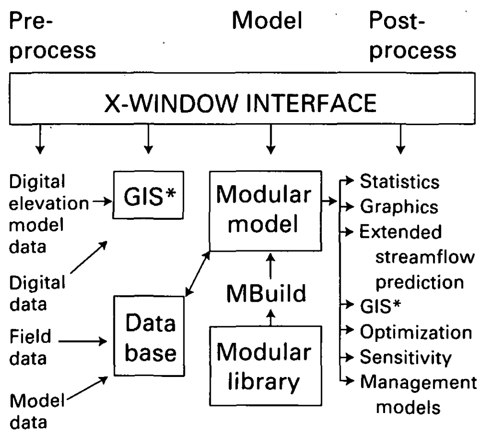
Watershed Modeling Systems

Competition for water resources in the Western United States has become very intense, involving conflicts among agricultural, industrial, and municipal water uses and requirements for hydroelectric peaking power, recreation, and preservation of habitat and endangered species. The job of managing water resources has, as a result, become exceedingly complex. To deal successfully with these complexities, a new generation of highly flexible water-management models and supporting data is needed, both for short-term (hours to months) operational simulations and long-term (years to decades) planning studies.

As part of a broad effort to apply its scientific research and technical development capabilities to the improvement of resource management, the U.S. Geological Survey (USGS) is providing the U.S. Bureau of Reclamation with improved data handling, reporting, and analytical tools, decision support models, and information to carry out its water-management mission. The purpose of the collaborative program between these two Department of the Interior bureaus is to develop, test, and implement water-resources models and fully integrated data-management systems designed to help water managers and

> The Reclamation Act of 1902 (43 U.S.C. 371 et seq.) authorized the Secretary of the Interior to administer a reclamation program that would provide the arid and semiarid lands of the 17 contiguous Western States (Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming) a secure, year-round water supply for irrigation. To perform the mission, the Reclamation Service was created within the USGS. In 1907, the Reclamation Service was separated from the USGS and in 1923 was renamed the Bureau of Reclamation.

USGS Modular Modeling System.



*Geographic Information System

water users improve the utilization of water and the management of the water-related infrastructure in the Reclamation Act States. The objective of this program are to:

- Improve environmental quality (including protection or enhancement of wetlands), improve water quality (including reduction of salinity), preserve in-stream or riparian habitat, and protect and enhance endangered species.
- Increase the benefits associated with various water uses, such as agriculture, hydropower, municipal and industrial water supply, and recreation. Of particular interest are increases that can be achieved by using the existing water-resources infrastructure of dams, pipelines, canals, and hydroelectric generating capacity.
- Increase the available supply of water by more efficient water management and use or reduction of nonbeneficial system losses (including evaporation or canal seepage).

The achievement of such improvements requires an ability to predict the outcomes of a wide range of water-management actions under a wide range of hydrologic conditions. The predictions needed are of two kinds: long-term simulations of the operation of complete water-resource systems under a modified management strategy and short-term simulations that predict the effects of some specific management action, such as a reservoir release or the delivery of some quantity of water to a point of demand. The techniques used to make either kind of prediction are usually referred to as "modeling." The two situations described above require planning models and forecasting models, respectively. The computer systems, basic understanding, and data-management requirements for these two types of models are much the same, and the development, testing, and calibration process for both can be done jointly by the USGS and the Bureau of Reclamation.

Recent developments have brought water-resources modeling capabilities to a point where the two agencies are poised to enter an implementation phase. These breakthroughs include improvements in the scientific understanding of processes related to climate and hydrologic interactions, production of runoff, and the interaction of surface and ground waters; improvements in the quality and timeliness of data, including use of satellite data relay, new weather radar (to estimate precipitation intensities), and new land- and satellite-based techniques for measuring snowpack; and improvements in the capability of computer hardware and software. Computer models make it possible to test many management scenarios and provide graphical results that are easy to evaluate.

The tools involved are relational and spatial database-management systems integrated with improved models of the water resources of western river basins, as characterized by the USGS Modular Modeling System. The models will be used to test and improve long-term operating policies responsive to the multitude of competing demands for water and other project benefits and to produce state-of-the-art operational analyses (at hourly, daily, weekly, seasonal, and interannual time scales) necessary to manage these water-resources systems efficiently. The benefits of the program are the increased savings and revenues associated with improved operations and the savings in capital expenditures that would result from more efficient water use.

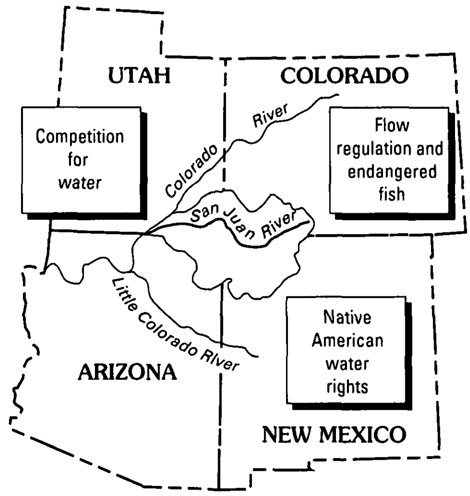
Examples of the types of questions for which the models would provide answers include:

- How much water would be "saved" by implementing conservation measures such as canal lining? Will these savings affect wetland habitat, ground- or surface-water supplies, or water quality downgradient from the canal? How could the "saved" water be beneficially used, and what are the management options?
- How would a new operating policy for a reservoir (for example, a lower normal pool elevation or increased instream flows) affect hydropower revenues, reliability of delivery of water to downstream users, total system losses by evaporation and seepage, reservoir water quality, and water temperature (in the reservoir and downstream)?

- What is the probability that normal reservoir operations will lead to a shortfall from contractual water deliveries or reservoir pool elevations falling below some critical level in the current water year? How would a modified operation over the next week change this probability?
- How would a new reservoir release schedule (focused on diurnal and weekly fluctuations) affect hydropower peaking revenue, channel geometry, beaches, recreational opportunities, and habitat for sport fish or an endangered species?
- How would a major land-use change in the basin (related to logging, urbanization, or agriculture) affect water availability? How would changes in climate (storm tracks, temperature) affect water availability?
- How could ground-water pumpage, reservoir releases, and artificial ground-water recharge operations be optimized to maintain ground-water quality and desired water levels?

USGS efforts in this joint program include (1) further research, development, and refinement of hydrologic modeling tools, including writing new computer programs, supporting and documenting existing programs, and providing training in the use of the models; (2) research on hydrologic processes, the results of which would be incorporated into the models to improve the reliability and scope of the predictions; and (3) basin-specific development and calibration of hydrologic models to the selected river basins for case studies. Research topics include aspects of snow accumulation and melt in mountainous areas, changes in channel morphology that result from changes in sediment supply and flow regime, long-term changes in reservoir water quality (salinity and eutrophication), and consequences of soil drainage and ground-water development on salinity and trace-element contamination.

The Bureau of Reclamation's efforts focus on development and improvement of data-management and modeling tools, which include modeling of system operations, water management and deliveries, and the hydraulics of water delivery to agricultural fields and the subsequent drainage and evaporation from those fields. Specific topics include water use, land use, simulation of the water rights system, balancing project benefits, optimization of system operations, stochastic hydrologic modeling, runoff forecasting, real-time operational modeling, and expert system techniques. As the models become operational, the Bureau of Reclamation plans to



The San Juan River Basin of Utah, Colorado, Arizona, and New Mexico and associated water-management issues. Improved watershed modeling systems are being applied directly to these issues and others being faced by water-management organizations in the Western United States.

integrate them into current basin-management systems.

Both bureaus are working together to ensure that the data and models from one bureau interact efficiently with those from the other and on basin-specific model calibration and implementation. They also are developing integrated training activities in support of the program.

A pilot study is currently underway in the San Juan River Basin, which is centered in the Four Corners area of Utah, Colorado, Arizona, and New Mexico. The major management issues relate to streamflow regulation and endangered fish, competition for water, and Native American water rights. The final product of this pilot study will be an integrated system of models, databases, and decision-support tools implemented within the operating systems of the Bureau of Reclamation and other agencies responsible for aspects of river-basin management. The models, databases, and decision-support tools will be thoroughly documented by user manuals and technical reports in the scientific and engineering literature. The central focus of the integrated systems will be a river-basin model capable of predicting the timing and amount of runoff and simulating the operations of reservoirs and diversions according to specified operating rules. The models will be used to assess the risk of water shortage or flooding over a period of months to years. They also will be used to assess the changes in these risks associated with changes in the operating policies or in the physical infrastructure.

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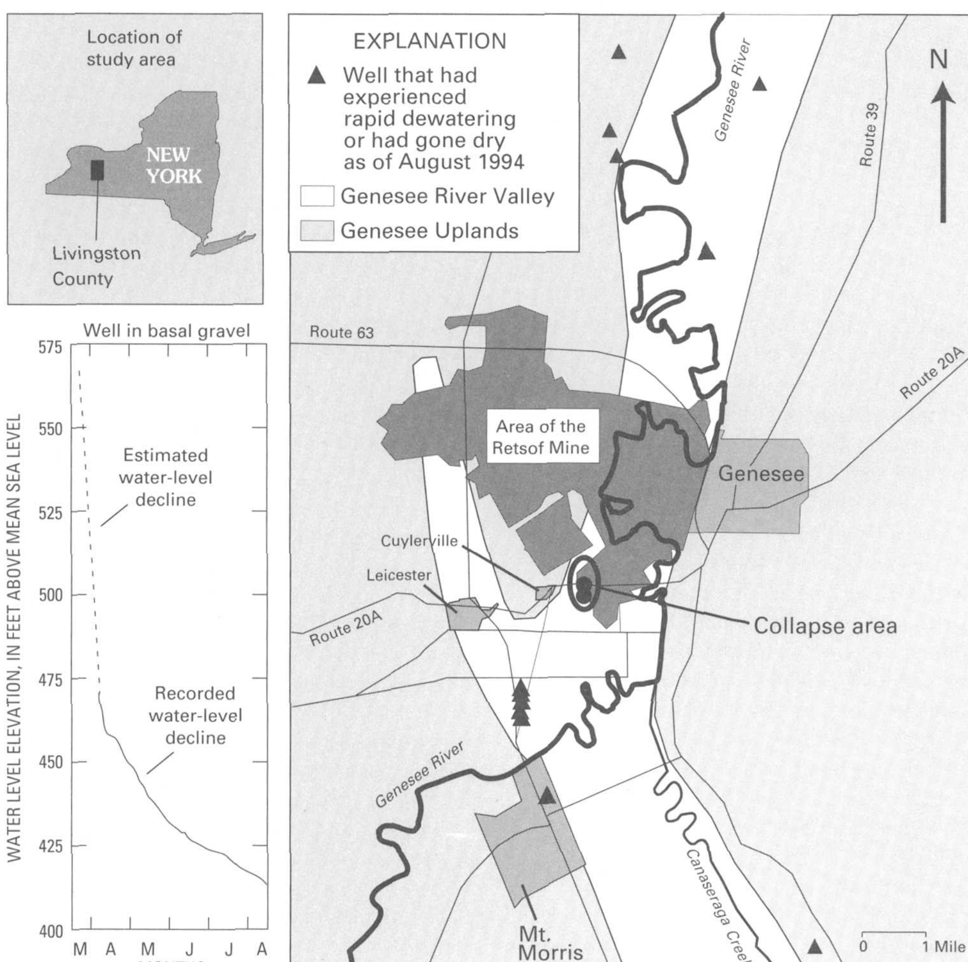
Hydrogeologic Effects of the Partial Collapse of the Retsof Salt Mine in Western New York

The Retsof Salt Mine is in Livingston County, N.Y., about 25 miles southwest of Rochester. This mine, which has been in operation for 110 years and is located about 1,100 feet below land surface, supplies road salt to 14 States in the Northeast. It is the largest salt mine in the Western Hemisphere and includes an underground area that is roughly the size of Manhattan (about 6,500 acres).

An underground room near the southern end of the mine near Cuylerville collapsed on March 12, 1994, and an adjacent room collapsed on April 18. Two large, circular collapse features that are several hundred feet apart have developed at land surface above the two collapsed mine rooms. The northernmost feature, which is about 700 feet in diameter, includes a central area that is about 200 feet wide and has subsided about 20 to 30 feet. The southernmost feature, which is about 900 feet in diameter, includes a central area that is about 700 feet wide and has subsided about 70 feet. The subsidence in the collapse area has forced the closure of a section of State Route 20A as a result of the partial collapse of a State Department of Transportation bridge.

During the formation of these collapse features, hydraulic connections formed between aquifers that previously had been isolated from each other by confining units. These new connections have provided routes for rapid migration of ground water downward to the mine level. Since March 12, ground water draining from overlying aquifer systems has been progressively flooding the



Location of the Retsof Salt Mine and the collapse area and a selected hydrograph for the period from March 12 to August 12, 1994.

mine at inflow rates averaging about 18,000 gallons per minute. This aquifer drainage has caused inadequate water supplies in a number of local wells, some of which have actually gone dry. Land subsidence that might be related to compaction due to aquifer drainage has occurred near Mt. Morris, about 3 miles southwest of the collapse area.

The U.S. Geological Survey (USGS) has been working with the Livingston County Department of Health since March 1994 to provide technical expertise in dealing with this situation. A regional ground-water-level-monitoring network has been established to observe the rate, magnitude, and extent of aquifer drainage related to the mine collapse. Water levels in some wells drilled in the floodplain sediments and upland bedrock units are showing only expected seasonal changes since the collapse. Water levels in some wells drilled in glacial deltaic deposits and a basal gravel on top of the bedrock surface, however, show significant declines that are a result of the aquifer drainage.

A conceptual model of the ground-water-flow system has been developed on the basis of knowledge of the hydrogeology of similar valleys in central and western New York, borehole geophysical surveys of 18 wells drilled in and adjacent to the collapse features, and marine seismic-reflection profiling on the Genesee River. The complex ground-water-flow system involves multiple aquifers in the glacial sediments and the bedrock.

In June 1994, a team of specialists from the USGS examined the environmental effects of the partial collapse of the mine. They compiled a list of recommendations for further short- and long-term studies to address the major issues of public safety, aquifer drainage, and subsidence.

The USGS continues to monitor ground-water levels in the area and is constructing a preliminary numerical model to assess the long-term impacts of the partial mine collapse on the regional ground-water-flow system.

Dorothy Tepper
is Project Chief of the Retsof Salt Mine study and has studied ground-water flow in glacial sediments and bedrock for the past 15 years.

Todd Miller
has studied glacial geology and ground-water flow in glacial sediments for the past 16 years.

Bill Kappel
has studied the interactions of surface water and ground water for the past 21 years.

John Williams
is the ground-water specialist for the New York District and a borehole geophysics advisor.

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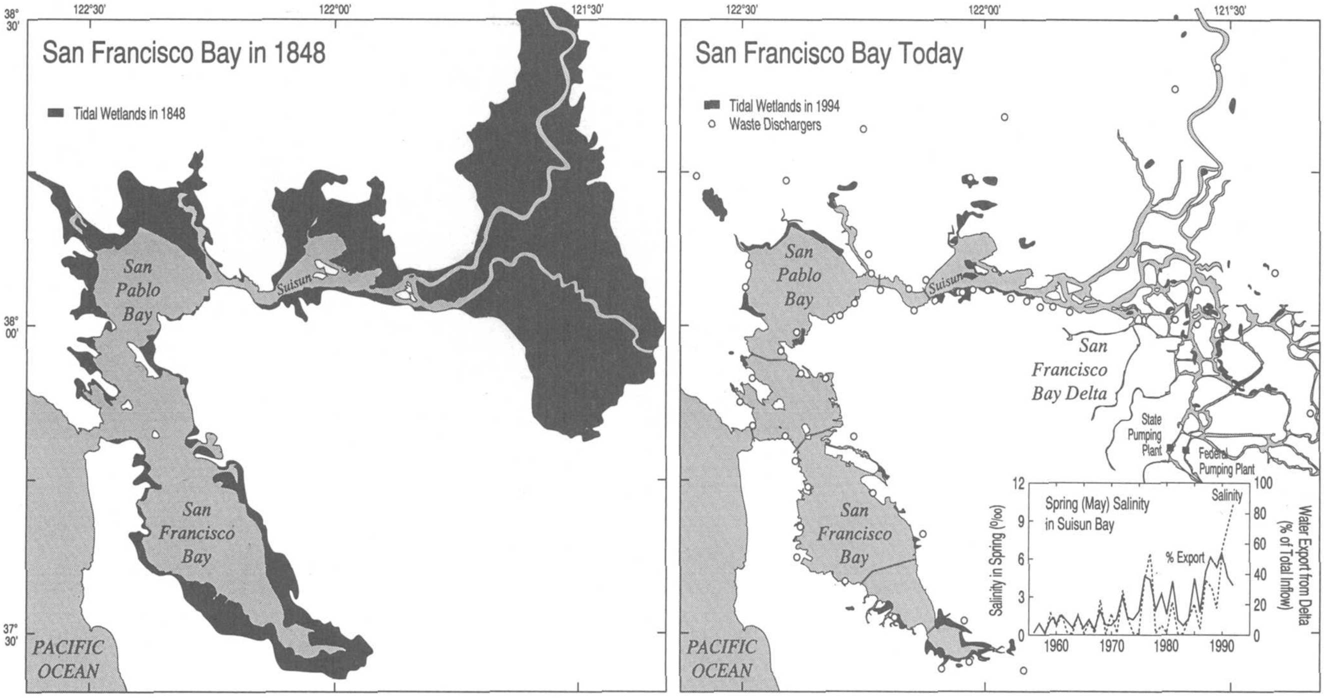
The San Francisco Bay and Delta: An Estuary Undergoing Change

The San Francisco Bay Estuary, which is at the confluence of the Sacramento and San Joaquin Rivers in central California, is renowned for its natural beauty, international commerce, recreation, and sport fishing. However, the estuary has been greatly modified by 150 years of intensifying human activity.

The U.S. Geological Survey (USGS), recognized internationally for its interdisciplinary expertise and experience in the study of estuarine processes and as a long-time leader in studies of the San Francisco Bay Estuary, has provided much of the fundamental knowledge about interrelations among the hydrology, geology, chemistry, and ecology of this complex estuarine system. For example, USGS studies have documented changes in the estuary's shoreline; changes in patterns of water and sediment movement; contamination of its water, sediments, and organisms; and alterations of biological communities. The USGS is now focusing field, laboratory, and modeling studies on the effects of freshwater flow on the estuary's chemistry and biology, the distribution and influence of contaminants on estuarine invertebrates, and the processes that influence the character and stability of the remaining wetlands.

More than 95 percent of the historical tidal marshes have been leveed and filled, the result being losses in fish and wildlife habitat. The flow of freshwater into the estuary has been greatly reduced by water diversions to support, for the most part, irrigated agriculture. Harbor and channel dredging has changed the dredged areas and disposal sites and altered water-flow patterns and salinity. Contaminants enter the estuary in municipal and industrial sewage and urban and agricultural runoff. Introduced exotic species continue to change the bay's biota by altering its



The San Francisco Bay Estuary and Delta at the time of the discovery of gold in the Sierra Nevada foothills (left) and at present (right).

food webs. These changes have had marked effects on the estuary's biological resources, particularly well documented by declines in abundance of fish species.

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It is not clear which and to what extent particular human activities are responsible for specific unwanted ecosystem changes. Thus, determining which courses of action would be most effective in bringing about improvements in the estuary's water quality and restoration of its fish populations has been difficult. Potential limitations to additional economic development include demands on land and water supplies, increasing constraints on diverting water away from the delta because of concerns for endangered species, pressures to shift consumption of managed water from agricultural use to urban use, future land subsidence as a result of increasing dependence on ground-water supplies in dry years, further loss of tidal wetlands to urban encroachment, and constraints on harbor improvements because of potential changes in salinity and contaminant levels as a result of dredging and spoils disposal.

Conflicts among the many uses of the bay/delta system have led resource managers and regulators, elected officials, and the public to recognize the need for credible, unbiased scientific information on the significance of river-flow diversion, contaminant inputs, dredging, and habitat alteration.

Effects of Freshwater Flow

Changes in the quantity, timing, and quality of freshwater that flows into the delta and the bay as a result of diversion by means of pumps within the delta are implicated in declines of fish species. Young fish are physically removed by the pumps, and changing flow patterns and salinity distributions create habitat changes. The U.S. Environmental Protection Agency has proposed a salinity standard that would require the salt content of the water in ecologically sensitive regions of the estuary to be maintained at specified levels. There is need for a better quantitative understanding of flow patterns and salinity distributions within the delta and

Suisun Bay and the relations between the two.

The USGS has conducted broad-scale field and modeling studies of water movement and salinity distributions within the estuary. In cooperation with other agencies in the Interagency Ecological Program (IEP), the USGS is applying new technologies to measure within-delta water transfers and delta outflow into the bay, providing information needed for documenting salt-transport mechanisms, and managing freshwater flow to meet salinity standards. The USGS also is developing statistical models to relate anomalous precipitation, snowpack, temperature, and atmospheric circulation to combined monthly flows in the Sacramento and San Joaquin Rivers.

The relation between freshwater flow and contaminant transport to and through the estuary is important. For example, USGS studies have detected pulses of pesticides (applied during winter in the Sacramento and San Joaquin Valleys) that flow through the delta and upper estuary during winter runoff. These pesticide pulses reach concentrations that have been shown to be toxic to aquatic life in the delta and Suisun Bay. At the same time, sediments and sediment-bound contaminants are being transported through the delta into the bay. The mechanisms of dissolved contaminant and sediment transport in the bay must be understood in order to estimate organism exposure and evaluate mitigation alternatives.

Correlations between flows and most biological populations in the bay and the delta are well documented. For example, scientists know that river flow is a source of organic matter supporting biological productivity within the estuary and that transfers of organic matter among different levels of the food web are influenced by fluctuations in freshwater inflow. They also know that flow conditions are implicated in ecological disruptions (major changes in the estuary's food web) that follow invasions by exotic species. Unfortunately, many of the underlying causes of these changes have not been identified. In particular, establishing the connections between flow-related habitat features and the sustainability of individual fish populations is a high priority. The USGS maintains a baseline measurement program (mapping temperature, salinity, turbidity, and chlorophyll in the channel and emphasizing sampling of benthic invertebrate species abundances and phytoplankton blooms) in San Pablo Bay, Central Bay, and South Bay that complements the IEP program in the upper estuary and delta. Additionally, USGS laboratory experimentation and modeling efforts are providing an understanding of the couplings between water and sediment movement, the biogeochemical cycling of nutrients, the population dynamics and primary production of phytoplankton, and the establishment of introduced species.

Distribution and Effects of Contaminants

Contaminants from numerous sources are pervasive throughout the estuary and its watershed. Agencies charged with protecting and enhancing the estuary's biological resources recognize the need for a much better understanding of contaminant distribution and ecological effects.

The USGS is examining trace-metal and pesticide concentrations in sediments and benthic invertebrates to provide this understanding. For example, the biological effects of pesticides entering the bay during high river flows are being examined by conducting laboratory toxicity tests on local invertebrate species. The USGS also is using models and field studies to investigate recycling of metals and nutrients from internal sedimentary sources in the estuary.

In cooperation with the San Francisco Regional Water Quality Control Board and the U.S. Army Corps of Engineers (COE), the USGS also is quantifying the physical factors (for example, tidal currents and wind waves) that control resuspension and transport of fine sediment in the shallows of the bay to assess the importance of resuspension events on metals concentrations in the water.

Wetlands Processes

The loss of 95 percent of the estuary's wetlands since 1850 has increased the importance of the remaining 125 square kilometers, which continue to be threatened by development, erosion, pollution, and rising sea level. Wetland management agencies (for example, the COE and the San Francisco Bay Conservation and Development Commission) must develop viable strategies for creating new wetlands in leveed areas used as farmland or as salt-evaporation ponds that have subsided since being isolated from bay

> Agencies participating in the Interagency Ecological Program include the U.S. Fish and Wildlife Service, the Bureau of Reclamation, and the U.S. Geological Survey (all bureaus in the Department of the Interior), the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the California Water Resources Control Board, the California Department of Water Resources, and the California Department of Fish and Game.

To access the USGS Home Page, open the Uniform Resources Locator (URL) and enter:

http://www.usgs.gov

To access the San Francisco Bay Home Page, open the URL and enter:

http://bard/bay/access_usgs.html

waters. As an example, filling these areas with dredge spoils raises questions about the release of contaminants and changes in wetland-habitat values. The USGS is participating in the restoration of a 350-acre tract of land on San Pablo Bay by monitoring the development of tidal channels and flow patterns, changes in geotechnical and geochemical properties of preexisting and new sediment (dredge spoils), and sedimentation patterns within the restored wetlands and adjacent areas. The USGS also is mapping wetlands distributions by using remotely sensed image data and monitoring physical processes (including currents, wind, and waves) that alter wetlands and adjacent shallows; by quantifying the distribution and elevations of the shoreline; and by developing models that characterize the physical forces acting upon wetlands.

Information Transfer

The USGS is developing new tools and procedures to make existing and newly developed information about the San Francisco Bay Estuary and Delta readily available. The accessibility of existing spatial data scattered among several USGS laboratories will be increased by the creation of a World Wide Web information interface. World Wide Web navigators, such as Mosaic, will enable any user with Internet access to browse and retrieve information relevant to the San Francisco Bay and Delta (including text, pictures, maps, and animations) and interact directly with USGS experts.

Long-term USGS monitoring and research programs in San Francisco Bay provide needed data, information, interpretations, and assessments that contribute to the work of other Federal and State agencies. This linkage of science and decisionmaking ensures the coordination of activities necessary for effective environmental resource management.

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Frederic H. Nichols
has participated in USGS studies of San Francisco Bay since 1972.

Environment

USGS

Issues such as hazardous wastes, environmental degradation, population growth, soil contamination and erosion, water quality and adequate water supplies, and atmospheric changes are of paramount importance today as the Nation and the world wrestle with the impacts of human activity on the natural environment. Understanding the conditions and functions of environmental systems and the factors that are changing them is an important function of the USGS scientific mission. Policymakers and resource managers need to have scientific information on both natural and impacted environments in order to recognize and mitigate adverse effects on these systems from human activities and to develop strategies accommodating natural environmental variation. Improving the technical basis for maintaining the environmental systems that sustain and improve the quality of human life, as the articles in this section discuss, is part of the ongoing work of the USGS.

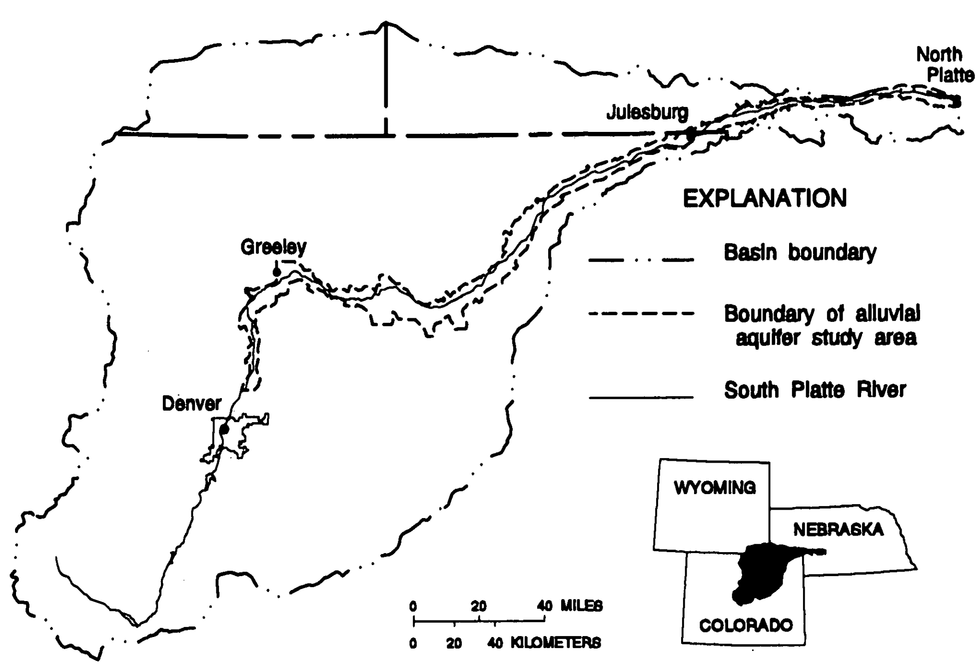
Nitrate in the South Platte River Alluvial Aquifer, Colorado

The South Platte River alluvial aquifer between Denver and Greeley, Colo., covers an area of about 75 square miles. The predominant land use in the area is irrigated agriculture, which has changed the chemistry and hydrology of the alluvial aquifer in at least two important ways. First, the infiltration of irrigation water has resulted in a buildup of dissolved nitrate in ground water in the aquifer. Second, it has increased the amount of discharge from the aquifer to the South Platte River. One objective of the study was to determine if naturally occurring processes in the aquifer reduce nitrate concentrations in the water prior to its discharge to the South Platte River, thereby decreasing the effect of irrigated agriculture on water quality in the river.

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program began in 1991 and describes the status of and trends in the quality of the Nation's surface- and ground-water resources. The program provides a thorough understanding of the natural and human factors that affect the quality of those resources. NAWQA plans to conduct investigations in 60 study areas that represent a variety of geologic, hydrologic, climatic, and geographic conditions throughout the Nation. The South Platte River Basin study unit, which is in parts of Colorado, Nebraska, and Wyoming, was among the first 20 study units in which work was begun in 1991.

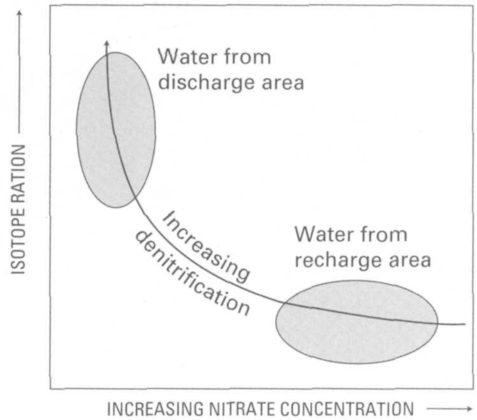
The South Platte River alluvial aquifer is the most productive aquifer in the basin; most of its water is used to irrigate overlying cropland. The aquifer consists of unconsolidated clay, silt, sand, and gravel and ranges in thickness from about 15 to 60 feet and in width

One objective of the study was to determine if naturally occurring processes in the aquifer reduce nitrate concentrations in the water prior to its discharge to the South Platte River, thereby decreasing the effect of irrigated agriculture on water quality in the river.

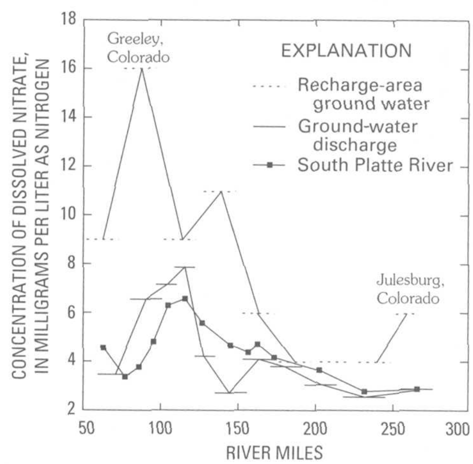


Alluvial aquifer study area in the South Platte River Basin.

Relative changes in nitrate concentrations and nitrate nitrogen isotope ratios in samples of ground water from the recharge and discharge areas.



Median concentrations of nitrate in water in the recharge area for indicated river reaches. Median concentrations of nitrate were calculated for samples collected from 1992 through 1994. Mass-balance-estimated nitrate concentrations in the ground-water discharge are for samples collected in April 1994.



Microbial denitrification is a bacterial process that converts nitrate (NO_3) to nitrogen gas (N_2). Nitrogen gas is a harmless end product and is the major component in the air we breath.

For more information on nitrates in the South Platte River alluvial aquifer, contact Peter McMahon at:

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from about 0.5 to 5 miles. Recharge to the aquifer is from infiltration of irrigation water and precipitation, and both occur over most of the floodplain and terrace deposits adjacent to the river. Discharge from the aquifer is to the river.

Long-term agricultural activity on land that overlies the South Platte River alluvial aquifer has resulted in a buildup of dissolved nitrate in water in the recharge area. Nitrate concentrations in ground water from the recharge area near Greeley ranged from less than 0.1 to greater than 45 milligrams per liter as nitrogen; the median concentration was 26 milligrams per liter as nitrogen. The maximum contaminant level for nitrate is 10 milligrams per liter as nitrogen in drinking water as established by the U.S. Environmental Protection Agency. Measurement of the stable nitrogen-isotope ratios of the nitrate indicated that the nitrate was derived from animal waste–an interpretation that is consistent with the long-term practice in the area of fertilizing fields with animal manure from feedlots.

Nitrate concentrations in water from the discharge area near the South Platte River were substantially lower than concentrations in water from the recharge area. Nitrate concentrations in ground water from the discharge area ranged from about 2 to 30 milligrams per liter as nitrogen; the median nitrate concentration was 6 milligrams per liter as nitrogen. The decrease in nitrate concentrations between the recharge and the discharge areas indicated that nitrate concentrations were attenuated along flow paths in the aquifer.

Microbial denitrification in aquifer sediments in the discharge area was at least partly responsible for the decrease in nitrate concentrations between the recharge and discharge areas. For example, concentrations of dissolved oxygen were high in water from the recharge area. Denitrifying activity is inhibited in the presence of oxygen; therefore, nitrate persists in water from the recharge area. In contrast, dissolved oxygen was absent or at very low concentrations in water in the discharge area, which allowed denitrification in sediments in discharge areas. The stable nitrogen isotope ratios of nitrate in the ground water increased (became more enriched in the heavy isotope ^{15}N compared with the light isotope ^{14}N) as the nitrate was transported from the recharge area to the discharge area. At the same time, the ground water became enriched in dissolved nitrogen gas, which is the major product of the denitrification reaction. Increases in nitrate nitrogen isotope values and nitrogen gas concentrations along with decreases in nitrate concentrations further indicated that denitrification in sediments in the discharge area was at least partly responsible for reducing nitrate concentrations in the ground water before its discharge to the river.

A mass balance based on nitrate concentrations in surface-water inflows and outflows indicated that the concentration of nitrate in ground water that discharges to the South Platte River in the study area was much less than what would be predicted on the basis of nitrate concentrations in the water from the recharge area. Differences between ground-water nitrate concentrations in the recharge area and those in the discharge area were observed elsewhere along a 250-mile segment of the alluvial aquifer from north of Denver to Julesburg, Colo.; these differences indicate that denitrification may have occurred in discharge areas throughout the alluvial aquifer in Colorado. Despite the effect of denitrification in reducing nitrate concentrations in ground-water discharge, the process did not completely denitrify the ground water. As a result, ground-water discharge still affected the quality of water in the South Platte River.

Peter McMahon
has over 10 years of experience as a USGS hydrologist. His work focuses on the impacts of biological processes on ground-water quality.

John Karl Böhlke
is a research hydrologist whose recent work has focused on applications of chemical and isotopic methods for determining ground-water residence times and resolving sources, histories, and reactions of anthropogenic contaminants affecting aquifers.

David Litke
has worked as a USGS hydrologist in Colorado for the last 10 years. His areas of interest include surface-water quality, water use, and the use of geographic information systems in water studies.

Environmental and Resource Studies in the U.S.–Mexico Border Region

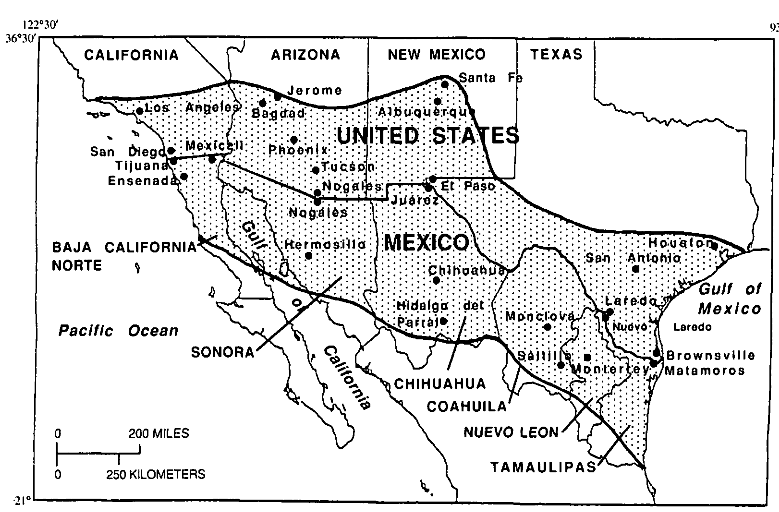
Ratification of the North American Free Trade Agreement (NAFTA) reinforces the need for geoscience data and information in the U.S.–Mexico border region. NAFTA will accelerate urban, agricultural, and industrial growth and trade along the border. Such growth and the current and anticipated potential for increased effects on the environment necessitate development of a large, coherent geoscience database. Such a database is vital to both nations in many disciplines, including land-use management, urban planning, civil engineering, exploration geology, environmental sciences, environmental regulation, resource management, waste treatment, and industrial mineral supply. The U.S. Geological Survey (USGS) has begun several cooperative projects to compile existing data and to provide new data related to these issues.

Data on the distribution and characteristics of mineral sites are essential for effectively planning industrial and urban development and for improving the quality of life in the border region. A computerized mineral-site database containing information on more than 10,000 sites near the U.S.–Mexico border has been compiled in the USGS Mineral Resources Data System. Each site record provides the name of the site, its location, the commodity mined, the geology of the site, a description of the workings and deposits, and a history of exploration, development, and production at the site. The database includes both metallic and nonmetallic minerals and materials. Analysis of this information indicates that a wide variety of nonfuel mineral commodities are present in the border region. Mineral resources and mineral-related issues in the border region that will affect the economies of the United States and Mexico include the following.

- Many nonmetallic minerals are used for improving water quality, isolating waste, and mitigating environmental hazards. Important resources in the border region include diatomite and zeolites for waste treatment, clays for sealing waste dumps, and limestone for removing sulfur from emissions produced in coal- or oil-fired power stations. Mineral occurrences and abandoned mine sites may be sources for acid-mine drainage and elevated levels of toxic trace elements in soils and ground water.
- Mineral materials such as limestone, sand, gravel, and gypsum are widely used in the border region as construction materials, especially in rapidly growing urban areas.
- The border region produces about 18 percent of the world's copper as well as other metallic commodities, including zinc, lead, silver, and gold. Metals used in alloy manufacture, such as aluminum, cobalt, nickel,

Mineral-site data are available from the Minerals Information Offices of the U.S. Geological Survey in digital form or as listings, tables, and plots and are summarized in Circular 1098.

Area defined as the U.S.–Mexico border region.



and iron, are produced in relatively small quantities or not at all; thus, for economic growth, these metals will need to be imported into the border region.
- Minerals such as gypsum, clays, and sulfur are used to produce fertilizers, animal feeds, and pesticides.

Another important layer of geoscience information for the U.S.–Mexico border region is a geologic map in digital format. The border region extends across six different geologic provinces from east to west–from the Gulf of Mexico Coastal Plain, across ancient rocks of the stable continental platform and remnants of past volcanic eruptions, to regions where the Earth's crust has been stretched and areas where rocks from ancient ocean environments have been stuck on to the continent. This complex geology complicates the task of producing a coherent map. Geologic maps of the States of Arizona and New Mexico are now available from the USGS in digital format at a scale of 1:1,000,000. The geology of the border region of Texas is being digitized at a scale of 1:500,000, as is the geology of California.

Other current investigations pertinent to the border region include evaluating hydrologic basins that contain aquifers along the border, establishing baseline geochemical information in the larger drainage areas, and examining the dispersion of metals and the natural availability of potentially toxic substances in the region. The San Pedro River Valley in southern Arizona and northern Sonora, Mexico, is composed of several subbasins. A multidisciplinary study to determine the three-dimensional shapes of these subbasins, to describe the relations among the subbasins, and to assess the character and distribution of the sediments filling the basins is underway.

This project is an essential first step in assessing the potential for ground-water contamination in subbasin aquifers. Existing geochemical databases are being analyzed and evaluated to provide a geochemical baseline. Some of the samples are being reanalyzed for elements particularly important in identifying potential sites of pollution. These data will also provide a regional hydrogeochemical framework for a large part of southern Arizona and for investigations related to the USGS National Water-Quality Assessment Program in central and southern Arizona. Several investigations are being conducted on the dispersion of metals from mined and unmined ore deposits. Such data will allow the effect of natural mineralization on the natural distribution of potentially toxic systems to be compared with anthropogenic activities such as mining.

The establishment and continued construction of a geoscience database, including elements of geology, geochemistry, geophysics, and mineral sites, will allow for effective implementation of NAFTA. The geoscience database forms part of the necessary framework for development of land- and ecosystem-management plans and increased infrastructure, industry, and agriculture in the border region.

For more information on USGS studies in the U.S.–Mexico border region, contact Norman J Page at:
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Pesticides in the Atmosphere

One of the first issues to be addressed by the National Water-Quality Assessment (NAWQA) Program National Synthesis is the presence of pesticides in the environment. The goal of the National Synthesis is to use existing data and new data collected during NAWQA studies to assess the status, trends, and cause-and-effect relations for the Nation's highest priority national and regional water-quality issues. About 1.1 billion pounds of pesticides are used each year in the United States to control many different types of weeds, insects, and other pests in a variety of agricultural and nonagricultural settings.

