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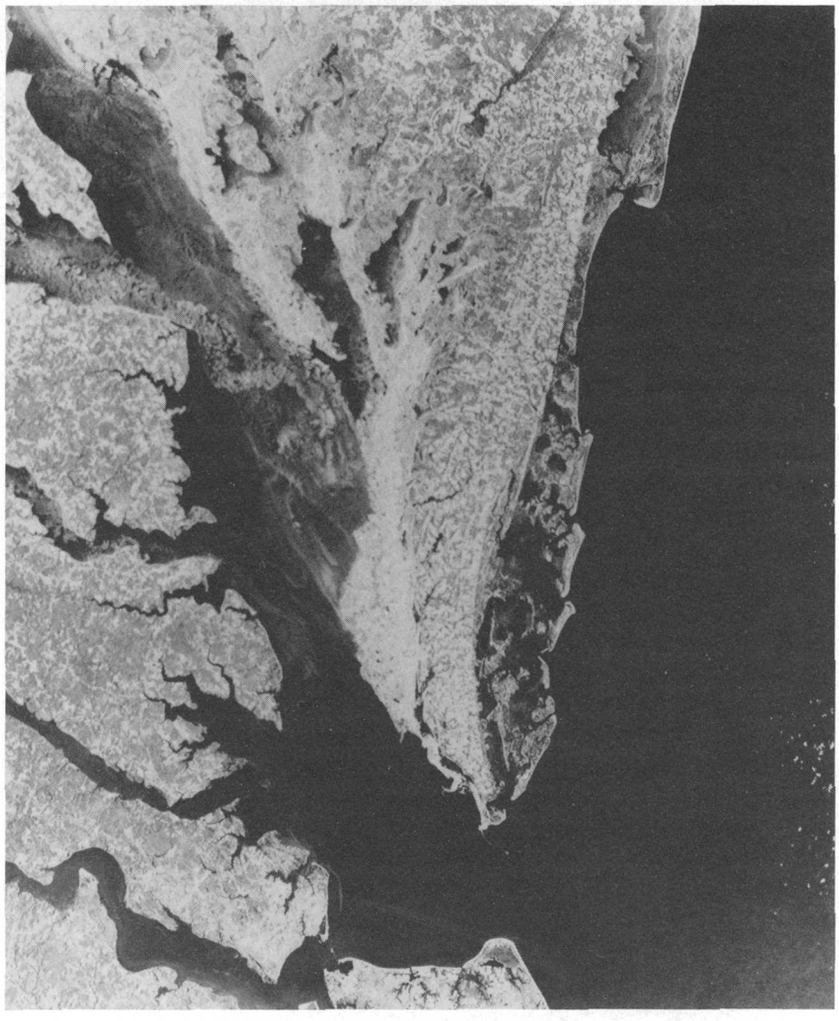

United States Geological Survey Yearbook, Fiscal Year 1978

COVER: Temporal mapping with Landsat color image shows the maximum extent of ice around the Delmarva Peninsula during the record cold winter of 1976–77. New ice appears blue or green, and thick older ice is white; open water is generally black. This image is a portion of a published U.S. Geological Survey color image map titled "Chesapeake Bay and Vicinity, Winter 1976–77."

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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The Year in Review

INTRODUCTION

Fiscal year 1978 saw the U.S. Geological Survey continuing to perform its basic historical missions of collecting, analyzing, and disseminating information about the Earth, its processes, and its water and mineral resources. Classifying Federal lands and supervising lessee mineral extraction operations on those lands were also major Survey concerns during the year. In addition, substantial progress was made in the exploration and assessment of the petroleum potential of the National Petroleum Reserve in Alaska, a recently assigned mission.

These basic missions found expression in a wide range of program activities and interests as diverse as the sands of Mars and the volcanoes of Hawaii. Programs included assessment of numerous potential energy and mineral resources, study of earthquakes and other geologic hazards, appraisal of the magnitude and quality of the Nation's water resources, and supervision of lease operations on Federal lands. The Survey also was involved in developing data on land use and producing topographic, geologic, and hydrologic maps for public and private use. In cooperation with other Federal agencies, the Survey participated in studies under the U.S. Climate Program and continued its analysis of data received from the two Viking landers on the surface of Mars.

On April 3, 1978, Dr. H. William Menard became the 10th Director of the U.S. Geological Survey. Dr. Menard, who, until his appointment, was Professor of Geology at the Scripps Institution of Oceanography, San Diego, Calif., brings to the Director's post the experience gained in a long and successful career as a marine geologist and oceanographer. He succeeds Dr. Vincent E. McKelvey, who continues with the Survey as a senior research scientist.

SURVEYING AND MAPPING

During fiscal year 1978, the Geological Survey produced more than 2,400 new and revised 1:24,000-scale quadrangle maps, bringing the total coverage of the United States to 71 percent at that scale. In addition, the Survey received nearly 40,000 requests for 1:24,000-scale format topographic quadrangle maps, intermediate- and small-scale maps, orthophotoquads, and digital cartographic data. Approximately 6.2 million map copies at all scales were sold.

Cost-sharing agreements were in effect with 38 States and Puerto Rico in fiscal year 1978. Through these agreements, the Survey is able to jointly establish selection procedures and prioritize mapping projects. The State Mapping Advisory Committees in 23 States meet with the Survey periodically to discuss State mapping requirements and to coordinate mapping programs.

Efforts continue to modernize the National Mapping Program by the introduction of advanced technologies. The digitization of cartographic information and the refinement of airborne surveying techniques are among these modernization efforts.

The Digital Cartographic Applications Program, begun in 1978, included a number of pilot projects with other agencies to refine digital cartographic data formats, verify production techniques, and validate user requirements. When the computer-based cartographic information systems are refined and established, the full potential of rapid data manipulation and analysis can be realized.

Construction has begun, by means of a contract, on the Aerial Profiling of Terrain surveying system. The system is made up of two parts: an inertial navigation subsystem and laser tracker that provides the latitude, the longitude, and the altitude of an aircraft and a laser ranging instrument that measures the distance to a series of points on the ground along the flight path for which precise coordinates in three dimensions can be computed. The system will have wide application in surveying and mapping including flood plain mapping, standard topographic maps, and monitoring strip mining and reclamation.

During 1978, a study was undertaken to improve distribution procedures for Geological Survey maps. The study, which is scheduled for completion in 1979, is expected to identify optimum printing and inventory procedures for the many Geological Survey information products and to reduce the cost of delivering maps to the public.

GEOLOGIC STUDIES AND MAPPING

The Geological Survey's continuing programs of basic geologic mapping and research provide the fundamental knowledge of the geologic framework of

◀ Storm clouds gather over wind-gnarled timberline trees in the Granite Mountains, northwestern Wyoming.

the Nation. These activities enable the Survey to respond to increasing needs for basic geologic information.