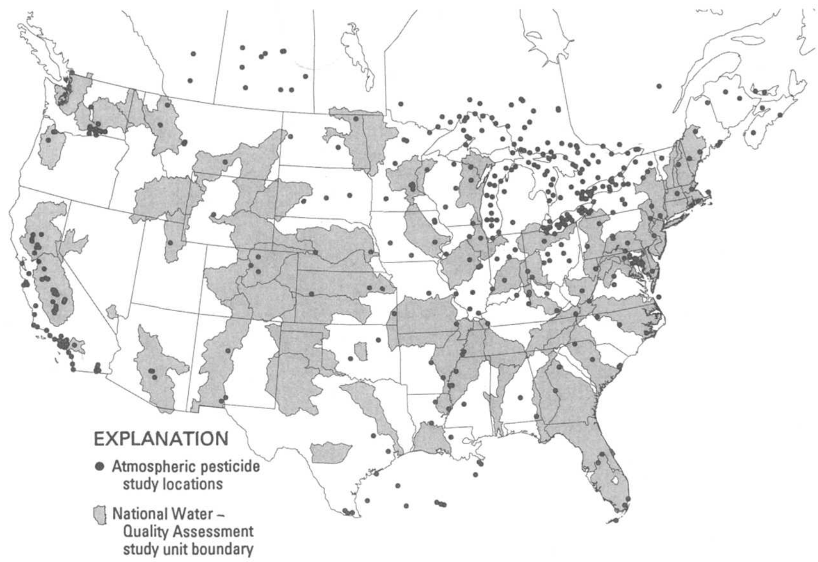
Total agricultural use and the number of different chemicals applied to crops have more than tripled since the early 1960's. Increased use has resulted in increased crop production, lower maintenance costs, and control of public health hazards, but concerns about the potential adverse effects of pesticides on the environment and human health also have grown steadily. The Pesticide National Synthesis begins with detailed reviews of existing information on pesticides in the hydrologic system, including ground and surface waters and the atmosphere. Results for the atmosphere are summarized below.

Pesticides have been recognized as potential atmospheric pollutants since the

1940's. Early in the history of agricultural pesticide use, off-target drift of applied pesticides was a concern. Long-range movement of pesticides was thought to be minimal, if any, because of their physical and chemical properties (low volatility and low solubility in water). The detection of DDT and other organochlorine compounds in Arctic and Antarctic snow, ice, fish, and mammals changed this notion. The atmosphere is now recognized as a major pathway by which pesticides can be transported and deposited in areas sometimes far removed from their sources.

Early in the history of agricultural pesticide use, off-target drift of the applied pesticides was a concern. Long-range movement of pesticides was thought to be minimal, if any, because of their physical and chemical properties....

The geographic distribution of sampling sites for the 127 studies reviewed is highly uneven, and many areas of the Nation have never been sampled. The most extensive data-collection efforts have been concentrated in the Great Lakes area and California. Most of the studies reviewed were short term, seldom lasting more than 1 year, and focused on sites in or near agricultural areas; as a result, the data display a general bias toward this land use.

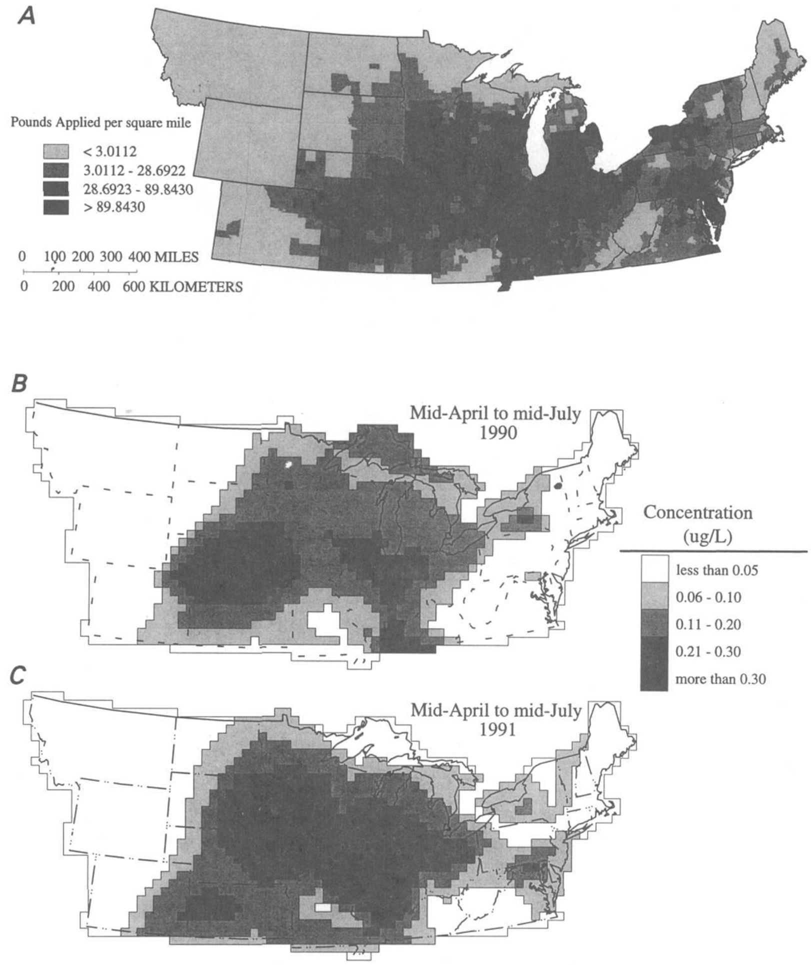


Site locations for those studies that sampled for pesticides in one or more atmospheric matrices in the United States and the bordering provinces of Canada.

Number of different pesticides detected in air, rain, snow, and fog per State by major class. *A*, Organochlorine insecticides; *B*, organophosphorous insecticides; *C*, triazine and acetanilide herbicides; *D*, other herbicides.

Atmospheric Pesticides

One or more types of pesticides have been found in every part of the Nation. Although no study analyzed for every pesticide or even representative pesticides from every class, taken together, the results show that a wide variety of pesticides is present in air, rain, fog, and snow. The pesticides detected most frequently in the atmosphere fall into four main categories–organochlorine insecticides (such as DDT, chlordane, toxaphene), organophosphorous insecticides (such as diazinon, malathion, parathion), triazine and acetanilide herbicides (such as atrazine, cyanazine, metribuzin and acetochlor, alachlor, metolachlor, respectively), and other herbicides (such as 2,4-D, DCPA, trifluralin). Because of their widespread use during the 1950's through the 1970's and their resistance to environmental transformations,



Atrazine use in 1988 through the study area (*A*) and the precipitation-weighted concentrations of atrazine throughout the Midwestern and Northeastern United States from mid-April through mid-July 1990 (*B*) and 1991 (*C*).

organochlorine insecticides have been detected in the atmosphere of every State in which they were sought. Organophosphorous insecticides also have been heavily used for decades and are still in high use. As a class, they are not as environmentally persistent as the organochlorine compounds, but they have been detected in most States in which analyses have been made. Triazine herbicides have been in use since the 1960's, but studies in which these compounds are analyzed from the atmosphere did not begin until the late 1970's, when atrazine was found in rain in Maryland. Subsequent studies have detected high levels of triazine herbicides in rain in major corn-producing areas, such as the Midwestern United States. Acetanilide herbicides are frequently used in conjunction with triazine herbicides. Although they are not as environmentally stable as the triazine herbicides, they have been detected in rain at equivalent and even higher concentrations. Many other types of herbicides are used in agriculture, and many of them have been detected in the air or precipitation throughout the United States.

Most Pesticides Studied Have Been Detected

Evidence from the reviewed literature shows that most of the pesticides for which analyses have been made have been detected in at least one atmospheric matrix. Compared with the hundreds of pesticides that have been and are being used, the number and variety of pesticides analyzed from and detected in air and rain are few. These figures do not mean, however, that the majority of pesticides used are not present in the atmosphere. There are several reasons why a particular pesticide has not been found–for example, low use, short atmospheric residence time (considering deposition and transformation), the timing of the sampling relative to the timing of use, the predominant atmospheric phase in which it will accumulate relative to the phase being sampled, and, perhaps most important, whether it has been analyzed for in the atmosphere.

High Atmospheric Concentrations of Pesticides Show Seasonal Trends

Pesticide occurrences in air, rain, and fog often show seasonal trends; the highest concentrations correspond to local use and planting seasons. In a recent U.S. Geological Survey (USGS) study, samples of rain collected throughout the Midwestern and Northeastern United States were analyzed for a variety of triazine and acetanilide herbicides used in corn and soybean production. The analyses show that the highest concentrations occurred where corn was most intensively grown and corresponded to the spring and summer planting seasons. Observed concentrations for August through March were considerably less. There is a very detailed and strong relation, both spatially and temporally, between atrazine use and concentrations in rain. Pesticides also have been detected at low levels during periods before and after the high-use seasons. These off-season occurrences could be the result of the volatilization and wind erosion of previously applied material or long-range transport from areas where the planting/growing season started earlier. The more persistent pesticides, such as organochlorine insecticides, have been detected in the atmosphere at low levels throughout the year even though they are no longer used in the United States. Another source of pesticides in our atmosphere is from long-range transport from areas outside the United States, such as Mexico, Eastern Europe, and Asia, where many organochlorine insecticides that have been banned in the United States are still being used in large quantities.

Effects of Pesticides on Water Quality Not Well Documented

The potential contribution and relative importance of pesticides from the atmosphere to a body of surface water depend on pesticide levels in atmospheric deposition and on how much of the water budget is derived from surface runoff and direct precipitation. However, very little research has been done on the deposition of pesticides into surface waters. The most clearly documented effects of atmospheric pesticides on human health and aquatic life, even at the low levels commonly found in air, rain, snow, and fog, are related to long-lived, environmentally stable organochlorine insecticides that concentrate in organisms through biomagnification (food chain accumulation), bioconcentration (environment/organism partitioning), or both. An example is the organochlorine insecticide toxaphene in the Great Lakes region. Toxaphene, which is carcinogenic to laboratory animals, was never used to any great extent in this area but has been detected in the air, rain, water, sediments, and fish. The most probable source for this contamination is long-range atmospheric transport from the high-use areas in the Southern United States and Mexico.

Determining the environmental significance of pesticides in air, rain, snow, and fog is difficult, and there are no existing national standards or guidelines for these matrices. The only available guidelines are for contaminants in terrestrial waters. In addition to human health concerns, aquatic organisms are often more sensitive to low-level pesticide exposures than humans are, and the U.S. Environmental Protection Agency and the National Academy of Sciences have set maximum levels of several pesticides for the protection of aquatic life. The majority of pesticides in use today, however, do not have such established levels. Pesticide concentrations in rain usually are one order of magnitude or more below the human health standards or maximum contaminant levels for water. There have been several instances, though, where the concentrations of pesticides in rain and fog have exceeded the maximum contaminant level values for aquatic life in or near agricultural areas.

Improved Databases Are Needed

The extent of pesticides in our atmosphere and their deposition into surface waters are not well known because there is no consistent nationwide monitoring of pesticides and their transformation products in atmospheric deposition. Existing data on pesticides in the atmosphere show that pesticides have been found in air, rain, snow, or fog throughout the Nation and that most pesticides studied have been found. The potential significance to water quality has not been extensively studied except in the Great Lakes area. The effects on the health of humans and aquatic organisms brought about by chronic exposure to low levels of a wide variety of insecticides, herbicides, and fungicides also are not well known. Water-quality investigations conducted as part of the NAWQA Program will consider atmospheric deposition as a potentially important source of pesticides, particularly during high-use seasons in high-use areas, but generally will not conduct extensive sampling of atmospheric media. The NAWQA Program will work with other agencies and programs to encourage the development of more comprehensive monitoring and the study of atmospheric contaminants.

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Contaminants in the Mississippi River

The first ever intensive water-quality study of the entire Mississippi River system was conducted by the U.S. Geological Survey (USGS) and others from 1987 to 1992. This article is an excerpt from the complete report on that study, *Contaminants in the Mississippi River, 1987–92*, edited by Robert H. Meade and scheduled for publication in 1995 as Water-Supply Paper 2440. The study was conducted by USGS scientists in cooperation with agencies from States along the Mississippi River, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers.

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is a geologist who has spent the last 20 of his 38 years with the USGS investigating the waters and sediments of large rivers.

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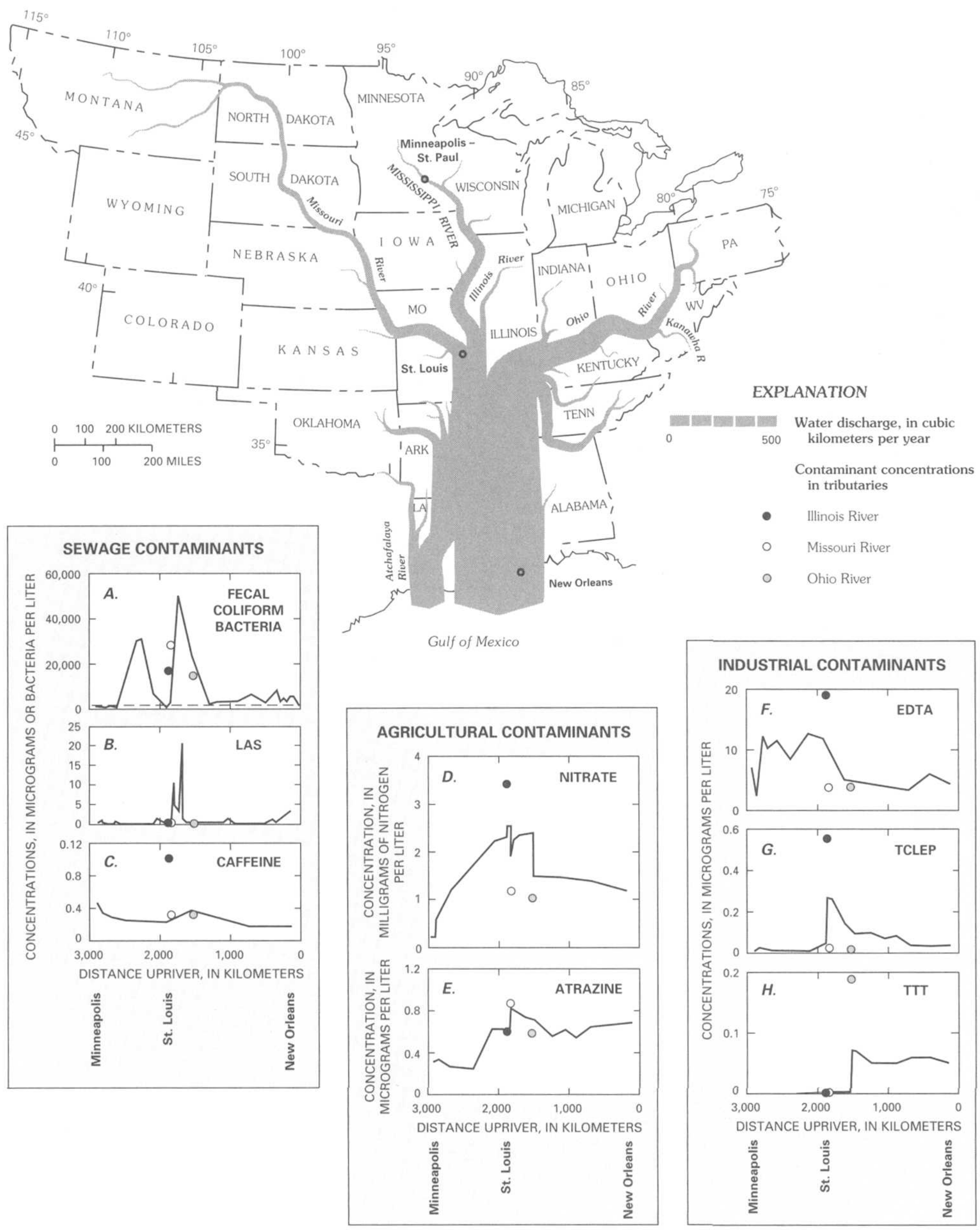


← The waters of the Mississippi River carry dissolved contaminants and bacteria that originate from a variety of municipal, agricultural, and industrial sources. This map shows the amounts of water discharged by the Mississippi River and its tributaries during an average year. About 2 percent of the average discharge of the Mississippi River comes from municipal and industrial point sources. The distribution of contaminants along the Mississippi River depends on the nature and locations of their sources, the degree of wastewater treatment, and the stability of the contaminants and their dilution by receiving waters. The graphs show the concentrations of contaminants dissolved in the Mississippi River between Minneapolis–St. Paul, Minn., and the Gulf of Mexico. The data in the graphs are generalized from chemical analyses of representative samples of water collected at between 10 and 15 sites along the Mississippi River on as many as 10 separate occasions from 1987 to 1992 in the lower river and on 3 separate occasions during 1991 and 1992 in the upper river.

As the Mississippi River flows southward from its headwaters in the northern States of the Midwest, its discharge is more than doubled by the waters it receives from the Illinois and Missouri Rivers. This combined discharge is more than doubled again as it is joined by the waters of the Ohio River. About 500 kilometers upriver of its principal mouth, the Mississippi River bifurcates, and a quarter of its discharge is diverted by way of the Atchafalaya River to the Gulf of Mexico.

A. Fecal coliform bacteria derived from human and animal wastes survive only briefly in river water, but their averaged concentrations exceed the maximum contaminant level of 2,000 per liter for recreational use in much of the Mississippi River because of incomplete wastewater treatment.

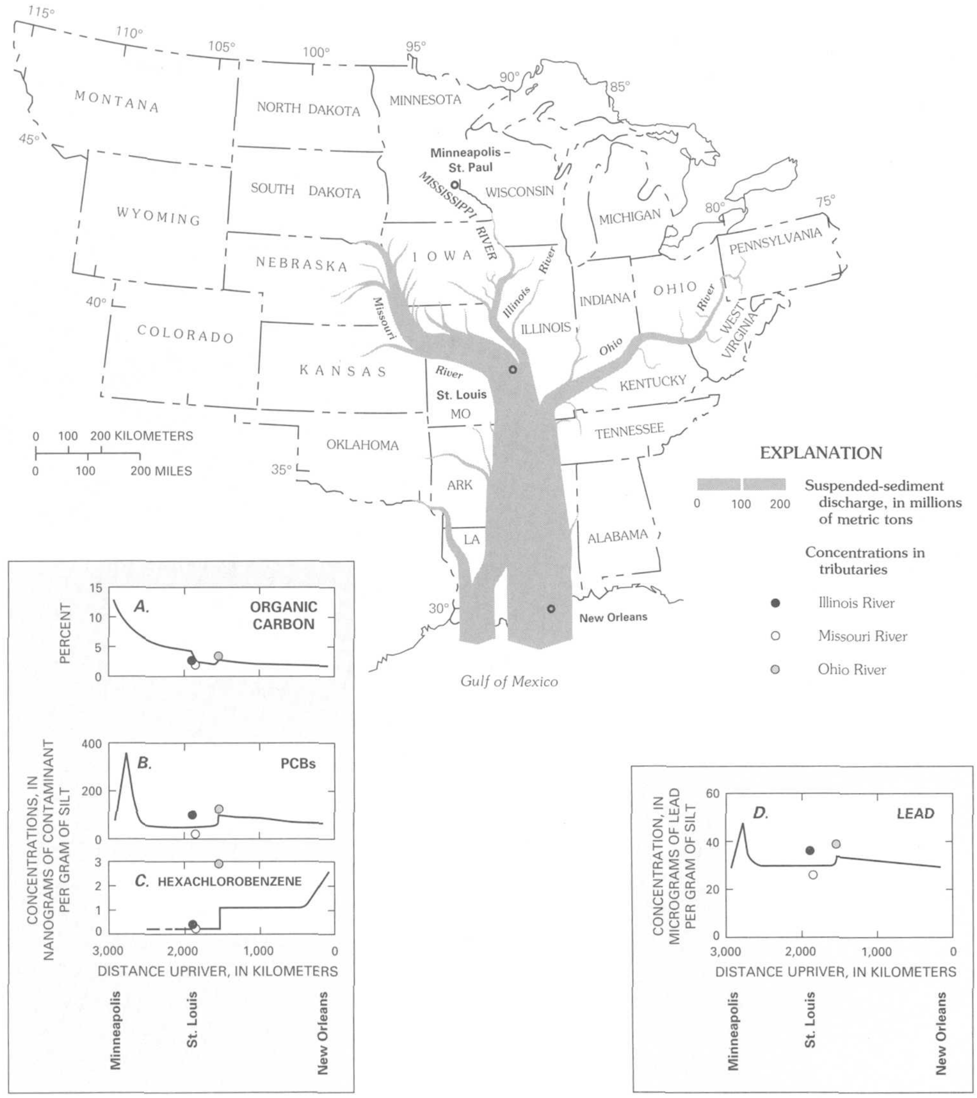
B. Linear alkylbenzene sulfonate (LAS) is a biodegradable detergent primarily derived from domestic sewage. Its presence in high concentrations in the Mississippi River in the St. Louis metropolitan area corresponds with elevated counts of coliform bacteria and probably reflects the incomplete treatment of wastewater discharged into the river.

C. Caffeine is a stimulant chemical in coffee and soft drinks. Because it is consumed only by humans, it serves as an indicator of domestic sewage and illustrates the extent to which sewage is diluted by the river. Concentrations of caffeine in municipal wastewaters usually range between 20 and 300 micrograms per liter. The much lower concentrations of less than 1 microgram per liter of caffeine shown in the graph indicate that municipal wastewaters may be diluted as much as a thousand fold after they are well mixed into the Mississippi River.

D, E. Agricultural chemicals enter the rivers from mostly nonpoint sources, usually as runoff from croplands during spring and summer. Nitrate in the Mississippi River (*D*) comes mostly from fertilizers. Its concentration in the river fluctuates seasonally, depending on when it is applied to farmlands and the timing of rainfall and runoff. Nitrate concentrations generally are smaller in the Mississippi River below the confluence of the Ohio River; the major portion of nitrate in the Mississippi River is derived from tributaries that drain intensively farmed regions in Illinois, Iowa, and Minnesota. Atrazine (*E*) is a preemergent herbicide that is used mostly on corn fields and is nearly ubiquitous in the Mississippi River. Atrazine concentrations usually are greatest near St. Louis because of inputs from the Missouri and Illinois Rivers and other rivers that drain the farming regions of the Corn Belt. Concentrations usually are smaller in the lower Mississippi because of dilution by water from the Ohio River. Atrazine concentrations vary seasonally and occasionally exceed the maximum contaminant level of 3 micrograms per liter during spring runoff in the Mississippi River between St. Louis and the Ohio River confluence.

F. Ethlenediaminetetraacetic acid (EDTA) is the dissolved organic chemical contaminant present at the greatest concentration in the Mississippi River. Generally considered nontoxic, this chemical is a general indicator of industrial contamination and is found in the Mississippi River at about one-fourth of the concentration found in some European rivers.

G, H. Two examples of contaminants from industrial point sources are tris-2-chloroethylphosphate (TCLEP) and 1,3,5-trimethyl-2,4,6-triazinetrione (TTT). TCLEP (*G*) is a flame retardant that is added to polyurethane foams and textiles; in the Mississippi River system, it is derived almost exclusively from the Illinois River Basin. Its exclusive source and its persistence in solution make TCLEP a useful tracer and indicator of waters from the Illinois River as they mix down the Mississippi River with waters from other tributaries. TTT (*H*) is a byproduct of the manufacture of methylisocyanate. Its overwhelmingly singular source in the Mississippi River system is the basin of the Kanawha River of West Virginia, which is a tributary of the Ohio River. Proportions of TTT dissolved in the water can be used to follow the mixing of the Kanawha River with the Ohio River and the Ohio with the Mississippi River.


MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
IOWA
WISCONSIN
MICHIGAN
PENNSYLVANIA
COLORADO
KANSAS
ILLINOIS
INDIANA
OHIO
WEST VIRGINIA
KENTUCKY
TENNESSEE
OKLAHOMA
MO
ARK
LA
ALABAMA
Minneapolis - St. Paul
St. Louis
New Orleans
MISSISSIPPI RIVER
Missouri River
Illinois River
Ohio River
Gulf of Mexico
0 100 200 KILOMETERS
0 100 200 MILES
EXPLANATION
Suspended-sediment discharge, in millions of metric tons
0 100 200
Concentrations in tributaries
Illinois River
Missouri River
Ohio River
A. ORGANIC CARBON
PERCENT
B. PCBs
C. HEXACHLOROBENZENE
CONCENTRATIONS, IN NANOGRAMS OF CONTAMINANT PER GRAM OF SILT
DISTANCE UPRIVER, IN KILOMETERS
Minneapolis
St. Louis
New Orleans
D. LEAD
CONCENTRATION, IN MICROGRAMS OF LEAD PER GRAM OF SILT
DISTANCE UPRIVER, IN KILOMETERS

← The suspended sediments that are transported by the Mississippi River and its tributaries adsorb and carry pollutants. Organic pollutants, such as polychlorinated biphenyls (PCB's), and inorganic pollutants, such as lead, are many times more likely to adhere to sediment particles than they are to remain in the dissolved state. The map shows the amounts of suspended sediment discharged by the Mississippi River and its tributaries during an average year near 1990. The graphs show the concentrations of the constituents adsorbed on the sediments in suspension in the Mississippi River between Minneapolis–St. Paul, Minn., and the Gulf of Mexico. The data in the graphs are generalized from chemical analyses of representative samples of suspended sediment collected at between 10 and 15 sites along the Mississippi River on as many as 10 separate occasions from 1987 to 1992 in the lower river and on 3 separate occasions during 1991 and 1992 in the upper river.

Suspended-sediment discharges in the upper Mississippi River are fairly small when compared with those of the major tributaries. The sediment discharge of the upper Mississippi is increased 5 to 10 times by the sediment discharge of the Missouri River. The average sediment load is increased by another significant increment by the contribution from the Ohio River.

A. Organic carbon (expressed here as a weight percentage of dried suspended silt and clay) is proportionately greater in the uppermost Mississippi River, and its proportion decreases downriver. Particulate organic carbon in the Mississippi River is mostly natural, but it affects the ways in which pollutants, especially organic pollutants, are adsorbed by suspended sediment. The Missouri and Illinois Rivers transport suspended sediment in which organic carbon is somewhat less concentrated; where these two tributaries enter the Mississippi (near kilometer 1850), the organic carbon percentages are decreased by dilution. Organic carbon percentages in the suspended sediment of the Ohio River, however, are typically greater than those in the Missouri and Illinois Rivers, and the organic carbon in suspended sediment is increased slightly where the Ohio River joins the Mississippi (kilometer 1535).

B. PCB's, which are pollutants that were once widely used in industrial applications, are typically most concentrated on the suspended sediments in the upper Mississippi River near Minneapolis–St. Paul. The difference between PCB concentrations on the suspended sediments near Minneapolis and those near St. Louis is the result of the greater amounts of suspended sediment in the river at St. Louis rather than an indication that Minneapolis–St. Paul contributed 5 to 10 times more PCB's to the river than St. Louis did. The high concentrations in the upper river decrease rapidly downriver, and they are increased significantly only as the suspended sediment from the Ohio River, which usually contains more PCB's than the middle reaches of the Mississippi River do, enters and mixes.

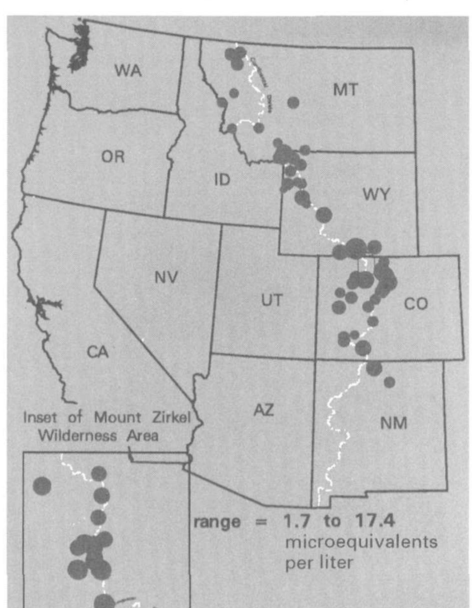
C. Hexachlorobenzene, another organic pollutant of industrial origin, is predominantly derived from two main sources in the Mississippi River basin—the Ohio River, which enters the Mississippi at kilometer 1535, and the industrial corridor that lines the lowermost 400 kilometers of the Mississippi River.

D. Lead and other heavy metals are associated with the suspended sediments along the length of the Mississippi River. Spatial variations in their concentrations are less pronounced than in those of PCB's and hexachlorobenzene. However, they do tend to be most concentrated on the suspended sediments in the river just downstream from Minneapolis–St. Paul (as in the case of PCB's, because of the relative scarcity there of suspended sediment), and they show slight increases related to more concentrated inputs from the Ohio River.

Effects of Energy-Resource Development on Lakes: What Do We Need to Know?

The alpine and subalpine zones of the Rocky Mountains constitute one of the largest undisturbed ecosystems in the United States. The Wilderness Act and the Clean Air Act gave congressionally designated Wilderness Areas special protection from anthropogenic change. However, many Wilderness Areas of the Rocky Mountains are located near to and downwind from developed or economic deposits of fossil fuels, which include coal, petroleum, natural gas, and oil shale. The need for abundant and reliable new energy sources likely will result in increased use of fossil fuels in the Rocky Mountains and other areas in the West. To use these energy minerals without damaging nearby Wilderness Areas and other Federal lands, we need to understand the present status of the Wilderness Areas and the potential risk associated with projected atmospheric emissions from energy-resource development.

Very little is known about the aquatic chemistry and biology of Rocky Mountain Wilderness Areas, which are characterized by a lack of roads, steep terrain, and a seasonal snowpack that lasts about 9 months. Most information regarding these areas consists of a few synoptic samplings and some monitoring and research at only a few small watersheds. Lack of information on Rocky Mountain Wilderness Areas hampers both their protection and the development of fossil fuels. Without the information necessary to predict the effects of new emissions sources, the Federal land manager is required by law to err in the direction of assuring that damage is not done. As a result, worst-case estimates of potential risks posed by proposed energy-resource development commonly are used.



Hydrogen ion (acidity) levels in the Rocky Mountain snowpack at the end of the 1992–93 snow season. The greatest concentrations are in and near the Mount Zirkel Wilderness Area, Colorado.

Most knowledge of the present status of the aquatic chemistry and biology of Rocky Mountain Wilderness Areas and of the risk of damage to them comes from studying acid rain and related problems. The National Atmospheric Deposition Program monitors the chemistry of rain and snow at about a dozen sites in the Rocky Mountain area. No sites are located in Wilderness Areas, and few are located at high elevations. The U.S. Geological Survey (USGS) has conducted a survey of snowpack chemistry throughout the Rocky Mountains. Generally, the smallest concentrations of fossil-fuel combustion products, such as sulfate, nitrate, and acidity in rain or snow and the snowpack, are found in Montana. Concentrations progressively increase in Wyoming and Colorado. Some of the largest concentrations of sulfate, nitrate, and acidity were measured at several sites in an area in northern Colorado downwind (east) of the Yampa River Valley, an area of energy development (especially coal mining and electrical generation from coal).

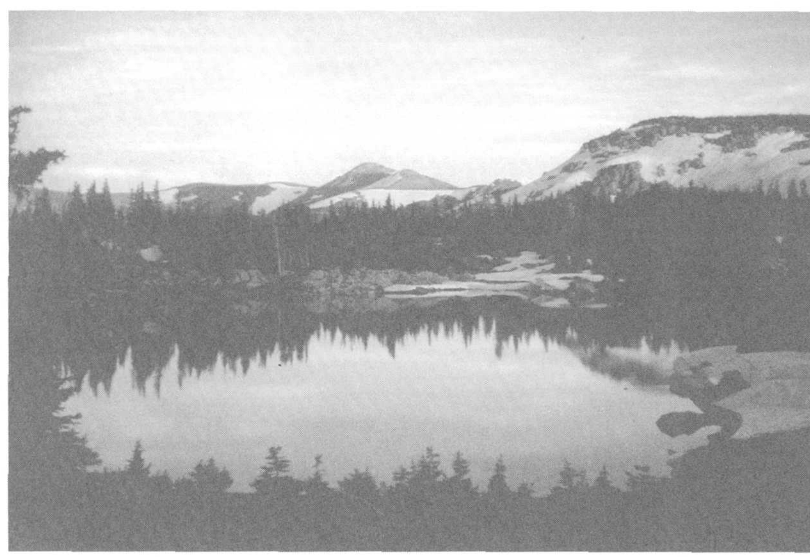
The Western Lake Survey, which was conducted by the U.S. Environmental Protection Agency in 1985, and numerous smaller surveys have indicated that the median acid neutralizing capacity, which is a measure of a lake's ability to neutralize acidity, is smallest in Wyoming and southern Montana and greatest in Colorado. Thus, the lakes that have the smallest median acid neutralizing capacity and thus are the most sensitive to acidification tend not to be in the area where concentrations of sulfate, nitrate, and acidity in wetfall and in snowpack are greatest.

Effects of energy development on wilderness hydrologic systems of median sensitivity are of secondary concern to the Clean Air Act and the Wilderness Act; instead, concern is greatest for those systems that are considered to be the most sensitive. Even though median acid neutralizing capacity differs greatly among regions in the Rocky Mountains, data indicate that lakes where acid neutralizing capacity is small are found throughout the Rocky Mountains. Because of differences in bedrock geology, soil development, and hydrology, those lakes having the smallest acid neutralizing capacity tend to be in specific mountain ranges such as the Bitterroot Range (Montana), the Wind River Range (Wyoming), the Uinta Mountains (Utah), and the Colorado Front Range and the northern Park Range (Colorado).

One area having a large concentration of sulfate, nitrate, and acidity in wetfall and snowpack overlaps with another area having a very small acid neutralizing capacity in lakes in northern Colorado downwind of the Yampa River Valley. At present levels of emissions from all sources, this area, which includes the Mount Zirkel Wilderness Area, likely contains hydrologic systems that are the most affected in the Rocky Mountains. No lakes are acidic during the summer when all sampling has been done. However, the initial stages of acidification would be greatest during early snowmelt, when the greatest concentrations of acidity are preferentially released. Such episodic acidification most likely would first affect small, ephemeral snowmelt pools favored by amphibians for breeding. Other studies indicate that the tiger salamander, which is endemic to the area, is sensitive at pH values commonly observed in the snowpack and wetfall in and near the Mount Zirkel Wilderness Area. Thus, a combination of chemistry in wetfall, snowpack, and lakes might be predicted to result in biological effects in and near the Mount Zirkel Wilderness Area, which is a Class 1 area (those given the greatest level of protection) under the Clean Air Act. Farther downwind is Rocky Mountain National Park, another Class 1 area.

The likelihood that this area is the most affected in the Rocky Mountains offers some opportunities to protect Rocky Mountain Wilderness Areas in general. Little information exists to tell us what aspects of the hydrologic and biologic systems of Rocky Mountain watersheds are most responsive to acidification. Further, although some damage might occur at present levels of emission, it is possible that hydrologic and other processes might protect these systems in ways not observed elsewhere. Thus, a well-planned evaluation of effects on lakes and aquatic organisms would be useful in predicting the effects of energy development and associated emissions everywhere in the Rocky Mountains.

A



B

Clean air is critical to maintain spectacular vistas, such as that of Big Agnes Mountain (*A*). Clean air also is critical to the health of wilderness streams and lakes, such as Seven Lakes (*B*). Both photographs are from the Mount Zirkel Wilderness Area of Colorado, which has the most acidic snow in the Rocky Mountains.

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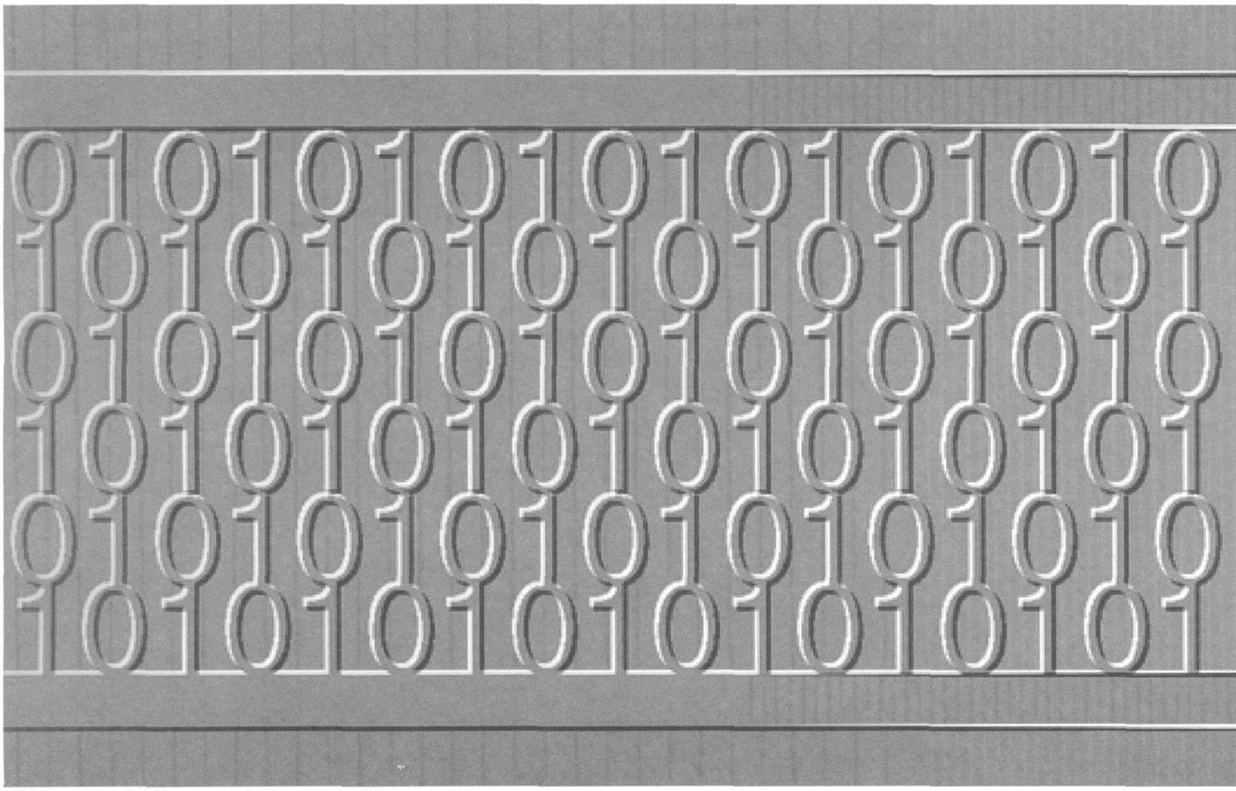
As the Nation's largest earth-science research and information agency, the USGS maintains a long tradition of providing "Earth Science in the Public Service."

The USGS, a bureau of the U.S. Department of the Interior, was established 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. Will we have adequate supplies of quality water available for national needs? 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? How can we predict, prevent, and 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.

The design on the front cover represents the four thematic "faces" of the USGS. Also reflected are images of the USGS mission such as flowing water, topographic contours, geologic cross sections, and profiles.



Information and Data Management

Providing the public with timely, objective, high-quality technical information that is relevant to public issues and useful to policymakers is at the foundation of the USGS mission. In addition to conducting scientific investigations to gather vital data on the Earth, its processes, and its resources, the USGS is charged with promoting information sharing and providing consistent information management. A focused effort in information management enables the USGS to be more productive and more responsive to the public's need for information, as the articles in the following section show. Through the use of innovative technologies, educational programs, and integrated policies for communicating and sharing information, the USGS fulfills its mandate of providing "Earth Science in the Public Service."

Multi-Resolution Land Characteristics Monitoring System

The U.S. Geological Survey (USGS) has a tradition of leadership in land characterization research and development. The agency was instrumental in the establishment of a comprehensive earth observation program and also developed both a landmark strategy for land-use and land-cover classification and a national 1:250,000-scale land-use and land-cover mapping program. In addition, the USGS met the need for a catalog of Alaska's vegetation resources through a mammoth effort to use Landsat images and digital image classification to inventory more than 75 percent of Alaska's vegetation.

The USGS continues to pioneer efforts in land characterization by developing and using a prototype land-cover database using satellite data. Environmental research and management demand current data on land cover, but there is no consensus on the format, scale, contents, and frequency of the required databases. The common ground between organizations is that land characteristics data must reflect multiple scales, sources, and times to satisfy a broad range of applications and be able to serve as a baseline for monitoring changes in land surface.

The USGS began a multi-resolution land characteristics monitoring system using a baseline of multiscale environmental characteristics and mechanisms for monitoring environmental changes. The system is based on the needs of such Federal environmental analysis programs as the USGS National Water-Quality Assessment (NAWQA), the National Biological Survey's Gap Analysis Project (GAP), the U.S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP), and the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP). It also contributes to the U.S. Global Change Research Program. The multi-resolution land characteristics monitoring system has three objectives: building a global database, building a regional database, and developing a multi-resolution monitoring system.

Global Database

A global land-cover characteristics database has been developed for use in global change, sustainable development, and environmental assessment applications. This activity is an extension of the USGS research on conterminous U.S. land-cover characterization.

Regional Database

A regional land-cover characteristics database has been devised for use in Federal environmental programs. Landsat Thematic Mapper (TM) data are the primary source of the land-cover characteristics data. This activity is a partnership between the USGS and the agencies leading the NAWQA, GAP, EMAP, and C-CAP programs.

Multi-Resolution Monitoring System

A multi-resolution monitoring system for targeting areas of potential change and assessing the types, extent, and causes of land-cover change has been constructed. The system will use high-frequency, advanced very high resolution radiometer (AVHRR) data from NOAA and will verify and quantify local land changes by using Landsat data.

The initial emphasis is on the first two objectives to establish baseline conditions from which changes can be monitored.

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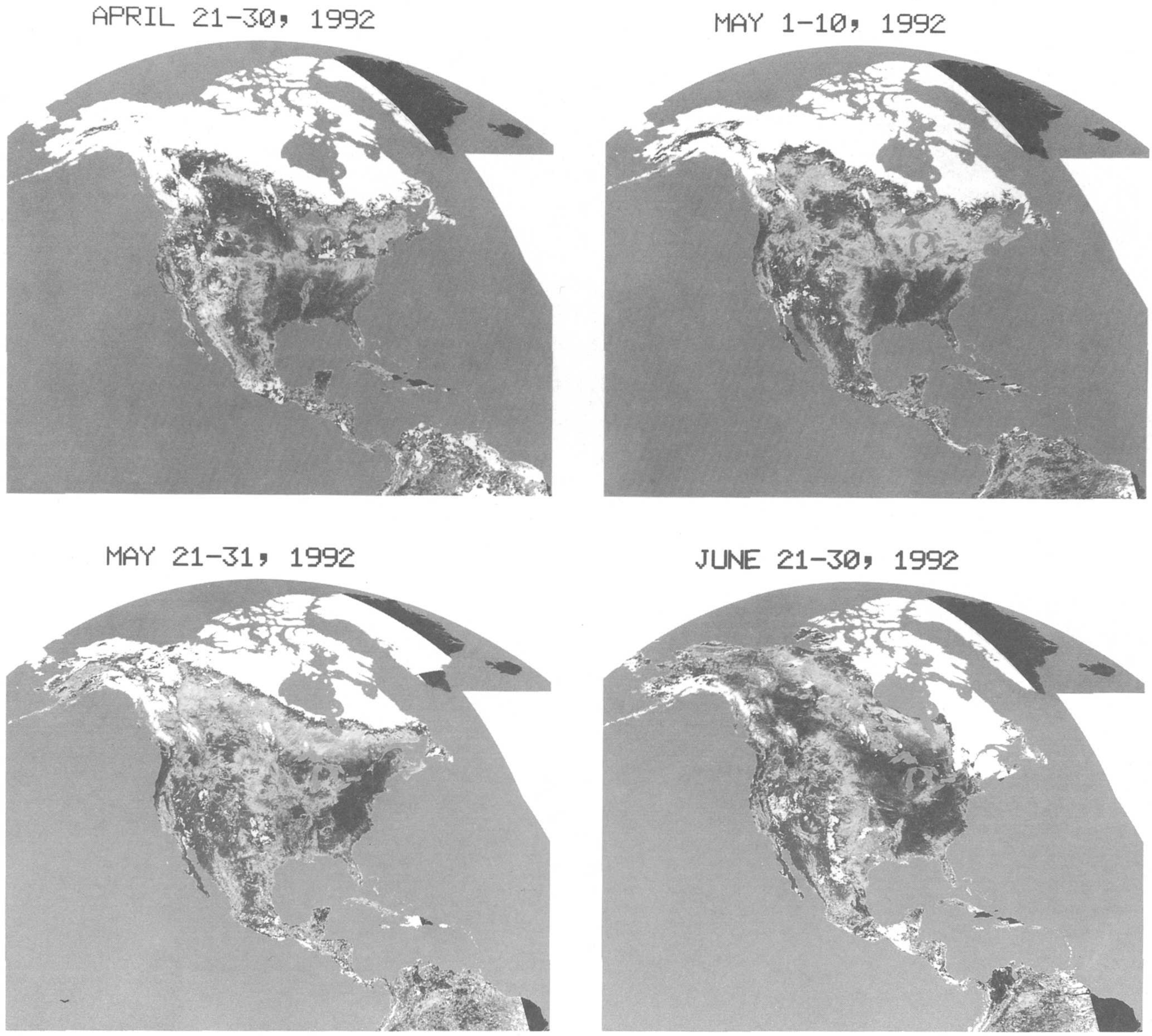
Global Land-Cover Characterization

The USGS is committed to developing the 1-kilometer global land-cover characteristics database within 3 years. The project will begin with the North and South America



These images illustrate temporal changes in vegetation conditions during the early portion of the growing season in North America. The changes in tone reflect the amount of photosynthetic activity in each area. Clouds and snow are depicted in white, and black represents areas where data are missing. The information is derived from 1-kilometer AVHRR data from NOAA.

For more information on the multi-resolution land characteristics monitoring system, contact Thomas Loveland at:

Telephone: (605) 594–6066
Fax: (605) 594–6589
Internet: loveland@edcserver1.cr.usgs.gov

components, which will be completed in 1995.

The USEPA and the U.S. Forest Service are helping fund the database. The United Nations Environment Programme is coordinating the participation of international experts to help evaluate preliminary land-cover descriptions. The Japan Ministry of Construction and the National Autonomous University of Mexico are providing staff. The activity has been accepted by the International Geosphere Biosphere Programme as a component of its "fast track" global land-cover product.

Regional Land Characterization

The regional land-cover characterization objective is based on agency partnerships and a flexible strategy in which the partners share in all aspects of the mapping process. For example, because each agency develops land-cover data to its own specifications, the multi-resolution land characteristics monitoring system partners have identified areas in which their needs overlap and will share interpretations as appropriate.

In the last year, the EROS Data Center (the USGS satellite research and archiving facility in Sioux Falls, S. Dak.) purchased the required Landsat TM data covering the conterminous 48 States and completed the processing–including registration and distribution to the partners–of nearly half of 600 scenes.

The first land-cover classifications developed by the partners are expected in early 1995. The tentative goal is to have national coverage by late 1996.

Monitoring and Change Analysis

A multiple-resolution land characteristics monitoring system will support a broad range of environmental assessment and earth system process studies. The monitoring system will use coarse-resolution data having high temporal frequencies such as AVHRR to identify anomalous landscape conditions. The assessment of anomalies is based on higher resolution images such as those from the Landsat program.

The multi-resolution land characteristics monitoring system depends on the development of the global and regional land characteristics databases. The former will be related to the global 1-kilometer AVHRR data. The scale of the latter will be commensurate with that of the Landsat data. As these databases evolve, so will the structure and capabilities of the multi-resolution land characteristics monitoring system

Thomas R. Loveland
is a remote-sensing scientist as the USGS EROS Data Center in Sioux Falls, S. Dak.

National Spatial Data Infrastructure

The National Spatial Data Infrastructure (NSDI) is being established as a means to find and cooperatively produce and use geospatial data as an information resource for the Nation. The NSDI consists of organizations and individuals who generate or use geospatial data, the technologies that facilitate use and transfer of geospatial data, and the actual data themselves. The Federal Geographic Data Committee (FGDC) is the group charged with implementing the NSDI. U.S. Geological Survey (USGS) scientists are extensively involved in all aspects of NSDI development, including providing staff support for the FGDC.

1994 Plan for the NSDI

At the March 1994 meeting of the FGDC, a plan for the NSDI identified six actions:

- Conducting and participating in national forums as a means of debating issues, policies, and technical procedures related to the NSDI.
- Improving access to geospatial data by establishing a clearinghouse and completing a data documentation standard.
- Producing a framework of national digital geospatial data on which other data sets can be built.
- Developing thematic data sets to meet critical national needs.
- Developing educational and training programs to ensure the availability of trained personnel for future geospatial data activities.
- Developing partnerships among all sectors to coordinate geospatial data collection, management, and use.

Executive Order

On April 11, 1994, President Clinton signed Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure.* The order directs all Federal agencies to contribute to the development of the NSDI and lays out key activities that Federal agencies must conduct in conjunction with State and local governments, academia, and the private sector to ensure the evolution and growth of the NSDI. Agencies are called upon to:

- Contribute to a national geospatial data clearinghouse and use that clearinghouse to determine data availability before starting new data collection projects.
- Document data sets according to metadata standards and support public access to data.
- Cooperatively develop data content standards and other geospatial data standards as necessary.

According to Executive Order 12906, "geospatial data" means information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the Earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. Statistical data may be included in this definition at the discretion of the collecting agency.

- Develop a plan for a national digital geospatial data framework.
- Develop strategies to cooperate more fully with State and local governments, the private sector, and other non-Federal organizations to share costs and improve efficient acquisition of geospatial data.

Agencies are called upon to develop strategies to cooperate more fully with State and local governments, the private sector, and other non-Federal organizations to share costs and improve efficient acquisition of geospatial data.

The Geological Survey Geographic Data Committee (GSGDC) was charged to lead in developing the bureau's response to the Executive Order. An NSDI Action Plan Committee delivered a strategy to the GSGDC at the end of August, and an Action Plan Implementation Team was activated to carry the plan through its initial steps in January 1995.

Content Standards for Digital Geospatial Metadata

On June 8, 1994, the FGDC, under the chairmanship of Secretary of the Interior Bruce Babbitt, approved the Content Standards for Digital Geospatial Metadata. The standard is a common set of terms and definitions for documenting important aspects of geospatial data, including identification, data quality, spatial reference, spatial data organization, feature and attribute definitions, and distribution. The standard was developed over the last 2 years with input from numerous groups.

The USGS began to develop software to assist in the creation of metadata compliant with the standards. The USGS also sponsors training and workshop sessions to educate data producers and users on the value of metadata and the metadata standards.

National Geospatial Data Clearinghouse

A network-based clearinghouse for geospatial data is being developed to provide both metadata and geospatial data. Instead of centralizing all information, the Internet is used to link the sites where data are produced or maintained. By using this approach, data producers can control and maintain information provided about their data. The Internet then is used to find what data exist, the quality and condition of those data, and the terms for obtaining them.

The USGS has been particularly active in clearinghouse efforts. Servers for geospatial data and metadata within the USGS include the National Digital Cartographic Data Base servers at the EROS Data Center, which recorded nearly 40,000 downloads during their first 3 months, and the Distributed Spatial Data Library, which serves as the testbed for Wide-Area Information Server (WAIS) software development.

Instead of centralizing all information, the Internet is used to link the sites where data are produced or maintained.

Continued development of spatial enhancement to the WAIS software, together with workshops and training sessions, has helped spread knowledge of these new capabilities.

NSDI Competitive Cooperative Agreements Program

The NSDI Competitive Cooperative Agreements Program was established in 1994 as a mechanism for the FGDC to use in forming partnerships with the non-Federal sector to assist in the development of the NSDI. This program provides cooperative funding to State and local government agencies, institutions of higher education, and (or) private organizations to encourage resource-sharing projects through the use of technology, networking, and enhanced interagency coordination efforts. Funding for the first year totaled $250,000 in nine individual awards. Awards were targeted toward two major elements of the NSDI. One element involved the development of the National Geospatial Data Clearinghouse to increase awareness and use of geospatial data; the second involved developing and furthering the use of FGDC-endorsed standards.

Awards were given to:

- ***Texas***–Texas Water Development Board: An Internet Node for the State of Texas.
- ***North Carolina***–North Carolina Center for Geographic Information and Analysis: North Carolina Geographic Data Clearinghouse.
- ***Wisconsin***–Wisconsin Land Information Board: Wisconsin NSDI Clearinghouse Initiative.
- ***Florida***–Florida State University: The Integration of Citizens and State and Local Governments into the NSDI Initiatives.
- ***Iowa***–Iowa Department of Natural Resources: Establishing a National Geospatial Data Clearinghouse Node in Iowa.
- ***New Mexico***–Earth Data Analysis Center, University of New Mexico: Conversion of New Mexico's Resource Geographic Information System Metadata to FGDC Metadata Standards.
- ***Minnesota***–Alexandria Technical College, Minnesota: Geospatial Data Standards Education.
- ***Montana***–Natural Resource Information System, Montana State Library: Montana GIS Data Clearinghouse.
- ***New Jersey***–New Jersey Department of Environmental Protection: Contributing New Jersey's GIS User Network and Geographic Information to the NSDI.

National Geospatial Data Framework

Representatives from local, State, and Federal agencies are developing the concept of a geospatial data framework to manage the variety of common information being collected by the public and private sectors. A Framework Working Group, organized by the FGDC, is identifying the purpose, goals, and content of the framework, how it should work, and reasons why organizations should participate.

The framework is a basic, consistent set of digital geospatial data and supporting services that will provide a geospatial foundation to which an organization may add detail and attach attribute information. Organizations will be able to use such a framework to accurately register and compile other themes of data and link the results of application to the landscape. Implementation will be phased, the goal being to have an initial geospatial data framework in place by the year 2000.

Thomas M. McCulloch
is clearinghouse coordinator on the Federal Geographic Data Committee staff.

For more information on the NSDI, contact Thomas McCulloch at:

Telephone: (703) 648–4543
Internet: tmccullo@usgs.gov

Internet: Earth Science Link to the Information Superhighway

The development of high-speed computer networks available to the general public provides new opportunities for the U.S. Geological Survey (USGS) to distribute the results of its research, including reports, data sets, and maps. Computer networks also allow the public to get questions answered more rapidly and inexpensively than ever before.

The largest of these high-speed networks is the Internet. The Internet was developed by the Department of Defense Advanced Research Projects Agency during the 1970's to study computer networking technology. At that time, it was called ARPAnet and was available to a small number of researchers. In the 1980's, it was expanded and supported by the National Science Foundation to enhance communication within the academic and Government research community. During this period, the main backbone of the Internet was called NSFnet. In 1993, the Internet was opened for commercial (nonresearch) uses. The commercialization of the Internet has created new methods and opportunities for communicating with millions of users.

Today, the Internet is a collection of over 20,000 individual computer networks

Sample Mosaic screen showing the USGS WWW Library Home Page.

that span the globe. Information available on the Internet ranges from classic literature like *Alice in Wonderland* and the collected works of William Shakespeare to technical reports, data sets, and commercial products. The Internet now is being expanded to include extensive facilities for many kinds of electronic commerce.

One historical problem with the Internet has been the difficulty in finding and viewing the information that it contained. Because it was originally created to support the research community, a high level of technical expertise was needed to operate the system. A recent technical development has helped solve this problem. A program called Mosaic, written at the National Center for Supercomputing Applications at the University of Illinois Urbana–Champaign, now provides a method by which casual users can access Internet and get useful information and services. Mosaic uses text, images, audio, and animation to communicate information through a computer. The user no longer needs to know the technical details for access to the Internet. Mosaic can access the many different types of information services through a graphical user interface.

When accessing the Internet through Mosaic, a user can take advantage of active references to additional information that are embedded within each document. These "links" are a little like reference citations in a paper document, but they are much easier to use. Instead of tracking down the additional information in some other publication, the user simply clicks a mouse button to access the new material.

The network of documents created by these links, called the World Wide Web (WWW), is not a publication or a database. The WWW is a virtual library within the Internet that contains publications, databases, and access to products. This library does not physically exist. It is created by many computers on the Internet working together. The USGS WWW Library is implemented as a distributed computer system; many USGS computers participate by providing access through Mosaic to the data that they contain. The WWW is not just one library but a collection of interaccessible libraries. These virtual libraries conceptually consist of "rooms": a reference room, a general reading room, and a special collections room.

The reference room of the USGS portion of WWW contains the official publications of the USGS. It is the central location for finding USGS information products on the Internet. The documents in the WWW reference room, unlike those in traditional library reference rooms, may circulate. Users may "borrow" a document, making a complete duplicate of the document for their full use. Many copies of a given document eventually may exist in satellite WWW libraries around the world. Because these copies may have been modified or altered, users must know where to find the original version of any given USGS document, data set, or electronic product. The WWW reference room provides access to that original version. All documents in the reference room of the USGS WWW Library have been approved for publication by the Director.

The USGS WWW Library, like any traditional library, also contains books, maps, data sets, and other products that support the mission of the USGS but were not created by the USGS, such as historical documents or duplicate copies of reports or data sets. Many may have been created at the USGS but have been extended by others to create valuable new products. They are held in the general reading room, which is analogous to the "stacks" of a paper library.

The USGS uses computers and networks in many phases of its research. Unfinished works in progress are not generally released to the public until they have been completed and granted Director's approval. These resources are kept in the special collections room of the USGS WWW Library. Access is restricted, much as access to rare books is restricted in a paper library or as

The development of the U.S. Geological Survey World Wide Web Library was accomplished with the help of dedicated volunteers from the Volunteer for Science Program. Special thanks are due to volunteer **Joann Miller**, who volunteered more than 2,400 hours between June 1993 and June 1994 to help launch this new effort.

The USGS Home Page can be accessed by opening the Uniform Resource Locator and entering:
http://www.usgs.gov

For more information on the USGS on the Internet, contact William Miller at:

Telephone: (703) 648–6721
Internet: bmiller@oemg.er.usgs.gov

research collections are restricted in a museum.

The USGS WWW Library is accessed through its front door, which is called the USGS Home Page. Upon entering the library, the user is presented with several options to help find the information desired. Most users will probably be one of three types: general public, student or teacher, or research scientist. Different areas can be provided on the Home Page for each type of user.

The Home Page consists of four major areas: (1) a navigational tool for finding information, (2) a short introduction to the USGS, (3) a menu of options for using the resources of the library, and (4) information on how to contact the USGS. A user needs merely to click a mouse button on any of the underlined words or phrases to be shown the new page of information selected.

A variety of USGS information is currently available on the Internet. Many publications, including some written for a general audience, are available. Job announcements and news releases are regularly posted and updated. Many data sets are available for direct downloading or can be ordered on the network for delivery in other formats. The list of available information is growing as USGS customers become aware of this service.

A "visitors center" is being added to the USGS WWW Library to guide the public on tours through the USGS. These predefined paths through the body of information available from the USGS on the Internet will make the service more useful and entertaining for the public, especially students and teachers. Sample tours will include "Geographic Information Systems," "Earthquake!", and "The Water Cycle."

The USGS WWW Library has been available on an experimental basis since June 1993. During the 1-year period from June 1993 to June 1994, use of the service grew at about 20 percent per month. More than 10,000 people per month are now accessing more than 100,000 pages of information per month, and use of the service continues to expand.

The Internet has become a crucial tool for disseminating USGS information and products in fulfillment of the USGS mission.

William Miller
studies computer systems and their application to the earth sciences.

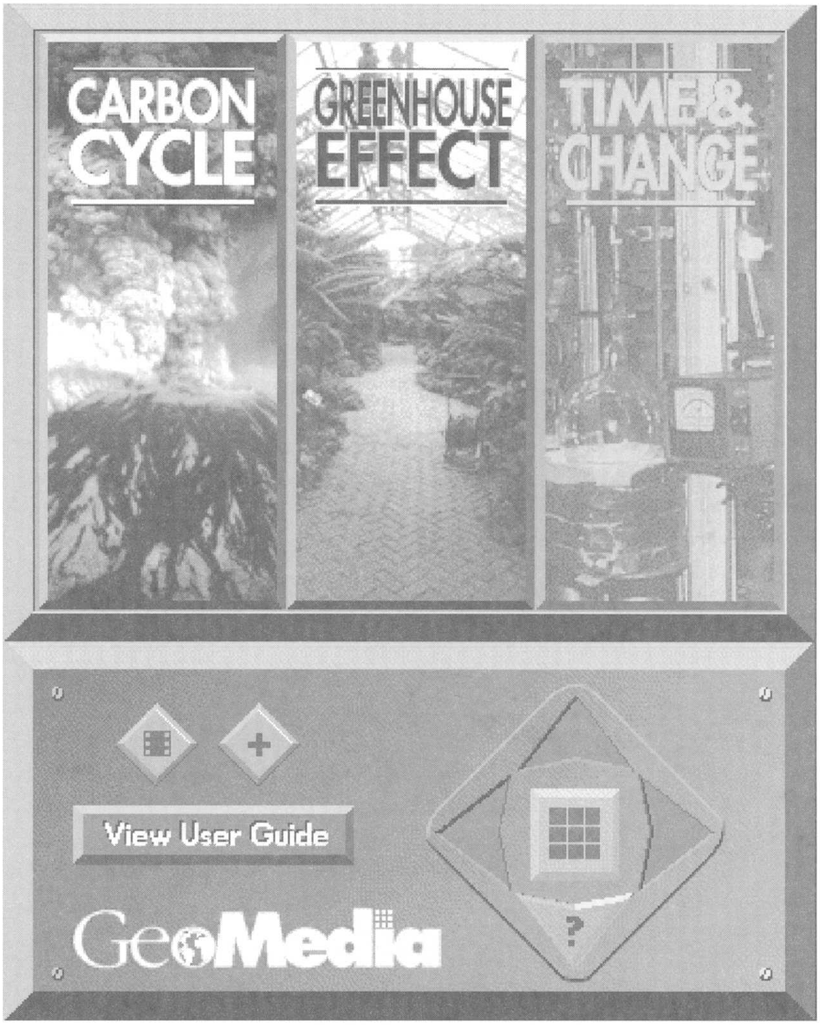
GeoMedia2 Shows the Wonder of Earth Science

The best teachers are those who instill a sense of wonder in their students–whether about earth processes, the evolution of life, or the rise and fall of ancient civilizations. Evoking curiosity about the Earth continues to challenge educators, particularly as science literacy has declined in the United States. As environmental issues become more complex, the country needs informed citizens capable of making decisions and voting on legislation about natural resources and hazards and planning for the 21st century. Legislation known as "Goals 2000: Educate America" calls for assistance to States and local communities in meeting the President's education goals. Making the United States first in the world in math and science is one of the goals of this legislation.

To meet these educational challenges, the U.S. Geological Survey (USGS) has been exploring new ways of communicating earth science topics to pre-college students. Through a long-term research and development project, the USGS has been assessing the effectiveness of teaching earth science through the use of hypermedia, a computer technology that allows users to choose their own path through information in a variety of formats.

In 1991, the USGS began to develop its first earth science computer system based on

The concept of hypertext, also known as hypermedia, was first proposed in 1945 by one of the first computer scientists, Vannevar Bush, in an article titled "As We May Think," which was published in the *Atlantic Monthly.* Bush envisioned a device called the memex where all types of information, such as books, pictures, records, and letters, could be stored. Bush imagined that the information could be accessed in a nonlinear method more closely aligned to cognitive processes by creating links between associative material. The term was popularized by Ted Nelson, a leading proponent of hypertext technology, in 1965. Today, hypertext has come to mean a software environment for creating nonsequential database management systems. Hypertext techniques provide the capability to create associative links between structured and unstructured information that may include text, graphics, animation, and sound.



Computer screen from *GeoMedia2* showing table of contents.The application was designed for Apple Macintosh computers and developed by using Macromedia Director authoring software, which is produced by Macromedia, Inc.

GeoMedia Computer Configuration Requirements

Macintosh

Macintosh suite of computers with System 7.0 or later
13-inch or larger color monitor
5 megabytes of memory
CD–ROM drive

Windows

In 1995, *GeoMedia* (volumes 1 and 2) will be replicated for Windows. Configuration requirements for computers running Windows have not been determined at this time. Additional information on these forthcoming products is available from the authors of this article or InterNetwork Media, Inc., at the address listed below.

Address inquiries about purchasing *GeoMedia* discs to:

InterNetwork Media, Inc.
1130 Camino Del Mar, Suite H
Del Mar, CA 92014

For more information on developing educational hypermedia systems, contact Denise Wiltshire at:

Telephone: (703) 648–7114
Internet: dwiltshi@ridgisd.er.usgs.gov
OR
Carmelo F. Ferrigno at:

Telephone: (703) 648–7142
Internet: cferrign@ridgisd.er.usgs.gov

hypermedia technology. The objective of this research and development project was to design and implement a hypermedia educational system aimed at middle-school students. The project resulted in the development of a prototype entitled *GeoMedia*, which presents information on the water cycle, earthquakes, and understanding maps. Each of the three modules contains animations, illustrations, text, a glossary of terms, and a reading list. *GeoMedia* was distributed on digital compact disc to earth science teachers in the United States from 1992 to 1994. To date, approximately 2,500 discs have been distributed to educators who agreed to participate in the project by evaluating the information on the disc.

Favorable responses to *GeoMedia* from USGS employees and the educational community led to the development of a second hypermedia system on global environmental change. Again, the targeted academic level is middle school. The basic design of *GeoMedia2* is patterned after the original system–a tour of earth science topics with video-game overtones. *GeoMedia2* includes three modules: the carbon cycle, the greenhouse effect, and the monitoring of environmental change over time. The graphical user interface is the same but incorporates a few modifications based on teacher evaluations of *GeoMedia*. The modules each contain four sections: animation, elements, glossary, and further reading. The carbon cycle module illustrates the movement of carbon through the environment and the effect of human interactions on the cycle. The greenhouse effect module explains a natural environmental process that traps heat in the lower part of the Earth's atmosphere to keep the planet warm enough to sustain life. In the time and change module, students learn about the geologic history of the Earth and the evolution of living organisms. *GeoMedia2* focuses on the many changes that have occurred throughout the 4.5-billion-year history of the Earth in the physical, chemical, geological, and biological characteristics of the planet. The USGS multimedia educational team will continue to distribute *GeoMedia2* to teachers participating in the project until the fall of 1995, when both volumes will become available commercially.

Plans are underway to develop a hypermedia system that enables students to navigate through a nonsequential arrangement of information and further participate in the creative process by authoring their own multimedia reports. This application will explain earth science processes that relate to natural hazards, such as volcanoes and earthquakes. Students will explore earth science topics by selecting geographic regions that are notable for natural hazards. The approach to the information will be by using maps and satellite images instead of picking topics from a table of contents, which was the approach used in *GeoMedia*. The USGS expects to complete this prototype by the winter of 1996.

The USGS continues to design software that is in concert with national curriculum standards and reform movements, such as Project 2061 sponsored by the American Association for the Advancement of Science (AAAS). The AAAS emphasizes several key concepts for teaching science in a report entitled "Science for All Americans." Among the principles of learning discussed in the report are two key philosophies embraced by the team during the software design process: (1) do not separate knowing from finding out and (2) science teaching should reflect scientific values by welcoming curiosity, rewarding creativity, and encouraging a spirit of healthy questioning.

Denise A. Wiltshire
is a writer and information scientist currently serving as a multimedia producer for the USGS.

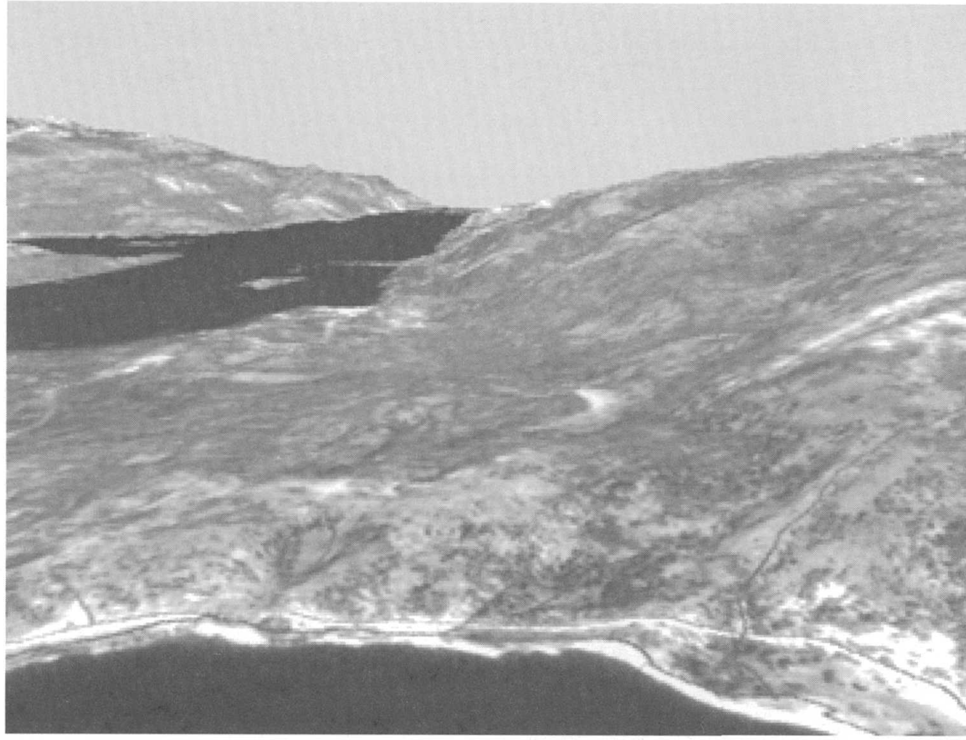
Carmelo F. Ferrigno
is a USGS computer scientist specializing in scientific data visualization and multimedia application development.

Using Geographic Information, Image Processing, and Animation Systems to Visualize a Digital Terrain Flyby

Terrain flyby animation tools are being used by the U.S. Geological Survey (USGS) and other agencies such as the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the Department of Defense to analyze terrestrial and extraterrestrial data and to showcase data. To reduce the costs of buying analytical software to construct and view these animations, a multidivision, multiagency technology assessment project focused on integrating readily available commercial geographic information systems software (ARC/INFO), free image processing software (Khoros), and low-cost terrain-rendering software (Surveyor) to merge several USGS data sets and produce terrain flybys.

The merged data sets included a digital orthophoto quadrangle (DOQ), a digital elevation model (DEM), and the transportation and hydrography digital line graph (DLG) layers for a mountainous area in Idaho. The DOQ data are a photograph of the Earth's surface. The DEM is a series of regularly spaced elevation points for this same area. The DLG is the line data from the digital data used in the production process of the USGS paper maps. Preprocessing of the data was performed with ARC/INFO software. After merging a DOQ image and the DLG images, computer scientists used routines constructed in Khoros to produce red, green, and blue images, which were then reformatted for input to Surveyor. Surveyor software was then used to produce several DOQ and DLG terrain flybys. Integrating the three existing software packages and using the best features of each saved money by eliminating the need to procure a single equivalent expensive software package

Perspective of the McCall, Idaho, digital orthophoto quadrangle showing elevations, roads, and streams.



For more information on digital terrain flybys, contact Robert G. Clark at:

Telephone: (703) 648-7123
Internet: bclark@ridgisd.er.usgs.gov

Products generated by this project were made available to the public and private sectors.

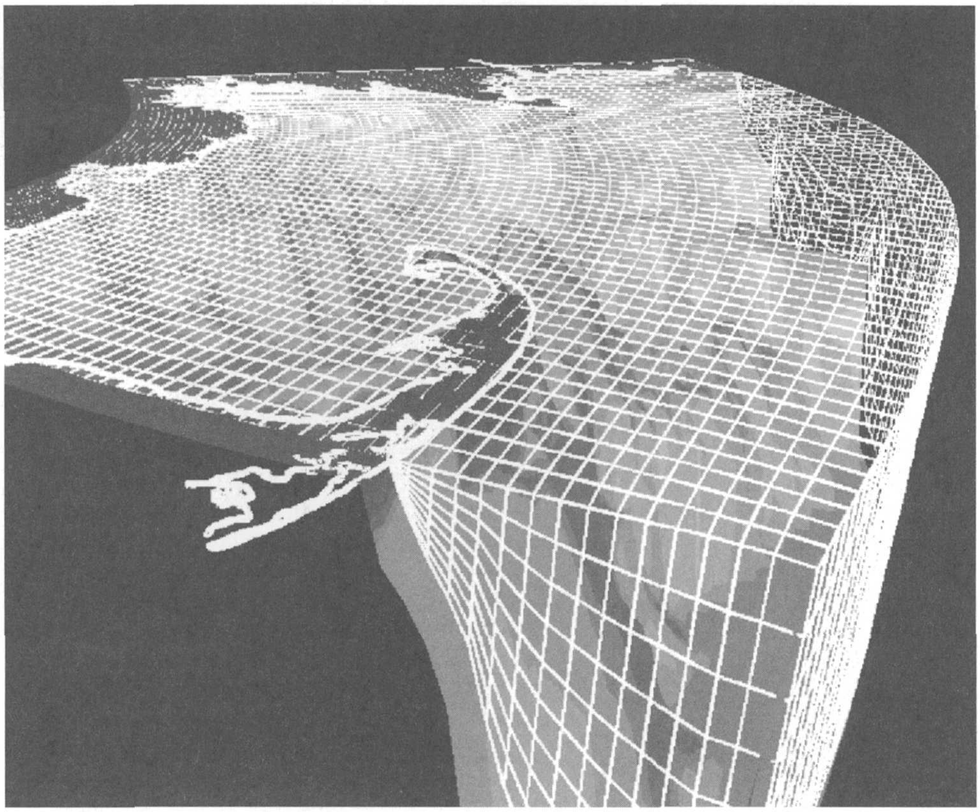
Robert G. Clark
is a USGS computer scientist who has worked in technology assessment for the past 9 years.

Parallelizing a Coastal Circulation Computer Model

The transport of water and its properties are governed by the laws of mass, momentum, and energy conservation. These laws have been translated into equations that, in turn, have been coded as Fortran computer language routines in a computer model called ECOM-si. This model is used by the U.S. Geological Survey (USGS) to investigate the flow of water and transport of waterborne constituents in the coastal ocean. Most recently, for example, it has been used to answer questions related to the construction, placement, and operation of a new sewage treatment plant and ocean outfall for the city of Boston, Mass. Specifically, ECOM-si is used to predict time and space dependencies of water properties such as surface elevation, velocity, temperature, salinity, and dissolved constituent (for example, nonreactive dye released at the Boston outfall site) concentration as functions of winds, precipitation, atmospheric heating and cooling, tides, and river inflows.

ECOM-si is a three-dimensional, time-dependent, finite-difference hydrodynamics circulation model that uses a curvilinear coordinate system to define a spatial domain consisting of discrete cells. The computer program calculates velocity, temperature, salinity, and dye concentration for every cell in the grid at evenly spaced intervals in time called time steps. In the Massachusetts Bay study case, the model runs on a grid of 68× 68×11 or roughly 50,000 cells representing the bay and Boston Harbor. This grid provides spatial resolution of 600 to 6,000 meters horizontally and 30 centimeters to 14 meters vertically. The model's time step is roughly 6 minutes.

Use of the model can be time intensive. Computer simulations of 1 year of dissolved constituent transport take roughly 10 days to complete on a Sun SPARC station 2, 3 days on an IBM RISC 6000 model 580, 0.8 day on a Cray X-MP, and 0.15 day on a Cray C90 single central processing unit (CPU) system. To make calculations at finer spatial and temporal scales, which some coastal



Three-dimensional perspective view of the ECOM-si model grid for Massachusetts Bay as viewed from south to north. Cape Cod is in the foreground, and Boston Harbor is in the background on the left. ECOM-si calculates temperature, velocity, salinity, and dye concentration as a function of time in each of the roughly 50,000 grid cells shown in the figure.

circulation problems require, and to make calculations over longer simulation periods without extending the total length of time required to complete the calculations, new techniques for solving the model's equations must be explored.

One promising approach for accelerating these computations is splitting the model's computations over multiple processors (parallelizing the model). For example, the model's computations can be divided for distributed-memory multicomputer systems such as the Thinking Machines Corporation's (TMC) Connection Machine CM–5. A CM–5 uses multiple processors to execute a parallel program. This program typically consists of separate tasks running on separate processors. All processors can execute the same task for independent data sets or different tasks for a single data set. In any case, a processor may have to communicate data–that is, send or receive the results of computations to or from another processor–to proceed with its own calculations.

To perform a large-scale circulation simulation on a distributed-memory multicomputer, the serial computation can be split "in time," "in space," or both. An example of time splitting is dividing the problem so that each parallel processor performs the calculations for a given month of a year-long simulation. This procedure is clearly inefficient, because each month's result depends on the previous months' results; consequently, a processor has to sit idle while waiting for the previous months' processors to finish. Space splitting has the potential to be much more advantageous. In space splitting, subsections of the model grid are distributed to the processors, and calculations for all the subsections are performed simultaneously. There remains a need for adjacent subsections to communicate information to one another, so processors must be able to communicate during the calculation process. The efficiency of this communication is a key to achieving good parallelization of the ECOM-si code. At present, the focus of the research presented here is on this spatial partitioning of the ECOM-si model grid; the Massachusetts Bay model is being used as a test case.

Automatic parallelizing compilers typically do not convert existing serial code into optimally efficient parallel code. However, the process of recoding a serial program is made simpler by such parallel languages as Fortran 90 or TMC Fortran, both of which are well suited for scientific computations. These languages permit a single operation,

Administrative Support for Information Management

Interior Department Electronic Acquisition System.—The Washington Administrative Service Center (WASC) of the U.S. Geological Survey (USGS) is heading the Department of the Interior (DOI) effort to establish electronic commerce (EC) projects in support of an Executive Order. In June 1994, the USGS began using EC at two pilot procurement offices in Reston, Va., and Denver, Colo. Three additional sites within the DOI are participating in the EC pilot: the U.S. Bureau of Mines in Pittsburgh, Pa., and Denver, Colo., and the Minerals Management Service in Herndon, Va.

Use of EC and the Interior Department Electronic Acquisition System (IDEAS) is expected to streamline small purchase activities and reduce procurement costs. DOI's early success with EC has already come to the attention of other Government agencies: the Treasury, Commerce, and Energy Departments have approached DOI about supporting their EC initiatives.

Electronic commerce involves creating requests for quotations (RFQ's) in a standard electronic format that can be transmitted to an electronic bulletin board on a commercially operated value-added network (VAN). Commercial vendors subscribe to one of several VAN's to access Government RFQ's and to submit quotations to Government agencies electronically. An electronic purchase order can be issued to the winning vendor, and unsuccessful vendors also can be notified of their status electronically. Currently, DOI requirements are posted on 15 VAN's via the FEDNET Gateway operated by the Department of Defense.

The DOI EC pilots have resulted in immediate savings to the Government by improving processing time and effort in the procurement offices, expediting purchasing through paperless processing, and reducing prices that the Government pays for products. Since the use of EC began, the reduction of paper in the purchasing process has decreased the 5- to 10-day processing time to 2 to 5 days and has resulted in savings in effort for both the Government and vendors. In addition to the reduced time frame, competition has increased. The number of vendor responses (quotes) has averaged 10 per RFQ.

USGS Modernizes Product Sales and Inventory System.—The USGS modernized the product sales and inventory system used for USGS maps and books and improved its accounting for product sales by modifying the Federal Financial System (FFS) Inventory Subsystem. The new system represents a pioneering effort to integrate the Departmental accounting system with a major business application, because the revised FFS Inventory software is fully integrated with the current DOI FFS application. The system ensures the integrity of the financial data available to the bureau financial system for fiscal year-end reporting to the Department; eliminates accounting weaknesses; reduces manual processing; integrates USGS product sales billing and accounts receivable information with the FFS; and improves inventory management capabilities. In its first 2 months of operation by employees who meet the demands of the public and of other Federal agencies for USGS maps and other earth science information products, over 20,000 orders were processed, representing the sale of several hundred thousand USGS products.

EROS Data Center Adds Space for Data Storage.—The USGS EROS Data Center (EDC) in Sioux Falls, S. Dak., is a data archiving, processing, distribution, and research facility for remotely sensed and other earth science data. The EDC has been a partner in the land satellite (Landsat) program since 1972, first with the National Aeronautics and Space Administration (NASA), then with the National Oceanic and Atmospheric Administration, and currently with Landsat's commercial operator, the Earth Observation Satellite Corporation. The Land Remote Sensing Policy Act of 1992 established the USGS as the permanent archive for Landsat data.

A contract valued at $8,654,200 was competitively awarded by the USGS for the construction of a 65,000-square-foot addition to the EDC. The addition will house computers and peripherals that will also support the high-speed and high-volume processing and storage of data gathered by NASA under the Earth Observing System program, the principal component of NASA's "Mission to Planet Earth." The first satellite launch in support of the program is scheduled for 1998; subsequent launches will follow over the next 15 years. The EDC will be the archiving, processing, and distribution center for all land processes data from this program as well as the sole repository for all Landsat data collected by the five satellites operated during the program's 20-year life.

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such as addition, to be executed in parallel on the respective components of two objects. To code an efficient parallel program, the programmer must still be aware of the hardware characteristics (the computational and communications speeds of the parallel machine) as well as software issues such as data layout.

In the ECOM-si serial code, calculations involving discrete cells often take three forms: operations that combine matrices by using the same subscript values, those combining matrices indexed by differing values, and those combining matrices having different dimensions.

A conversion of the ECOM-si code to TMC Fortran is currently underway. Preliminary versions of the code have been tested by using 64 and 128 CM-5 processor systems. These tests have been performed with relatively small numbers of grid cells, and performance gains over serial workstations have been attained. At present, the Massachusetts Bay model runs at speeds comparable to those of a Cray X-MP. However, the code needs to be optimized, and data partitioning needs to be improved to achieve better performance.

The key to a successful parallel implementation of the coastal circulation model is to achieve a balance between computation and communication speeds. Further, it is important to use algorithms that lend themselves to parallelization for the particular parallel system being employed. As CPU development bumps up against the serious engineering barriers of faster computer clock speeds, parallel computing may become the only option for increasing model computation speed as well as for increasing the size of the model grid available to address coastal ocean resource management questions in the future.

Harry L. Jenter
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Pearl Y. Wang
is a professor of computer science at George Mason University.

Awards for Digital Orthophoto Quarter Quadrangle and Digital Line Graph Production

As part of expanded partnerships with industry, the U.S. Geological Survey (USGS) has contracted with seven firms to produce digital orthophoto quarter quadrangles, or DOQ's. DOQ's are digital images of aerial photographs that combine the image characteristics of a photograph with the geometric qualities of a map. These innovative cartographic products are used by planners, engineers, and Government agencies to update changes in land use, transportation, and utility corridors and can also be used to analyze vegetation patterns, manage timber resources, assess wildlife habitats, delineate floodplains, and identify areas of potential soil erosion. DOQ's are part of the National Digital Cartographic Data Base and are available to the public. Additionally, DOQ's are shared with requesting State agencies and Federal Government agencies such as the Soil Conservation Service, the U.S. Environmental Protection Agency, the U.S. Forest Service, and the National Park Service.

Orders worth a total of $1.8 million also were placed under 10 contracts with private firms for digital line graph (DLG) production services in support of the USGS's responsibility to administer the national mapping program and to populate the National Digital Cartographic Data Base (NDCDB). The services performed by the companies holding these contracts include digitizing features portrayed on USGS topographic quadrangle maps at scales ranging from 1:24,000 to 1:100,000 and processing these data into one of two DLG-compatible formats. These contracts are a means through which all Department of the Interior bureaus can digitize base category data from USGS topographic base maps in a form that the USGS can upgrade and (or) enter into the NDCDB and thereby eliminate duplicate projects conducted by individual bureaus.