Research continued in the field of plate tectonics and its relationships to other geologic phenomenon. As a result of these efforts, Survey scientists are beginning to unravel the complex history of the unstable western margin of the North American Continent from southern Alaska to Baja, Calif. This new understanding of the geologic framework of the continent can have enormous implications for energy and mineral resources exploration, earthquake hazard reduction, and nuclear reactor siting in California, Oregon, Washington, and Alaska.

A new geologic map (scale 1:250,000) has been completed for the State of Kentucky. This represents the culmination of 18 years of cooperative State-Federal efforts. The map was compiled from detailed (1:24,000) geologic maps recently completed for the entire State. This new geologic map is expected to aid significantly in public and private decision processes regarding resource development and management.

A major new Geological Survey program concerning paleoclimate was launched in fiscal year 1978 as part of the U.S. Climate Program. The Geological Survey's main effort will be in refining our knowledge of past climates to provide a better basis for evaluation of present climate patterns and predicted weather cycles.

Survey scientists continued their analysis of data from the two Viking landers on the surface of Mars. Study of these data may provide further clues as to the origin of the high alluvial channels, the history of Martian volcanism, the possibility of radical climate changes, and the reasons for the lack of plate tectonic activity similar to that of the Earth. The Survey is also preparing to assist in the analysis of data from the Voyager mission to Jupiter and Saturn, which should shed new light on the origin of the solar system and the reasons for the striking differences among the planets.

GEOLOGIC HAZARDS

During fiscal year 1978, the Geological Survey continued efforts aimed at acquiring a better understanding of the nature and causes of various geologic hazards. These efforts included (1) identification, accession, and monitoring of potentially hazardous areas, (2) development of capabilities to predict the time, the place, and the severity of hazardous geologic events, and (3) effective dissemination of the information and findings.

It was determined through expanded monitoring efforts that Mauna Loa Volcano, Hawaii, is continuing its slow but persistent buildup toward eruption but without the corresponding heightened seismicity that typically accompanies such buildup. The Geological Survey is actively working with Hawaii County and State Civil Defense officials to improve coordination and communication to better respond to the next eruption from either Mauna Loa or Kilauea.

Interagency agreements were signed with the Bureau of Reclamation and the Corps of Engineers by which the Survey will provide regional geologic and seismic data and advice to assist in the safe siting and design of major dams. One of the first tasks completed under these agreements was an extensive review of the Foothills fault system in California because of concerns about the design of a proposed dam at Auburn.

Research is focusing within the Earthquake Hazards Reduction Program on devising accurate methods for earthquake prediction. The possibility of predicting earthquakes, which was hardly taken seriously before 1971, came to be viewed with cautious optimism in the early 1970's as observations accumulated of many possible earthquake precursors. For example, analyses of foreshocks before several earthquakes in Alaska and California show that foreshocks may be identifiable by their patterns of spatial distribution, by their time sequence, and by changes in the orientation of their fault planes with time. If this pattern proves to be of wide applicability, foreshocks should be identifiable before the main shock occurs. In another example, precursors in seismicity, radar levels, volumetric strain, and uplift were observed before an earthquake of magnitude 6.8 in Japan.

There has been an excellent information exchange with scientists in Japan and the Soviet Union, where major prediction programs also are underway. Exchange with scientists in China has been steadily improving. During the year, Geological Survey personnel met with representatives of 30 State and 7 Federal agencies to develop procedures for communicating geologic-related hazards for use by State and Federal agencies. Based on its investigations, the Survey will provide information on potential hazards such as active faults, landslides, rockfalls, and fissuring and faulting associated with subsidence caused by ground-water withdrawals, which pose a threat to life and property, to State and local officials, and to the public.

ENERGY AND MINERALS

In fiscal year 1978, the Survey initiated 12 studies in the Conterminous United States Mineral Appraisal Program to systematically assess the mineral resource potential of selected 1:250,000-scale quadrangles in

the conterminous United States. This effort, like the ongoing Alaskan Mineral Resource Appraisal Program, combines geologic, geochemical, geophysical, and mineral deposit studies. The resultant information on mineral resource potential is an essential input to numerous land use decisionmaking processes.

A new series of coal folios that combine coal resource, environmental, and land use information on coal lands in the Western States was initiated to support the Department of the Interior's Coal Program. The folios combine a variety of 1°×½° quadrangle maps at a scale of 1:100,000 showing distribution, thickness, and quality of coal; character and thickness of overburden; climatic factors; and land use; all of these must be considered in preparation of Environmental Impact Statements and decisions regarding leasing of Federal coal to help meet the Nation's energy demands. The first folio covering the Recluse quadrangle, Wyoming, has been completed and is being readied for publication.

More than 4,800 nautical miles of marine seismic and gravity data was collected off the northern coast of Alaska in the eastern Beaufort Sea to map the geologic structures of the Continental Shelf and to evaluate the area for potential oil and gas resources.

WATER RESOURCES

The year 1978 saw an end to the severe drought that characterized the previous 2 years, but other critical national water problems remained. Some of them are as follows:

- Water pollution increased, affecting both surface and ground water.
- Though generally the Nation has ample water resources, in many sections of the country the imbalance between supply and demand remained serious and emphasized the need for informed management of available water.
- Investigation of the quantity and quality of surface and ground water as they relate to environmentally sound energy development became a growing challenge.

In response to these problems, the Geological Survey increased its efforts to collect and to present adequate water data to aid decisionmaking by management.

As part of the Federal-State Cooperative Program, projects were implemented in 16 States to fill an information gap that has long existed in data on "water use." The National Water Use Data Program, was initiated to provide comprehensive and systematic collection, analysis, and distribution of water use data throughout the United States. The system will be be operating in all 50 States by 1982.

A program of indepth studies of the Nation's 29 major regional aquifer systems was initiated. Studies were begun on the High Plains, northern Great Plains, and Central Valley of California; three additional studies are scheduled to start in 1979. The information will aid in planning for conjunctive use of surface and ground water where feasible, will reveal the sources and quality of ground water for potential use in times of serious shortage, and will add background data on water supply for energy development.

The River Quality Assessment Program continued in fiscal year 1978. Assessments for the Upper Chattahoochee Basin, Ga., and the Yampa River basin in Colorado-Wyoming were completed, and reports were in preparation at the end of the fiscal year. Three additional river assessments will begin in 1979.

The Central Laboratories System, which analyzes water quality, added nearly 150 new analyses to its catalog of analytical services. Water analyses became more complex as the result of Federal legislation such as the Clean Water Act of 1977 and the Safe Drinking Water Act of 1977.

New and sophisticated sensing and recording equipment was developed that increases the possibilities for prediction within the hydrologic system and will contribute valuable information for pollution control, flood control, sea water intrusion into fresh ground-water supplies, and other complex problems.