"National Water Conditions" Report Goes "Online"

The monthly "National Water Conditions" report was made available on the Internet in October 1994. Within a month, circulation of the new electronic format had exceeded that of the former paper version, and it continues to increase. Readers can view maps of monthly streamflow conditions, ground-water levels, and charts of monthly streamflow at more than 200 stations. Response to the new electronic format and the timeliness has been enthusiastic.

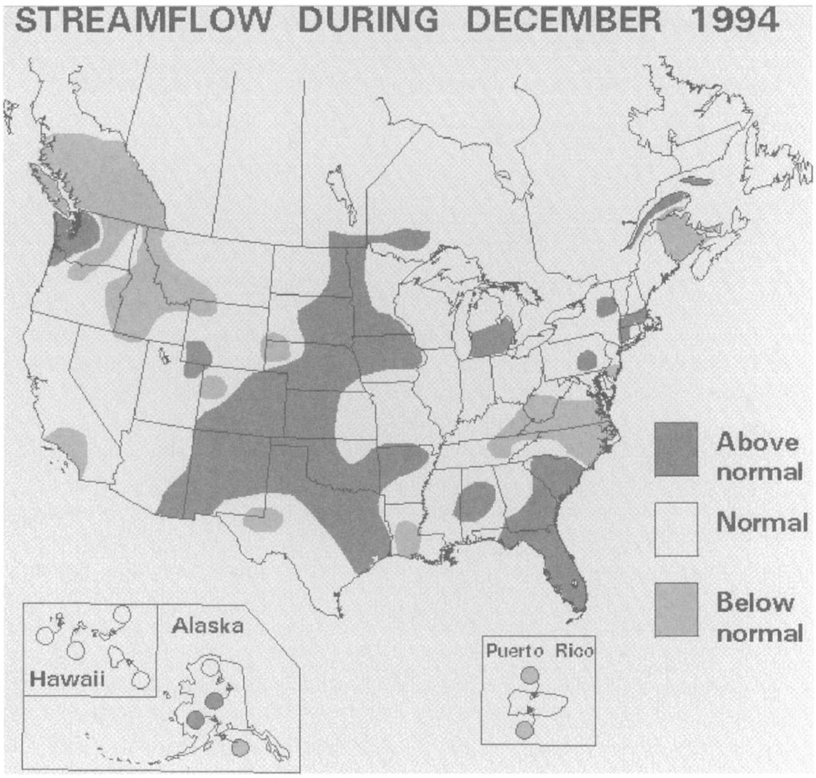
The "National Water Conditions" report, which is produced in cooperation with Environment Canada, had been published monthly since 1944 and mailed free to 5,000 subscribers. Postage and printing costs, however, continued to rise, and readers wanted to see the information more quickly. In August 1994, a team was formed to investigate electronic distribution of the report; by October, the team's recommendations had been accepted, and the first electronic version was released.

Readers can view the report by using the popular Mosaic software package, which is available at no cost over the Internet. Mosaic is used for many scientific and commercial presentations because of its ability to show text and graphics. A key decision was to discontinue the paper version of the report and to focus on producing the electronic version. The Mosaic software allows users to print individual pages on their own printers.

Producing an all-electronic report introduced several new opportunities. Page limits imposed by the paper report restricted streamflow charts to only six to eight carefully selected stations. The new format allows users to customize their own reports either by selecting stations from a scrolling list of more than 200 station names or by pointing to a map of the stations. Because printing and

Earth science information ranging from the latest flood data through scientific animations of currents in Boston Harbor and flyovers of digital landscapes to the latest USGS press releases can be found by accessing the USGS Home Page on the World Wide Web. To reach the Home Page, open the Uniform Resource Locator (URL) and enter:
http://www.usgs.gov.

To access the "National Water Conditions Report," open the URL and enter:
http://h2o.usgs.gov



Example of the map of monthly stream conditions shown in the "National Water Conditions" report.

mailing have been eliminated, sections of the report can be released as soon as they are prepared (similar to the "early" and "late" editions of a newspaper), so that a delay in one section does not delay the whole report. As a result, more information gets to more users faster and at less cost.

The new "National Water Conditions" report has been a big success so far. Readers have accessed it from more than 4,000 sites from all over the world. A new (and instantaneous) "feedback" page included with the report has returned many positive comments and indicated great interest in more such publications. As one reader said, "Every time I see real solid information added to the web I am absolutely delighted. Great job all of you."

Kenneth J. Lanfear
is responsible for ensuring that "cybersurfers" on the Internet can find and retrieve the water-resources information that they need.

Accessing the World Wide Web server requires a program that can communicate with the hypertext transfer protocol (HTTP) and that can display the hypertext, graphics, audio, and scientific visualizations that are currently available. Mosaic, a program from the National Center for Supercomputer Applications, will allow this information to be displayed on computers using HTTP, Gopher, WAIS, Telnet, or FTP protocols. Internet users who do not have access to the World Wide Web can still retrieve a number of USGS databases by using FTP protocols. For example, the National Cartographic Data Base, which includes both cartographic and topographic digital databases at scales ranging from 1:24,000 to 1:2,000,000 can be found at "edcftp.cr.usgs.gov." The data are in directories found under the "/pub/data" directory. For further information on the USGS World Wide Web server, contact "Webmaster@usgs.gov."

For more information on the "National Water Conditions" online report and other digital water-resources information, contact Kenneth Lanfear at:

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A Distributed Spatial Data Library for the U.S. Geological Survey

A conceptual design is being implemented for an online library of spatial data, programs, and documentation to support hydrologic studies in the U.S. Geological Survey (USGS). Called the Distributed Spatial Data Library (DSDL), it is a set of local spatial data libraries that will house spatial data and data indexes for common use. The library concept includes definitions of format and organization of spatial and attribute data, programs, and associated documentation used by USGS databases and applications programs; programs required to query and evaluate the data stored in the library; and the anticipated processing environment in which the library would operate. These concepts are being used to implement and populate the DSDL in nearly 100 offices that collect digital spatial data within the USGS by September 1995.

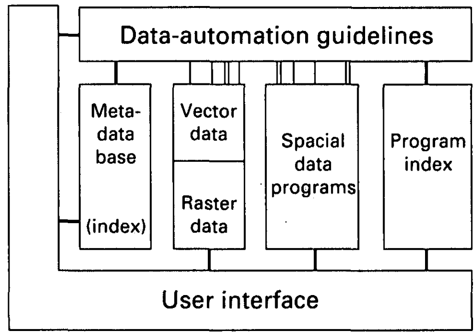
Conceptual Organization of the Distributed Spatial Data Library

The library includes a core of common spatial data, metadata that document each data set, software that is designed to operate on specific data sets or to work generically within a geographic information system (GIS), and indexes and help files for the available supported software. Standard "recipes" for the preparation or use of specific data layers would be developed by authors and users of the data sets, thus relating the various pieces in what are termed "data-automation guidelines."

New emphasis has been placed on the value of digital information within the Federal Government in general and on digital spatial data in particular. Office of Management and Budget Circular A-130 specifies that agencies must make information available in digital form and make more information electronically accessible through online computer networks, such as the Internet, or through dial-in bulletin board services. The need for a DSDL has long been recognized by the user community. The Federal Geographic Data Committee (FGDC) began a prototype spatial data clearinghouse activity in late 1992 to identify spatial data holdings, their applicability, and their availability. Proposals to develop a National Information Infrastructure and a National Spatial Data Infrastructure underscore this general requirement to organize and document spatial data holdings and to improve access to them (see p. 63).

At present, GIS software does not provide for the consistent management of descriptive information about data sets, known as metadata, or permit discovery and retrieval of such data, computer programs, and recognized techniques among users in either a local- or a wide-area network setting. A need exists in the USGS and the U.S. Environmental Protection Agency (USEPA) to develop an online system to manage digital spatial data, associated computer programs, standardized procedures and data-set-naming conventions, and related documentation to support a variety of hydrologic and database applications in a distributed processing environment. The USEPA is assisting in the development of this online system with the USGS.

The premise of DSDL–applying a distributed database approach to disparate collections of spatial data–was adopted by the FGDC in 1993 as part of a prototype spatial data clearinghouse. The clearinghouse prototype involved more than 60 participating Federal, State, and private organizations in the preparation and online dissemination of descriptions of spatial data holdings. The USEPA also has begun to apply DSDL concepts and software in the development of its spatial-data-management plan and has been helping develop the software tools required to make DSDL a reality.



Conceptual organization of DSDL. At the core of DSDL are collections of vector and raster spatial data sets and programs that work on specific or general types of data. The data sets and, in particular, their documentation can be indexed by textual content and by geographic location, or footprint. Users must be able to browse existing data holdings before beginning a new project to avoid reprocessing or digitizing existing data. They should be able to query the holdings of a database on the basis of a combination of text terms and geographic extent through the interactive definitions of a polygon on the screen and to have potential matches listed and accessible.

Design of the Data Structure

If a library concept is to be successful and be accepted by the end user, all data types must be identifiable and accessible through a common set of tools. A library is defined as a collection of map themes that have the same inherent tiling, or partitioning, structure. Multiple map libraries, which correspond to different collections of data, may be created and managed at a single site. Tiles are defined as closed geographic areas or units of map management by which data are produced, edited, and distributed. Some States build map libraries in which the tiling unit is a township because lands are administered in those units. Updates are typically processed by township, reports are typically written by township, and queries are typically run against a given township. Some States manage their map data by quadrangle because they are collected by quadrangle. For scientific applications, it is preferable that data be managed in units that correspond to the way the data were collected and the way they will be used. Collections of stream traces, like the USEPA River Reach File, should be logically organized by river basin rather than by quadrangle. Other data may be organized by State or county or by project area.

A library of data layers for the conterminous United States (CUSA) is maintained by the USGS in Reston, Va., and contains small- and intermediate-scale data sets giving full coverage of the lower 48 States. These data are prepared for Statewide, regional, and national analysis and are often used as backdrop maps or for the preparation of base-map materials. The CUSA library has been distributed internally within the USGS on CD-ROM for reference by water-resources applications, such as the National Water Information System.

Data Access in a Distributed Environment

It was originally anticipated that specialized software would be needed to provide nonproprietary access to spatial data, programs, and documentation, such as guidelines and data dictionaries. In late 1991, the Wide Area Information Server (WAIS) software was identified by the USGS as a potentially useful public-domain software system for the dissemination of earth science data. The WAIS software was jointly developed by Apple Computer, Thinking Machines Corporation, and Dow Jones and Peat Marwick as a means to rapidly index and to provide access to searching through entire text documents by using unstructured text queries across a wide-area network. The WAIS software has proved robust enough to permit custom enhancements, such as fieldlike data retrieval, spatial indexing and retrieval of documents, and support of multiple file types (for example, a text file, a graphic file, and a binary data file all as a result of a single query) by USGS and collaborating authors.

To access the USGS node of the National Geospatial Data Clearinghouse, open the Uniform Resource Locator (URL) and enter:
http://h2o.er.usgs.gov
Then click on:
USGS Node of the National Geospatial Data Clearinghouse
Then click on:
Spatial search

The WAIS software is being used by the DSDL project for online posting of digital data set documentation, graphic "snapshot" files, compressed GIS data layers for retrieval, data-dictionary entries, and software available within the USGS. Spatial extensions to WAIS were done in concert with the FGDC's Geospatial Data Clearinghouse Workgroup to provide Internet accessibility to data and descriptive information held by primarily Federal users of GIS.

The concepts of DSDL and WAIS rely on the fact that the data most likely to be updated and properly maintained are those that are kept in the local office and are in constant local use. Rather than creating a centralized repository of digital spatial data, individual offices with GIS capability will manage and post spatial data, programs, and documents from the local site. A central directory of servers–a "who's who" of digital spatial data–will be created by the USGS Reston DSDL office but only as a referral service to aide the discovery of actual data distributed in the field. This directory of servers also will reference other catalogs of earth science information known to be held in WAIS servers by the USGS and other earth science agencies. The accessibility of information has been greatly increased by World Wide Web clients such as Mosaic, which also are able to access and query these stores of data via gateway programs.

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Publication of Digital Spatial Data

The USGS and the USEPA have developed a spatial-data-documentation program (DOCUMENT) that facilitates the collection and management of important metadata. This program facilitates the collection of information that will be mandatory for data transfer by using the Spatial Data Transfer Standard. DOCUMENT will document any spatial data set that will be used in hydrologic investigations to prepare soft- or hard-copy maps or will be accessed by more than one user. It also manages four types of information–basic data-set characteristics, a data dictionary, references to published source(s), and a narrative section for extended discussion of data automation techniques and revisions. Where such information exists, all four types of information will be collected and managed for all types of spatial databases to facilitate appropriate use and reuse of the data. The output of the DOCUMENT program has been modified to be compliant with the FGDC Content Standard for Digital Geospatial Metadata. This modification allows exchange of metadata in a common set of terms.

Placement of standardized and reviewed data in DSDL will permit access to local data, remote data libraries, and indexes and will provide a mechanism for the automated retrieval of published spatial data sets across the wide-area network. Documented digital spatial data sets must be published on a digital medium suitable for distribution or placed online to provide automated access. online indexes of approved digital spatial data sets will be developed to refer prospective users either to the online location of the data or to where a copy of the distribution medium can be obtained.

Douglas D. Nebert
has worked for the last 12 years on information systems development and applications of geographic information systems in the USGS.

Experiments with Volume Visualization

Scientific visualization has proven to be an effective tool for the display of earth science data. The U.S. Geological Survey (USGS) has used visualization to portray flooding in the Mississippi River Basin, sewage outflow distribution in Boston Harbor, and the growth and distribution of hydrilla in the Potomac River. Volume visualization (VV) is an emerging technique in the field of scientific visualization that extends its applicability. VV is the science of generating images from volume data sets consisting of information that defines the internal attributes of a model as well as surface attributes.

In VV, three-dimensional (3-D) objects are represented as collections of small cells. These cells have attributes associated with them that can be portrayed in many ways, including color coding. Images of these cells are then rendered to portray objects that convey a sense of depth or thickness or both to the viewer. Modern computer hardware and software allow rapid manipulation of these renderings for closer investigation. Object rotation, subsetting, zoom in and zoom out, and arbitrary slicing of cross sections in 3-D space to view internal structures are a few of the features that make VV a valuable visualization tool.

Volume visualization has been successfully applied to earth science data. USGS computer scientists have developed techniques that allow exploration of the vertical sequence of the coal beds on the Crow Indian reservation in Montana (fig. 1). These visualizations proved valuable in identifying irregularities in the original coal models that scientists had been using.

Computer scientists are also investigating the use of VV to visualize and interactively construct 3-D models of aquifers. Volume visualization should prove useful in studying flow vectors within these structures.

USGS computer scientists have been experimenting with the VV tools available in the commercial software package Application Visualization System (AVS) from Advanced Visual Systems, Inc. These tools are known as the undefined cell data (UCD) modules of AVS. Research has been performed on a Silicon Graphics Indigo workstation with 96 megabytes of random access memory and 2

Financial Management Process Redesign

During FY 94, the Washington Administrative Service Center of U.S. Geological Survey (USGS) led a team for the Department of the Interior to identify financial procedures and financial systems areas where increased efficiency and savings could be obtained through modernization, streamlining, standardization, and reduction or elimination of unnecessary, labor-intensive, and duplicate activities. This effort, the Financial Management Best Practices Project, focused on the reinvention of accounting, payment, and reporting processes as well as on supporting automated systems functions to significantly increase customer satisfaction and reduce related costs.

Significant, tangible benefits to the customers and reductions in costs of at least 20 percent are readily achievable by this approach. Greater use of technology such as automated systems interfaces—in particular, the electronic transmission of invoices and receiving reports—would speed up payments to the public and reduce the effort associated with making the payments. Placing the capability to enter data, make adjustments, and create reports in the hands of end users would empower the end user, increase customer satisfaction with timeliness, accuracy, and ownership of the information, and reduce costs associated with duplicate data entry, reconciliations, and reports development.

The Best Practices Project Team completed a thorough and accurate benchmarking of a Federal administrative function, the methodology and framework of which can be used on a governmentwide basis and across different administrative disciplines to generate large savings through identifying broadly applicable efficiencies and meaningful performance measures.

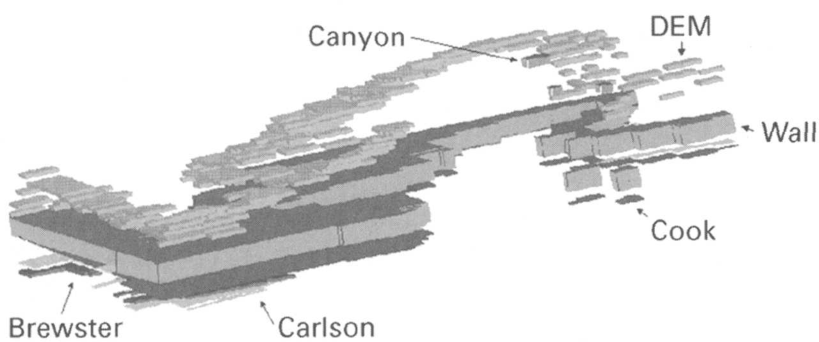

Figure 1. Three-dimensional visualization used to portray surface topography and coal beds in the northern region of parcel 1 of disputed lands adjacent to the Crow Indian Reservation in Montana.

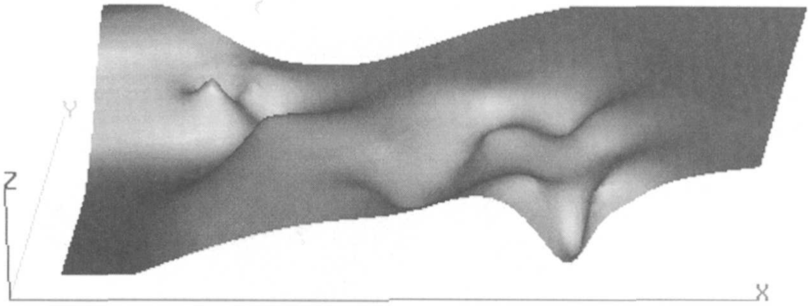

Figure 2. Surface mesh generated via AVS.

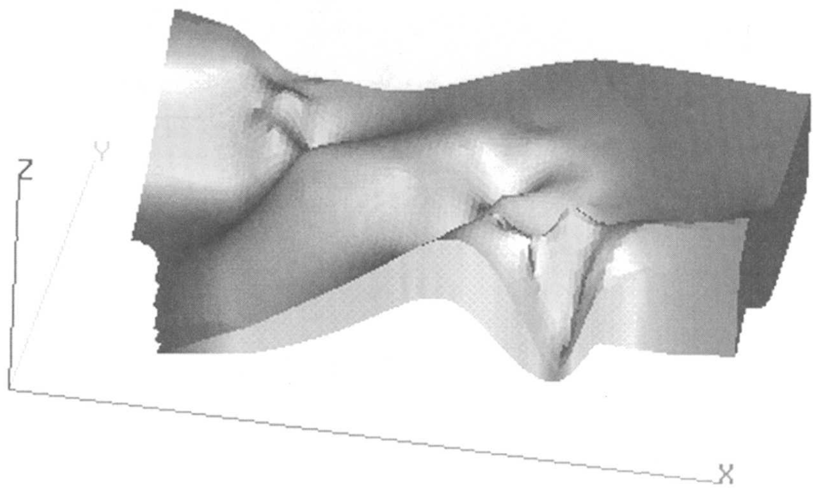

Figure 3. Top view of UCD model.

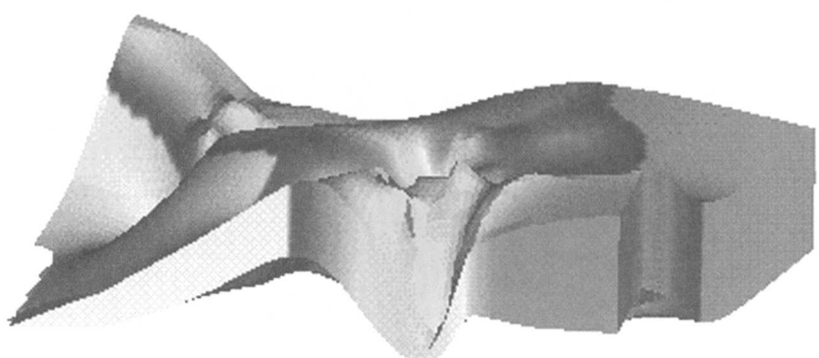

Figure 4. Side view of UCD model.

For more information on volume visualization, contact Gerry Lebing at:

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gigabytes of disk space. Similar hardware and software configurations are available at the USGS Scientific Visualization Laboratory in Reston, Va.

Volume visualization provides scientists with a realistic view of objects in space. Data visualization of a two-dimensional gridded data set is relatively simple when AVS is used. The surface mesh depicted in figure 2 was generated from an ASCII file of gridded data containing 95 rows and 59 columns. Each line of the ASCII file contained three entries: *x*, *y*, and thickness, where *x* and *y* are location coordinates and thickness is a function of the two. These surface representations can be effective as a visualization of some earth science models such as the terrain characteristics of a watershed. This image does not, however, provide the visual cues that help the user form a mental conception of a volume in space. Seeking to improve this visualization, USGS computer scientists began investigating the use of UCD, which represents geometric structures as a collection of cells in 3-D space. With minor data restructuring, UCD proved to be an effective tool for portraying this data set as a volume (figs. 3, 4), which allows scientists to show detailed spatial relationships of coal beds.

Construction of UCD models varies in complexity. Small, gridded, 3-D data sets can usually be transformed into UCD by using AVS-provided modules. Public-domain modules available from the AVS International Center have also proven useful in converting data to UCD. Additionally, USGS computer scientists have developed algorithms that transform earth science data into UCD structures.

Application of VV techniques to earth science data will be an ongoing endeavor for USGS researchers. These techniques have already demonstrated their usefulness in the display and analysis of some types of geologic models. Future research will investigate the use of UCD to help model and depict flow vectors inside of aquifers. As the use of VV is expanded, it should continue to prove a valuable tool in the understanding of earth science phenomena.

Gerry Lebing
is a computer scientist with the USGS.

Technology Transfer and Outreach: The USGS at Work with Industry

Within the U.S. Geological Survey (USGS), technology transfer and outreach historically have been accomplished by publication and widespread dissemination of scientific information. However, since the passage of the Technology Transfer Act of 1986, the USGS has been able to participate in a broader range of proprietary exchange activities, which have included individual licensing and partnership projects designed to enable private industry to address specific competitive concerns.

Under the enabling legislation, Federal agencies may develop Cooperative Research and Development Agreements (CRADA's) for scientific research or application purposes. The agreements may be between one or more Federal laboratories and one or more non-Federal parties (units of State or local governments, industrial organizations), including corporations, partnerships, and industrial development organizations; public and private foundations; or nonprofit organizations.

During FY 94, the USGS negotiated six CRADA's, seven licenses, and one technology transfer interagency personnel exchange with the Department of Energy. In total, the projects are expected to add more than a million dollars a year to USGS outreach and research efforts.

The executed CRADA's are collaborative arrangements under which the participant and the USGS jointly contribute research staff, equipment, technical information, and occasionally funds into (but not out of) the USGS to investigate issues of interest to industry. Areas of research and development within all CRADA's span the four USGS themes of resources, hazards, environment, and data gathering and information management.

Resources

A CRADA has been executed with a consortium of oil companies to evaluate the potential petroleum resources of Kazakhstan (see p. 85). Another agreement is for studies of the nucleation and growth of gas hydrates. A third CRADA is with the Electric Power Research Institute and the U.S. Department of Agriculture to develop a computer model that managers of hydroelectric power installations can use to predict water availability within a river basin. This model will be used to predict summer and fall water volume available for power generation on the basis of winter and spring climatological factors and other parameters.

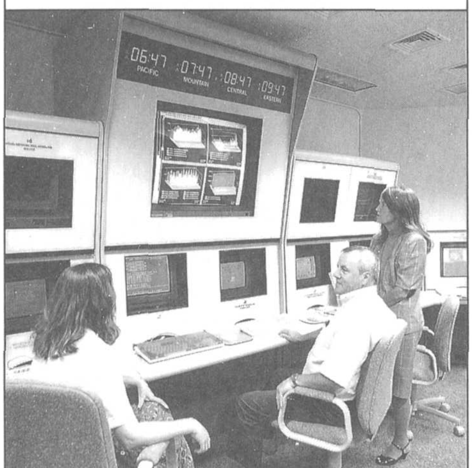
Hazards

A CRADA with the Pacific Gas and Electric Company of California will develop a real-time earthquake notification system that allows power stations time to shut down their generators before an earthquake occurs.

Environment

A CRADA will develop reliable methods for predicting the effectiveness of coal-cleaning procedures in removing potentially hazardous trace elements before the coal is used in electric generation plants. Another CRADA is for the development and demonstration of a water-monitoring system.

U.S. Geological Survey Network Control Center



Telecommunications is key to sharing information and technology among U.S. Geological Survey (USGS) locations. From the Network Control Center, located at the National Center in Reston, Va., the USGS monitors activity at 13 major telecommunications sites. Two hundred field locations are monitored for potential problems, and the flow of data going to and coming from each location is measured. The Network Control Center augments contractor monitoring of the network, which is done 24 hours a day, 7 days a week.

Data Gathering and Information Management

CRADA's will enhance USGS geographic information system (GIS) software and incorporate USGS standards into commercial GIS software; research the technology needed to collect, update, manage, and use digital geographic databases; and develop software for feature extraction and classification from image sources.

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Videoconferencing

To reduce travel costs and enhance productivity, the U.S. Geological Survey (USGS) is taking advantage of advances in technology, such as faster computer chips and better video signal compression techniques, that have reduced videoconferencing costs to an affordable level. The USGS evaluated emerging standards and different videoconferencing systems and for maximum flexibility selected a fully integrated video system for a test phase. Existing USGS digital transmission lines provided the necessary circuitry for videoconferencing trial conditions. The three USGS sites selected for this trial were Reston, Va., Denver, Colo., and Menlo Park, Calif., where nearly 50 percent of the USGS workforce is stationed. The results of a 6-month trial period showed that videoconferencing could be an effective alternative to travel and could enhance communications among sites.

Videoconferencing has shown a steady growth in use from two to three meetings a week to six to seven meetings a week since the test phase in 1990. Two more locations— Rolla, Mo., and Sioux Falls, S. Dak.–have been added to the network. Dedicated videoconferencing rooms at most sites make the equipment readily available and easy to use.

Videoconferencing has changed rapidly in the last few years. New video compression techniques now permit relatively high video quality at even lower data rates. Improvements in hardware and software have brought video technology to the desktop; in the very near future, video equipment and services will be available to smaller USGS field offices. As with all emerging technologies, costs have decreased, so the technology is now affordable for a wide customer base. Just as the personal computer has improved dramatically in a short time, it is expected that improvements in videoconferencing hardware and software will continue at a rapid pace. By the late 1990's, videoconferencing is expected to be as widespread as the use of facsimile machines is today.

A primary concern in acquiring new videoconferencing equipment is compatibility with existing USGS video equipment and interoperability with videoconferencing equipment throughout the Department of the Interior, other Federal agencies, and nongovernmental organizations. Although the vast majority of projected videoconferencing use will be within the USGS community, the ability to videoconference with organizations outside of the USGS is essential. With the recent emergence of international video standards (with which existing USGS equipment is compatible), all future procurements of videoconferencing equipment will specify that new equipment must be compatible with industry standards.

Jay O'Donnell
has over 25 years of telecommunications experience and currently manages USGS voice and video telecommunications activities.

National Performance Review: Reinvention Lab at the U.S. Geological Survey

U.S. Geological Survey (USGS) information exists in many forms–maps, books, photographs, diskettes, CD-ROM's, and videotapes. Most of these products, including more than 130,000 different maps and reports, are distributed from a central facility in Denver, Colo. More than 5 million products were distributed in FY 93 to the general public, Federal and State organizations, private industry, and a network of commercial map sellers for resale to the public.

Over the past several years, numerous studies have attempted to address specific problems related to information and product distribution. The current distribution system has been in place for more than 50 years; during that time, no substantive design changes have occurred. Recent studies have recognized several critical issues:

- Quality customer service is not sustainable.
- Computer systems do not support effective management.
- The culture of the USGS places little or no value on the operation.
- Processes are encumbered with real and perceived policies and procedures.
- Personnel policies are not flexible enough to accommodate changing workloads.

In June 1993, information and product distribution was identified as the subject for the first round of Reinvention Lab activities at the Department of the Interior as part of the National Performance Review called for by Vice President Gore. A team was chosen from several levels of employees: warehouse staff, first-line supervisors, and program managers. Using reengineering processes (beginning with a "clean plate," identifying root causes of problems and organizational core competencies, and benchmarking the approaches used by the best in the business), the team developed a three-tiered approach that was approved by USGS management in October 1993.

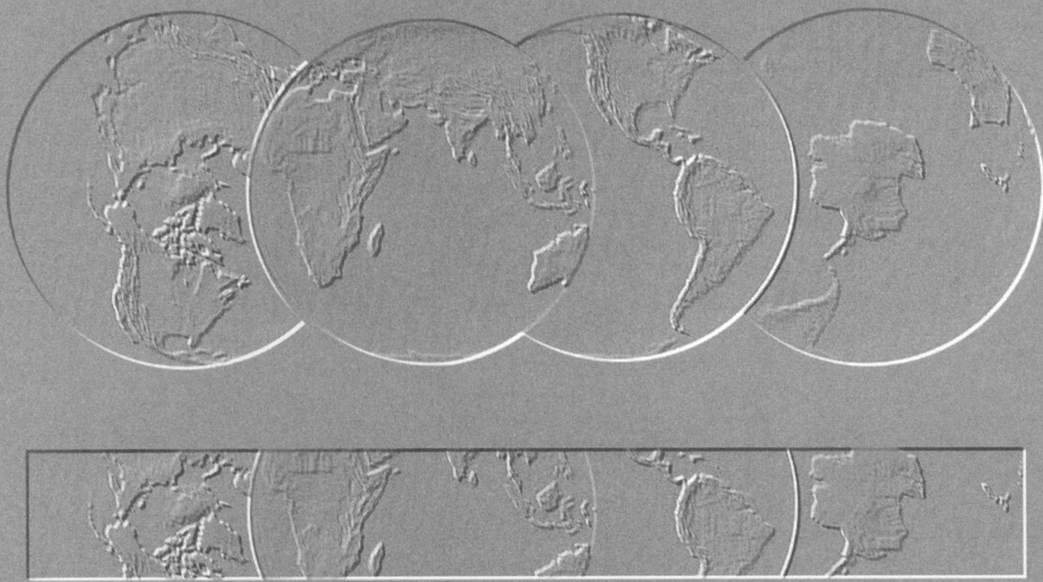
The new three-tiered approach to information and product distribution recognizes that distribution is a part of a wider customer service environment. The tiers are interrelated but functionally distinct: (1) information exchange, (2) product distribution, and (3) product supply. Tier 3 activities supply products to Tier 2, which then distributes those products; Tier 1 is the information environment in which customers (assisted by USGS information specialists) identify and order the products that they need. Tiers 1 and 3 are functions that exist in many parts of the USGS, whereas Tier 2 involves activities in the warehouse at the Denver Federal Center.

A core team began working to implement this design in November 1993, focusing on Tier 2. Recommendations were submitted to management in March 1994, and implementation began in May. Meanwhile, two new teams were established to address Tiers 1 and 3. These teams included representatives from USGS operating divisions, and each included a member of the core team to act as a liaison and ensure an integrated approach. As the Tier 1 and Tier 3 teams worked on their respective issues, the core team began the implementation process.

In July 1994, the Federal Financial System Inventory Subsystem–a new computerized accounting and inventory system–came online. The technological transition to this system accompanied an organizational change that merged the Branch of Distribution and the Earth Sciences Information Center at the Rocky Mountain Mapping Center into the new Branch of Information Services. The goals of this new branch were consistent with the goals of the National Performance Review, spearheaded by Vice President Gore.

Implementation of Tier 2 plans have involved process streamlining, cross-functional position descriptions, personnel changes, training, further definition of implementation plan elements, and planning for the changes that will result from the branch's move to new quarters. The Tier 1 and Tier 3 teams have gathered and analyzed information concerning larger information and product supply issues. Implementation has already begun in some areas and will ultimately integrate the activities of all three tiers.

USGS



International

International studies in earth science and technology are an important adjunct to the domestic research and investigations of the USGS. Authorization for foreign investigations is provided by the Organic Act, the Foreign Assistance Act, and related legislation. Activities are conducted under bilateral or multilateral agreements that require approval by the U.S. Department of the Interior and the U.S. Department of State. In the theme areas of hazards, resources, environment, and information, domestic research objectives are expanded and advanced through comparative studies of the geology, hydrology, and topography of other countries. Information about existing and potential foreign resources of interest to public and private sectors in the United States is obtained through collaborative research and is incorporated into databases that are worldwide in scope. USGS international activities futher the foreign policy objectives of the Department of State—for example, by revitalizing the earth sciences in central and eastern Europe. International programs of other Federal agencies, academia, and the private sector are supported as well through international activities. Training programs for foreign scientists lead to technology exchange that directly benefits the U.S. private sector. Fostering cooperative relationships with foreign counterpart earth science institutions facilitates technology transfer, data exchange, and the creation of research partnerships in areas of mutual interest that benefit all of the participating nations.

Opening New Doors to Scientific Cooperation and Exploration for Energy Resources in the Former Soviet Union

The immense territory of the former Soviet Union, which spans almost 12 time zones, contains keys to a large part of the Earth's geologic history and huge resources of oil, gas, and coal. For decades, much of this part of the world was closed to Western scientists interested in cooperative geoscience studies. With the breakup of the Soviet Union in 1991, however, many parts of the newly independent states have become accessible to the Western World, not only for joint research efforts but also for commercial ventures in exploring for and producing energy resources.

The U.S. Geological Survey (USGS) currently has cooperative energy projects in five countries of the former Soviet Union. These projects cover a broad spectrum of activities to assess and characterize energy resources, provide technical assistance to improve the efficiency of exploration and development of these resources, and develop data sets and other information to help these countries attract international investment. USGS activities in Russia, Armenia, the Ukraine, and Kyrgyzstan are supported by the U.S. Agency for International Development (USAID) through a service agreement to provide technical assistance in the area of oil, natural gas, and coal resources. USGS research in Kazakhstan is supported by a Cooperative Research and Development Agreement (CRADA) with U.S. and European petroleum companies (see "Technology Transfer and Outreach: The USGS at Work with Industry," p. 78).

Russia.–In 1994, USGS scientists began a 3-year cooperative program with several research institutes of the Russian State Committee on Geology and the Use of Underground Resources (ROSKOMNEDRA). The overall goals are (1) to improve the ability of Russian and U.S. petroleum geologists (in both the public and private sectors) to communicate in mutually understandable terms and concepts, (2) to improve the efficiency and effectiveness of the exploration programs of the Russian petroleum industry and to encourage participation by the U.S. private sector, and (3) to make available to the U.S. petroleum industry a considerable quantity of exploration data not previously available to the West.

Under the program, the USGS will train Russian specialists, procure equipment, and provide the technical design to establish five petroleum technology facilities at Russian research institutes. Three centers will be established in ROSKOMNEDRA research institutes in the city of Moscow. These centers will specialize in seismic data processing; the geochemical analysis of oil, natural gas, and organic matter extracted from petroleum source rocks; and the digitization of petroleum-related geologic information for conversion to geographic information system formats. A second seismic data processing center and a geochemical laboratory will be established at ROSKOMNEDRA institutes in Tyumen, West Siberia.

...the USGS will train Russian specialists, procure equipment, and provide the technical design to establish five petroleum technology facilities at Russian research institutes.

The products of this program will include:

- A digitized base map of petroleum basins at a scale of 1:5,000,000.
- Digitized geologic and topographic maps of Russia at a scale of 1:2,500,000, with an accompanying cadastre (database) of oil, gas, coal, and mineral deposits.
- Regional seismic profiles from key Russian petroleum basins, reprocessed from the original Russian data by using modern processing software.
- Geochemical analyses characterizing the source-rock potential of significant Russian oil and gas basins and incorporation of these data into petroleum basin models and exploration strategies.

These products, together with other data produced by the petroleum technology

Map of the former Soviet Union showing Russia, Armenia, the Ukraine, Kyrgyzstan, and the Republic of Kazakhstan.

centers, will also be used to support several cooperative research projects involving USGS and Russian specialists. These projects will contribute to a better understanding of the amounts and distribution of oil and gas resources in the principal petroleum-producing basins of the Russian Federation. During the first stage of this program, project scientists from the USGS and ROSKOMNEDRA will concentrate their efforts in the Timan-Pechora Basin, which is located in northern Russia just west of the northern Ural Mountains. This petroleum-rich basin is one of the most favorable regions for oil and gas exploration in Russia and should attract the attention of international petroleum companies. Using this basin as an example, collaborative research will demonstrate how modern equipment and methodologies can provide new insights in petroleum geology and improve the efficiency of oil and gas exploration.

Armenia.–Armenia is an ancient country rich in historical, cultural, and natural resources. However, with the exception of hydropower and nuclear power, Armenia's energy resources were not extensively developed while it was part of the Soviet Union owing to the availability of inexpensive imported sources of energy, such as natural gas and residual fuel oil. Following the breakup of the Soviet Union, Armenia's subsequent war with Azerbaijan, and the resulting cutoff of energy supplies, Armenia has suffered major energy shortages that have reached crisis conditions each winter since 1991–92.

Responding to the acute need to assess the nation's energy resources, the Armenian Ministry of Mineral Resources began a coal exploration program that included mapping, exploratory trenching and excavation, core drilling, and geochemical analyses. To support this program, the USGS, with support from USAID, conducted a preliminary assessment of coal and other solid fuel resources in 1993. The Armenian coal deposits evaluated in the preliminary study were found to be similar to Appalachian coals and Gulf Coast lignites in the United States that are used extensively for industry and for generating electricity.

On the basis of the preliminary assessment, the USGS began an expanded program of coal exploration and development in 1994. USGS scientists will train Armenian geologists to assess their country's coal resources, to develop efficient exploration strategies, and to provide the Armenian Government with a plan for increasing the nation's energy self-sufficiency. This cooperative effort will include exploration drilling and geophysical logging, establishment of laboratories for coal-quality analysis, creation of computer facilities for developing databases and estimating coal resources, geologic framework studies that will aid in devising coal-development strategies, and evaluation of data for best-use scenarios. The program will ultimately provide Armenia with the facilities and expertise necessary to explore for coal and independently determine the best means of developing its coal resources.

Ukraine.–There are three full petroleum basins and part of a fourth basin within Ukrainian territory and on the Black Sea and Azov Sea shelves. Onshore, these basins have been extensively explored to depths of 3 to 4 kilometers. Although the Ukraine will probably never achieve energy self-sufficiency, preliminary indications are that exploration at greater depths could significantly ease this country's dependence on imported oil and gas. In an effort to assist the Ukraine in modernizing its petroleum exploration capabilities, USGS scientists are currently conducting a cooperative program that will (1) establish a modern seismic processing facility and train Ukrainian geophysicists in seismic processing techniques, (2) assist Ukrainian scientists in developing a comprehensive database of petroleum information to guide exploration strategy, (3) perform geochemical analyses of petroleum source rocks from the Dnieper-Donets Basin, and (4) conduct a quantitative assessment of Ukrainian conventional and unconventional petroleum resources. This work is being conducted collaboratively with the Ukrainian National Geophysical Institute and the National Petroleum Exploration Company.

Preliminary work on this project began in 1994, when a Ukrainian geophysicist spent several months at the USGS Central Region center in Denver, Colo., using the USGS interactive seismic data processing system to reprocess Ukrainian seismic data from the Dnieper-Donets Basin. The resolution of the resulting profiles is much higher than that of the profiles processed with older technology. This enhancement of processing capabilities will directly influence exploration for oil and natural gas by allowing Ukrainian geologists and geophysicists to identify potential structural and stratigraphic petroleum traps that could not be seen on the old profiles.

Once the seismic processing facility is established in the Ukraine, scientists will begin to reprocess and reevaluate comprehensive seismic data sets from the Dnieper-Donets and Carpathian Basins. These data will help Ukrainian geologists and geophysicists identify new petroleum exploration targets. This capability, together with other products of this effort, will provide the Ukraine with information needed to expand petroleum production and attract foreign investment in petroleum exploration, which will help support the Ukrainian economy.

Kyrgyzstan.–Located in southern Asia between China and Kazakhstan, Kyrgyzstan is relatively small in size; its economy is less than 1 percent of the former Soviet Union's economy. The country does, however, possess enough coal resources to provide for its own heating and power generation needs and still have coal left for export. All of the coal presently mined in Kyrgyzstan–about 2 million tons annually–is used for heating. Coal in some unmined deposits may be suitable for steel production. Rocks deposited in central and eastern Asia 150 to 200 million years ago contain major coal deposits and are mined extensively for electric power generation and domestic and industrial heating. Coals of the same age also occur in Kyrgyzstan, but most deposits are in rugged terrain that may limit access for exploration, mining, and transportation. Also, some of the coal is of low rank and therefore less suitable for mining.

In 1994, the USGS began a project on behalf of USAID to assist in an assessment of the nature, extent, and characteristics of Kyrgyzstan's coal resources. A team of USGS specialists will work with counterparts from Kyrgyz organizations responsible for coal exploration, recovery, and utilization. The team's research will be integrated with supplementary efforts by mining engineers and utilization specialists provided by USAID. The project will result in an assessment of the total coal resources as well as an evaluation of the status of exploration, recovery, and utilization capabilities and options.

Kazakhstan.–The Republic of Kazakhstan is the second largest republic of the former Soviet Union (more than 2.7 million square kilometers) and is thought by many specialists to possess petroleum resources as large as some of the significant fields found in the Middle East. For example, the North Caspian Basin of western Kazakhstan, which is larger than the petroleum-rich Permian Basin of West Texas, contains several supergiant oil and natural gas fields (5–25 billion barrels of oil equivalent). Relatively little is known, however, about the geologic evolution and structure of this basin or about the oil and gas potential of other basins in southern and eastern Kazakhstan.

In conjunction with Kazakh and Russian scientists, the USGS has been conducting research in Kazakhstan and eastern Siberia on the ancient rocks that host these massive oil and gas deposits since 1987. In 1994, the USGS developed an innovative CRADA with U.S. and European oil companies to study the Kazakh deposits. This new 3-year international cooperative research venture is the first of its kind between the USGS and private industry. These studies are being conducted in collaboration with Kazakh scientists from the Ministry for Geology and Conservation of Mineral Resources in Almaty, Kazakhstan, and with Russian scientists from the Institute of Oceanology of the Russian Academy of Sciences in Moscow, Russia.

This research is currently being conducted in the Bolshoi Karatau and Malyi Karatau mountains of southern Kazakhstan, which are the northwestern extension of the Tien Shan Mountains of Kyrgyzstan and China. Project scientists are attempting to understand the geologic nature and evolution of the oil-bearing rocks of southern Kazakhstan and, subsequently, to conduct comparative studies on similar rocks in the Ural Mountains of Russia. These data and interpretations are being used to develop surface analogs that can help in exploring for supergiant oil and gas fields in the North Caspian, Volga-Ural, and Timan-Pechora Basins and in other similar basins of Asia. Papers coauthored by USGS, Kazakh, Russian, and industry scientists will assist in understanding the geologic origin, evolution, and potential of hydrocarbon resources in Kazakhstan. These publications will also be vital references for understanding the geologic development and potential energy resources in neighboring regions of Kyrgyzstan, Russia, and China.

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E.R. Landis
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is an authority on the origin, evolution, and sedimentology of carbonate reefs and carbonate platforms in the Republic of Kazakhstan.

Mining and Environmental Mercury in Venezuela

Decades of intense exploitation of small, "informal" gold placer mines in the Guayana Shield region of eastern Venezuela (figs. 1*A*, *B*) have resulted in deforestation, erosion, and release of the toxic metal mercury over a broad region. Severe mercury toxicity has been a recognized human health issue in Venezuela and greater Amazonia for some time but has now reached critical levels. Mercury in the environment is toxic to people both when it is inhaled as metal vapor and when it is ingested as methylated mercury, which commonly accumulates in fish. It is estimated that global atmospheric mercury levels have tripled in the past century, owing exclusively to human activities. Some of this atmospheric mercury eventually settles out over land and becomes incorporated into plants, animals, and soils.

Placer gold is concentrated in ancient, highly weathered sedimentary rocks and in modern placers derived from these rocks. Mercury was used to extract gold from ore by the earliest European settlers, and the technique was adopted by local mine workers. The mercury amalgamation process unfortunately is still widely used in Venezuela because there is no effective, low-cost alternative (fig. 2). The process involves relatively simple, inexpensive methods (such as the use of hand-hewn wooden riffles and traps), so it is accessible to even the smallest mining operations. The mercury amalgamation technique is nearly identical to the techniques used by miners in California during the mid-1800's and in the early Alaska gold-rush period some 40 years later.

These small but numerous mining operations in Venezuela recover only a fraction of either the total gold or the added mercury. For example, tailings that were sampled downstream from a sluice-box operation in the Rio Caroni Basin showed that effective gold recovery is commonly less than half. In addition, the mass of mercury lost to the environment is estimated to be about 1.0 to 1.5 times the mass of gold recovered. Of this mercury, about 40 percent is associated with the tailings. The rest is lost to the atmosphere when the amalgam is roasted during the gold recovery process. Although the amalgam is squeezed by hand to remove excess mercury, much still remains in the tailings. The tailings themselves are released into rivers during mining, excavations, and natural weathering.

The widespread use of mercury in the informal exploitation of surficial deposits was prohibited by presidential decree in Venezuela in July 1991. However, centuries of use combined with the recent upsurge in gold mining activity have left an estimated 40 tons of mercury behind in the forests and rivers.

To assess both the extent and the severity of the mercury contamination problem in the Guayana Shield, it is necessary to understand the biogeochemical cycling of mercury in this complex tropical ecosystem. Unfortunately, little is known about either the transport and release of mercury or the processes that control its form, sorption, and deposition. Because the high temperatures and humidity in the tropics accelerate many chemical and biological reaction rates, mercury moves rapidly through terrestrial ecosystems and accumulates readily in aquatic ecosystems.

Cooperative studies of these issues by the U.S. Geological Survey (USGS), the U.S. Forest Service (USFS), and the Venezuelan Government go back several years. Specifically, the Corporacion Venezolana de Guayana (CVG), under the bilateral Venezuelan Cooperative Project with the USGS, requested technical assistance in remediating some of the environmental damage caused by mining. In 1991, the USGS and the USFS presented a short course on environmental considerations and reclamation in mineral development for Tecnica Minera (TECMIN), the branch of CVG that deals with mining issues in eastern Venezuela. In 1992–93, the USGS completed the geology and mineral resource assessment of the Venezuelan Guayana Shield (published in 1994 as USGS Bulletin 2062). During that period, various geologists at the USGS Center for Inter-American Mineral Resource Investigations in Tucson, Ariz., laid the groundwork for a joint study of the distribution of mercury in the environment.

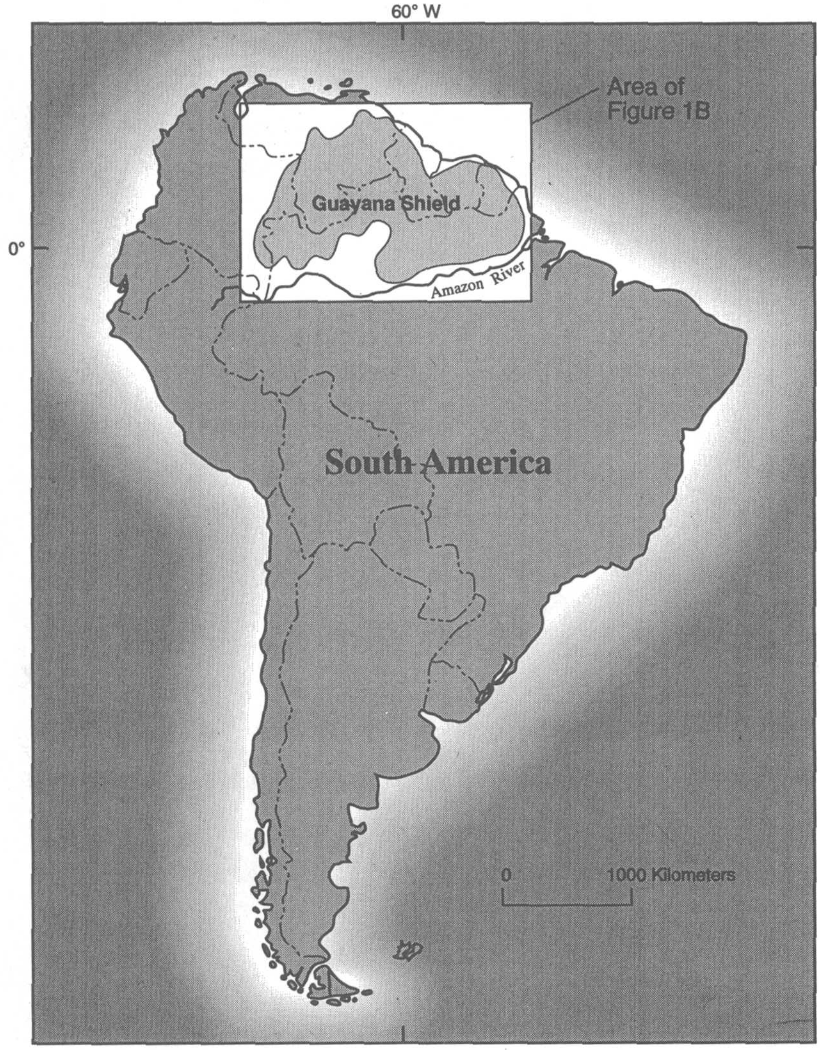

Figure 1A. *Location of the Guayana Shield of the Amazonian craton, South America. (Map by G.B. Sidder and V. Mendoza.)*

Figure 1*B*. Geography of northern South America. Dark shaded area indicates the Venezuelan part of the Guayana Shield. (Map by G.B. Sidder and V. Mendoza.)

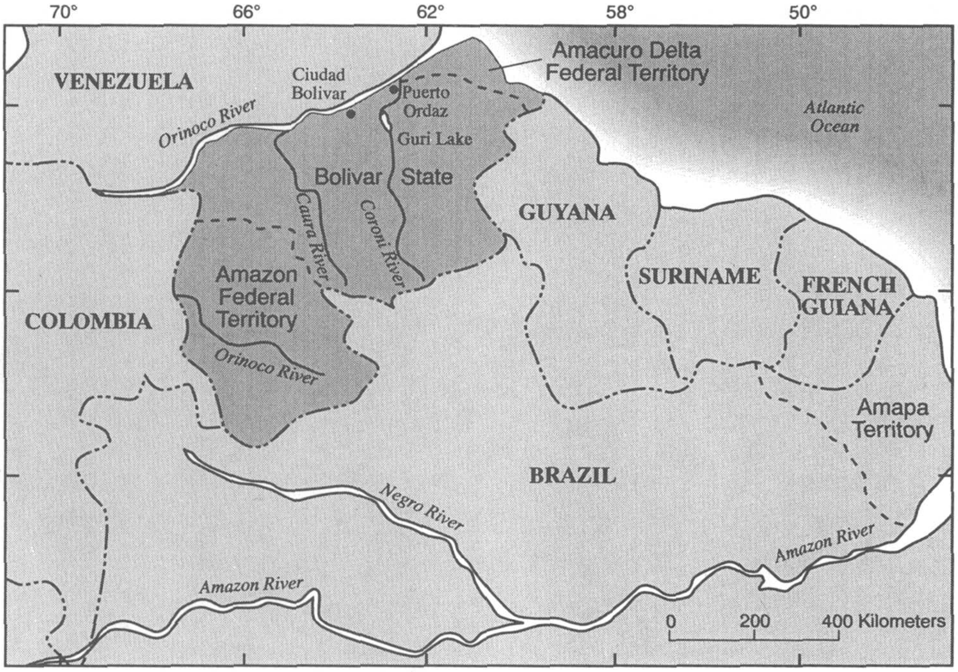

Figure 2. Gold miner panning ore using a wooden "batea." Mercury is added to the panned concentrate and combines with minute gold particles to form an amalgam. The amalgam is then "roasted" (commonly by using a blowtorch), and mercury is driven off as a vapor. Unused liquid mercury is often lost to the river.

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USGS scientists play an important role in defining the research needs that will be critical to understanding the extent and relative severity of mercury contamination in this environmentally sensitive region. For example, in 1993, a symposium on mercury in tropical ecosystems was held in Puerto Ordaz, Bolivar State, Venezuela. Scientists and engineers from the Venezuelan Government and mining interests (CVG), the USFS, the U.S. Environmental Protection Agency, U.S. mining companies, and the USGS participated in 5 days of discussions that centered on the extent of available information and areas needing further research. The USGS and USFS then summarized the recommendations of the workshop and proposed areas of future collaboration with Venezuela.

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Floyd Gray
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Contaminant Migration in Fractured Swedish Rock

Since 1989, scientists from the U.S. Geological Survey (USGS) and the Swedish Ministry of the Environment and Natural Resources have worked together to advance the state of the art in evaluating specific sites for a nuclear-waste repository in Sweden. As part of their efforts to ensure public safety, the Swedish agency responsible for building the nuclear-waste repository has, for the past 20 years, made unprecedented measurements to characterize the underground environment in which the waste will be isolated. The goal is to ensure that the repository function will not be compromised by water flow through rock fractures or any other process.

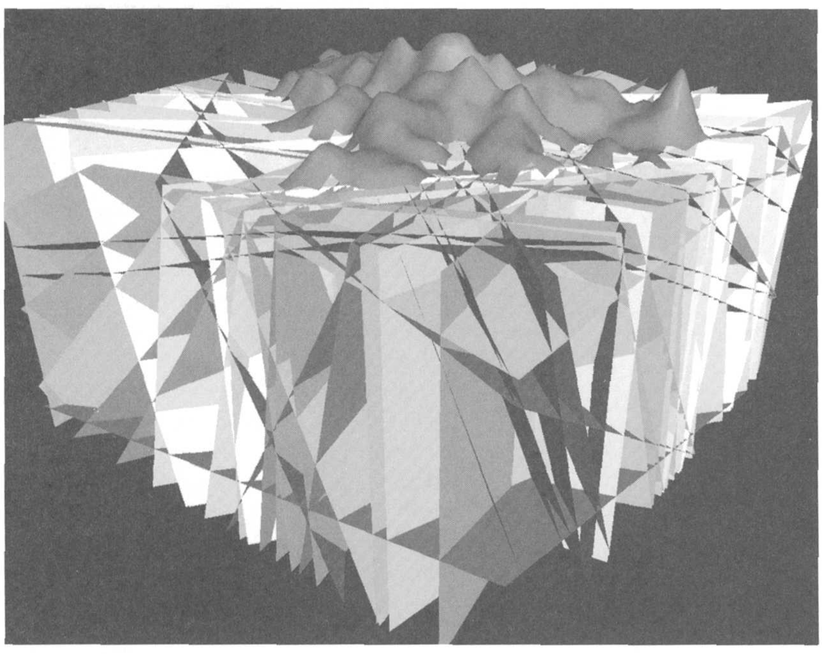
Sweden's plan is to isolate the waste from contact with people for more than 100,000 years in manmade horizontal tunnels, 500 meters below ground, in solid granitic rock. Dangerous nuclear fuel rods would be sealed in containers covered with a thick shell of copper and buried in impermeable bentonite-clay-lined holes in the bottom of each tunnel. When disposal is complete, the tunnels would be refilled and the land surface restored. If research can prove the safety of this theory, then actual construction of disposal facilities could begin within 10 years.

At the depth of the planned repository, subsurface rock is saturated with water; although the rock is virtually a solid granite, it is highly fractured. The potential safety hazard caused by such fractures is that water can flow through them and, as a result, around and through the repository, corroding the canisters, dissolving the toxic radionuclides contained within, and carrying them to the surface where people may be exposed to the radiation. This type of rock also is found extensively in the United States.

Recent work on this project includes hydrogeologic characterization of the bedrock at a site in southeastern Sweden. The illustration shows all of the structures (fractures) found in the bedrock to date in the cooperative project. The image is based on an integrated interpretation of Swedish data on geology, geophysics, and geochemistry by scientists from the USGS and Sweden. Because water flows through most of these structures, the area is more permeable than expected in such bedrock and less than ideal for subsurface waste isolation.

In the United States, toxic waste contaminates many bedrock areas; as it does in Sweden, the waste migrates with water that flows through fractures. The paths of contaminant migration through such fractures are extremely complicated. Most often, it is not economically feasible to further an understanding of how the contaminant is spreading and what procedures are required for site restoration. Through cooperative projects with agencies in Sweden, the USGS is sharing data collected at sites in Sweden and conducting analyses in cooperation with international teams to clarify how water and contaminants

A view of structures found underground at the site of an underground laboratory in fractured granitic rock. The block shown is 2 kilometers wide in each direction and 1 kilometer deep. The relief shown at the Earth's surface is Aspo Island, located on the coast of southeastern Sweden.



move through fractured rocks. By employing the advanced measurements made in Sweden

By employing the advanced measurements made in Sweden and through research efforts shared with teams of international scientists, the USGS has an opportunity to make significant advances in understanding and remediating similar problems within the United States.

and through research efforts shared with teams of international scientists, the USGS has an opportunity to make significant advances in understanding and remediating similar problems within the United States.

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Scientific Contributions to the Middle East Peace Initiative

In an effort to achieve a just and lasting peace among Israelis, Palestinians, and Jordanians, U.S.-led bilateral negotiations on Middle East peace were convened in Madrid, Spain, in October 1991. The talks, which were cosponsored by Russia, Canada, the European Union, and Japan, have played a key role in making possible the historic Declaration of Principles on Interim Self-Government Arrangements signed by Israeli and PLO representatives on the White House lawn in September 1993 and the Peace Treaty signed by Israeli and Jordanian representatives during October 1994 in Eilat on the Jordan-Israel border.

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Multilateral working groups to the Middle East Peace Initiative were formed in January 1992 to consider five major problem areas–arms control and regional security, environment, economic development, refugees, and water resources–in support of the ongoing negotiations and to build confidence among regional parties. The U.S. Department of State requested several Federal agencies, which included the U.S. Geological Survey (USGS), to provide technical support and advice to the Multilateral Water Resources Working Group (WRWG). Water-data enhancement, water-supply technology, and water management were selected as topics of vital importance, and the USGS was designated as the lead Federal agency for water-data enhancement. Since 1992, the USGS has provided one or more technical experts as members of the U.S. delegation to each of the WRWG meetings.

In addition, the USGS has been involved in successful efforts to use science as a catalyst to build confidence and friendship among Palestinian, Israeli, and Jordanian scientists and political leaders while advancing awareness of the need for cooperation in the field of water resources. Beginning with a study tour of the Colorado River Basin, the USGS, which was assisted by other Federal water agencies and the Department of State, has worked to demonstrate to Middle Eastern water managers and officials the necessity for management of scarce water resources on a regional, rather than a national, basis. USGS scientists then designed a water-data questionnaire that was distributed to all parties in the region. The questionnaire responses advanced USGS understanding of water data in the Middle East while providing an opportunity for cooperation among Middle Eastern water agencies.

On the basis of responses to the questionnaire, USGS scientists, who were assisted by water experts from the European Union and Canada, visited Palestinian, Israeli, Jordanian, and Egyptian water agencies to assess the availability and adequacy of water data and to develop recommendations for improvements in existing water-data collection systems. Following the mission to the region, the USGS developed and hosted a workshop for regional parties to devise plans for standardizing methods for water-data collection and analysis. This highly successful workshop resulted in a request from the Department of State for the development of a Middle East Water Data Banks Implementation Plan. The plan, which was written by the

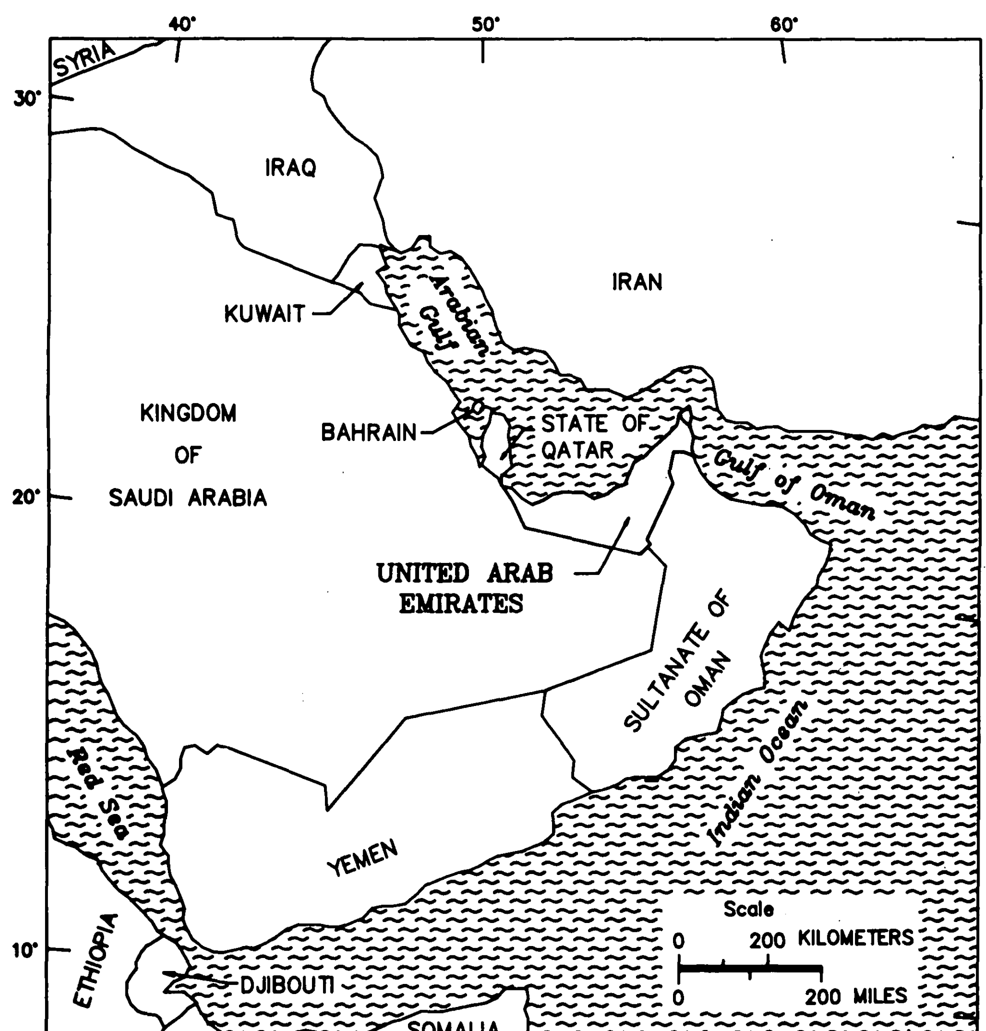
USGS, received consensus approval from 45 nations and international organizations convened at the sixth meeting of the Multilateral Water Resources Working Group in Athens, Greece, in November 1994.

Implementation of the plan is scheduled to begin in 1995, and the USGS will play a key role as facilitator, advisor, and mentor as well as advocate of U.S. national interests. The collection of hydrologic and hydrometeorologic data is the basis upon which a water-management program must be built. A major objective of the plan will be to support the concept of data comparability among the parties. This task includes establishing, or upgrading and strengthening, water-data programs while maintaining data-collection standards that will enable the parties to exchange water data. Implementation of the multimillion-dollar plan will be shared by donor nations throughout the world through contributions of technical expertise, equipment, and funding.

Anna Lenox
coordinates USGS contributions to and is the U.S. representative to the Water Resources Working Group of the Middle East Peace Initiative.

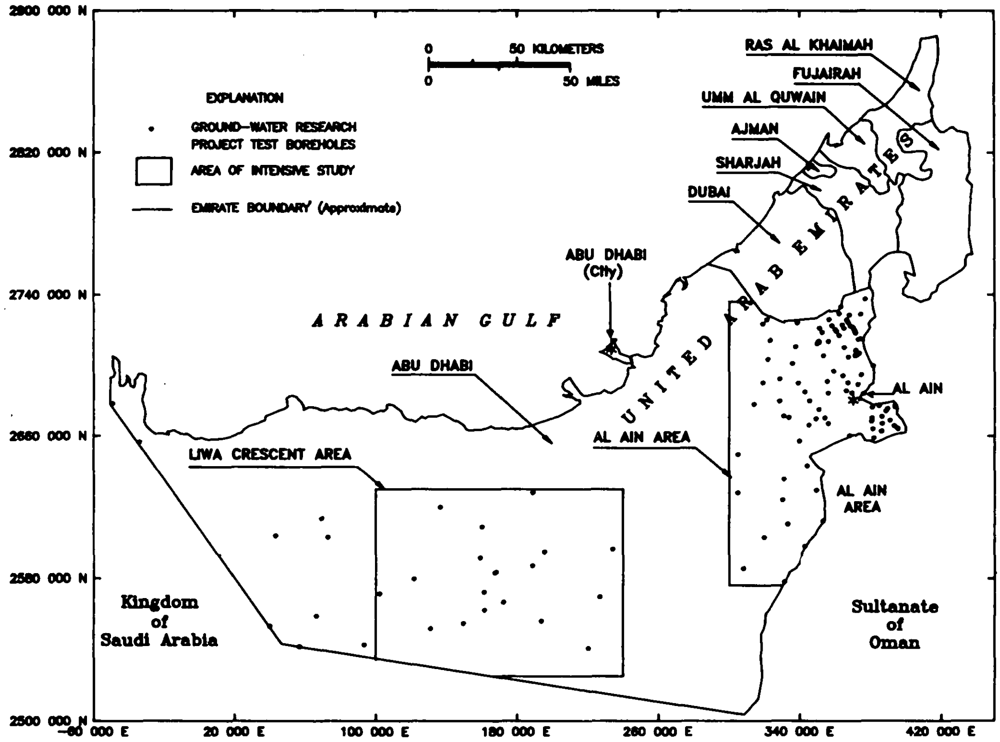
Water in the Desert: Ground-Water Studies in the United Arab Emirates

The United Arab Emirates (UAE) is a Middle Eastern country that comprises seven federated Emirates, or sheikdoms, and encompasses an area of 83,000 square kilometers. Located on the northeastern coast of the Arabian Peninsula between Qatar and



Arabian Peninsula and location of the United Arab Emirates.

Locations of area of intensive study from 1988 to 1993 and USGS Ground-Water Project test boreholes, July 1994.



Oman, the UAE was known as the Trucial States until the termination of their defense treaty with Great Britain and the establishment of an independent federation in 1971. Abu Dhabi Emirate, which has an area of about 67,000 square kilometers, is the largest of the seven Emirates. The natural resources of Abu Dhabi are characterized by an abundance of oil and a serious scarcity of freshwater.

In 1988, at the request of the U.S. Ambassador to the UAE, the U.S. Geological Survey (USGS) entered into a 5-year agreement with the National Drilling Company (NDC), which is an agency of the Abu Dhabi Government, to carry out ground-water investigations in the Emirate. The NDC-USGS Ground-Water Research Project office is located about 160 kilometers from the Arabian Gulf in the inland oasis city of Al Ain, which means "The Spring" in Arabic. The project is staffed by 6 to 8 USGS employees who serve 2-year assignments and 49 NDC employees (1 from Canada and 48 from the UAE and other African, Middle Eastern, and Far Eastern countries, including Nigeria, Egypt, Yemen, Jordan, Sudan, Somalia, India, Bangladesh, and the Philippines). About 20 percent of the workforce are UAE nationals, and 80 percent are expatriates who reside in the country on work visas.

The first phase of the study was to evaluate the fresh and slightly saline ground water of the 10,000-square-kilometer Al Ain area and the 14,600-square-kilometer Liwa Crescent area to provide the Emirate with a sound scientific basis for utilizing and managing its limited water resources. Additional objectives were to conduct research in arid-zone hydrology and to provide training in hydrologic techniques to the diverse international staff of hydrologists and technical support personnel. The initial phase was completed in 1993, and the agreement was extended for an additional 5 years to accommodate the second phase, which extends the evaluation of water resources to include the unstudied areas within the Emirate. A major element of the combined evaluations is the drilling, logging, testing, and sampling of about 165 wells and test holes, drawing on the expertise of numerous USGS researchers and other technical specialists.

The project has addressed a broad variety of research topics, such as wadi (stream) channel geophysical techniques, isotopes and trace elements in ground water, reinterpretation and reprocessing of petroleum seismic survey data, Landsat/SPOT (Satellite pour l'Observation de la Terre) composite mapping, borehole geophysical techniques, and tectonics and stratigraphy. Training activities conducted for project employees by USGS

For more information on ground-water studies in the United Arab Emirates, contact Anna Lenox at:
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Internet: alenox@qvarsa.er.usgs.gov

permanent and temporary duty personnel include classes and workshops on such subjects as borehole geophysics, report writing, water chemistry, aquifer-test analysis, ground-water modeling, and geographic information systems. In addition to the in-house training, NDC employees have attended several training courses at the USGS National Training Center in Denver, Colo., and at other U.S. educational institutions.

The NDC-USGS Ground-Water Research Project has successfully developed special procedures and techniques for drilling water wells, interpreting petrophysical logs, reprocessing existing petroleum seismic data, constructing water wells, and reinterpreting uphole-velocity survey data associated with petroleum exploration, all of which have direct application to investigations in the United States. In meeting its basic objective of providing a sound scientific basis for water management, the project has refined the understanding of the hydrogeologic framework of the Emirate, mapped the areal extent of fresh and brackish ground water, established hydrological and meteorological monitoring networks, and compiled maps of water levels and water quality. This information has been used, in conjunction with water-use inventories, to develop a hydrologic budget and a ground-water model that can be used as a tool to evaluate and manage the nonrenewable ground-water resources of this strategically important, oil-rich Middle Eastern ally.

Craig Hutchinson
heads the NDC-USGS Ground-Water Research Project in Al Ain, UAE.

Anna Lenox
coordinates USGS international water resources activities.

Toward a Safer World: Natural Disaster Reduction

The risk from natural hazards is increasing with time worldwide. As a nation's population grows, more people are concentrated in a small number of large metropolitan areas having vulnerable buildings and lifeline systems. In the United States, for example, much of the population lives in hazard-prone regions. The 12,000 miles of U.S. coastline are subject to hurricanes, storm surges, and tsunami flood waves; areas in and adjacent to the floodplains along the 6 million miles of the Nation's river system are vulnerable to flooding; areas in or near known active fault zones are threatened by possible damaging earthquakes. Whereas the number of deaths from natural hazards is decreasing, direct economic loss is increasing. Successful warning programs have caused a decline in casualties owing to floods, tsunamis, and wildfires; mitigation and preparedness programs have reduced casualties for earthquakes. However, building density and the rising cost of building and construction materials contribute to increasing economic losses.

The first world conference to address loss of life and other concerns related to natural disaster reduction was convened in Yokohama, Japan, by the United Nations (UN) on May 23–27, 1994, at the midpoint of the UN's International Decade for Natural Disaster Reduction (IDNDR). Hosted by the Government of Japan, the conference was attended by more than 2,000 participants representing 148 nations, UN bodies, specialized agencies, intergovernmental and nongovernmental organizations, and regional banks. Scientific and technical disciplines involved in risk assessment, mitigation, and warning systems for earthquakes, floods, severe storms, volcanic eruptions, tsunamis, landslides, wildfires, and droughts were represented at the conference.

The outcome of the conference was summarized in the Yokohama Statement and Plan of Action for a Safer World, which specified activities at community, national, subregional, regional, and international levels. The plan calls upon governments of every country at risk from natural hazards to develop strategies for reducing the potential impacts of future natural disasters. It also calls upon more developed countries to assist less developed nations through technology transfer and other means of assistance.

Each country attending the conference prepared and distributed a national report that gave the status of current activities and plans for the future on risk assessment, mitigation, warning systems, and international cooperation. A call was made for accelerated technology transfer (that is, transfer and enhanced utilization of information, data, and experienced people) to reduce the increasing

For more information on the International Decade for Natural DIsaster Reduction, contact Walt Hays at:

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Fax: (703) 648-6717
Internet: lhuey@usgs.gov

toll of deaths and economic impacts worldwide, especially in developing countries.

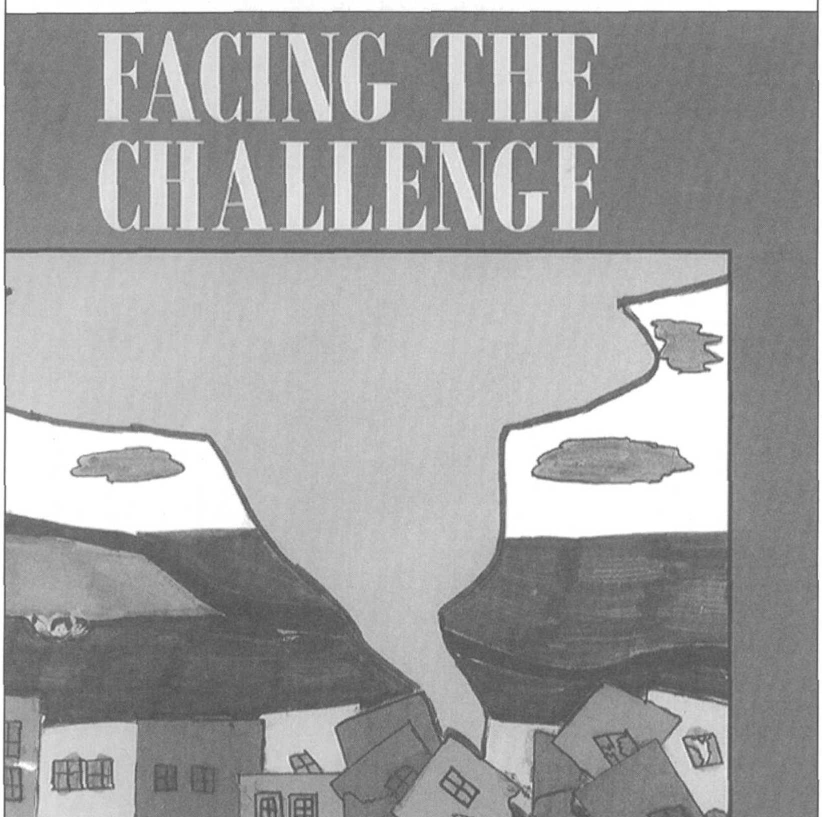
The U.S. Geological Survey (USGS) conducts research, facilitates the transfer of technology to end users, and fosters the adoption and implementation of public policies and professional practices to reduce losses from earthquakes, volcanic eruptions, landslides, and hydrologic hazards in the United States and abroad. Many USGS research projects contribute to IDNDR goals of risk assessment, mitigation, warning systems, and international cooperation. For example, the goal of the urban hazard, risk, and mitigation program for earthquakes is to develop methodologies and strategies for making land-use, zoning, business, and consumer decisions about loss-reduction measures in urban centers throughout the Nation. Another example is the multidisciplinary studies of Mount Rainier, an active volcano in the Cascade Range of Washington State, 21 miles southeast of the Seattle-Tacoma metropolitan area. This volcano has been designated for focused research as a Decade Volcano, 1 of only 14 worldwide (see p. 20).

The USGS operates the National Seismic Network and a nationwide stream-gaging network. The seismic network is a satellite-based system consisting of digital seismicity and strong-motion instruments located in earthquake-prone regions of the Nation. Local seismicity networks managed by universities complete the national network. The stream-gaging network consists of more than 7,000 stations where continuous records of streamflow are collected and another 3,000 stations where intermittent records are collected. At the continuous-record stations, the flow rate can be determined at any moment on any day of the year. This information, collected in cooperation with many other Federal, State, and local agencies, is vital to predicting and studying floods and droughts.

The USGS organizes and conducts post-disaster investigations in the United States and abroad. Through its international programs, it provides technical assistance and training in support of the IDNDR's goal of international cooperation.

Walt Hayes
is an internationally recognized expert on natural hazards and their effects on society.

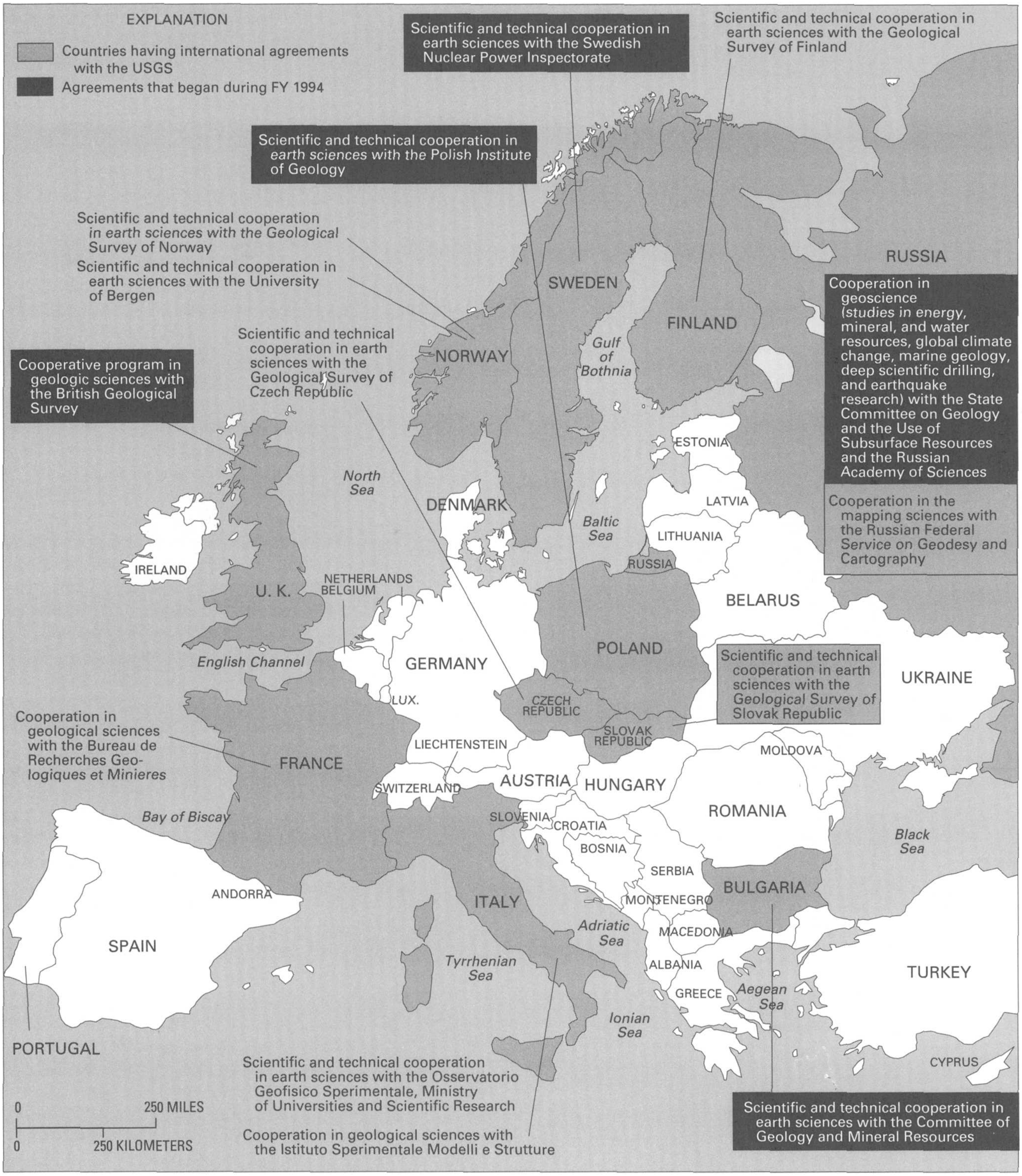
Colorado Student Wins International Poster Contest on Hazards

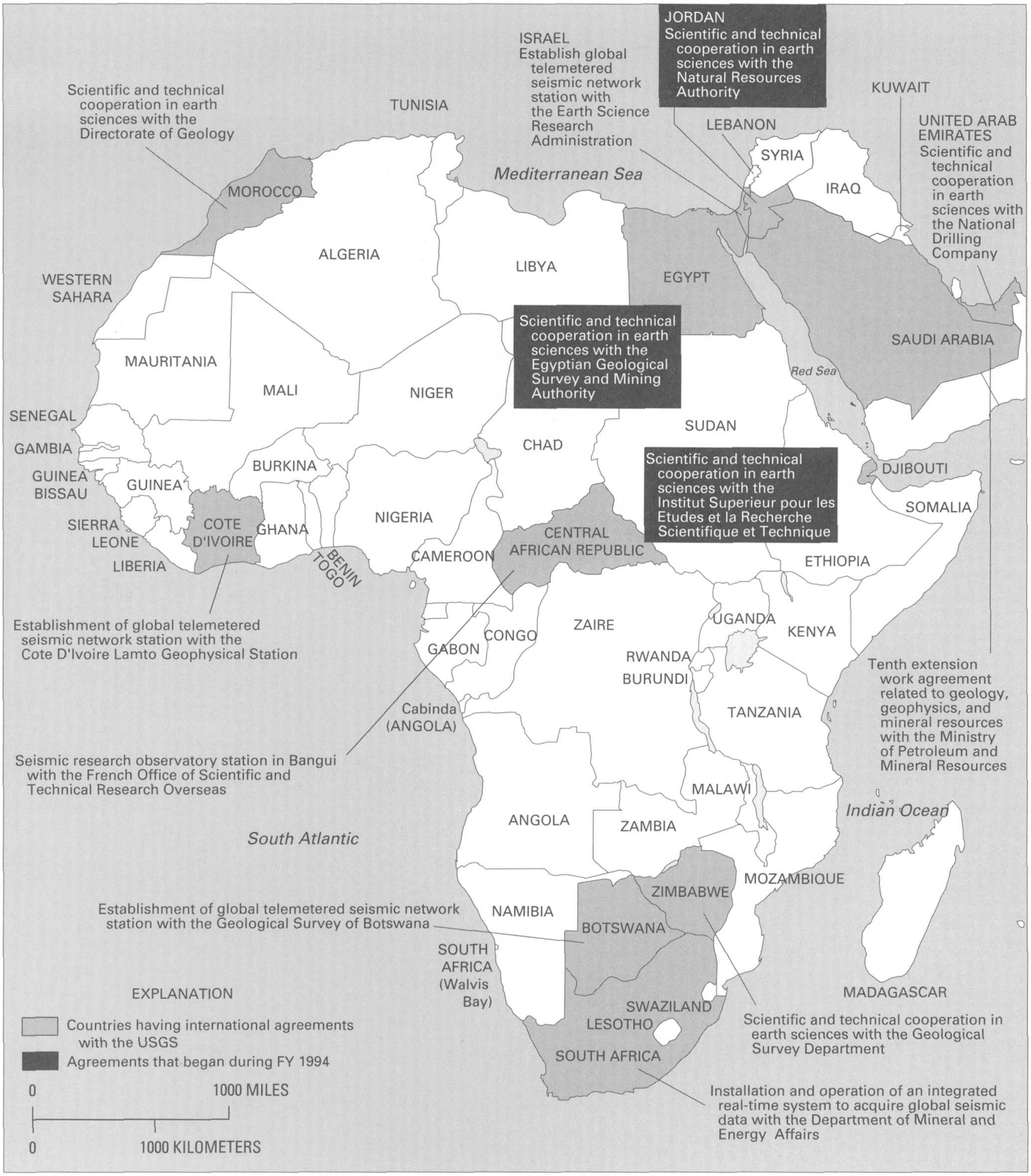


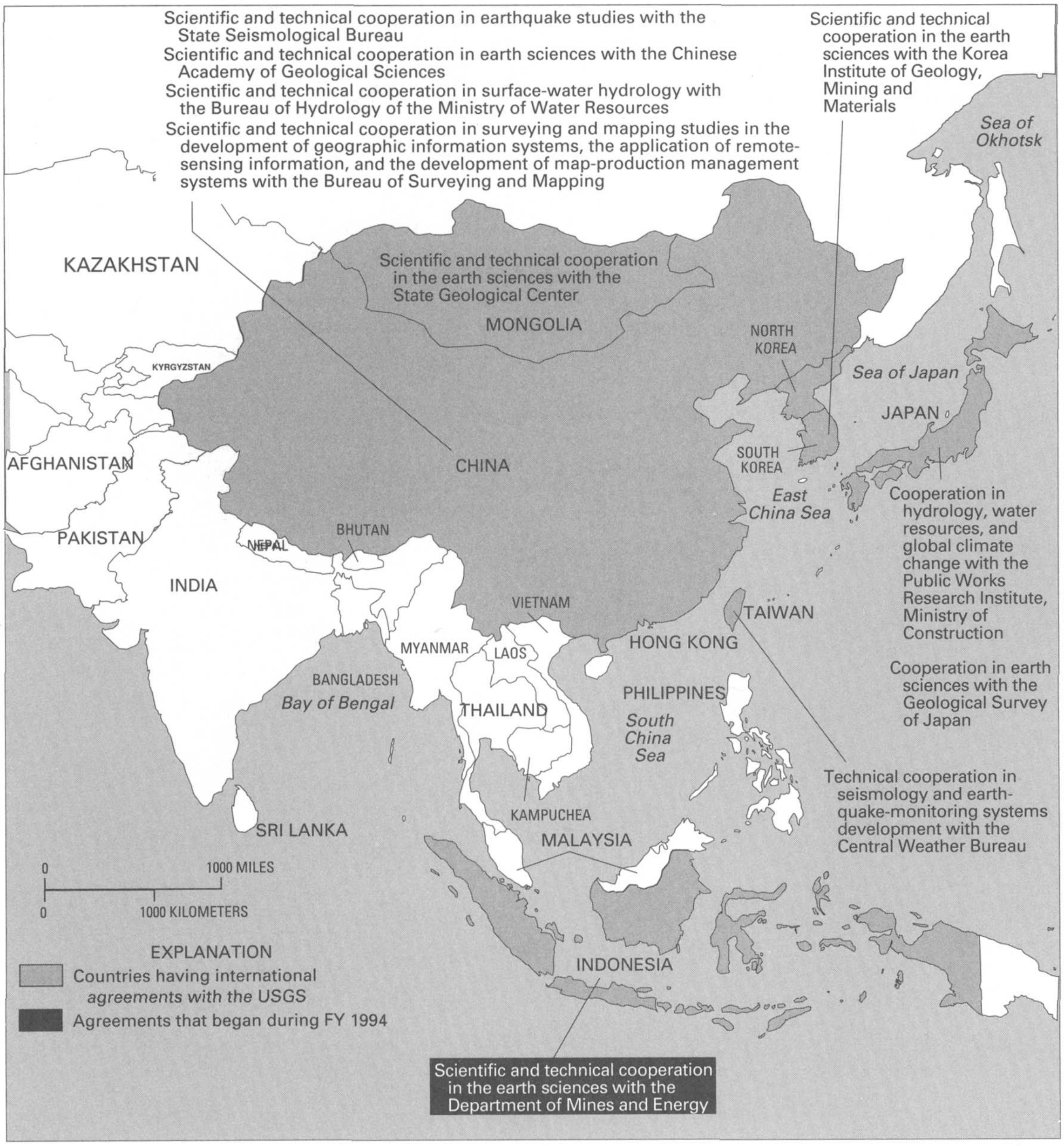
The International Decade for Natural Disaster Reduction Secretariat sponsored an exhibit of children's art from around the world, which was displayed at the May 1994 world conference in Yokohama. Participating countries held student poster contests and chose winners in three categories.