In addition to studies of basic water supply for coal and oil shale development, the pressing problem of radioactive waste disposal and its potential effects on ground water received considerable attention. During the year, the Geological Survey conducted a number of studies relating to low-level radioactive waste disposal including the use of modeling techniques for the prediction of ground-water flow characteristics, methodologies for the detection and identification of radionuclides, and assessments of geochemical characteristics of trace elements in the natural environment.

LAND INFORMATION AND ANALYSIS

The Geological Survey continued its effort to bridge the communications gap between the earth scientist and the variety of users of earth science information. This effort has involved interpreting and presenting land resources information in a variety of new report and map formats as well as holding workshops.

Work continued in developing interpretative earth science information on the Colorado Front Range Urban Corridor, Fairfax County, Va., and the Puget Sound area of Washington. Approximately 40 new

reports and maps were released during 1978 concerning "urban" projects. Perhaps the most important publication in terms of broad interest was "Nature to be Commanded . . .," (U.S. Geological Survey Professional Paper 950), which describes, in a readily understandable format, the uses of earth science information by public and private decisionmakers in six varied environmental settings across the country. Other efforts during the year involved projects with the Council on Environmental Quality (CEQ) under contract with the American Arbitration Association to assess test methods and to develop a computer information system supporting the National Environmental Protection Act; with the Department of Energy (Argonne National Laboratories) to develop methods for integrated mining, reclamation, and regional land use planning; with the Council of State Governments to assess the automation of land records systems (prototype—State of Wisconsin); and with the Missouri River Basin Commission to conduct a Western Coal Planning Assistance Project.

Medium-scale (1:250,000) land use and land cover mapping of the entire United States proceeded as did development and operation of a computer-oriented Geographic Information System for land use and land cover data, and research activities addressing the trends in land use change.

During 1978, 1,000,000 square miles were mapped, bringing the total coverage of the United States to 28 percent.

During 1978, a variety of research projects and training sessions were carried out concerning the application and interpretation of remotely sensed data. In addition, the Earth Resource Observation Systems Data Center in Sioux Falls, S. Dak., produced and distributed photographs, images, and computer-compatible tapes valued at $3,200,000. Since its establishment in 1972, the center has distributed approximately 2,000,000 reproductions of satellite and aircraft imagery and data.

During the year the Geological Survey had lead or joint-lead responsibility for the preparation of 14 Environmental Impact Statements (EIS's), principally concerned with coal. The Survey also directly participated in the preparation of 17 EIS's in a nonlead capacity. The Geological Survey initiated efforts to simplify EIS preparation and review by use of new formats that eliminate redundancies and highlight findings in summary fashion. This new EIS procedure is still being evaluated and will be adopted, with the concurrence of CEQ, if the results are positive. In addition, approximately 1,800 EIS's and related documents were reviewed.

Landsat image of a 13,255-square-mile area in southwestern Queensland, Australia. The dark area is the alluvial valley of Cooper Creek, which has a high grazing capacity. The lighter tones show uplands and minor valley areas, which have a lower and more variable grazing capacity. Maps of land units related to grazing capacity can be made by digital analysis of Landsat images and used for land management. This method has been tested in Australia and the Western United States. (Landsat E–1365–23570–5.)

MINERAL RESOURCE EVALUATION AND LEASE MANAGEMENT

U.S. Geological Survey lease management activities during fiscal year 1978 extended into the frontier Outer Continental Shelf (OCS) areas of the Lower Cook Inlet in Alaska (OCS Sale C–1) and the South Atlantic (OCS Sale No. 43). A third OCS sale was held for tracts in the Gulf of Mexico (OCS Sale No. 45). Exploratory drilling operations were also initiated during this time in the frontier Mid-Atlantic Baltimore Canyon Trough area. The first promising encounter with natural gas in the Baltimore Canyon was made during the testing of Texaco's wildcat well. Approximately 2,250 oil and gas leases were under the supervision of the Geological Survey in the OCS.

In onshore oil and gas lease operations, 3,425 new exploration and development wells were approved, 3,525 environmental analyses of proposed operations were prepared, and 27,630 on-site inspections of drilling and producing operations were conducted.

At the end of the fiscal year, 50 geothermal wells were completed on Federal leases; 36 of these, although producible, are shut-in awaiting powerplant facilities. One powerplant has been started in the East Mesa area, California.

Construction of surface facilities and shafts preparatory to development of a modified in-situ extraction process was initiated on Federal Oil Shale Tracts C–a and C–b.

Waterpower and water-storage site potential of 10,000 acres were classified or reclassified during the fiscal year.

A Continental Offshore Stratigraphic Test (COST) well, No. 3, was completed in the Gulf of Alaska (Kodiak) in October 1977. The report on the COST No. GE–1 (Southeast Georgia embayment area, South Atlantic OCS) was issued as Open-File Report 78–668.

The second annual report on estimated oil and gas reserves for the Gulf of Mexico was released as Open-File Report 78–87. The first annual report on the estimated oil and gas reserves for the southern California OCS was released as Open-File Report 78–384.

Eighteen new Known Recoverable Coal Resource Areas (KRCRA's), covering about 4.2 million acres were defined, and 748,161 acres were added to existing KRCRA's.

Contracts for 234 Coal Resource Occurrence–Coal Development Potential maps were issued in fiscal year 1978.

At the end of the fiscal year, 878 test holes had been drilled for coal in Colorado, Montana, North Dakota, New Mexico, Utah, and Wyoming under State grants and contracts and by use of Survey-owned drilling equipment.

NATIONAL PETROLEUM RESERVE IN ALASKA

Fiscal year 1978 marked the first full year of exploration activities on the National Petroleum Reserve in Alaska (NPRA). The 37,000-square-mile area, formerly Naval Petroleum Reserve No. 4, was transferred from the Department of the Navy to the Department of the Interior on June 1, 1977. By the terms of the transfer, the Geological Survey was charged with evaluating the petroleum resource potential of NPRA, continuing to develop and produce gas from the South Barrow gas field for the village of Barrow and installations in the vicinity of Barrow, and continuing environmental rehabilitations of certain areas of the Reserve disturbed by previous exploration and construction activities.

The Geological Survey, through a contract operator, drilled four exploratory wells in the northern coastal area, three to completion and one for reentry and completion in fiscal year 1979. A deep well was started in the eastern part of the Reserve to test deeper structures and to gain stratigraphic information on the rocks in the interior of the Reserve. The well is scheduled for completion in May 1979. A second deep-well site, in the western part of the Reserve, was prepared with an all-season pad, roads, and an airstrip. This well will commence drilling in fall 1979. A second drilling pad was constructed in the north-central part of the Reserve for a medium-depth well to be drilled in fiscal year 1979. All the exploration wells drilled to date have been dry or, at best, had only slight indications of oil and gas.

Geophysical studies continued with acquisition, processing, and interpretation of reconnaissance and fill-in detail seismic surveys in various parts of the Reserve. Reconnaissance data was acquired in the Driftwood, southern Foothills, and Umiat areas, and high-resolution data was collected along the Arctic Coastal Plain.