One of the contest winners was Paige Murphy from Horace Mann Middle School in Denver, Colo. Paige's poster (above), which shows the power of a tornado as well as people making themselves safe, was also selected to be on the cover of the U.S. national report presented at the conference.

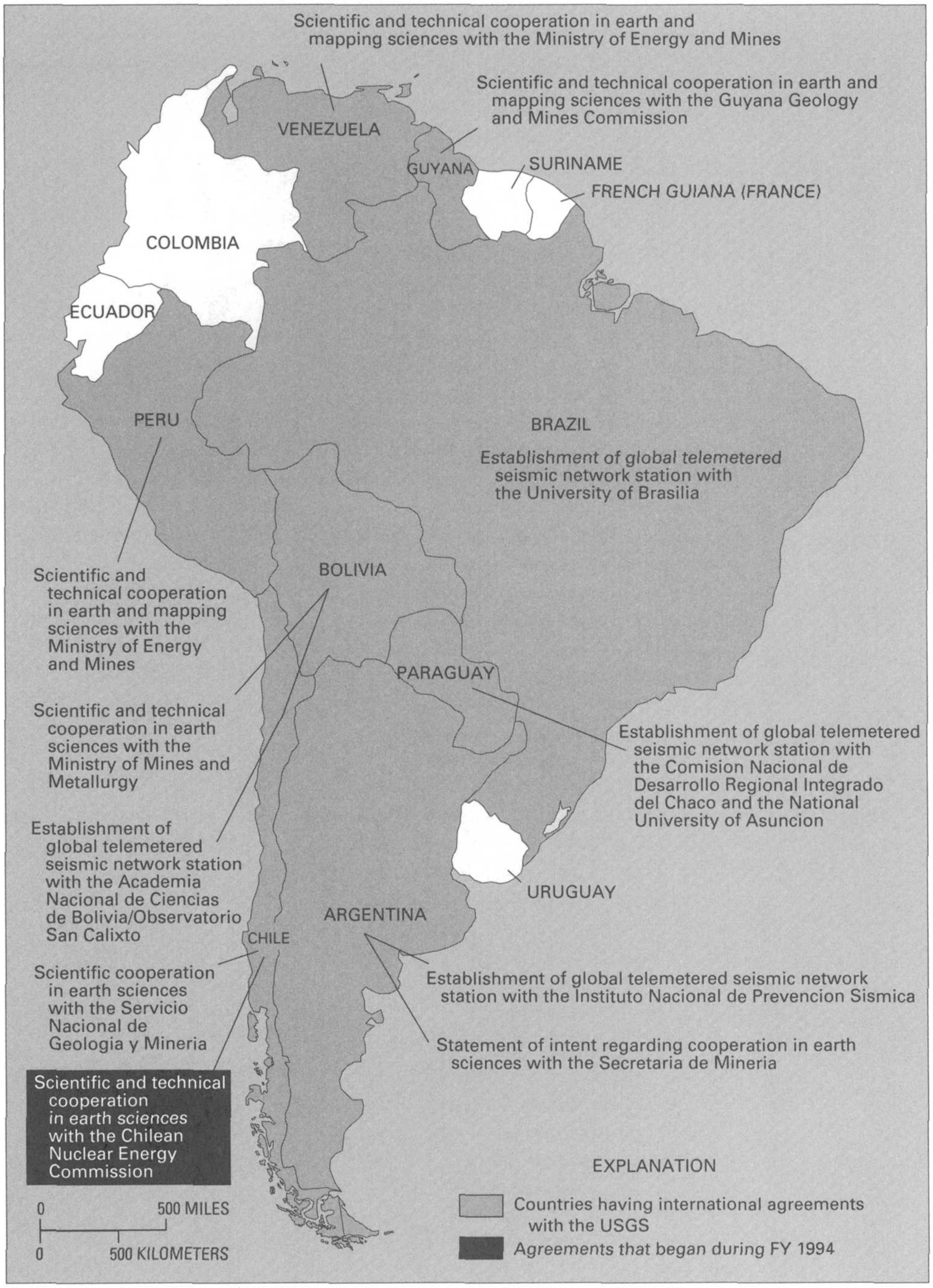
In 1992, Horace Mann became a USGS partnership school, a program in which resources are shared and USGS employees assist students with math and science activities.


EXPLANATION
Countries having international agreements with the USGS
Agreements that began during FY 1994
Scientific and technical cooperation in earth sciences with the Swedish Nuclear Power Inspectorate
Scientific and technical cooperation in earth sciences with the Geological Survey of Finland
Scientific and technical cooperation in earth sciences with the Polish Institute of Geology
Scientific and technical cooperation in earth sciences with the Geological Survey of Norway
Scientific and technical cooperation in earth sciences with the University of Bergen
Scientific and technical cooperation in earth sciences with the Geological Survey of Czech Republic
Cooperative program in geologic sciences with the British Geological Survey
Cooperation in geoscience (studies in energy, mineral, and water resources, global climate change, marine geology, deep scientific drilling, and earthquake research) with the State Committee on Geology and the Use of Subsurface Resources and the Russian Academy of Sciences
Cooperation in the mapping sciences with the Russian Federal Service on Geodesy and Cartography
Scientific and technical cooperation in earth sciences with the Geological Survey of Slovak Republic
Cooperation in geological sciences with the Bureau de Recherches Geo-logiques et Minieres
Scientific and technical cooperation in earth sciences with the Osservatorio Geofisico Sperimentale, Ministry of Universities and Scientific Research
Cooperation in geological sciences with the Istituto Sperimentale Modelli e Strutture
Scientific and technical cooperation in earth sciences with the Committee of Geology and Mineral Resources
RUSSIA
SWEDEN
FINLAND
NORWAY
Gulf of Bothnia
ESTONIA
LATVIA
LITHUANIA
RUSSIA
BELARUS
North Sea
DENMARK
Baltic Sea
IRELAND
U. K.
NETHERLANDS
BELGIUM
GERMANY
POLAND
UKRAINE
English Channel
LUX.
CZECH REPUBLIC
SLOVAK REPUBLIC
LIECHTENSTEIN
MOLDOVA
FRANCE
SWITZERLAND
AUSTRIA
HUNGARY
ROMANIA
Bay of Biscay
SLOVENIA
CROATIA
BOSNIA
SERBIA
Black Sea
ANDORRA
ITALY
MONTENEGRO
BULGARIA
SPAIN
Adriatic Sea
MACEDONIA
Tyrrhenian Sea
ALBANIA
TURKEY
GREECE
Aegean Sea
Ionian Sea
PORTUGAL
CYPRUS
0 250 MILES
0 250 KILOMETERS

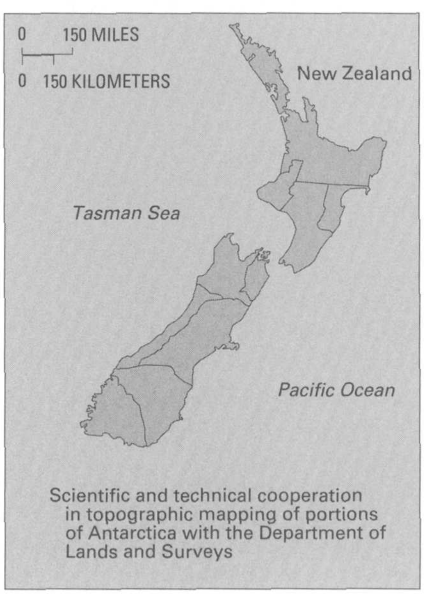

JORDAN
Scientific and technical cooperation in earth sciences with the Natural Resources Authority
ISRAEL
Establish global telemetered seismic network station with the Earth Science Research Administration
Scientific and technical cooperation in earth sciences with the Directorate of Geology
TUNISIA
KUWAIT
LEBANON
UNITED ARAB EMIRATES
Scientific and technical cooperation in earth sciences with the National Drilling Company
SYRIA
IRAQ
Mediterranean Sea
MOROCCO
ALGERIA
LIBYA
EGYPT
WESTERN SAHARA
Scientific and technical cooperation in earth sciences with the Egyptian Geological Survey and Mining Authority
SAUDI ARABIA
MAURITANIA
MALI
NIGER
Red Sea
SENEGAL
SUDAN
CHAD
GAMBIA
Scientific and technical cooperation in earth sciences with the Institut Superieur pour les Etudes et la Recherche Scientifique et Technique
DJIBOUTI
GUINEA BISSAU
GUINEA
BURKINA
SOMALIA
SIERRA LEONE
COTE D'IVOIRE
GHANA
NIGERIA
CENTRAL AFRICAN REPUBLIC
LIBERIA
BENIN
TOGO
CAMEROON
ETHIOPIA
Establishment of global telemetered seismic network station with the Cote D'Ivoire Lamto Geophysical Station
UGANDA
ZAIRE
KENYA
CONGO
GABON
RWANDA
BURUNDI
Tenth extension work agreement related to geology, geophysics, and mineral resources with the Ministry of Petroleum and Mineral Resources
Cabinda (ANGOLA)
TANZANIA
Seismic research observatory station in Bangui with the French Office of Scientific and Technical Research Overseas
MALAWI
Indian Ocean
ANGOLA
ZAMBIA
South Atlantic
MOZAMBIQUE
ZIMBABWE
Establishment of global telemetered seismic network station with the Geological Survey of Botswana
NAMIBIA
BOTSWANA
SOUTH AFRICA (Walvis Bay)
MADAGASCAR
EXPLANATION
SWAZILAND
LESOTHO
Countries having international agreements with the USGS
Agreements that began during FY 1994
Scientific and technical cooperation in earth sciences with the Geological Survey Department
SOUTH AFRICA
0
1000 MILES
0
1000 KILOMETERS
Installation and operation of an integrated real-time system to acquire global seismic data with the Department of Mineral and Energy Affairs

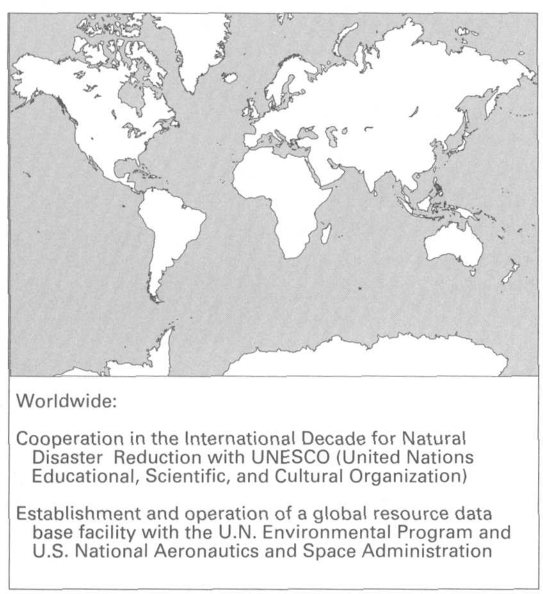

Scientific and technical cooperation in earthquake studies with the State Seismological Bureau
Scientific and technical cooperation in earth sciences with the Chinese Academy of Geological Sciences
Scientific and technical cooperation in surface-water hydrology with the Bureau of Hydrology of the Ministry of Water Resources
Scientific and technical cooperation in surveying and mapping studies in the development of geographic information systems, the application of remote-sensing information, and the development of map-production management systems with the Bureau of Surveying and Mapping
Scientific and technical cooperation in the earth sciences with the Korea Institute of Geology, Mining and Materials
Sea of Okhotsk
KAZAKHSTAN
Scientific and technical cooperation in the earth sciences with the State Geological Center
MONGOLIA
NORTH KOREA
KYRGYZSTAN
Sea of Japan
JAPAN
SOUTH KOREA
AFGHANISTAN
CHINA
East China Sea
Cooperation in hydrology, water resources, and global climate change with the Public Works Research Institute, Ministry of Construction
PAKISTAN
NEPAL
BHUTAN
INDIA
VIETNAM
TAIWAN
HONG KONG
MYANMAR
LAOS
Cooperation in earth sciences with the Geological Survey of Japan
BANGLADESH
Bay of Bengal
THAILAND
PHILIPPINES
South China Sea
Technical cooperation in seismology and earth-quake-monitoring systems development with the Central Weather Bureau
KAMPUCHEA
SRI LANKA
MALAYSIA
0
1000 MILES
0
1000 KILOMETERS
EXPLANATION
Countries having international agreements with the USGS
Agreements that began during FY 1994
INDONESIA
Scientific and technical cooperation in the earth sciences with the Department of Mines and Energy

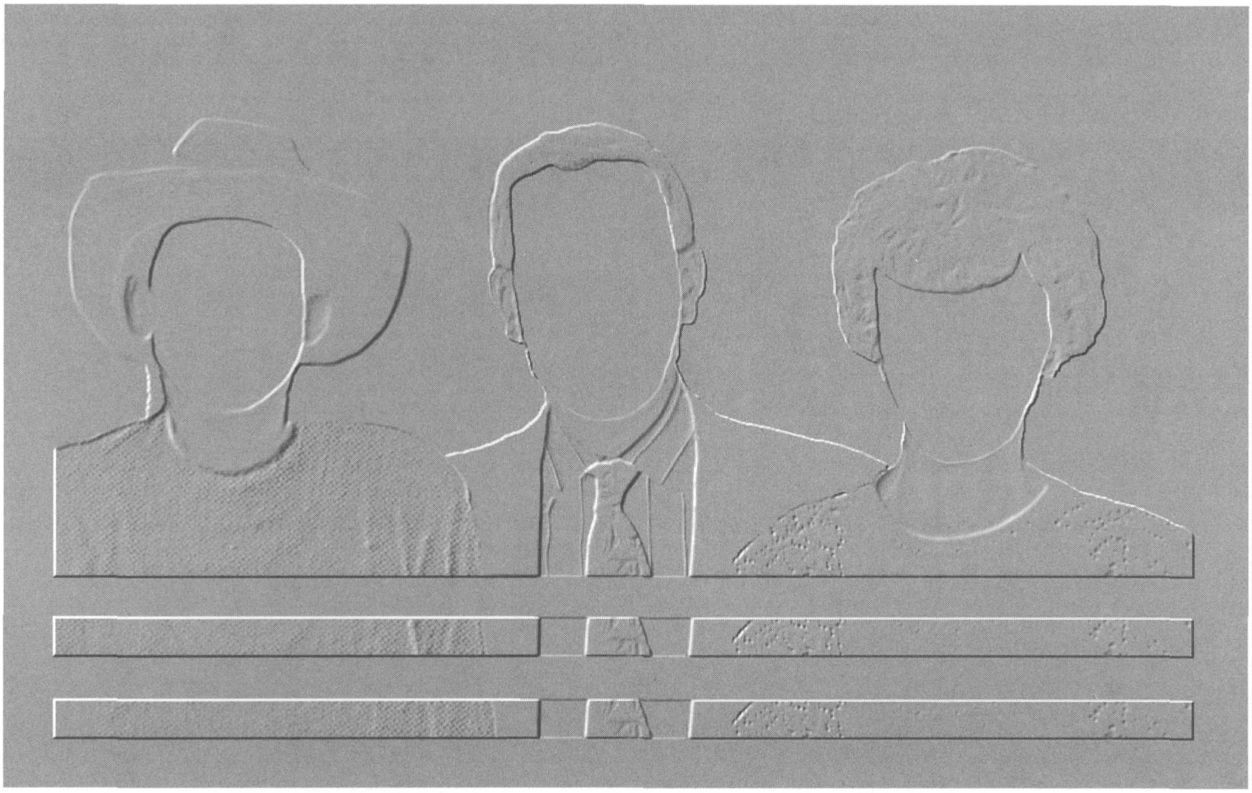

Cooperation in surveys, mapping, and remote-sensing activities in the areas of international border mapping, and the accessing of global change data with the Canadian Surveys, Mapping, & Remote Sensing Sector of the Department of Energy, Mines, and Resources
Statement of intent regarding cooperation in geological sciences with the Geological Survey of Canada
Scientific and technical cooperation in earth sciences with the Icelandic Council of Science
Arctic Ocean
Beaufort Sea
UNITED STATES
GREENLAND (DENMARK)
ICELAND
Baffin Bay
Yukon Territory
Pacific Ocean
CANADA
Northwest Territories
Labrador Sea
British Columbia
Alberta
Hudson Bay
Newfoundland
Manitoba
Saskatchewan
Quebec
Ontario
P.E.I.
New Brunswick
Nova Scotia
EXPLANATION
Countries having international agreements with the USGS
0
500 MILES
0
500 KILOMETERS
Atlantic Ocean
UNITED STATES


Scientific and technical cooperation in earth and mapping sciences with the Ministry of Energy and Mines
Scientific and technical cooperation in earth and mapping sciences with the Guyana Geology and Mines Commission
VENEZUELA
GUYANA
SURINAME
FRENCH GUIANA (FRANCE)
COLOMBIA
ECUADOR
PERU
BRAZIL
Establishment of global telemetered seismic network station with the University of Brasilia
BOLIVIA
Scientific and technical cooperation in earth and mapping sciences with the Ministry of Energy and Mines
Scientific and technical cooperation in earth sciences with the Ministry of Mines and Metallurgy
Establishment of global telemetered seismic network station with the Academia Nacional de Ciencias de Bolivia/Observatorio San Calixto
PARAGUAY
Establishment of global telemetered seismic network station with the Comision Nacional de Desarrollo Regional Integrado del Chaco and the National University of Asuncion
URUGUAY
ARGENTINA
CHILE
Scientific cooperation in earth sciences with the Servicio Nacional de Geologia y Mineria
Scientific and technical cooperation in earth sciences with the Chilean Nuclear Energy Commission
Establishment of global telemetered seismic network station with the Instituto Nacional de Prevencion Sismica
Statement of intent regarding cooperation in earth sciences with the Secretaria de Mineria
EXPLANATION
Countries having international agreements with the USGS
Agreements that began during FY 1994
0 500 MILES
0 500 KILOMETERS


MEXICO
Gulf of Mexico
MEXICO
Technical cooperation in cartography, geographic information systems, and remote sensing with the Institute of Statistics, Geography, and Information
Scientific and technical cooperation in earth and mapping sciences with the National Autonomous University of Mexico
Scientific and technical cooperation in earth and mapping sciences with the Secretariat of Energy, Mines, and Parastatal Industry
BELIZE
Scientific, technical, and policy cooperation in the earth and mapping sciences with the Ministry of Natural Resources
GUATEMALA
HONDURAS
EL SALVADOR
NICARAGUA
Lago de Managua
Lago de Nicaragua
Technical cooperation in resources management and development with the Organization of American States in Latin America
0 200 MILES
0 200 KILOMETERS
COSTA RICA
North Pacific Ocean
Panama Canal
PANAMA
EXPLANATION
Countries having international agreements with the USGS
Agreements that began during FY 1994

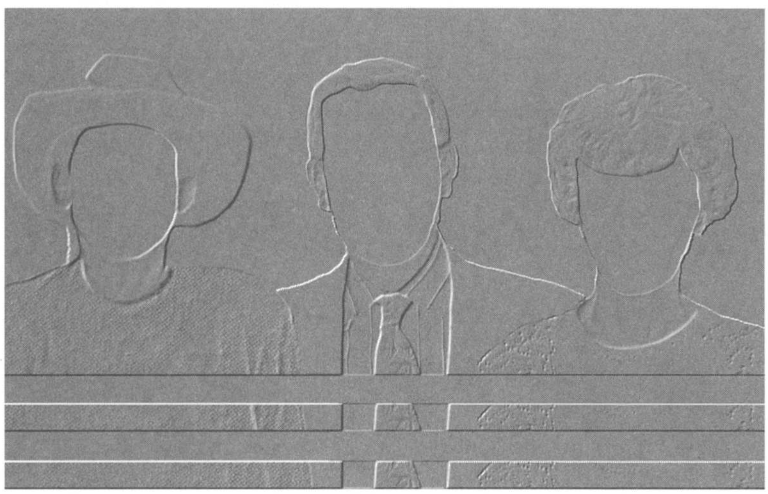

0 150 MILES
0 150 KILOMETERS
New Zealand
Tasman Sea
Pacific Ocean
Scientific and technical cooperation in topographic mapping of portions of Antarctica with the Department of Lands and Surveys


Worldwide:
Cooperation in the International Decade for Natural Disaster Reduction with UNESCO (United Nations Educational, Scientific, and Cultural Organization)
Establishment and operation of a global resource data base facility with the U.N. Environmental Program and U.S. National Aeronautics and Space Administration



Human Resources

USGS



Honors and Awards

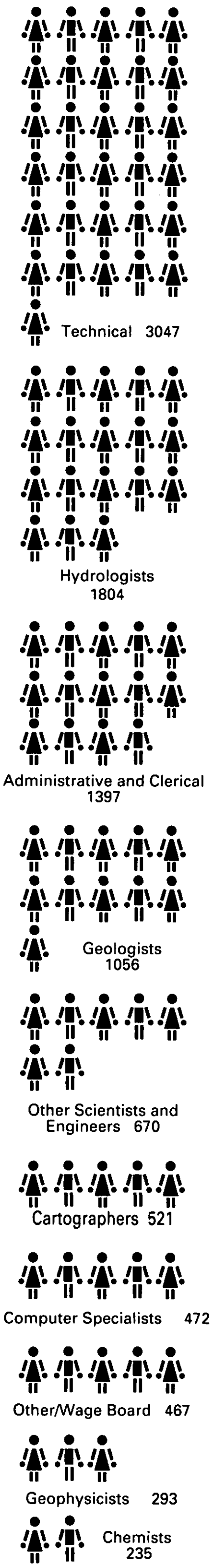
Each year, U.S. Geological Survey (USGS) employees receive awards and honors that range from certificates of excellence and monetary awards to recognition of their achievements by election to membership or office in professional societies.

Distinguished Service Award

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 16 USGS employees in 1994:

- **Earl E. Brabb**, for outstanding contributions to the field of environmental geology and for contributions to the direction of the geologic hazards and geographic information systems programs of the USGS.
- **Max C. Brewer**, for outstanding contributions to geology and geophysics and their applications to environmentally sound engineering design practices and for sound management of logistical operations in the permafrost environment of the Arctic.
- **T. John Conomos**, for exceptional achievements in estuarine research and management of water programs in the nine-State USGS Western Region.
- **Avery A. Drake, Jr.**, for significant contributions toward a better understanding of the geology of the Appalachian Mountain chain.
- **William W. Dudley, Jr.**, for exceptional contributions in the interdisciplinary fields of ground-water hydrology and engineering geology.
- **Warren I. Finch**, for outstanding contributions to uranium resource assessment studies and for his many contributions to the administration of USGS scientific programs.
- **Anita G. Harris**, for outstanding research and leadership in conodont paleontology, biostratigraphy, paleotemperature assessment, and hydrocarbon resource potential programs of the USGS.
- **Robert M. Hirsch**, for exceptional contributions to the USGS in the fields of statistical hydrology, program planning, and research management and for leadership contributions to the development of the National Water-Quality Assessment Program and the Global Change Research Program. Hirsch was also awarded the Presidential Rank of Merit for serving as Acting Director of the USGS during a period of transition, for career-long efforts to apply basic hydrologic research to real-world problems, and for consistently developing successful program contributions in both the scientific and the policy arenas.
- **Irwin H. Kantrowitz**, for outstanding contributions to the management of bureau water-resources programs, particularly in Florida, and for significant contributions to the Regional Aquifer Systems Analysis Program.
- **Vance C. Kennedy**, for significant research in the field of solute transport in stream water and bed sediments and in acid rain geochemistry and as a leader in the development of acid rain programs and policies.
- **Janis C. Nash**, for significant contributions to bureau human resources management programs.
- **Richard W. Paulson**, for exceptional contributions in the field of real-time hydrologic data-collection systems development and the management of National Water Summary activities.
- **James R. Plasker**, for outstanding achievements as an engineer, cartographer, and manager of the USGS National Mapping Program. His innovative approaches to technical and management issues have led to production agreements with other Federal agencies.
- **Hedy J. Rossmeissl**, for outstanding scientific and management contributions to the USGS National Mapping Program, particularly the development and testing of the Spatial Data Transfer Standard, and for advancing the acceptance and promulgation of the standard as a Federal Information Processing Standard.
- **John H. Stewart**, for outstanding contributions to understanding the geology of western North America. His studies have provided important clues for developing mineral assessments of undiscovered mineral deposits.
- **Ralph J. Thompson**, for outstanding service and contributions to the scientific data management, processing, and information systems activities of the USGS.

Personnel, by Occupation



1994 total = 9962

Meritorious Service Award

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 in 1994 were:

Rex V. Allen, Donald E. Anders, Dudley J. Andrews, Emil D. Attanasi, Roy A. Bailey, John A. Barron, Richard J. Blakeley, David M. Boore, Roger D. Borcherdt, Eurybiades Busenberg, Norma J. Campbell, Wallace H. Campbell, Philip J. Carpenter, Michael A. Domaratz, Wendell A. Duffield, Thomas D. Fouch, Marvin O. Fretwell, Donald L. Gautier, Judith A. Gunnells (posthumous), Carl E. Hedge, Flora A. Heggem, Thomas G. Hildenbrand, C. Judy Huffman, James R. Jancaitis, Joan L. Johnson, Donald G. Jorgensen, John R. Keith, Yousif K. Kharaka, Hugh H. Kieffer, William J. Kockelman (posthumous), Gerald F. Lindholm, Thomas L. Loesch, Baerbel K. Lucchitta, Richard B. McCammon, Bonnie A. McGregor, Edward J. McFaul, John S. McLean, Cornelius M. Molenaar, Donald G. Moore, Charles W. Naeser, Charles E. Ogrosky, Robert N. Oldale, Paul P. Orkild, Robert C. Pearson, John K. Peterson, Ernest L. Ray (retired), Bruce L. Reed, Charles L. Rice, Dale E. Robertson, David H. Root, Keven S. Roth, Robert O. Rye, Andrei M. Sarna-Wojcicki, David H. Scott, John F. Slack, Robin U. Spriggs, William D. Stanley, Elaine M. Stout, William J. Strahle, Wayne R. Thatcher, Ted G. Theodore, Tracy L. Vallier, James N. VanDriel, Bruce R. Wardlaw, Florence R. Weber, Barbara L. Whitford, Paul L. Williams, Kathryn C. Wortman, Thomas L. Wright, Sherman S.C. Wu, Jeffrey C. Wynn.

Superior Service Award

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 USGS mission. Recipients in 1994 were:

David P. Adam, Lee W. Aggers, Karl W. Ahlstrom, Tau Rho Alpha, William C. Andrle, Janet N. Arneson, Brian F. Atwater, Robert A. Ayuso, Colleen A. Babcock, Stanley Baldys III, Brian S. Bennett, Darleen K. Berry, Russell D. Berry, Julio L. Betancourt, Elisabeth M. Brouwers, David P. Brown, Alex P. Cardinell, Thomas J. Casadevall, Paul R. Celluzzi, Michael J. Chambers, Robert G. Clark, Harold S. Cogle III, Thomas H. Cooper, John E. Cotton, Harry R. Covington, David P. Dee, Ronald E. DeMatteo, Allan D. Druliner, Stephenson D. Ellen, Keith H. Elliott, Michael R. Elliott, Sherman R. Ellis, Stephen J. Field, Michael A. Fisher, Carolyn Gail Folger, Marta J.K. Flohr, Douglas W. Franz, David Frishman, Ronald G. Garrett, Karl W. Gatson, Eric L. Geist, William C. Good, David L. Govoni, Gregory N. Green, Thomas P. Grover, David E. Hair, John R. Hebron, Henry E. Herlong, Debra K. Higley, Richard A. Hollway, Anton L. Inderbitzen, Ronald V. James, Francis J. Jelinek, Evan C. Jenkins, David A. John, Margaret F. Johnson, Robert L. Johnson, Robert F. Johnstone, Diane N. Jones, Michael T. Jones, Gail E. Kalen, Kenneth R. Kauffman, Carol Kendall, Mary C. Kilpatrick, Randolph L. Kirk, Randolph A. Koski, Thomas R. Loveland, Brent H. Lowell, Jean Louise Marlowe, George T. Mason, Jr., Jill McCarthy, Robert G. McCausland, Alfred S. McEwen, Benjamin F. McPherson, Robert J. Miller, John A. Moody, Edward N. Moser, Jerry M. Motooka, Vivian S. Olcott, Robert J. Omang, Kenneth J. Osborn, William S. Parks, Jocelyn A. Peterson, Lawrence R. Pettinger, M. Jeanne Placanica, James E. Poole, Earl Reaves, George O. Riddle, Donald O. Rosenberry, Jane D. Rothenbuehler, Roger P. Rumenik, Kenneth A. Salts, Robin A. Schmutzler, Robert B. Scott III, William B. Scott, Marvin G. Sherrill, Jeffrey D. Simley, Floyd L. Snow, Louis T. Steyaert, Jeffrey D. Stoner, Thomas A. Stum, Lindsay A. Swain, James W. Terry, John E. Terry, Jr., Charles H. Tibbals, Alfred Travnicek, John Van Brahana, George VanTrump, Jr., Robert F. Wakelee, Robert H. Webb, J. Shelley Welch, Judith C. Wheeler, Joe D. Wildman, John H. Wittmann, David M. Wood, Robin D. Worcester, David L. Wright, Chester T. Wrucke, Ross A. Yeoman, Robert S. Zech.

(Left to right) Secretary of the Interior Bruce Babbitt; Vice President Al Gore; Wendy Hassibe, Mike McDermott, K. Lea Ginnodo, Ed Burke, and Mary Buchwald (all of USGS); and Sharon Kemp (National Oceanic and Atmospheric Administration) at the Vice President's National Performance Review awards ceremony, May 31, 1994.

Unit Awards for Excellence of Service

The Financial Management Best Practices Team received a unit award from the Department of the Interior for developing new financial management procedures for the Department. The team was charged with following the recommendations of Vice President Gore's National Performance Review team, which called for the review of all Interior administrative activities for possible streamlining, increased efficiency, and cost reductions. The team developed a list of recommended improvement opportunities for each major component of the Department and its bureaus.

The Eighth Annual V.E. McKelvey Forum Organizing Committee received a unit award from the Department of the Interior for its outstanding efforts in planning and managing this major national forum for the exchange of information on the latest research discoveries and emerging theories in the field of energy resources.

The USGS Transition Team received a unit award in recognition of exceptional service in the pursuit of new directions for the bureau. Within a 2-month period, the team reviewed the bureau's missions, program priorities, and organizational and managerial structure and provided a set of issues and options for addressing them to the newly appointed USGS Director in a report entitled "A Vision for the Twenty-First Century."

Awards and Honors Received by USGS Employees in 1994

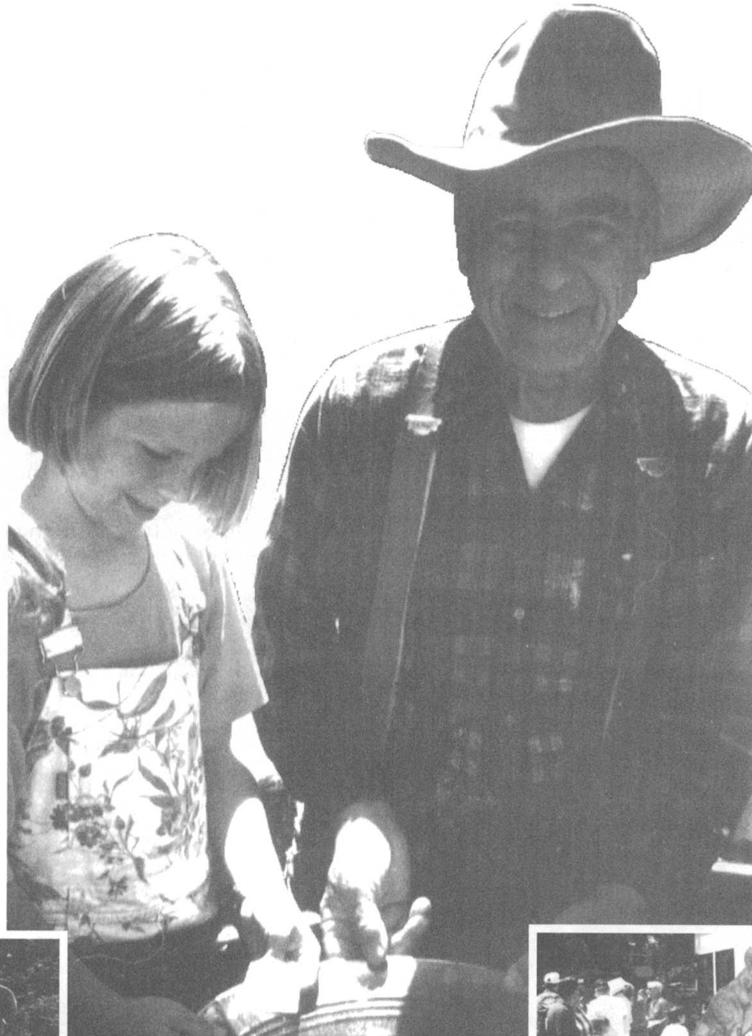
Paul Barton received the Penrose Medal, the highest award of the Geological Society of America, in recognition of his career-long contributions to the understanding of ore-forming processes.

Michael H. Carr received the G.K. Gilbert Award for outstanding work in the field of astrogeology, including a broad range of extraterrestrial topics such as cosmic dust and nuclear fallout, lunar mapping, and the geology of Mars.

Ralph Cheng received the Federal Engineer of the Year award for scientific contributions to the fundamental understanding of hydrodynamics in bays and estuaries and for studies of the importance of long-term water-movement patterns relative to key water-quality issues such as the fate of pollutants in tidal ecosystems.

Menlo Park Open House

25,000 Visitors • More than 200 exhibits • 400 USGS volunteers • Great Time! • Great Fun • Great Science!



May 21 & 22 1994

Eliot Christian received the *Government Computer News* award for outstanding leadership in data management, especially the use of standards-based data dissemination technology.

Charles G. Cunningham was designated an Honorary Visiting Professor by the National University of San Luis, Argentina. He was honored by the Executive Council of the Faculty of Sciences for his contributions to economic geology studies at the Ag-Zn-Pb-Sn deposits at Cerro Rico de Potosi in Bolivia.

Harold J. Gluskoter received the Gilbert H. Cady Award from the Coal Geology Division of the Geological Society of America for his distinguished contributions to coal geology.

Rosalind Helz was elected President of the Geological Society of Washington (GSW), only the second woman ever to have held this office. Of the 30 geologists who founded GSW in 1893, 28 were from the USGS.

Richard B. McCammon received the William C. Krumbein Medal, the highest award of the International Association for Mathematical Geology, for career-long contributions in the field of mathematical geology.

Douglass Owen received an Outstanding Achievement Award from the U.S. Environmental Protection Agency for his commitment and contributions to the scientific and public understanding of wetland resources in Colorado and the Rocky Mountain region.

Geoffrey Plumlee received the Society of Economic Geologists' Lindgren Award for his chemical models of ore deposits and for his work on mine drainage and environmental remediation at the Summitville mine in southwestern Colorado and other mines.

David Roddy (emeritus) received the Barringer Award from the International Meteoritic Society for his studies of impact and explosion craters and for his career-long work in the field of impact crater mechanics.

Robert L. Schuster received the first Civil Engineering Alumni Achievement Award from Purdue University and was also named an Honorary Member of the Association of Engineering Geologists. Highlights of his career include an investigation of the causes of the 1976 failure of the Teton Dam in Idaho, the study of ground-failure hazards along the Columbia River in Oregon and Washington, slope stability analysis of glaciofluvial terraces on Lake Roosevelt for the Spokane Indian Nation, and a study of the engineering implications of the eruption of Mount St. Helens in 1980.

Geologic Division Women's Advisory Committee

The Women's Advisory Committee (WAC) of the Geologic Division continues to address issues that affect not only women but all employees of the U.S. Geological Survey (USGS). Several issues that are now coming to the fore in response to President Clinton's Family-Friendly Work Place initiative (July 11, 1994) have long been goals of the WAC. WAC has supported alternative work schedules, alternative work sites (flexiplace), maternity and paternity leave, pre-tax deductions for dependent (child and elder) care, and elimination of sexual harassment and gender discrimination. WAC also has strongly recommended the formation of a USGS-wide Advisory Committee on Human Resources and stands prepared to help put the USGS on the cutting edge of human resource leadership in the Federal Government.

WAC designed a 3-year training program for all first-line supervisors, both official and unofficial, to increase their management, leadership, interpersonal, and basic communication skills. This training program will begin in FY 95 with a module entitled "The Role of the Supervisor." The final report of the WAC Statistics Task Force, which analyzed career development data on women scientists and technicians in the USGS, is expected in FY 95. In 1994, WAC sent representatives to the National Training Program of the Federally Employed Women (FEW) in Washington, D.C. WAC has participated in pre-FEW conferences, which have gathered together USGS women from across the country.

All of the regional centers have been very active during FY 94 in promoting the career development of women by means of newsletters, training, seminars, lectures, field trips, and technology enhancement.

Barbara J. Shaw was presented the Secretary of the Interior's Equal Opportunity Award, in the Selective Placement Program Achievement category, for career-long leadership in the recruitment, retention, and advancement of disabled individuals in the USGS.

Charles W. Spencer was selected as the Outstanding Scientist of the Year by the Rocky Mountain Association of Geologists for his extensive studies of energy resources in the Rocky Mountain region.

The Office of Procurement and Contracts received the "Employer of the Year" Award for supporting the National Industries for the Severely Handicapped in recognition of contracts that the USGS has awarded to Hope Rehabilitation Services for landscaping, janitorial, and mail services.

The Russian Academy of Sciences, Institute of Physics of the Earth, awarded the Academician O. Yu. Shmidt Medal to **John Filson, Robert Wesson, Robert Wallace** (emeritus), **Gary Fuis, James Byerlee, David Lockner**, and **Fred Fischer** for their outstanding contributions to research on seismological problems during 20 years of cooperative research. The medal, one of the Institute's highest honors, is presented in recognition of significant contributions to the science of geophysics.