Pursuant to the objective of providing natural gas to the village of Barrow, the Geological Survey completed three wells during 1978. The first was drilled as an exploratory well approximately 2 miles northeast of the South Barrow field in an attempt to locate a new gas field to supplement the diminishing South Barrow reserves. The "Barrow gas sand" was not encountered, and the well was plugged and abandoned. Two development wells were completed in a new gas field discovered by the Navy in 1977. Both of these wells, located about 10 miles east of the South Barrow gas field, produced gas upon test and were completed as shut-in gas wells. Production facilities to the new field will be constructed during fiscal year 1979.

Perspectives

Ground Water: An Undervalued Resource

By G. D. Bennett

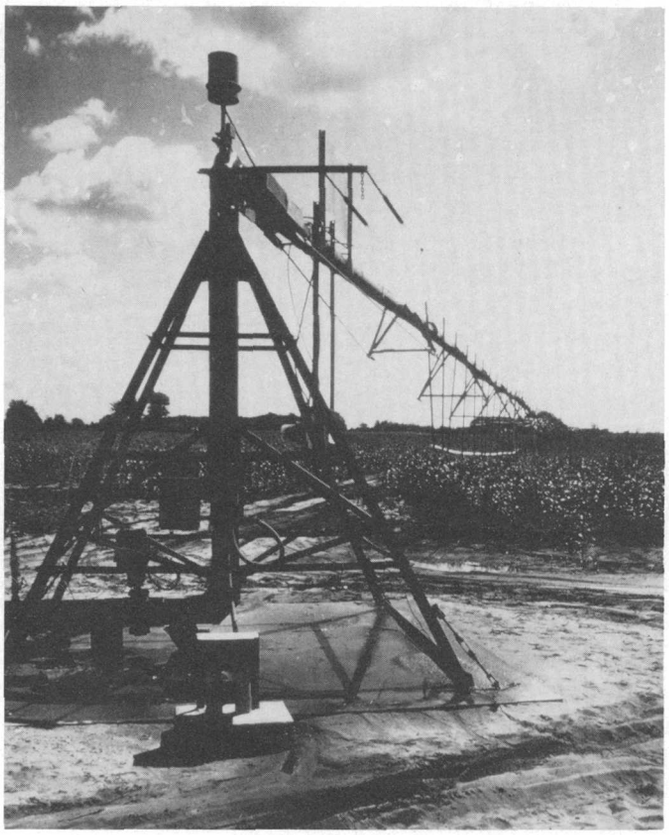
INTRODUCTION

Information on the ground-water resources of the Nation must be upgraded if intelligent management of those resources is to be attempted. In particular areas of the country, the value of ground water is understood, and enough is known about its local occurrence to permit heavy utilization. Frequently, this is because it is the single local source of supply. For example, thousands of communities in the United States obtain all of their water from wells; and many large municipal areas such as Long Island, N.Y., Memphis, Tenn., Miami, Fla., and Houston, Tex., obtain all or a large part of their water from the ground. In specific areas we have learned much about the nature of ground-water resources, but integrated information on the aquifer systems of the country is inadequate for the times.

During the coming decade, pumpage of ground water to supplement surface supplies is expected to increase dramatically throughout the country. The rapid growth of cities, particularly in the water-short Southwest, will be a prime contributing factor; the desire to develop water supplies capable of weathering extended drought will be another. Large amounts of water will be required for new energy-producing industries, particularly in the generation of power and the operation of coal slurry pipelines. Irrigation is fast becoming a routine component of agricultural practice even in humid areas. The development of center-pivot equipment, in which a moving sprinkler pipe rotates around a central well and irrigates a circular area, has caused a rapid increase in irrigated acreage and a growing emphasis on ground water as a source of irrigation supply. Finally, environmental objections to large surface reservoirs are forcing planners to consider ground water as an alternative source of supply for all applications.

This increasing use of ground water is certain to have varied and widespread impacts. From a strictly hydraulic point of view, all pumpage must result in a lowering of ground-water levels, and this in turn would affect all users of ground water in the area. In addition, pumpage tends to reduce the available surface-water supply by reducing natural accretion of

◀ Jagged peaks of the Teton Range tower more than 7,000 feet above the flat floor of Jackson Hole in northwest Wyoming.



Center-pivot irrigation systems, in which a rotating sprinkler arm is supplied from a central well, have placed an increasing demand on aquifers in many areas of the country.

ground water to streams and, in some cases, by inducing direct seepage from streams to the ground-water system. In some instances, the pumped ground water is returned to the stream system or directly to the ground-water regime through artificial recharge, irrigation field seepage, or certain forms of waste disposal after a cycle of use. The result may then be degradation in water quality rather than diminished supply. Finally, pumpage may have an impact on the structure of the Earth. Sustained withdrawals from some types of aquifers can cause compaction of the geologic column and subsidence of the land surface.

In the development of ground water, as in the development of any resource, well-informed management can make a great difference. The consequences of pumpage will depend to a large extent on the way in which it is implemented. If the results of various courses of development are understood in advance, planners will be in a position to choose the course for which the ratio of benefit to real cost is most favorable. Even where no planning authority exists that can guide and influence the development of ground water, an understanding of the consequences of various patterns of withdrawal is necessary if society is to be prepared to meet those consequences.

The prerequisite to any kind of successful management is information—particularly on the hydrologic impacts of various development alternatives. The requirement is for a predictive capability through which the planner can estimate in advance what will happen if this or that scheme of withdrawal is implemented. For a number of years, ground-water investigations inside and outside the U.S. Geological Survey have focused on the development of such predictive capabilities. In general, these efforts have been at a local scale because the state of the science has been limited and because the interest of planners has been largely at the local level. The anticipated increases in withdrawal over the next decade, however, will produce impacts which are regional in scope. To provide management information at a regional scale, including predictive capabilities, the Geological Survey has initiated a new series of hydrologic investigations — the Regional Aquifer-System Analysis (RASA) Program.

Pumpage of ground water in the San Joaquin Valley, Calif., has caused widespread subsidence of the land surface. The markers on this pole show former land surface elevation near Mendito, western Fresno County.

THE ROLE OF GROUND WATER IN THE ECONOMY

The significance of ground water to economics can best be illustrated through one or two examples. In California's Central Valley, pumpage for irrigation was curtailed prior to 1977 and was replaced with surface water in an effort to stem the land subsidence which had accompanied earlier heavy withdrawals. The drought of 1977 caused a failure of surface-water supplies, and there was widespread concern that the agricultural production of the valley, a vital factor in the State's economy, would fall seriously short. As surface-water supplies declined, however, pumpage from active irrigation wells was increased, idle wells were reactivated, and thousands of new wells were drilled. Irrigation supplies were thus maintained throughout the growing season, and the impact of the drought on food production in the valley was greatly reduced. With the passing of the drought, surface water has again become the major source of irrigation in the valley. The experience illustrates the importance of ground water as a drought-resistant component in the total water supply and shows the value of integrated management of ground water and surface water to meet current demands.