Public Service Recognition

Special awards were presented to nine employees for their outstanding contributions as public servants. Those receiving Public Service Recognition Awards in 1994 were:

- **Patricia A. Bushrod**, for outstanding contributions in advancing the financial management practices of the USGS.
- **Daphne L. Chinn**, for her contributions in the field of computer technology, enthusiastic support of educational outreach activities in the computer technology profession, and her support of Langston University and Hampton University, participants in the bureau's Historical Black Colleges and Universities program.
- **Kelvin DeVeaux**, for designing, installing, and maintaining computer system networks for the bureau's Central Region and for establishing and maintaining bureau connections to the Department of the Interior's wide-area network (DOINET) in the Denver, Colo., area.
- **Jennie M. Grant**, for her exceptional ability to prepare program planning and budget documents and for her efforts in the Womens Executive Leadership Program and the Volunteer for Science program.
- **Nancy S. Hawkins**, for career-long outstanding Federal service in a variety of capacities, in particular for preparing the human resources initiatives accomplishments report for FY 92.
- **Peggy S. Hughes**, for her dedication in providing earth science data to the user community as leader of the user services unit of the USGS Earth Science Information Center in Rolla, Mo.
- **Carl E. Mortensen**, for his leadership in integrating the USGS Earthquake Hazard Reduction Program into Federal, State, and local emergency response plans.
- **Ingrid M. Verstraeten**, for her work in support of the Ground Water Guardian Program in Seward County, Nebr. The Ground Water Guardian program is a national program that supports and recognizes communities that are taking steps to protect their ground-water supply.
- **Diane R. Welch**, for designing exhibits that effectively communicate the USGS message and for coordinating exhibits for the USGS.

Exemplary Act Award

The Exemplary Act Award was presented to **Ivan C. James II** for saving the life of a co-worker by applying the Heimlich maneuver.

John Wesley Powell Award

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 award is named in honor of John Wesley Powell, the second director of the USGS (1881–84), who was a geologist, a Civil War hero, a Native American ethnographer, and a pioneer explorer of the Colorado River.

Kenneth N. Weaver received the Powell Award for his years of service (from 1963 to 1992) as the Maryland State Geologist and as a key State official who supported cooperative programs with the USGS. He was a staunch advocate of "COGEOMAP," the Chesapeake Bay program, and the National Water-Quality Assessment Program, among others, for many years. His career-long efforts have left an indelible stamp on the direction and scope of much of the earth science research and scientific investigations undertaken by the USGS in the State of Maryland.

Conservation Service Award of the Department of the Interior

Jean Auer was awarded the Conservation Service Award for making outstanding contributions to the Department of the Interior's San Joaquin Valley Drainage Program and other water-resources and public involvement efforts of the Department and the USGS. She has been an innovative leader in many water-management areas and has made outstanding contributions to the Department's water-resources and reclamation programs for more than two decades.

Walter R. Lynn, Professor of Civil and Environmental Engineering at Cornell

University, has made outstanding contributions to the field of water-resources management and to the water-resources programs of the Department of the Interior and the USGS. His efforts have enhanced the ability of the Department and of the USGS to serve the Nation by providing water information for the wise management of water resources.

Public Service Award of the Department of the Interior

Maynard M. Hufschmidt, an internationally known educator and scientist, is currently a Senior Fellow at the East-West Center in Honolulu, Hawaii. He was presented the Public Service Award of the Department of the Interior for developing innovative interdisciplinary approaches to environmental management and problem solving for the Department and the USGS. A pioneer in the field of environmental planning, he has developed techniques that have greatly advanced the understanding of interactions between hydrologic, social, and economic factors impacting on environmental concerns.

Equal Opportunity Award for Long-Term Achievement from the Secretary of the Interior

The USGS was presented the Equal Opportunity Award for Long-Term Achievement in recognition of bureauwide efforts to increase the number of women and minorities in earth science careers. Since the program began more than 20 years ago, it has provided more than 1,500 students with an opportunity to pursue careers in the earth sciences.

U.S. Geological Survey Diversity Plan

The leadership and executive staff of the U.S. Geological Survey (USGS) realize the importance of diversity in maintaining the viability of the Nation's premier earth science research and information agency into the year 2000 and beyond. Affirmative action activities have identified and addressed some of the barriers that have inhibited diversification in the past. However, approaches without personal accountability will not create a more culturally diverse workforce that is representative of the overall working population. Thus, the bureau's Human Resources Management Committee (HRMC) responded to the dual challenges of workforce diversity and budget and full-time equivalent reductions in developing the USGS Diversity Plan.

Focusing on six goals, the USGS Diversity Plan provides executives, managers, and supervisors with meaningful and measurable actions to demonstrate diversity accomplishments.

Goal 1

Ensure commitment and accountability at all levels for achieving and maintaining diversity.–At locations throughout the country, top managers received training on the business rationale for workforce diversity. This training enabled USGS leaders to examine and strengthen their personal commitment to incorporating the principles and practices of diversity into the organizational culture and human resource processes of the bureau.

Educating all USGS personnel on diversity concepts and issues is not viewed as a one-time training requirement. A training program that incorporates the USGS vision and philosophy on workforce diversity will be presented in-house to all USGS employees. Managers will select individuals for specific training in how to effectively conduct these training sessions.

All USGS leaders are now accountable for accomplishing the objectives defined by diversity-related elements in their performance workplans and are also responsible for ensuring that employees attend sexual harassment awareness and prevention training and diversity training.

Goal 2

Increase the number of women, minorities, and persons with disabilities hired from outside the permanent workforce for available vacancies.–In FY 94, women and minorities participated in the Human Resources Initiatives program and the Federal Equal Opportunity Recruitment Program, with about 275 students enrolled in student employment programs. These efforts are being complemented by a new strategic recruitment plan piloted by the USGS water resources regional office in Atlanta, Ga.

This 2-year pilot project involves intensive training of a recruitment team, analysis and projection of staffing needs that cross division lines, conducting planning sessions, building relationships with seven universities whose enrollments include significant numbers of women and minorities in programs that are related to the USGS mission, providing employment opportunities for students from these institutions, and evaluating programs throughout the process.

Finally, USGS selecting officials are alerted to positions in which women and minorities are underrepresented.

Goal 3

Increase the representation of women, minorities, and persons with disabilities in executive, managerial, supervisory, and leadership positions.–Continuous improvement requires a change from the traditional, hierarchical management style of control and direction. Increasingly, the USGS mission is carried out by empowered, self-directed work teams. This change in philosophy–a commitment to the value of diversity in thought, approach, and viewpoint–immediately casts women, minorities, and persons with disabilities into decisionmaking roles. These teams set the standard for efficient Government operations and the redirection of natural resource policy.

The third and final section of the USGS *Career Planning Manual*—"Career Profiles"—was developed and printed in FY 94. This section showcases USGS employees who have achieved their personal career goals. These individuals not only agreed to tell their success stories and share advice, but they have also volunteered to serve as mentors to employees who are attempting to advance their own careers.

Goal 4

Increase opportunities for the career development of women, minorities, and persons with disabilities currently in the workforce.–A water resources regional office in Reston, Va., hosted the first USGS Federally Employed Women (FEW) preconference in July 1994 as a precursor to the FEW national training program in Washington, D.C. Human Resources Initiatives funding helped to maximize participation in career development activities such as computer courses, the FEW, and the Blacks in Government conference. The Western Regional Office in Menlo Park, Calif., sponsored "Disabilities World in Transition–The Technological Revolution," a workshop on how technology enhances the ability of people with disabilities to enter mainstream occupations.

Goal 5

Improve the visibility of the earth sciences among students at all educational levels to expand the future pool of underrepresented candidates for earth science careers.–A major thrust of the USGS Diversity Plan is to enhance awareness of earth science careers among students. To that end, many USGS education projects and recruitment initiatives are aimed at Historically Black Colleges and Universities (HBCU), the Hispanic Association of Colleges and Universities, Hispanic Serving Institutions, and Native American institutions. One example is the 2-week HBCU Summer Faculty Geographic Information Systems Symposium at North Carolina Central University, hosted by the USGS. In addition, the USGS sponsors numerous exhibits at career fairs and college campuses throughout the country to promote student employment programs that serve as a feeder system for future employees.

Educational projects aimed at students in grades K through 12 include a ground-water poster series in both English and Spanish, *Geomedia* training discs, and earth science teacher packets. Examples of these products were exhibited at the second annual Coalition for Earth Science Education national meeting hosted by the USGS in March 1994. In addition, the Volunteer for Science Program provides outstanding opportunities for internships, national service, and career exploration. Students on hundreds of university campuses can connect to the USGS Internet server for more information (see box, p. 115). Over 1,250 new volunteer agreements were signed in 1994.

Goal 6

Ensure the continuing involvement of the entire workforce in facilitating organizational change and instilling diversity values through performance management and employee recognition systems.–The USGS had a leadership role in developing a new performance management system for the Department of the Interior. This new system, which will be implemented after it has been approved by the Office of Personnel Management, focuses on continuing communication between supervisors and employees and on the accomplishment of individual, team, and organizational objectives, including diversity goals. The new system also provides awards for recognizing exemplary performance in achieving organizational and diversity goals. In addition to performance recognition, USGS managers are encouraged to become actively involved in helping the bureau achieve its diversity goals and to recognize the diversity achievements of supervisors and employees through special act and (or) honor awards.

Diversity Training

In support of its Six-Month Diversity Goals, which were developed by the HRMC to achieve and maintain workforce diversity, the USGS made plans in FY 94 to support diversity efforts in two ways: (1) training for executives, managers, and supervisors in "managing diversity" and (2) training for all employees in "hands-on" workforce diversity.

To successfully manage diversity, the USGS must establish an environment in which every employee feels empowered and is encouraged to tap his or her full potential. The focus must be on cultural, professional, cognitive, gender, and other differences throughout the USGS workforce. The dignity of each person must be recognized, and the contributions of all employees must be valued. Management's willingness to take responsibility for implementing this process and to be held accountable for its success or failure is indicative of the USGS commitment to workforce diversity.

Dr. Roosevelt Thomas, Jr., president of the American Institute for Managing Diversity, and members of his staff trained USGS executives, managers, and supervisors in managing diversity in the Reston, Va., office and at some field offices between January and March 1994. Thomas, an author and speaker who has gained national recognition for his groundbreaking work on managing diversity, helped clarify the USGS "corporate" diversity vision, a critical first step toward developing new methods of attracting, recruiting, developing, and retaining employees.

A video-based training program has been acquired to provide diversity education to all employees. The program addresses both the concept of workforce diversity and the process through which it is achieved, enabling management and employees to understand and appreciate the individual differences found in a diverse workforce, to express commitment by becoming "diversity change agents," and to encourage all employees to support workforce diversity.

For more information on the USGS Diversity Plan, contact Lynn Smith at:

Telephone: (703) 648–7111
Internet: jlysmith@usgs.gov

For more information on USGS volunteer programs, contact Susan Wells at:

Telephone: (703) 648–5752
Internet swells@usgs.gov

Earth Science Corps: Volunteers Mapping the Nation

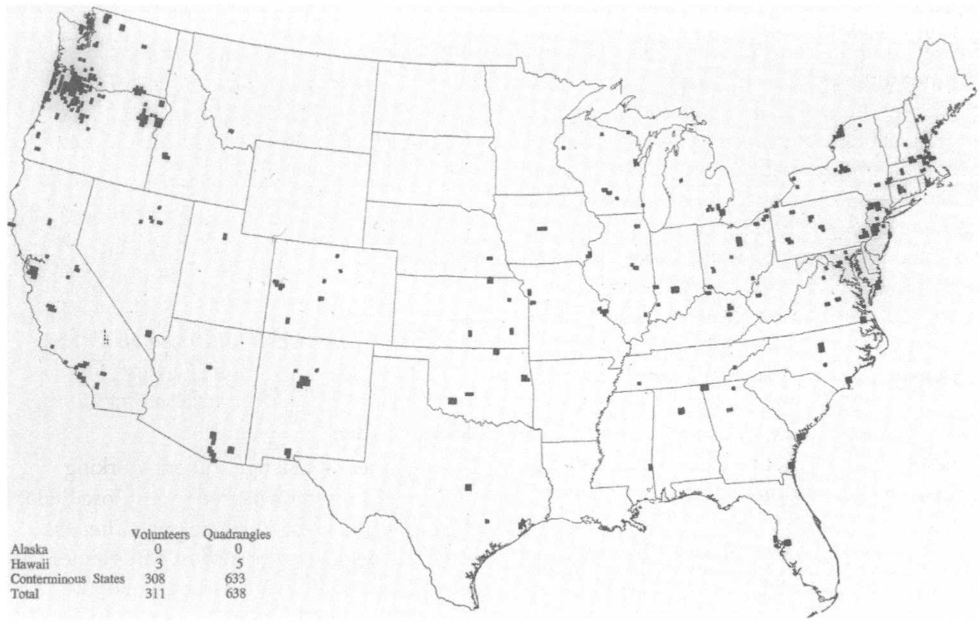
In May 1994, the Earth Science Corps (ESC) began operating as a new element of the Volunteer for Science Program of the U.S. Geological Survey (USGS). Through this program, volunteers are recruited nationwide to work in their local areas to provide map information for the USGS. These volunteers are available to respond to requests within their assigned work area or may travel at Government expense to other locations when authorized.

A map-annotation project was selected as the first major component of the ESC.

Minority Involvement

In 1994, the Ethnic Minority Advisory Committee (EMAC) worked to define the needs of minorities at the regional and field centers of the Geologic Division. Committee members and others from the EMAC community volunteered their time and efforts to assist on projects including the Affirmative Employment Plan, the USGS Diversity Plan, Presidential Executive Order 12898 on environmental justice, and a grass-roots effort with the National Park Service to address native Hawaiian reclassification. In addition, EMAC members have formed an ad-hoc committee with representatives from other U.S. Geological Survey (USGS) Divisions to formally establish a bureauwide Ethnic Minority Advisory Group.

EMAC has a profound commitment to educational outreach projects. Four active proposals are now in their second year of funding: (1) development of classroom modules demonstrating current USGS work and related scientific concepts; (2) participation in a 1-week summer workshop on image processing for teaching hosted by the University of Arizona; (3) participation in community and other agency programs (including the Minority Outreach Education/Employment program, the Inter-Tribal Youth Practicum, and the Stay-in-School program); and (4) development of a poster and stickers promoting "Diversity of People, Diversity of Earth Science Careers."



	Volunteers	Quadrangles
Alaska	0	0
Hawaii	3	5
Conterminous States	308	633
Total	311	638

Quadrangles assigned to USGS Earth Science Corps volunteers for mapping as of January 1, 1995.

Volunteers accept responsibility for specific geographic areas, which usually include their homes, workplaces, or recreational sites. The volunteers are given copies of USGS topographic maps, which they then review for changes that may have occurred since publication. They gradually visit all of their assigned area and annotate the maps, identifying any differences between published information and current ground conditions. Annotations are made according to instructions provided in a Volunteer Guide and are mailed upon completion to the responsible mapping center. When a survey has been completed, annual updates are submitted.

During the first 4 months of operation alone, 200 individuals joined the ESC. The overwhelming majority of the volunteers have some degree of experience in science or engineering, and nearly all are experienced map users. Occasionally, friends or family members have signed on together. Some employee groups and recreational associations are participating as units. Students and youth organizations are participating under adult leadership.

The ESC benefits both the Government and the individual volunteer. The program provides the Government with local contacts that can be used to obtain a variety of information without having to dispatch field crews. It also enhances public awareness of the work of the USGS and provides a source of public opinion data. Volunteers gain experience that can be used to acquire employment qualification and (or) academic credit through internship programs. The program also provides an opportunity to combine recreational pursuits with public service.

ESC activities are coordinated by a small number of paid USGS employees who contribute only a portion of their time. Correspondence and other clerical responsibilities are handled by a staff of volunteers from the Reston, Va., area. Additional volunteers will be recruited at field offices to manage data accumulated by ESC members.

Another major function of the ESC will be to promote public awareness. Volunteers will help to publicize USGS programs and products within their own community by providing information at conventions and public exhibitions, visiting classrooms to explain their map-annotation activities, or assisting their neighbors in obtaining information from the USGS and other agencies.

As the ESC matures, many of its volunteers may be linked by a computer network, expanding their involvement beyond the mapping program to include geologic and hydrologic data gathering. A program that has drawn more than 300 participants since its inception less than a year ago, the ESC has the long-term potential to become an information source for other bureaus of the Federal Government.

Melvin Y. Ellis
is a program developer.

For more information on the Earth Science Corps, contact:

Telephone: (800) 254–8040
Internet: escorps@usgs.gov

Volunteer for Science Program

The Volunteer for Science Program continued to grow in FY 94, using the services of 2,350 individuals, including 1,250 new volunteers. Volunteers donated 280,000 hours (134 staff years) through a wide range of projects from Alaska to Puerto Rico.

Volunteer recruitment activity in FY 94 targeted professional scientific organizations such as the Geological Society of America, high schools, colleges, universities, educational conferences, retiree and senior citizens groups, and the National Community Service Conference.

The *Volunteer/Intern/Teacher Opportunities Handbook* for 1994 was distributed to over 1,000 colleges and universities, including Historically Black Colleges and Universities and member schools of the Hispanic Association of Colleges and Universities nationwide and to hundreds of public school teachers across the Nation.

More than 250 USGS retirees donated their considerable talents and expertise to research projects through emeritus programs. Numerous high-school students provided assistance to administrative and scientific personnel. The Volunteer for Science Program also merged onto the Information Superhighway this year.

Highlights of USGS Volunteer Activities

Volunteers provided valuable assistance to the USGS across the Nation on projects too numerous to describe fully here. Some of their contributions in FY 94 included:

- A high-school student volunteer "telecommuted" from home, working on a prototype development project for the National Water-Quality Assessment Program using Hypertext Mark-Up Language to format documents for loading onto the World Wide Web for Internet access.
- A retired mechanical engineer assisted in the design, fabrication, and field testing of borehole instruments in Menlo Park, Calif.
- Two students from the College of Charleston in South Carolina assisted USGS employees on Sullivan's Island with the Charleston Harbor project and the aquifer storage and recovery project for the Charleston Commission of Public Works.
- As part of a job-training apprenticeship program for students with learning disabilities, a Northern Virginia Community College student volunteer assisted with data entry and map filing in the Reference Collection and Historical Map Archives of the USGS in Reston, Va.
- Students from the University of Puerto Rico entered data into geographic information system files, collected and analyzed sediment samples, and ran sediment transport models.
- A Japanese exchange student working toward a master's degree at San Jose State University worked on studies of the 1989 Loma Prieta earthquake in San Francisco, Calif.
- A volunteer was instrumental in placing USGS information on the Internet. Her vast knowledge of the Internet allowed her to assist with Information Superhighway presentations to the Vice President and members of the White House staff. She also assisted with Internet training programs at the USGS National Center in Reston, Va., for employees from the White House, the Department of the Interior, and other Federal agencies.
- A high-school student worked on a water-quality project, assisting in the analysis of water samples for pesticide concentration levels and collecting data in the field on Florida fish communities.
- Teachers from Massachusetts, Colorado, Missouri, Connecticut, Washington, Virginia, and Alaska served as curriculum specialists in the development of a water-resources education initiative in Denver, Colo.

More information on the USGS Volunteer for Science program can be obtained by accessing the Internet at:
volnteer@usgs.gov

A retired USGS employee serving as a docent in the Volunteer for Science Program shows school children around the USGS National Center in Reston, Va.

Electronic Job Hunting

The Automated Vacancy Announcement Distribution System (AVADS) is an example of the creative use of technology to meet customers' needs at the least cost to the Government. The Department of the Interior (DOI) has made all of its job-opening information available electronically to the public via a toll-free call to an electronic bulletin board or over the Internet. AVADS also allows for both the creation and nationwide electronic distribution of vacancy announcements to all DOI employees. Public access to AVADS is also available via walk-up kiosks at personnel offices throughout the USGS and at the Main Interior Building in Washington, D.C.

AVADS, originally designed and used by the U.S. Geological Survey (USGS), replaces a labor-intensive paper-based process in which copies of individual vacancy announcements were mailed to offices across the country. Electronic distribution through AVADS means that job-opening information is available much faster and updated more often and that the Government is saving the cost of mailing large quantities of paper. AVADS runs on the USGS mainframe computer and personal computers (MicroAVADS). The PC version is updated weekly and is available in both stand-alone and multiuser local-area network formats.

Now that AVADS is in place throughout the DOI, the length of time required to prepare a vacancy announcement in many cases has dropped from weeks to minutes. The flexibility of the system allows for the format of the announcements to be standardized yet permits the document to be customized for each bureau's needs. Vacancy announcements are also accessible over the Internet World Wide Web. Using a browser like Mosaic, CERN, or LYNX, applicants can browse and print vacancy announcements and related how-to-apply documents.

Vacancy announcements are... accessible over the Internet World Wide Web.

The Automated Vacancy Announcement Distribution System can be accessed via:

Telephone: 1–800–368–3321
Internet: Open the Uniform Resource Locator and enter: http://info.er.usgs.gov/doi/avads/index.html

Reengineering the Time and Attendance Process

Every 2 weeks, Department of the Interior (DOI) employees, timekeepers, and supervisors are required to record, verify, correct, and submit time and attendance (T&A) information to the departmental payroll system. The process is frequently time consuming, paper intensive, and, when performed manually, prone to many errors.

The U.S. Geological Survey (USGS) piloted an automated system that electronically processed T&A data for more than 800 employees and resulted in more accurate payroll information, a reduced workload for timekeepers, easier use for supervisors, and reduced cost as paper and errors are eliminated. On the basis of this success, the USGS is now engaged in a bureauwide effort to develop a paperless electronic T&A system. Departmentwide attention has also focused on this new system, because it could easily serve as a standard approach to T&A processing across all bureaus.

Benefits are expected to exceed costs by three to one in 1996 and by eight to one in 1997. A phased implementation for the entire bureau will begin in 1995, automating the T&A process for over 9,500 employees.

Coalition for Earth Science Education

The Coalition for Earth Science Education (CESE) is composed of member organizations representing State and Federal agencies, academia, and scientific societies and organizations, all fixed on a common vision–to promote an awareness of earth science as fundamental knowledge necessary for addressing societal, environmental, and economic issues. CESE's primary goal is to facilitate communication, cooperation, and coordination among geologic, hydrologic, astronomic, atmospheric, and oceanographic organizations in order to promote earth science education, to provide a united voice on national and regional education issues, and to establish the role of earth science in reforming interdisciplinary, hands-on science teaching.

As part of its continuing educational outreach program efforts, the U.S. Geological Survey (USGS) hosted representatives from 57 organizations at the second annual CESE national meeting, March 4–6, 1994, in Reston, Va. The theme of the meeting was "Supporting Systemic Reform in Science Education." Attendees were brought up to date on Project 2061 of the American Association for the Advancement of Science, the Scope Sequence and Coordination project of the National Science Teachers Association, the State Systemic Initiatives of the National Science Foundation, and the new National Science Standards from the National Academy of Sciences and the National Research Council. Meeting participants heard talks on Federal Government initiatives like the National Aeronautics and Space Administration's Project Weather Scope and two projects of the USGS's innovative CD-ROM program–one on the hazards of volcanic ash clouds to aviation entitled "Tracking Stone Winds" and the other a multimedia educational system on global environmental change for middle-school students entitled *GeoMedia 2*. Presentations on exemplary initiatives from the academic community included the Joint Education Initiative of the University of Maryland, the Denver Earth Science Project of the Colorado School of Mines, the Iowa Demonstration Classroom Project of Luther College, and the Program for Leadership in Earth Systems Education of Ohio State University. Presentations on teacher enhancement and material development programs from earth science societies were given by such prestigious organizations as the Geological Society of America, the American Astronomical Society, the American Meteorological Society, the American Geophysical Union, and the American Geological Institute.

The highlight of the meeting was a panel discussion on "The View from the Classroom." A panel consisting of teachers from elementary school through undergraduate school and a museum educator discussed current and future needs of earth science teachers and educators. Panelists confirmed the need for local and regional support for the classroom teacher. Teacher-scientist partnerships–two professionals merging their skills for the betterment of science–were hailed as the most effective way to enact true reforms in teaching science. The discussion also emphasized the need for teacher enhancement programs that bring teachers up to date on current relevant science and thus paved the way for additional discussions on the role of CESE and its member organizations in forging programs for the future.

For more information about the Coalition for Earth Science Education, contact Laure Wallace at:

Telephone (703) 648–6515
Internet: lwallace@usgs.gov

Budget Information

The U.S. Geological Survey receives funding through direct appropriations and reimbursable work. The following table reflects a FY 94 budget authority of $596.985 million to program element level. (Percentage of total funds by activity: Facilities, 3; General Administration, 3; Geologic and Mineral Resource Surveys and Mapping, 29; National Mapping, Geography, and Surveys, 19; Water Resources Investigations, 45. Computer Services are 1 percent.)

Activity/subactivity/program element	FY 94 enacted
National Mapping, Geography, and Surveys	**$136,725**
National Map and Digital Data Production	61,279
Cartographic Data and Map Revision	46,321
Thematic and Special Data	12,766
National Map and Digital Data Cooperative Program	2,192
Information and Data Systems	24,024
National Data Base Management	12,154
Information Dissemination Services	4,433
Global Change Data Systems	7,437
Research and Technology	18,769
Cartographic and Geographic Research	8,515
National Cartographic Requirements, Coordination, and Standards	5,073
Geographic and Spatial Information Analysis	5,181
Advanced Cartographic Systems	32,653
Geologic and Mineral Resources Surveys and Mapping	**223,531**
Geologic Hazards Surveys	77,008
Earthquake Hazards Reductions	54,361
Volcano and Geothermal Investigations	20,315
Landslide Hazards	2,332
Geologic Framework and Processes	27,588
National Geologic Mapping	23,012
Deep Continental Studies	2,772
Magnetic Field Monitoring and Charting	1,804
Global Change and Climate History	10,788
Global Change and Climate History	10,788
Marine and Coastal Geologic Surveys	35,635
Marine and Coastal Geologic Surveys	35,635
Mineral Resource Surveys	46,902
Mineral Resource Surveys	46,902
Energy Resource Surveys	25,610
Energy Resource Surveys	25,610

Activity/subactivity/program element	FY 94 enacted
Water Resources Investigations	**$187,561**
National Water Resources Research and Information System–Federal Program	118,303
Data Collection and Analysis	19,843
National Water Information Clearinghouse	962
Coordination of National Water Data Activities	1,488
Regional Aquifer System Analysis	5,064
Core Program Hydrologic Research	10,008
Improved Instrumentation	1,147
Water Resources Assessment	1,565
Toxic Substances Hydrology	14,178
Acid Rain	1,873
Scientific and Technical Publications	2,305
National Water-Quality Assessment Program	51,822
Global Change Hydrology	6,649
Truckee-Carson Program	1,399
National Water Resources Research and Information System–Federal-State Cooperative Program	63,488
Data Collection and Analysis, Areal Appraisals, and Special Studies	59,438
Water Use	4,050
National Water Resources Research and Information System–State Research Institutes and Research Grants Program	5,770
State Water Resources Research Institutes	5,529
Program Administration	241
General Administration	**26,018**
Executive Direction	7,935
Administrative Operations	8,719
Reimbursements to the Department of Labor	2,462
Payments to Others for Services	273
Washington Administrative Service Center	6,629
Facilities	**23,150**
National Center–Rental Payments to GSA	20,045
National Center–Facilities Management	3,105
Total, SIR	**$596,985**

Total includes $4.5 M supplemental for the Northridge earthquake and $7.8 M supplemental for flooding in the Midwest.

The following table reflects actual obligations from all sources of funds. In FY 94, the U.S. Geological Survey had actual obligations of $886.1 million, distributed as follows: $586.5 million from direct appropriations, $5.5 million from estimated receipts from map sales, and $294.1 million from reimbursements.
[Dollars in thousands]

Budget activity	1991	1992	1993	1994
Total	**$802,538**	**$851,979**	**$862,335**	**$886,093**
Direct program	575,044	586,699	582,891	[1]586,505
Reimbursable program	227,494	265,280	279,444	299,588
States, counties, municipalities	87,415	89,950	91,299	93,270
Miscellaneous non-Federal sources	13,499	14,609	14,842	13,572
Other Federal agencies	126,580	160,721	173,303	206,526
National Mapping	**162,421**	**164,981**	**156,898**	**165,507**
Direct program	132,395	132,612	126,092	129,406
Reimbursable program	30,026	32,369	30,806	36,101
States, counties, and municipalities	2,366	3,028	3,219	2,771
Miscellaneous non-Federal sources	9,722	10,633	10,562	9,174
Other Federal agencies	17,938	18,708	17,025	24,156
Geologic	**261,513**	**267,642**	**261,089**	**259,485**
Direct program	225,112	225,383	222,565	219,220
Reimbursable program	36,401	42,259	38,524	40,265
States, counties, municipalities	2,661	3,077	1,609	1,607
Miscellaneous non-Federal sources	1,260	536	834	687
Other Federal agencies	32,480	38,646	36,081	37,971
Water Resources	**32,480**	**363,287**	**384,467**	**400,122**
Direct program	177,969	184,489	186,933	188,631
Reimbursable program	155,269	178,798	197,534	211,491
States, counties, municipalities	82,388	83,845	86,471	88,892
Miscellaneous non-Federal sources	2,503	3,424	3,440	3,706
Other Federal agencies	70,378	91,529	107,623	118,893
General Administration	**21,528**	**25,028**	**25,886**	**28,765**
Direct program	21,206	23,883	24,506	25,951
Reimbursable program	322	1,145	1,380	2,814
Miscellaneous non-Federal sources	1	1	1	2
Other Federal agencies	321	1,144	1,379	2,812
Facilities	**18,314**	**20,304**	**23,111**	**23,368**
Direct program	18,314	20,304	22,750	23,282
Reimbursable program	0	0	361	86
Computer and Administrative Services	**5,476**	**10,709**	**10,839**	**8,831**
Reimbursable program	54,76	10,709	10,839	8,831
Miscellaneous non-Federal sources	13	15	5	3
Other Federal agencies	5,463	10,694	10,834	8,828
Operation and Maintenance of Quarters	**48**	**28**	**45**	**15**
Direct program	48	28	45	15
Working Capital Fund				**13,780**
Reimbursable program				13,780

[1]Includes actual obligations of $584,484 for current year, $1,887 for no-year and multi-year funds, $119 for contributed funds, and $15 for Operation and Maintenance of Quarters.

The U.S. Geological Survey (USGS) was reimbursed for work performed for other Federal, State, and local agencies whose need for earth science expertise complements USGS program objectives. Cooperative agreements with more than 1,000 Federal, State, and local agencies and the academic community support a large share of USGS research and investigations. Work for State, county, and municipal agencies is most often conducted on a cost-sharing basis. The following table provides detailed information on the particular agencies for which the USGS performs work.
[Dollars in thousands]

Source of funds	1991	1992	1993	1994
Department of Agriculture	$3,464	$3,714	$2,697	$5,620
Department of Commerce	323	9	103	196
National Oceanic and Atmospheric Administration	2,258	5,146	1,630	1,414
Department of Defense	42,002	56,461	64,518	71,281
Department of Energy	28,521	30,679	33,651	38,309
Bonneville Power Administration	159	217	445	481
Department of the Interior				
Bureau of Indian Affairs	1,834	1,347	881	1,462
Bureau of Land Management	1,256	1,508	1,797	1,535
Bureau of Mines	0	0	0	64
Bureau of Reclamation	6,259	5,990	6,495	7,133
Minerals Management Service	76	207	107	50
National Park Service	1,036	1,107	1,111	2,158
Office of the Secretary	1,549	1,551	1,298	1,159
Office of Surface Mining	67	8	22	0
Fish and Wildlife Service	456	733	379	586
Department of State	8,279	10,524	13,333	10,030
Department of Transportation	299	661	605	770
Environmental Protection Agency	4,302	6,414	7,671	10,422
Federal Emergency Management Agency				1,927
National Aeronautics and Space Administration	6,270	9,589	10,108	11,068
National Science Foundation	625	1,838	2,096	1,252
Nuclear Regulatory Commission	1,441	539	1,087	870
Tennessee Valley Authority	200	275	417	437
Miscellaneous Federal agencies	15,904	22,204	22,852	38,302
Total	**$126,580**	**$160,721**	**$173,303**	**$206,526**

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

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

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

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

Mississippi:
Bldg. 3101
Stennis Space Center, MS 39529

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

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

Utah:
2222 West 2300 South
Salt Lake City, UT 84119

Virginia:
Room 1C402
507 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Washington:
U.S. Post Office Bldg., Room 135
904 West Riverside Ave.
Spokane, WA 99201–1088

Earth Science and Environmental Information on the Internet

Selected USGS information and products are available on the Internet at the following Uniform Resource Locator:

http://www.usgs.gov

Additional information on Mosaic may be obtained by e-mailing questions to:

webmaster@www.usgs.gov

USGS Library System

The USGS Library system is one of the largest earth-science collections in the world and contains more than one million monographs, serial publications, maps, and microforms. The collection covers all aspects of the geological sciences and related subjects. An online catalog provides public access. The library honors the standard interlibrary loan request forms as well as requests received online from the Interlibrary Loan System of the On-Line Computer Library Center. Information and reference services are available from the following library locations:

USGS Library
950 National Center
Reston, VA 22092–0001

USGS Library
Mail Stop 955 (Bldg. 5, Room 507)
345 Middlefield Rd.
Menlo Park, CA 94025–3591

USGS Library
2255 N. Gemini Dr.
Flagstaff, AZ 86001–1698

USGS Library
Box 25046, Mail Stop 914
Denver Federal Center
Denver, CO 80225–0046

Water Information

Sources of Water Data

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

National Water Data Exchange
U.S. Geological Survey
421 National Center
Reston, VA 22092

Water-Data Acquisition Activities

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

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

Water Resources of Specific Areas

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

National Water Information Clearinghouse
U.S. Geological Survey
423 National Center
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:

Geologic Inquiries Group
U.S. Geological Survey
907 National Center
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
Corbett Bldg.
340 N. 6th Ave.
Tucson, AZ 85705–8325

Minerals Information Office, USGS
Box 25046, Mail Stop 936
Bldg. 20, Room B1324
Denver Federal Center
Denver, CO 80225–0046

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

Minerals Information Office, USGS
U.S. Post Office Bldg., Room 133
904 West Riverside Ave.
Spokane, WA 99201–1088

Maps and Books

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

USGS Map Distribution
Box 25286, Bldg. 810
Denver Federal Center
Denver, CO 80225

Open-File Reports

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

USGS Open-File Report Sales
Box 25286, Bldg. 810
Denver Federal Center, Mail Stop 517
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:

USGS New Publications
582 National Center
Reston, VA 22092

Earthquakes & Volcanoes

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

Superintendent of Documents
Government Printing Office
Washington, DC 20402

Memoranda of Understanding: FY 1994

Domestic Agreements

Counterpart Organization(s)	Description
• 194–01 Santa Fe Pacific Mining, Inc. Reno, Nev.	Cooperative research and development agreement (CRADA) to study the regional tectonics of north-central Nevada to reflect improved techniques for mineral resource assessments.
• 194–02 National Park Service	Coordination in the National Water-Quality Assessment Program.
• 194–03 Center for Hydrate Research Colorado School of Mines Golden, Colo.	Cooperative research and development agreement on the nucleation and growth of gas hydrate compounds.
• 194–04 ETAK, Inc. Menlo Park, Calif.	Cooperative research and development agreement (CRADA) for the technology needed to collect, update, manage, and use digital geographic databases.
• 194–05 Department of Defense	Provides Department of Interior with access to the DOD Navstar Global Positioning System for accurate real-time on-the-ground geographic locations.
• 194–06 National Biological Service	Joint collaboration to ensure that scientific initiatives and administrative functions are conducted to maximize the efficient and effective management of mission responsibilities.
• 194–07 Geological Research Affiliates Dallas, Tex.	Cooperative research and development agreement (CRADA) to perform extensive oil exploration in Kazakhstan (formerly part of the USSR). (See p. 85.)
• 194–08 Minerals Management Service	Sharing of resources and facilities in the Herndon/Reston commuting area in support of training and employee development functions and activities.
• 194–09 U.S. Bureau of Mines	Joint coordination of mineral-related environmental assessment, technology development, and remedial investigations.
• 194–10 Washington State University Vancouver, Wash.	Establishment and operation of shared research and support facilities on the Washington State University campus at Vancouver.
• 194–11 Electrical Power Research Institute, Palo Alto, Calif., and the U.S. Department of Agriculture	Cooperative research and development agreement (CRADA) to develop a computer model that can be used to predict water availability within a river basin for managers of hydroelectric power installations.
• 194–12 Unisys Corporation Government Systems Group Reston, Va.	Cooperative research and development agreement (CRADA) to develop software for feature extraction and classification from image sources. Software will be used in digitizing map information concerning land cover and land use.
• 194–13 Agricultural Stabilization and Conservation Service, the Natural Resources Conservation Service, and the U.S. Forest Service	Agreement to cooperatively produce digital quadrangle maps for the conterminous United States.

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 1994. 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)
•Emergency Management (w)
•Environmental Management (w)
•Highways, Department Nos. 1, 2, and 6 (w)
Anniston, City of (w)
Auburn University (w)
Baldwin County Commission (w)
Birmingham, City of (w)
Blountsville, Town of (w)
Coffee County Commission (w)
Geological Survey of Alabama (w)
Greenville, City of (w)
Huntsville, City of (w)
Jefferson County Commission (w)
Mobile, City of (w)
Montgomery, City of (w)
Parrish, Town of (w)
Prattville, City of (w)
Sumter, County of (w)
Tuscaloosa, City of (w)

ALASKA

Alaska Department of—
•Community and Regional Affairs, Division of Energy (w)
•Environmental Conservation (w)
•Fish and Game (g, w)
•Military and Veterans Affairs (g)
•Natural Resources (w)
Division of Mining and Water Management (w)
•Transportation (w)
Alaska Energy Authority (w)
AK Industrial Development and Export Authority (w)
Anchorage, Municipality of (w)
Cordova, City of (w)
DCRA, Division of Energy (w)
Juneau, City and Borough of (w)
Kenai Peninsula Borough (w)
Sitka, City and Borough of (w)
University of Alaska, Fairbanks (w)

AMERICAN SAMOA

Environmental Protection Agency of American Samoa (w)
Power Authority (w)

ARIZONA

Arizona Department of—
•Environmental Quality (w)
•Game and Fish (w)
•Water Resources (w)
Arizona State University (g)
Central Arizona Water Conservation District (w)
Cochise County Flood Control District (w)
Gila Valley Irrigation District (w)
Gila Water Commissioner, Office of (w)
Havasupai Tribe (w)
Hualapai Indian Tribe (w)
Hopi Tribe Department of Natural Resources (w)
Maricopa County Flood Control District (w)
Metropolitan Water District of Southern California (w)
Navajo Nation (w)
Petrified Forest Museum Association (g)
Pima County Board of Supervisors (w)
Safford, City of, Water, Gas, and Sewer Department (w)
Salt River Project (w)
Show Low Irrigation Company (w)
Tohono O'Dham Nation, Water Resources Department (w)
Tucson, City of (g, w)
University of Arizona (g)
•Research Lab for Riparian Studies (w)
Yavapai Tribe (w)

ARKANSAS

Arkansas Department of—
•Parks and Tourism (w)
•Pollution Control (w)
Arkansas Game and Fish Commission (w)
Arkansas Geological Commission (n,w)
Arkansas Soil and Water Conservation Commission (w)
Arkansas State Highway Commission (w)
Arkansas-Oklahoma: Arkansas River Compact Commission (w)
Drew, County of (w)
Fort Smith, City of (w)
Independence, County of (w)
Little Rock—
•Municipal Water Works (w)
•Public Works 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)
Atherton, City of (w)
Calaveras County Water District (w)
California Department of—
•Conservation (g, w)
•Fish and Game (w)
•Parks and Recreation (g, w)
•Water Resources (w)
California Water Resources Control Board (w)
California County Water District (w)
Carpinteria County Water District (w)
Casitas Municipal Water District (w)
Coachella Valley Water District (w)
Contra Costa County Flood Control and WaterConservation District (w)
Contra Costa Water District (w)
Desert Water Agency (w)
East Bay Municipal Utility District (w)
Eastern Municipal Water District (w)
Georgetown Divide Public Utility District (w)
Goleta County Water District (w)
Hetch Hetchy Water and Power (w)
Hoopa Valley Tribe (w)

CALIFORNIA (CONT.)