Another example of the economic significance of ground water can be found in the northern Great Plains States, where surface-water and shallow ground-water sources are already committed to irrigation and new sources are needed to supply the competing demands of energy production. The Madison aquifer, an extensive but deep-lying and, therefore, largely unutilized formation, has been proposed as a potential source of water for mining operations, coal slurry pipelines, and power generation. The feasibility of utilizing the Madison in this way is currently the subject of intensive investigation. Whatever the results of these investigations are, the competition between energy-related uses and other water demands will probably be a factor in the regional economy for many years to come. This situation will be repeated in other parts of the country as the effort toward greater domestic energy production intensifies, and, in many instances, ground-water development will be proposed as the solution.

As these examples illustrate, the management questions facing the planner are basically economic issues. Some are clear cut; for example, any new draft on the ground-water system must influence the pumping lift, flow rate, or quality of the supply to existing installations, and each of these factors has an influence on cost. The economic implications of other management questions may be less clearly defined, but they are real. Certain environmental impacts of pumpage, for example, may not usually be thought of in terms of dollars. However, if a development scheme is abandoned because of environmental considerations, a decision has implicitly been made to place a higher value on maintenance of the environment than on the benefit of the pumpage to the economy. This decision, intentionally or not, attaches a minimum dollar value to the environmental issue.

The need for management in any case is an economic need. Haphazard development of ground water will cost the Nation much more than well-managed development. Successful management of any resource depends upon adequate information, and ground water is no exception. An understanding of the natural flow system and of the way in which it will respond—hydraulically, chemically, and structurally—to imposed stresses is a necessary prerequisite to ground-water development planning.

The Nature of Ground-Water Flow Systems

The ground-water regime is a dynamic system in which water is continuously in motion from areas of recharge to areas of discharge. In a typical ground-water flow system, this movement occurs through an extensive heterogeneous but interconnected geologic framework. This framework generally includes permeable units, normally thought of as water-bearing zones or aquifers, and less permeable units, which were formerly considered confining zones (aquicludes) but are now more commonly thought of as semiconfining zones (aquitards). The chemical quality of ground water is recognized to be a function of the processes, particularly interaction with the geologic framework, that have occurred along the path of flow. Thus, chemical quality normally varies from one point to another in the flow pattern.

Prior to development in a given region, the flow regime is presumably in hydrologic equilibrium, having total recharge to the system equal to total discharge from it. Pumpage disrupts this equilibrium, causing a withdrawal of water from storage and a concurrent decline of water levels. As water levels fall, natural discharge from the system is reduced, and recharge may be increased. In time, these changes in natural inflow and outflow may be sufficient to balance the withdrawal; if this occurs, a new equilibrium is achieved in which recharge is balanced by the sum of natural outflow and pumpage, and depletion of storage no longer occurs. Such an equilibrium, however, may not always be possible at a given rate of withdrawal. If the pumpage from a given system exceeds the reductions in natural outflow and the increases in recharge which can be induced, wells will continue to draw from storage until depletion of the supply forces a reduction in withdrawal rate.

It is important to recognize that the reduction in natural outflow described above implies that withdrawal of ground water ultimately must have an impact on surface-water resources. If, for example, a ground-water flow system originally discharges to a stream, development of ground water will ultimately bring about a reduction in stream flow equal to the pumpage, provided a new equilibrium is achieved. In some applications, of course, much of the pumpage is returned to the stream system after use. As noted earlier, the impact on the stream is then largely one of degradation in quality rather than of reduction in flow. The significant point is that ground water and surface water are both parts of an integrated hydrologic regime and that a stress in either may have repercussions throughout the system.

The total volume of water in storage as ground water is extremely high relative to the rate of flow through the system. This high ratio of storage to flow rate tends to encourage development of ground water from storage; it also means that the ground-water system is a far more drought-resistant supply than most surface sources and that conjunctive management of ground water and surface water is an effective method of weathering fluctuations in surface supplies.

The Method—Computer Simulation of Ground-Water Flow Systems

During recent years, rapid strides have been made in the field of computer simulation of ground-water flow systems. These advances have had far-reaching effects on the techniques of ground-water investigations and on the potential for intelligent management of ground-water resources.

Briefly, simulation refers to the process by which the hydraulic (and perhaps other) characteristics of the flow system are represented by a set of equations which can be solved on a digital computer. The set of equations, the computer routines required for its solution, and the input data (specifying the properties of the geologic framework and of the ground water itself and outlining the problem to be solved) collectively constitute the "model" of the flow system. Hydraulic effects are addressed in all ground-water models; more sophisticated simulations may also treat corollary effects, such as land subsidence or solute transport. An example of the use of simulation is provided by the Geological Survey's work on Long Island, where a three-dimensional model of the flow system has been used to predict declines in water level and stream flow that would be caused by various development alternatives.

Initially, simulation was regarded by many primarily as an aid in hydrologic prediction. The normal sequence of operations involved hydrogeologic investigation, construction of a model based on the results, and use of the model as a planning tool to predict the effects of various proposed schemes of pumping. With the continued development of simulation technology, however, there has been a growing realization of the contribution the method can offer to the process of hydrogeologic investigation itself. Increasingly, models are thought of as investigative tools to be used in the study of existing ground-water flow systems. In a variety of ways, ranging from simple trial-and-error to sophisticated statistical approaches, simulation allows the investigator to test his hypotheses, to check the sensitivity of his results to various assumed conditions, and to generate a reasonable reconstruction of the flow system on the basis of available field data. In this sense, it has made the analysis of regional hydrology a much more realistic goal than it was a few years ago.

It is relatively uncommon for hydrologic investigation to precede ground-water development altogether in a given region. As a rule, hydrologic investigations are initiated in response to problems that normally arise only after pumping has been in progress for several years. Thus, the hydrologist rarely has a first-hand look at the undisturbed or natural condition of the system that he is studying. Rather, he sees it in some intermediate condition, disturbed by a certain level of development but not yet subject to the full stresses which are to be imposed. An understanding of the original flow system is a prerequisite to an analysis of many other facets of the hydrogeology, particularly those relating to water chemistry. Simulation has proven particularly useful in this aspect of hydrologic investigation. When a model has been developed that offers a satisfactory representation of present conditions, it can be used to simulate the pre-pumping situation, thus providing an analysis of the original flow pattern.

The use of simulation as an investigative tool has not diminished its significance in terms of hydrologic prediction. The development of a predictive capability for planning purposes remains the ultimate goal of most hydrogeologic work today; the only real difference is that simulation itself now plays a large role in the investigations leading to that goal.

ANALYSIS OF REGIONAL AQUIFER SYSTEMS

The RASA Program represents a systematic effort to study a number of extensive regional ground-water systems that together cover much of the country and represent a significant element of the national water supply. Twenty-five systems have been

identified for study, although the list is not necessarily in its final form. In general, the study areas transcend political subdivisions to which hydrologic investigations have often been limited in the past.