Hopland Band of Pomo Indians (w)
Humboldt Bay Municipal Water District (w)
Imperial County Department of Public Works (w)
Imperial Irrigation District (w)
Lompoc, City of (w)
Los Angeles, County of (w)
Madera Irrigation District (w)
Marin Municipal Water District (w)
Mendocino County Water Agency (w)
Menlo Park, City of (w)
Merced, City of (w)
Merced Irrigation District (w)
Mojave Water Agency (g, w)
Mono, County of (w)
Montecito Water District (w)
Monterey County Water Resources Agency (w)
Monterey Peninsula Water Management District (w)
Morongo Band of Mission Indians (w)
Orange County Water District (w)
Palmdale, City of (w)
Pechanga Indian Reservation (w)
Riverside County Flood Control and Water Conservation District (w)
Sacramento Regional County Sanitation (w)
San Benito County Water Control and Flood Control District (w)
San Bernardino Environmental Public Works Flood Control District (w)
San Bernardino Valley Municipal Water District (w)
San Diego County Department of Public Works(w)
San Francisco Water Department (w)
San Gorgonio Pass Water Agency (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)
Tulare County Flood Control District (w)
Turlock Irrigation District (w)
United Water Conservation District (w)
University of California, Berkeley (g)
•Lawrence Livermore National Laboratory (g)
•Los Alamos National Laboratory (g)
•Stanford University (g)
University of California, Davis (g, w)
Ventura, City of (w)
Ventura County Public Works Agency (w)
Water Master—Santa Margarita River Watershed (w)
Water Replenishment District of Southern California (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 Authority (w)
Arkansas River Compact Administration (w)
Aurora, City of (w)
Black Hawk, City of (w)
Boulder, City of (w)
Boulder, County of, Department of Public Works (w)
Breckenridge, Town of (w)
Centennial Water and Sanitation District (w)
Center Soil Conservation District (w)
Cherokee Metropolitan District (w)
Clear Creek Board of County Commissioners (w)
Colorado Department of—
•Agriculture (w)
•Health (w)
•Transportation (w)
Colorado Division of Parks and Outdoor Recreation (w)
Colorado Division of Wildlife (w)
Colorado Office of the State Engineer (w)
Colorado River Water Conservation District (w)
Colorado School of Mines (g)
Colorado Springs, City of—
•Department of Public Utilities (w)
•Engineering Division (w)
Crested Butte, Town of (w)
Delta County Board of Commissioners (w)
Denver Board of Water Commissioners (n, w)
Eagle County Board of Commissioners (w)
East Cherry Creek Valley Water and Sanitation District (w)
East Grand, County of (w)
Englewood, City of (w)
Evergreen Metropolitan District (w)
Fort Collins, City of (w)
Fountain Valley Authority (w)
Fremont Sanitation District (w)
Garfield, County of (w)
Glendale, City of (w)
Glenwood Springs, City of (w)
Greenwood Village, City of (w)
Gunnison, County of (w)
Lakewood, City of (w)
Lamar, City of (w)
Las Animas, City of (w)
La Plata County (w)
Littleton-Englewood Bi-City Wastewater Treatment Plant (w)
Longmont, City of (w)
Loveland, City of (w)
Lower Fountain Water-Quality Management Association (w)
Meeker, Town of (w)
Metropolitan Wastewater Reclamation District (w)
Moffat, County of, Commissioners (w)
Mt. Crested Butte Water/Sanitation District (w)
Northern Colorado Water Conservation District (w)
Pueblo Board of Water Works (w)
Pueblo, City of, Department of Utilities (w)
Pueblo, County of (w)
Pueblo West Metropolitan District (w)
Purgatoire River Water Conservancy District (w)
Rio Blanco, County of (w)
Rio Blanco Water Conservancy District (w)
Rio Grande Water Conservation District (w)
Rocky Ford, City of (w)
Routt, County of (w)
St. Charles Mesa Water District (w)
Southeastern Colorado Water Conservancy District (w)
Southwestern Colorado Water Conservation District (w)
Steamboat Springs, City of (w)
Teller-Park Soil Conservation District (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 Gunnison River (w)
Upper Yampa Water Conservancy District (w)

COLORADO (CONT.)

Urban Drainage and Flood Control District (w)
Vail Valley Consolidated Water Authority (w)
Westminster, City of (w)
Yellow Jacket Water Conservancy District (w)

CNMI

Commonwealth of Northern Mariana Islands (g)
Commonwealth Utilities Corp., Saipan (w)
•Division of Environmental Quality (w)
Municipality of Tinian (w)
Office of the Governor, Saipan (w)

CONNECTICUT

Connecticut Department of—
•Environmental Protection (g,n,w)
•Transportation, Bureau of Hydraulics and Drainage (w)
Fairfield, Town of, Conservation Department (w)
Lake Waramaug—
•Interlocal Commission (w)
New Britain, City of, Board of Water Commissioners (w)
South Central Connecticut Regional Water Authority (w)
Torrington, City of (w)
University of New Haven (g)
Woodbury, Town of (w)

DELAWARE

Delaware River Basin Commission (w)
Geological Survey (n,w)
University of Delaware (w)

DISTRICT OF COLUMBIA

Department of—
•Consumer and Regulatory Affairs, Environmental Control Division (w)
•Public Works (w)
University of the District of Columbia (w)

FLORIDA

Bay County Utilities (w)
Boca Raton, City of (w)
Bradenton, City of (w)
Broward, County of (w)
Cape Coral, City of (w)
Century, City of (w)
Cocoa, City of, Utilities and Public Works (w)
Daytona Beach, City of (w)
Deerfield Beach, City of (w)
Dunedin, City of (w)
Florida Department of—
•Environmental Regulation, Bureau of Drinking Water/Ground Water Resources (g,n,w)
•Natural Resources, Division of Survey and Mapping (n)
•Transportation (n,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, Department of Public Utilities (w)
Jacksonville Electric Authority (w)
Lake, County of, Water Authority (w)
Lee, County of (w)
Manatee County (w)—
•Environmental Action Commission (w)
Metropolitan Dade County (w)
Miami-Dade Water and Sewer Department (w)
North Port Water Control District (w)
Northwest Florida Water Management District (w)
Orange County of (w)
Orlando, City of (w)
Perry, City of (w)
Pinellas, County of (w)
Pompano Beach, City of (w)
Reedy Creek Improvement District (w)
Sarasota, City of (w)
Sarasota, County of (w)
Seminole, County of (w)
South Florida Water Management District (g, w)
South Indian River Water Control (w)
Southwest Florida Water Management District (n, w)
St. Johns River Water Management District (g, w)
St. Petersburg, City of (w)
Stuart, City of (w)
Suwannee River Water Management District (w)
Tallahassee, City of—
•Electric Department (w)
•Water Quality Laboratory (w)
Tampa, City of (w)
Tampa Bay Regional Planning Council (w)
University of Florida (g)
Volusia, County of (w)
Walton, County of (w)
West Coast Regional Water Supply Authority (w)

FREELY ASSOCIATED STATES

Palau, Government of (w)
Pohnpei State Government (w)

GEORGIA

Albany, City of (w)
Albany Doughtery Planning Commission (w)
Albany Water, Gas, and Light Commission (w)
Athens-Clarke County (w)
Attapulgus, City of (w)
Bibb, County of (w)
Blairsville, Town of (w)
Brunswick, City of (w)
Chatham, County of (w)
Cherokee County Water and Sewage Authority (w)
Clayton County Water Authority (w)
Covington, City of (w)
De Kalb County Water and Sewer Department (w)
Douglas, County of (w)
Georgia Department of—
•Natural Resources—
Geologic Survey (w)
Water Quality Management Program (w)
Water Resources Management Program (w)
•Transportation (w)—
at Atlanta (n, w)
at Forest Park (n, w)
Georgia Forestry Commission (w)
Gwinnett, County of, Department of Transportation (w)
Helena, City of (w)
Henry, County of (w)
Macon Water and Sewage Authority (w)
Monroe Water, Light, and Gas Commission (w)
South Florida Water Municipal Department (w)

GEORGIA (CONT.)

Springfield, City of (w)
St. Johns River Water Municipal Department (w)
Thomaston, City of (w)
Thomasville, City of (w)
Tift County Commission (w)
Tifton, City of (w)
Valdosta, City of (w)

GUAM

Guam, Government of, Environmental Protection Agency (w)

HAWAII

Hawaii, County of, Department of Water Supply (w)
Hawaii Department of—
•Agriculture (w)
•Land and Natural Resources (g)—
Commission on Water Resources Management (w)
Division of Forestry and Wildlife (n,w)
•Transportation (w)
Honolulu, City and County of—
•Board of Water Supply (w)
•Department of Public Works (w)
Kauai, County of, Department of Water Supply (w)
Maui, County of, Department of Water Supply (w)
National Tropical Botanical Gardens (w)
Office of State Planning (n)
State of Hawaii (g)
University of Hawaii (g)

IDAHO

Ada County Highway District (w)
Boise, City of, Public Works Department (w)
Boise State University (g)
Idaho Department of—
•Health and Welfare, Division of Environmental Quality (w)
•Transportation (n)
•Water Resources (w)
Nez Perce Indian Tribe (w)
Salmon River Canal Co., Ltd. (w)
Shoshone-Bannock Indian Tribes (w)
Southwest Irrigation District (w)
Teton County Board of Commissioners (w)
Water District No. 01 (Idaho Falls) (w)
Water District No. 31 (Dubois) (w)
Water District No. 32D (Dubois) (w)
Water District No. 65 (Payette) (w)
Weiser River SCD (w)

ILLINOIS

Bloomington and Normal Sanitary District (w)
Champaign, City of (w)
Cook County Forest Preserve District (w)
Danville Sanitary 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—
•Conservation (w)
•Energy and Natural Resources—
Geological Survey Division (n)
State Water Survey (w)
•Transportation—
Division of Highways (n, w)
Division of Water Resources (n,w)
Illinois Environmental Protection Agency (w)
Illinois State Geological Survey (g)
Kane, County of (w)
Kankakee Soil and Water Conservation District (w)
Lake County Stormwater Management Commission (w)
McHenry County Conservation District (w)
Monticello, City of (w)
Oak Brook, Village of (w)
Otter Creek Lake Utility District (w)
Springfield, City of (w)
University of Illinois (w)
Urbana, City of (w)
Winnebago County Department of Public Works (w)

INDIANA

Carmel, Town of, Utilities (w)
Elkhart, City of, Water Works (w)
Indiana Department of—
•Environmental Management (w)
•Natural Resources (n)—
Division of Water (w)
•Transportation (w)
Indiana Geological Survey (g)
Indianapolis, City of, Department of Public Works (w)
Purdue University (w)
St. Joseph County Drainage Board (w)

IOWA

Ames, City of (w)
Cedar Rapids, City of, Engineering Department (w)
Clinton, City of (w)
Coralville, City of (w)
Davenport, City of (w)
Des Moines, City of (w)
Fort Dodge, City of (w)
Geological Survey Bureau (w)
Institute of Hydraulic Research (w)
Iowa City, City of (w)
Iowa Department of Transportation, Highway Division (w)
Iowa State University (w)
Muscatane Water and Light Board (w)
Sioux City, City of (w)
University of Iowa (w)
•Hygienic Laboratory (w)

KANSAS

Arkansas River Compact Administration (w)
Brazos River Authority (w)
Emporia, City of, Department of Public Works (w)
Equus Beds Groundwater Management District No. 2 (w)
Harvey County Conservation Distict (w)
Hays, City of (w)
Iowa Tribe of Kansas and Nebraska (w)
Johnson, County of, Department of Public Works (w)
Kansas Geological Survey (g, n, w)
Kansas Highway Commission (w)
Kansas State Board of Agriculture, Division of Plant Health (w)
Kansas State Conservation Commission (w)
Kansas State University Department of Agronomy (w)
Kansas University Center for Research, Inc. (w)
Kansas Water Office (n, w)
Kickapoo Tribe of Kansas (w)
Lake Region Resources Conservation Council, Inc. (w)
Prairie Bend Potawatomie Tribe (w)
Riley, County of (w)
Sac and Fox Tribe of Missouri (w)
Topeka Public Works (w)
Wichita, City of (w)

KENTUCKY

Bullitt, County of (w)
Campbellsville Municipal Water (w)
Carrollton, City of (w)
Crab Orchard, City of (w)
Cumberland-Green River RC&D (w)
Elizabethtown, City of (w)
Georgetown, City of (w)
Glasgow Water Company (w)
Kentucky Department of—
•Health Services (w)
•Natural Resources and Environmental Protection Cabinet (w)
Kentucky State University (w)
Kentucky Water Office (n)
Madison County Conservation District (w)
Metropolitan Sewer District (w)
Middleboro, City of (w)
University of Kentucky, Kentucky Geological Survey (n)
University of Louisville (w)

LOUISIANA

Amite River Basin River Commission (w)
Capital-Area Groundwater Commission (w)
East Baton Rouge Parish (w)
Governor's Office of Coastal Activities (w)
Louisiana Department of—
•Environmental Quality (w)
•Natural Resources (w)
•Transportation and Development—
Bridge Hydraulics (w)
Office of Public Works (n, w)
Louisiana Geological Survey (n)
Louisiana Office of Emergency Preparedness (w)
Sabine River Compact Administration (w)
St. John the Baptist Parish (w)
West Monroe, City of (w)

MAINE

Aroostock County Water and Soil Management Board (w)
Greater Portland Council of Governments (w)
Jay, Town of (w)
Maine Department of—
•Environmental Protection (w)
•Human Services (w)
•Transportation (w)
Maine Geological Survey (w)
North Kennebec Valley Regional Planning Commission (w)
Northern Maine Regional Planning Commission (w)
Paris Utility District (w)
University of Maine (w)

MARYLAND

Baltimore, City of, Water Quality Management (w)
Calvert County Soil Conservation (w)
Delaware Geological Survey (w)
Hyndman, Borough of (w)
Interstate Commerce Commission (w)
Maryland Department of the Environment, Water Management Administration (w)
Maryland Geological Survey (n,w)
Maryland State Highway Administration, Department of Environmental Resources (w)
Prince Georges County Government (w)
University of Maryland (g)

MASSACHUSETTS

Burlington, Town of (w)
Dedham-Westwood Water District (w)
Executive Office of Environmental Affairs (n)
Massachusetts Department of—
•Environmental Management—
Division of Resource Conservation (w)
Division of Water Supply (w)
•Environmental Protection (w)—
Division of Water Pollution Control (w)
Division of Water Supply (w)
Massachusetts Highway Department (w)
Massachusetts Water Resources Authority (w)
Metropolitan District Commission—
•Parks, Engineering and Construction Division (w)
•Watershed Management Division (w)
Woods Hole Oceanographic Institution (g)

MICHIGAN

Adrian, City of (w)
Ann Arbor, City of (w)
Antrim County Drain Commission (w)
Battle Creek, City of—
•Board of Public Utilities (w)
Bay Mills Indian Community (w)
Cadillac, City of, Wastewater Treatment Plant (w)
Clare, City of (w)
Coldwater, City of (w)
Cliffs Mining Services Co. (w)
Consumers Power Company (w)
Delta Charter Township (w)
Elsie, Village of, Department of Public Works (w)
Flint, City of—
•Division of Water and Waste Services (w)
•Water Plant (w)
Huron-Clinton Metropolitan Authority (w)
Huron County Board of Commissioners (w)
Imlay, City of (w)
Kalamazoo, City of, Department of Public Works (w)
Lansing Board of Water and Light (w):
Macomb, County of (w)
Michigan Department of—
•Natural Resources, Land and Water Division (w)
•Transportation, Design 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)
Sault Ste, Marie Tribe of Chippewa Indians (w)
Southeast Michigan Council of Governments (w)
Sturgis, City of (w)
Tri-County Regional Planning Commission (w)
Wayne, County of, Division of Environmental Health (w)
Ypsilanti Community Utilities Authority (w)

MINNESOTA

Beltrami County SWCD (w)
Boris Forte Lake Superior Band (w)
East Otter Tail Soil and Water (w)
Elm Creek Conservation Management and Planning Commission (w)
Grand Portage-Chippewa Indians Natural Resources Department (w)
Hubbard County Conservation District (w)
Land Management Information Center (n)
Lower Red River Watershed Management Board (w)
Minnesota Department of—
•Natural Resources (g,w)

MINNESOTA (CONT.)

•Transportation (w)
Minnesota Pollution Control Agency (w)
Moorehead Public Service (w)
Northwest Minnesota Ground Water Steering Committee (w)
Pine County Soil and Water District (w)
Prairie Island Indian Community (w)
Rochester, City of (w)
Shakopee Mdowakanton Sioux Community (w)
Snake River Watershed Planning Committee (w)
Todd County Soil and Water Conservation (w)
University of Minnesota, Department of Soil Science (w)
Upper and Lower Sioux Indian Community (w)
Upper Sioux Indian Community (w)
Wadena Soil and Water Conservation (w)
Wilkin County Soil and Water Conservation (w)

MISSISSIPPI

Harrison, County of (w)
Jackson, City of (w)
Jackson County—
•Board of Supervisors (w)
•Port Authority (w)
Mississippi Department of—
•Agriculture and Commerce (w)
•Environmental Quality
•Highways (w)
Office of Land and Water Resources (w)
Office of Pollution Control (w)
Pat Harrison Waterway District (w)
Pearl River Basin Development District (w)
Pearl River Valley Water Supply District (w)
Yazoo Mississippi Delta Joint Water Management District (w)

MISSOURI

Cass County Soil and Water Conservation District (w)
Clean Water Commission (w)
Columbia, City of, Department of Public Works (w)
Illinois Environmental Protection Agency (w)
Independence Water Dependency (w)
Jefferson City Division of Health (w)
Mid-America Regional Council (w)
Missouri Department of—
•Conservation (n,w)
•Natural Resources, Division of Geology and Land Survey (n)
Missouri Division of Parks, Recreation, and History (w)
Missouri Highway and Transportation Commission (w)
Springfield, City of, City Utilities, Emergency Department (w)
St. Francois County Environmental Corporation (w)

MONTANA

Blackfeet Nation (w)
Chippewa Creek Tribe of Rocky Boy's Reservation (g)
Fort Peck Indian Reservation (w)
Greenfield Irrigation District (w)
Helena, City of (w)
Helena Valley Irrigation Disrict (w)
Lewis and Clark City-County Health Department (w)
Montana Bureau of Mines and Geology (w)
Montana Department of—
•Fish and Game (w)
•Health and Environmental Sciences (w)
•Natural Resources and Conservation (w)
•State Lands (w)
Montana Highway Commission (w)
Northern Cheyenne Tribe (w)
Ravalli County Commissioners (w)
Salish and Kootenai Tribes (w)
Two Leggings Water Users Association (w)
Wyoming State Engineer (w)

NEBRASKA

Blue River Compact Administration (w)
Central Platte Natural Resources District (w)
Lincoln, City of (w)
Lower Elkhorn Natural Resources District (w)
Lower Platte North Natural Resources District (w)
Lower Platte South Natural Resources District (w)
Lower Republican Natural Resources District (w)
Middle Republican Natural Resources District (w)
Nebraska Department of—
•Environmental Quality (w)
•Water Resources (w)
Nebraska Natural Resources Commission (w)
Nemaha Natural Resources District (w)
North Platte Natural Resources District (w)
Omaha, City of (w)
Papio-Missouri River Natural Resources District (w)
South Platte Natural Resources District (w)
Twin Platte Natural Resources District (w)
University of Nebraska, Conservation and Survey Division (w)
Upper Big Blue Natural Resources District (w)
Upper Loup Natural Resources District (w)
Upper Niobrara-White Natural Resources District (w)

NEVADA

Carson City Department of Public Works (w)
Carson Water Subconservancy District (w)
Churchill, County of (w)
Clark County Regional Flood Control District (w)
Clark County Sanitation District (w)
Douglas, County of (w)
Duck Valley Reservation (w)
Henderson, City of (w)
Las Vegas Valley Water District (g,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)
•Transportation (w)
•Wildlife (w)
Pyramid Lake Paiute Tribal Council (w)
Southern Nevada Water Authority (w)
Summit Lake Paiute Indian Tribe (w)
Tahoe Regional Planning Agency (w)
University of Nevada–Reno (w)
Walker River Pauite Tribe (w)
Washoe, County of (w)
Washoe County Planning Department (n)

NEW HAMPSHIRE

Keene, City of (w)
New Hampshire Department of—
•Environmental Services (w)
•Transportation (n)

NEW JERSEY

Atlantic Highlands, Borough of (w)
Bergen, County of (w)
Brick Township Municipal Utility Authority (w)
Gloucester County Planning Commission (w)
Hackensack Meadowlands Development Commission (w)
Medford, Township of (w)
Mercer County Park Commission (w)
Morris County Municipal Utility Authority (w)
New Brunswick, City of (w)
New Jersey Department of—

NEW JERSEY (CONT.)

•Environmental Protection (n,w)
•Transportation (w)
New Jersey Water Supply Authority (w)
North Jersey District Water Supply Commission (w)
Passaic Valley Water Commission (w)
Pinelands Commission (w)
Rutgers State University, Department of Radiation and Environment (w)
Somerset County Board of Chosen Freeholders (w)
Washington Township Municipal Utility Authority (w)
West Windsor, Township of (w)

NEW MEXICO

Albuquerque, City of—
•Public Works Department—
Hydrology Division (w)
Water Utility Planning Division (w)
Waste Water Utility (w)
Albuquerque Metropolitan Arroyo Flood Control Authority (w)
Arizona Department of Environmental Quality (w)
Canadian River Water Authority (w)
Costilla Creek Compact Commission (w)
Elephant Butte Irrigation District (w)
El Paso, City of, County Water Quality (w)
Jornada Research, Conservation and Development (w)
La Cienega Acequia (w)
Las Cruces, City of, Water Department (w)
New Mexico Department of—
•Environment (w)
•Highways and Transportation (w)
New Mexico State University, Water Resources Research Institute (w)
Office of the State Engineer (w)
Pecos River Commission (w)
Pueblo of Isleta (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 Rosa, City of (w)
Texas Water Development Board (w)
Tribal Council of the Pueblo of Nambe (g)
University of New Mexico (n)

NEW YORK

Amherst, Town of, Engineering Department (w)
Auburn, City of (w)
Chautauqua County Department of Planning and Development (w)
Cheektowaga, Town of (w)
Clifton Park Water Authority (w)
Columbia University (g)
Cornell University (w)
Cortland County Planning Department (w)
Erie, County of (w)
Hudson-Black River Regulating District (w)
Livingston County Departmenrt of Health (w)
Monroe County Department of Health (w)
Nassau County Department of Public Works (w)
New York City Environmental Protection Administration, Bureau of Water Supply and Wastewater (w)
New York State Department of—
•Environmental Conservation, Planning, and Restoration, Bureau of Monitoring and Assessment (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)
Onondaga Lake Management Conference (w)
Orange County Water Authority (w)
Saratoga Springs, City of (w)
Seneca Nation of Indians (w)
State University of New York, Binghamton (w)
State University at Syracuse, Department of Environmental Sciences and Forestry (w)
Suffolk, County of—
•Department of Health Services (w)
•Water Authority (w)
Syracuse, City of (w)
Tompkins County Department of Planning (w)
Ulster, County of (w)
Victor, Village of (w)

NORTH CAROLINA

Appalachian State University (g)
Asheville, City of (w)
Bethel, Town of (w)
Brevard, City of (w)
Chapel Hill, Town of (w)
Charlotte, City of (w)
Danville, Virginia, City of (w)
Durham, City of (w)
Greensboro, City of (w)
Jackson, County of (w)
Lexington, City of (w)
Lumber River Council of Governments (w)
Mecklenburg, County of (w)
Morganton, City of (w)
North Carolina Cooperative Extension Service, Dallas and Raleigh (w)
North Carolina State Department of—
•Environment, Health, and Natural Resources (n,w)
•Transportation (w)
Raleigh, City of (w)
Rocky Mount, City of (w)
Triangle Area Water Supply Monitoring, Project Steering Committee (w)
University of North Carolina, Wilmington, (g)
Western Piedmont Council of Governments (w)

NORTH DAKOTA

Devils Lake Sioux Tribe (w)
Dickinson, City of (w)
Lower Heart Water Resources District (w)
Minot, City of (w)
Nelson City Water Resources District (w)
North Dakota Department of—
•Game and Fish (w)
•Health, Water Supply, and Pollution Control (w)
•Parks and Recreation (w)
•Transportation (w)
North Dakota Geological Survey (n)
State Water Commission (w)
Three Affiliated Tribes (w)

OHIO

Akron, City of (w)
Canton, City of (w)
Columbus, City of (w)
Cuyahoga River Commission (w)
Eastgate Development Company (w)
Franklin, County of (w)
Fremont, City of (w)
Geauga, County of (w)
Lima, City of (w)
Madison, County of (w)
Miami Conservancy District (w)
Midwest University, Consortium for International Activities (g)
N.E. Ohio Regional Sewer District (w)
Ohio Department of—
•Natural Resources (w)

OHIO (CONT.)

•Transportation (n,w)
Ohio State University, Department of Agronomy (w)
Pickaway, County Commissioners (w)
Ross, County of (w)
Sumit County Engineers (w)
Washington, County Commissioners (w)

OKLAHOMA

Cheyenne and Arapaho Tribes (w)
McGee Creek Authority (w)
Oklahoma City, City of (w)—
•Public Works Department (w)
•Treatment Division (w)
Oklahoma Conservation Commission (w)
Oklahoma Department of Transportation (n)
Oklahoma Geological Survey (w)
Oklahoma State University, Division of Agricultural Sciences and Natural Resources (w)
Oklahoma Water Resources Board (n, w)
Ponca Tribe (w)
Sac and Fox Nation (w)

OREGON

Albany, City of (w)
Ashland, City of (w)
Bend, City of (w)
Coos, County of (w)
Coos Bay-North Bend Water Board (w)
Douglas, County of (w)
Eugene, City of, Water and Electric Board (w)
Gresham, City of (w)
Jackson, County of (w)
Jefferson County Commission (w)
Kalama, Port of (w)
McMinnville, City of (w)
Oregon Association, Clean Water Agencies (w)
Oregon Department of—
•Energy (w)
•Environmental Quality (w)
•Human Resources, State Health Division (w)
•Transportation, Highway Division (g, w)
•Water Resources (w)
Oregon State University (g)
Portland, City of—
•Bureau of—
Environmental Services (w)
Water Works (w)
Unified Sewerage Agency (w)
Warm Springs Tribal Council (w)
Washington State Department of Ecology (w)

PENNSYLVANIA

Allentown, City of, Engineering Department (w)
Bethlehem, City of (w)
Bucks, County of (w)
Chester County Water Resources Authority (w)
Cumberland, MD, City of (w)
Delaware County Solid Waste Authority (w)
Delaware River Basin Commission (w)
Doylestown Township Municipal Authority (w)
Fairfax County Water Authority (w)
Harrisburg, City of, Department of Public Works (w)
Hazelton City Authority Water Department (w)
JPC Lehigh-Northampton Counties (w)
Letort Regional Authority (w)
Media Borough Water Department (w)
New York State Department of Environmental Conservation Planning and Restoration (w)
North Penn Water Authority (w)
North Wales Water Authority (w)
Philadelphia, City of, Water Department (w)
Pennsylvania Department of—
•Environmental Resources—
Bureau of—
Mining and Reclamation (w)
Soil and Water Conservation (w)
Topographic and Geologic Survey (n, w)
Water Supply and Community Health (w)
•Transportation (w)
Pennsylvania State University (w)
Somerset Conservation District (w)
Sunbury, City of, Municipal Authority (w)
Susquehanna River Basin Commission (w)
Tinicum, Township of (w)
University Area Joint Authority (w)
University of Delaware, Geological Survey (w)
Warwick Township (w)
West Bradford, Township of (w)
Williamsport, City of (w)

PUERTO RICO

Puerto Rico Aqueduct and Sewer Authority (w)
Puerto Rico Department of—
•Health (w)
•Natural and Environmental Resources (w)
Puerto Rico Electric Power Authority (w)
Puerto Rico Environmental Quality Board (w)
Puerto Rico Industrial Development Company (w)
Puerto Rico Mineral Resources Development Corporation (g)

RHODE ISLAND

Narragansett Bay Water Quality Commission (w)
Providence, City of, Water Supply Board (w)
Rhode Island State Department of Environmental Management—
•Division of —
Water Resources (w)
Water Supply (w)
State Water Resources Board (w)

SOUTH CAROLINA

Beaufort-Jasper County Water and Sewer Authority (w)
Camden, City of (w)
Charleston Harbor Project (w)
Charleston Public Works (w)
Clarendon Sumter Soil and Water Conservation District (w)
Clemson University, Department of Fertlizers and Pesticides (w)
Greer Commission of Public Works (w)
Land Resources Conservation Commission (n)
Mt. Pleasant Waterworks and Sewer Department (w)
Myrtle Beach, City of (w)
Oconee County Sewer Commission (w)
South Carolina State—
•Department of—
Health and Environmental Control (w)
Highways and Public Transportation (w)
Natural Resources, Water Resources Division (w)
•Public Service Authority (w)
•Wildlife and Freshwater Fisheries Division (w)
Spartanburg Sanitary Sewer District (w)
Spartanburg Water Works (w)
University of South Carolina Department of Environmental and Health Services (w)
Waccamaw Regional Planning and Development Council (w)
Western Carolina Regional Sewer Authority (w)

SOUTH DAKOTA

Area II Minnesota River Basin (w)
Belle Fourche Irrigation District (w)
Cheyenne River Sioux Tribe (w)
Custer State Park Division (w)
East Dakota Water Development District (w)

SOUTH DAKOTA (CONT.)

Lake Kampeska Water Project District (w)
Lower Brule Sioux Tribe (w)
Mellette, County of (w)
Oglala Sioux Tribe (w)
Pelican Lake Water Project District (w)
Rapid City, City of (w)
Roberts, County of (w)
Rosebud Sioux Tribe (w)
Sioux Falls, City of, Utility Department (w)
Sisseton-Wahpeton Sioux Tribe (w)
South Dakota Department of—
•Environment and Natural Resources—
Environmental Regulation Division (w)
Geological Survey Division (w)
Water Rights Division (w)
•Game, Fish and Parks (w)
•Transportation (w)
South Dakota School of Mines and Technology (n, w)
South Dakota State University, Civil Engineering Department (w)
Spearfish, City of (w)
Stanley County Conservation District (w)
Watertown, City of (w)
West Dakota Water Development District (w)
West River Water Development District (w)
Wyoming State Engineer (w)

TENNESSEE

Alcoa, City of (w)
Athens Utility Board (w)
Camden, City of (w)
Crossville, City of (w)
Dickson, City of (w)
Eastside Utility District (w)
Franklin, City of (w)
Germantown, City of (w)
Grundy County Soil Conservation District (w)
Hamilton County Office of Emergency Management (w)
Harriman Utility Board (w)
Harpeth Valley Utility District (w)
Hixson Utility District (w)
Johnson City, City of, Public Works Department (w)
Knoxville, City of (w)
Memphis, City of, 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)
Oneida Water System (w)
Red Boiling Springs, Town of (w)
Rogersville, Town of (w)
Sevierville, City of (w)
Shelby, County of (w)
Shelby County Soil Conservation District (w)
Tennessee Department of—
•Agriculture (w)
•Environment and Conservation, Office of Water Programs (w)
•Transportation, Division of Structures (w)
Tennessee Wildlife Resources Agency (w)
Tullahoma Utilities Board (w)
Upper Duck River Development Agency (w)
Wartrace, City of (w)

TEXAS

Abilene, City of (w)
Arlington, City of (w)
Austin, City of (w)
Barton Springs/Edwards Aquifer Conservation District (w)
Bexar-Medina-Atascosa Counties (w)
Brazos River Authority (w)
Canadian River Water Authority (w)
Central Texas Council of Governments (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)
Fort Bend Subsidence District (w)
Fort Worth, City of (w)
Gainesville, City of (w)
Galveston, County 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)
Houston-Galveston Area Council (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 East Texas Municipal Water District (w)
North Texas Municipal Water District (w)
Nueces River Authority (w)
Orange, County of (w)
Pecos River Commission (w)
Sabine River Authority of Texas (w)
Sabine River Compact Administration (w)
San Angelo, City of (w)
San Antonio, City of—
•Public Service Board (w)
•Water Systems (w)
San Antonio River Authority (w)
San Antonio Water System (w)
San Jacinto River Authority (w)
Somerville County Water District (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 Commission (w)
Texas Water Development Board (n,w)
Titus, County of, Fresh Water Supply District No. 1 (w)
Trinity River Authority (w)
University of Texas, Austin (g, 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)

U.S. VIRGIN ISLANDS

Virgin Islands Department of Planning and Natural Resources (w)

UTAH

Arizona Department of Natural Resources (w)
Bear River Commission (w)
Central Utah Water Conservation District (w)
Goshute Tribal Government (g)
Kane County Water Conservancy (w)
Nephi, City of (w)
Nevada Department of Conservation and Natural Resources, Division of

UTAH (CONT.)

Water Resources (w)
Ogden River Water Users Association (w)
Salt Lake, County of (w)
St. George, City of (w)
Tooele, City of (w)
University of Utah (g)
Utah Department of—
- •Environmental Health, Division of Water Quality (w)
- •Natural Resources (g)—
  - Geological and Mineral Survey (n, w)
  - Oil, Gas, and Mining Division (w)

Water Resources Division (w)
Water Rights Division (w)
Weber Basin Water Conservancy District (w)
Weber River Water Users Association (w)

VERMONT

Agency of—
- •Administration (n)
- •Natural Resources (g,n)
- •Transportation (w)

Department of Environmental Conservation (w)

VIRGINIA

Accomack-Northampton Planning District Commission (w)
Alexandria, City of (w)
Danville, City of (w)
Delaware Geological Survey (w)
Hampton Roads Planning District Commission (w)
James City, County of (w)
Maryland, Department of State Highway Administration (w)
Newport News, City of (w)
Northern Virginia Planning District Commission (w)
Prince William Public Works (w)
Roanoke, City of (w)
Southeastern Public Service Authority of Virginia (w)
University of Virginia, Department of Environmental Sciences (w)
Virginia Department of—
- •Conservation and Reclamation (w)
- •Environmental Quality (w)
- •Highways and Transportation (w)
- •Mines, Minerals, and Energy, Division of Mineral Resources (n)

West Piedmont Planning District Commission (w)

WASHINGTON

Aberdeen, City of (w)
Bellevue, City of (w)
Chelan, County of, Public Utility District No. 1 (w)
Clallam County Department of Community Development (w)
Cowlitz, County of (w)
Douglas, County of, Public Utility District No. 1 (w)
Hoh Indian Tribe (w)
Jamestown Klallam Tribe (w)
Kent, City of (w)
King County Department of Public Works (w)
Lewis County Board of Commissioners (w)
Makah Indian Tribe (w)
Muckleshoot Indian Tribe (w)
Nisqually Indian Tribe (w)
Oregon Department of Fish and Wildlife (w)
Pacific County Commissioners (w)
Pierce, County of, Public Works Department (w)
Port Townsend, City of (w)
Quileute Tribal Council (w)
Quinault Indian Business Committee (w)
Seattle, City of, Light Department (w)
Skagit County Department of Public Works (w)
Snohomish, County of—
- •Board of Commissioners (w)
- •Public Utilities (w)

Spokane County Commissioners (n)
Tacoma, City of, Department of—
- •Public Utilities (w)
- •Public Works (w)

Thurston County Department of Public Works (w)
Umatilla Tribal Council (w)
University of Washington (g)
Washington Department of—
- •Ecology (w)
- •Fisheries and Wildlife (w)
- •General Administration (w)
- •Health (w)
- •Highways (w)
- •Information Services (g, n)
- •Natural Resources (n, w)

Washington State Community Development (w)
YakimaTribal Council (w)

WEST VIRGINIA

Morgantown, City of, Utility Board (w)
New Martinsville, City of (w)
West Virginia Department of Abandoned Mines and Reclamation (w)
West Virginia Division of—
- •Environmental Protection (w)
- •Highways (w)
- •Natural Resources, Office of Water Resources (w)

West Virginia Geological and Economic Survey (g, w)

WISCONSIN

Alma/Moon Lake District (w)
Auburn, Town of (w)
Balsam Lake Protection and Rehabilitation District (w)
Barron, City of (w)
Beaver Dam, City of (w)
Big Muskego Lake District (w)
Brookfield, City of (w)
Cedar Lake, Town of (w)
Dane, County of—
- •Department of Public Works (w)
- •Lakes and Watershed Management (w)
- •Regional Planning Commission (w)

Darboy Sanitary District #1 (w)
Delavan, Town of (w)
Druid Lake Inland Protection and Rehabilitation District (w)
Eagle Spring Lake Management (w)
Elkhart Lake Improvement Association (w)
Fond Du Lac, City of (w)
Fontana Walworth Water Pollution Control Commission (w)
Fowler Lake Management District (w)
Geological Survey (n, w)
Green Bay Metropolitan Sewerage District (w)
Green Lake Sanitary District (w)
Hillsboro, City of (w)
Kansasville, Town of (w)
Kaukauna Electric and Water Utilities (w)
Kimberly Water Works Department (w)
Lac Du Flambeau Indians (w)
Lake Keesus Management District (w)
Lake Nebagamon, Village of (w)
Lauderdale Lakes Lake Management District (w)
Little Arbor Vitae Protection and Rehabilitation District (w)
Little Chute, Village of (w)
Little Green Lake Protection and Rehabilitation District (w)
Little Muskego Lake District (w)
Little St. Germain Lake District (w)
Madison Engineering Department (w)
Madison Metropolitan Sewerage District (w)
Marinette County Soil and Water Conservation Department (w)

WISCONSIN (CONT.)

Mead, Township of (w)
Menasha, Town of, Sanitary District No. 4 (w)
Menominee Indian Tribe of Wisconsin (w)
Muskego, City of (w)
Norway, Town of (w)
Oconomowoc Lake, Village of (w)
Okauchee Lake Management District (w)
Oneida Indian Tribe of Wisconsin (w)
Park Lake Management District (w)
Peshtigo, City of (w)
Potters Lake Rehabilitation and Protection District (w)
Powers Lake Management District (w)
Pretty Lake Management District (w)
Rock, County of, Public Works Department (w)
St. Germain, Town of (w)
Southeastern Wisconsin Regional Planning Commission (w)
Sparta, City of (w)
Stockbridge-Munsee Indians (w)
Summit, Town of (w)
Thorp, City of (w)
Troy, Town of (w)
University of Wisconsin Extension, Geological and Natural History Survey (n)
Upper Nemahbin Lake Management District (w)
Waterford, Town of (w)
Waupun, City of (w)
Whitewater-Rice Lake Management District (w)
Wind Lake Management District (w)
Wisconsin Department of—
•Justice (w)
•Natural Resources (n, w)
•Transportation (w)
Wisconsin Regional Planning Commission (w)
Wittenberg, Village of (w)
Wolf Lake Management District (w)

WYOMING

Alaska Department of Natural Resources (w)
Cheyenne Board of Public Utilities (w)
Cheyenne, City of (w)
Colorado State University (w)
Evanston, City of (w)
Freemont County Weed and Pest Division (w)
Joint Business Council (w)
Lincoln, County of (w)
Midvale Irrigation District (w)
Sheridan Water Supply Board (w)
Star Valley Conservation District (w)
Teton, County of (w)
Teton County Natural Resources District (w)
Water Development Commission (w)
Water Resources Center (w)
Wind River Environmental Quality Commission (w)
Wyoming Department of—
•Agriculture (w)
•Environmental Quality (w)
•Game and Fish (w)
•Highways (w)
Wyoming State Engineer (w)

FEDERAL COOPERATORS

Central Intelligence Agency (g)

Department of Agriculture
Agricultural Research Service (w)
Forest Service (g,n,w)
National Finance Center (w)
Soil Conservation Service (n,w)
Stabilization and Conservation Service (w)

Department of the Air Force (w)
Aeronautical Systems Command (w)
Air Combat Command (w)
Air Education and Training Command (w)
Air Mobility Command (w)
Headquarters, AFTAC/AC (g)
Patrick Air Force Base (g)
Department of the Army (w)
Aberdeen Proving Ground (w)
Army Belvoir RDE Center (g)
Army Construction Engineering Research Lab (w)
Corps of Engineers (g, n, w)
Directorate of Public Works (w)
Engineer Topographic Laboratory (w)
National Training Center (g)
Picatinny Arsenal (w)
Rocky Mountain Arsenal (w)
White Sands Missle Range (w)
Yuma Proving Ground (w)

Department of Commerce
Bureau of the Census (n)
National Institute of Standards and Technology (g)
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, n)
Defense Intelligence Agency (g)
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)
Brookhaven National Laboratory (w)
Hanford Project (w)
Idaho Falls Operations Office (w)
Los Alamos National Laboratories (w)
Morgantown Energy Technology Center (g)
National Geothermal Program (g)
Nevada Operations Office (w)
Oak Ridge Operations Office (g, w)
Pittsburgh Energy Technology Center (g)
Rocky Flats Operations Office (w)
Sandia National Laboratories (g, w)
Savannah River Operations Office (g, w)
Schenectady Naval Reactors Office (w)
Southwestern Power Administration (w)
Yucca Mountain Project (g, w)

Department of Health and Human Services
National Institutes of Health (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)
National Biological Survey (w)
National Park Service (g, n, w)
Office of the Secretary (w)
U.S. Fish and Wildlife Service (n, w)

Department of Justice (w)

Department of the Navy
- Naval Facilities Engineering Command (g, w)
- Naval Air Warfare Center (g)
- Naval Oceanographic Office (g)
- Naval Research Laboratory (g)
- Naval Surface Warfare Center (w)
- Naval Weapons Center, China Lake (g)
- Naval Weapons Station (w)
- Navy Engineering and Logistics Office (g)
- Office of Naval Research (g, 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 Aviation Administration (w)
- Federal Highway Administration (w)

Environmental Protection Agency (g, n, w)
- Corvallis Environmental Research Laboratory (w)
- Environment Research Laboratory (g)
- Hazardous Waste Management Division (g)
- Region IX, San Francisco (g)
- Robert S. Kerr Environmental Research Lab (w)
- Summitville Mining Site—Terrace Reservoir (g)

Federal Emergency Management Agency (g,w)

Federal Power Commission (w)

Federal Energy Regulating Commission Licenses (w)

National Aeronautics and Space Administration (g,n,w)

National Science Foundation (g,n,w)

Nuclear Regulatory Commission (g, w)

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 (w)

*U.S. G.P.O.:1995-387-030:78

USGS

METRIC CONVERSION FACTORS

Multiply	By	To obtain
	Length	
millimeter (mm)	0.0394	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
square centimeter (cm^2)	0.1550	square inch
square meter (m^2)	1.196	square yard
hectare (ha)	2.471	acre
	Volume	
cubic centimeter (cm^3)	0.06102	cubic inch
liter (L)	1.057	quart
	Mass	
kilogram (kg)	2.205	pound avoirdupois

1994 Yearbook Staff

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Cover and graphic designs on p. I, II, III, IV, 1, 2, 27, 28, 43, 44, 59, 60, 81, 82, 101, and 102 by Maura Jean Hogan, 1995.

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 included 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 has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S administration.