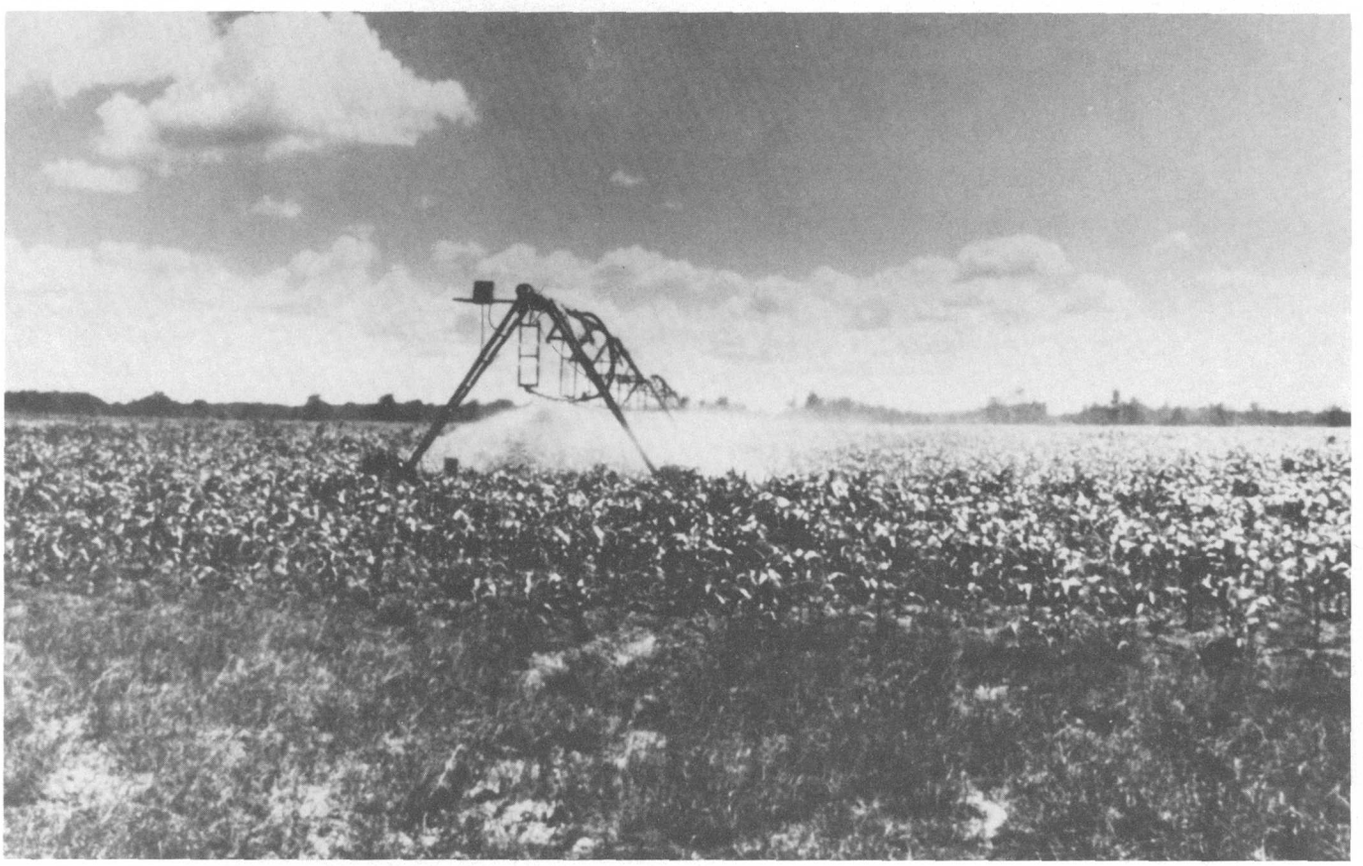
A regional aquifer system may be defined as an extensive set of aquifers within a given geographic region and made up of units that are hydraulically interconnected or that share so many common characteristics that it is efficient to study them in a single exercise. The hydraulic interconnection may be within the ground-water system or may be external to it, as in the case of a number of aquifers linked to a common stream network.

Needless to say, this is a broad definition and allows consideration of a wide range of candidate studies. The projects scheduled to date have been selected on the basis of further criteria, including (1) the significance of the aquifer system as a present or potential supply of water—particularly its significance to the national economy or, at least, to the economies of more than one State, (2) the severity of the water problems facing the project area, and (3) the potential water needs in the project area—particularly those connected with energy projection, increasing irrigation, and increasing urban development. Although most of the project areas are of an interstate nature, this is not a necessary requirement.

Three studies were initiated in fiscal year 1978, including the California Central Valley, the northern Great Plains, and the High Plains. The importance of ground water in the Central Valley and the northern Great Plains has already been mentioned. The Central Valley Study will concentrate on evaluating effects of continued or expanded use of ground water as an adjunct to surface water in the irrigation system. The program in the northern Great Plains represents an expansion and extension of an existing Survey investigation of the Madison aquifer in that area.

In the High Plains States, pumpage for irrigation from the Ogallala aquifer has sustained the agricultural economy for several decades. The withdrawals greatly exceed recharge, and, at present pumpage rates, the area appears to face exhaustion of the resource during the remainder of this century. The study will address the hydrologic impacts of varying the pumpage according to different plans and will be coordinated with an economic analysis of the region commissioned by the Economic Development Administration.

Three new RASA studies will be initiated in fiscal year 1979. These will include the Cambro-Ordovician aquifers of the northern Midwest, the carbonate aquifers of the Southeast, and the alluvial basin aquifers of the Southwest.



Center-pivot irrigation system.

Future plans call for initiating three or four new studies each year. The average length of study will be 4 years. The first two completions will occur in 1981; following this, three or four studies should be completed each fiscal year through the end of the program.

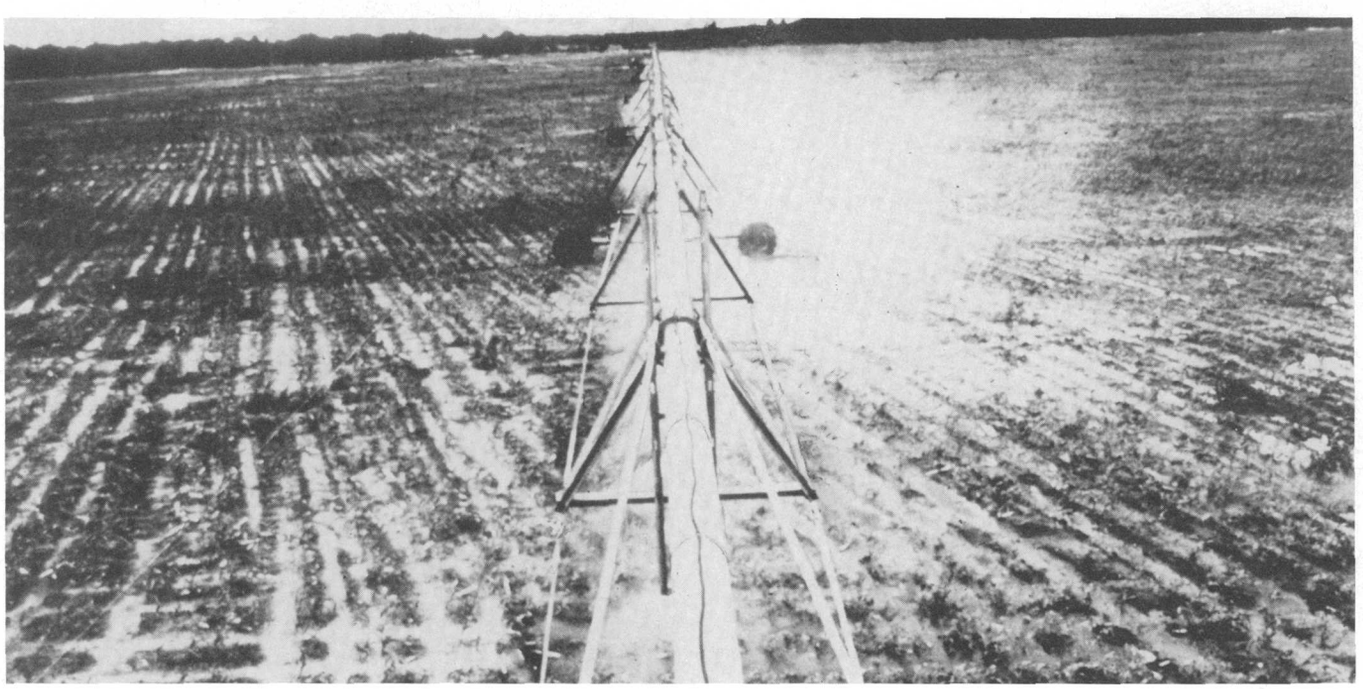
Although each investigation will be designed to fit the particular problems of the study area, the general approach will be to develop a computer simulation for the overall aquifer system, supported by more detailed simulations of local or subregional problem areas. These simulations will assist in forming an understanding of the natural (prepumping) flow regime and of the changes brought about by human activities. They will also provide a means of predicting the hydraulic effects of stress, such as pumpage, artificial recharge, or waste disposal. In some studies, associated effects, such as land subsidence, changes in water quality, or costs of pumping, may be incorporated in the models. The simulations will be based on a full assemblage of existing data and on such new data as are required to fill critical gaps in the available information. In some cases, collection of this new data will require extensive field operations.

Simulation will be initiated early in each project to study the overall nature of the flow system, to identify sensitive parameters and data needs, and to determine what segments of the system, if any, can be treated independently in further work. As additional data are assembled, the simulation of the regional system will be refined progressively, and detailed models of local problem areas will be developed. The regional model, apart from contributing to an understanding of the overall hydrologic system, will provide the boundary conditions for experiments on the local models, thus tying the local simulations into the regional analysis.

Each study will address water quality as well as hydraulics. The present water-quality distribution throughout the study area will be described, and an effort will be made to interpret this distribution in terms of the original flow pattern, the changes in response to development, and the associated geochemical processes.

The products of these investigations will vary according to the needs of the area, although, again, some common patterns will be followed. In particular, results will be released continuously during each study through a series of data reports and short papers, and the full results of the investigation will be summarized in a comprehensive final report.

The studies are designed to complement the Survey's continuing program of cooperative groundwater investigations. As a general rule, investigations initiated under the cooperative program are of a local nature, and, frequently, they are oriented to the solution of specific problems. Because the RASA studies are designed to look at the regional picture, they will serve to tie together local investigations, whether past, present, or future; in terms of simulation, they will provide boundary flows for detailed local models. Thus, the RASA Program is expected to act as a stimulus to other hydrologic investigations rather than as a replacement for any existing program.



Center-pivot irrigation system.

Landslide Hazards and Their Reduction

By Robert W. Fleming, David J. Varnes, and
Robert L. Schuster

INTRODUCTION

Massive landslides triggered by a major earthquake in Kansu Province, China, in 1920 killed nearly 200,000 people. Three major landslides in Peru within the last 20 years have killed nearly 25,000 people. Landslides have also caused secondary effects resulting in many deaths and much damage. For example, in 1963, a rockslide into the Vaiont Reservoir in Italy displaced a huge volume of water and created a wave that overtopped the dam. The flood wave swept through towns downstream killing nearly 3,000 people.

In contrast, losses and damages from landslides in the United States are hidden disasters in most respects. U.S. Geological Survey studies of some recent disasters in the United States reveal that landslides are responsible for considerably greater damage than is generally recognized and are a costly part of many major disasters in which the landslide damage is overlooked by the news media. For example, the tremendous destruction in central Virginia in 1969 is remembered as an effect of Hurricane Camille, although most of the 150 people killed during the storm were not drowned by flooding but were killed by debris avalanches that cascaded down steep slopes during the heavy rainfall. More than one-half of the damage from the 1964 Alaskan earthquake was the result of landslides triggered by the quake. Landsliding may have been a critical part of the sequence of failure of the Buffalo Creek Dam in West Virginia in 1972 and of the St. Francis Dam in southern California in 1928.

The term "landslide" denotes downward and outward movement of slope materials composed of natural rock, soil, artificial fill, or combinations of these materials. In recent years, there has been a great deal of interest in classifying the different types of landslides, and the term "slope movement" seems to be preferred to landslide because not all of the damaging movements involve sliding of materials. Here, recognizing that the different types of slope movement involve *sliding, flowing, falling, toppling, spreading,* and combinations of these, landslide and slope movement are used interchangeably.

In the simplest form of classification, names of different types of slope movements are assigned by combining the name of the material involved with the predominant type of movement to produce a one- or two-word descriptor such as rock fall, debris topple, or earth flow. Slides with significant rotation are termed "slumps," and the term "slide" (rock slide, debris slide, or earth slide) is reserved for downslope movement along more or less planar surfaces without rotation of slide material.

The variety of types of movements and the factors responsible for the movements would seem to make the technical problem of landslide hazard reduction inordinately complex, but this is not so. Leighton (1976) estimated that in California, a 95- to 99-percent reduction in damaging failures is technically attainable through the use of three levels of investigation. These levels are regional, tract or community, and site, with progressively more detailed investigations in the smaller areas. However, the solutions to the technical problems are only a part of the process of achieving landslide hazard reduction. The transfer of information into an orderly program to reduce hazards and damages is perhaps more formidable than the technical problem. Implementation of technology is subject to pressures from groups that range from those that dislike regulation or interference to those that do not consider landslides amenable to loss-reduction measures or do not consider landslides a serious enough economic problem to justify the effort required to make a program work.

WIDESPREAD HAZARDS

Landslides are a significant hazard in virtually every State of the United States. Although individual landslides generally are not as spectacular or as costly as certain other natural catastrophes such as earthquakes, major floods, or tornadoes, they are more widespread and the total financial loss due to slope failures probably is at least equivalent to any other single geologic hazard in the United States.

Reliable estimates of the overall costs of landslides are difficult to obtain for geographical entities as large as the United States. In 1958, a study reported by the Highway Research Board stated that "the average yearly cost of landslides in the United States runs to hundreds of millions of dollars," an estimate which

FIGURE 1 .—A landslide has virtually destroyed this building in Cincinnati, Ohio. The toe of the landslide crushed the rear of the building, and slide debris, including trees and rubble, has been pushed across the floor. Part of the direct losses from the landslide include the intrinsic value of the building and associated costs of dismantling and removing it. (Photograph courtesy of J. O. Maberry.)

at that time was probably realistic. However, in the 20 years since those data were assembled, a combination of inflation, increased construction in landslide-prone areas, and the use of larger cuts and fills in construction has resulted in considerably increased annual costs of landslides. A study by the Transportation Research Board in 1978 has concluded that a reasonable estimate of landslide damages to public and private property exceeds $1 billion annually.

Costs include both direct and indirect losses from landslides affecting highways, railroads, industrial installations, mines, homes, and other public and private properties. Direct costs are those losses incurred in actual damages to installations or property (see fig. 1). Examples of indirect costs (fig. 2) are (1) loss of tax revenues on properties devalued as a result of landslides, (2) reduced real estate values in areas threatened by landslides, (3) loss of productivity of agricultural or forest lands affected by landslides, and (4) loss of industrial productivity due to interruption of transportation systems by landslides. Indirect costs of landslides are difficult to evaluate, but they may be larger than the direct costs.

Somewhat more accurate cost estimates can be made for individual landslides or for landslides occurring in relatively small areas. For instance, in a classic study of slope-movement costs in the San Francisco Bay area, Taylor and Brabb (1972) documented costs for nine bay-area counties during the winter of 1968–69. Costs of slope movements totaled at least $25 million, of which approximately $9 million was direct loss or damage to private property (due mainly to drop in market value), $10 million was direct loss or damage to public property (chiefly for repair or relocation of roads and utilities), and about $6 million consisted of miscellaneous costs that could not be easily classified in either the public or private sector. This is a tremendous expense for the relatively small area involved. In addition, Taylor and Brabb noted that their data were incomplete in that they were not able to obtain costs on many of the slope movements. They felt, therefore, that the total cost of the 1968–69 slope movements for the bay area may have been several times greater than the estimated $25 million.

A 1973 survey conducted by the Federal Highway Administration indicated that approximately $50 million is being spent annually to repair major land-

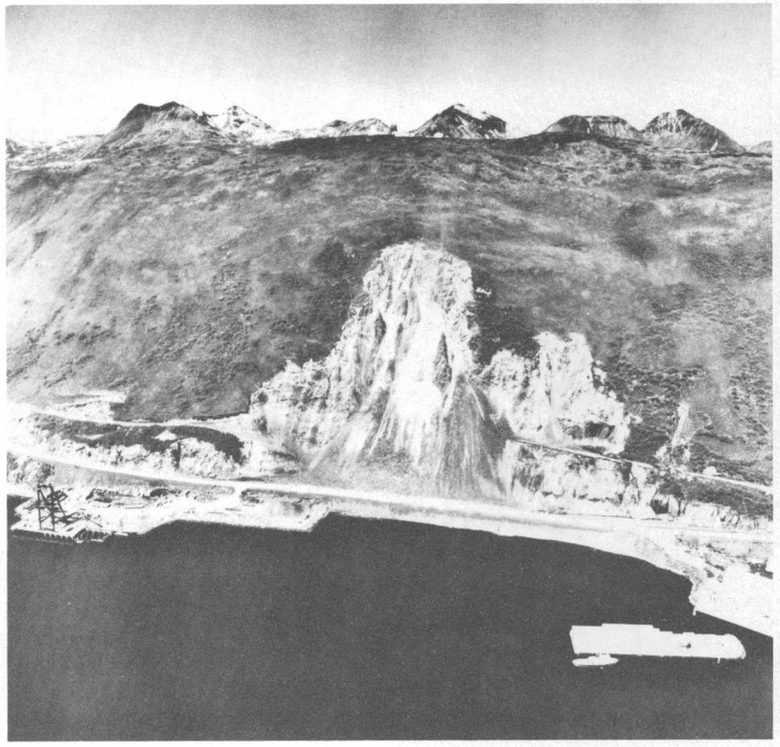


FIGURE 2 .—This view of landslide scars on the face of Pillar Mountain, Kodiak, Alaska, illustrates some indirect costs associated with landsliding. Open cracks above the landslide scars have produced concern that a much larger mass of rock and debris, comprising up to 13 million cubic yards of debris, could fail abruptly. Such a slide might destroy the new cargo dock and might create a large wave that could severely damage the city of Kodiak. The threat of a disaster has produced only minimal direct costs, but indirect costs related to investment, planning, and city expansion have been substantial (Blackburn, 1978).

slides on the federally financed portion of the national highway system (Chassie and Goughnor, 1976). Total annual costs of landslides to highways in the United States are difficult to determine precisely for a variety of reasons. For example, it is difficult to define the direct costs of smaller slides that are routinely repaired by maintenance forces and the various slides remedied on non-Federal-aid routes, as well as the indirect costs for landslide-related damages. Indirect costs including traffic disruption and delays, inconvenience to the traveling public, engineering costs for investigation, and analysis and design of mitigation measures are commonly overlooked. With these factors included, Chassie and Goughnor believed that $100 million is a conservative estimate of total annual cost of landslide damage to highways and roads in the United States.

For planning purposes, other studies have attempted to project costs of landslides. In a study predicting the cost of geologic hazards in California from 1970 to 2000, the California Division of Mines and Geology (Alfors and others, 1973) estimated that the costs of slope movements throughout the State during that period would be nearly $10 billion, or an average of over $300 million per year. This estimate was based on the assumption that California loss-reduction practices in use in 1970 for slope failures will remain unchanged. Shown in figure 3 is a comparison taken from the California study of the estimated losses due to slope movements with losses due to other geologic hazards and urbanization. Of the so-called catastrophic geologic hazards included in the study, losses due to landslides exceed those predicted for floods and, in turn, are exceeded by those due to earthquakes. It must be remembered that California is particularly prone to earthquake activity. In most other States, the losses due to slope movements probably would be greater than those due to earthquakes.

In addition to the economic losses resulting from landslides, significant loss of human life in many parts of the world has been directly attributable to slope failure. Landslides in the United States have not commonly resulted in major losses of life because

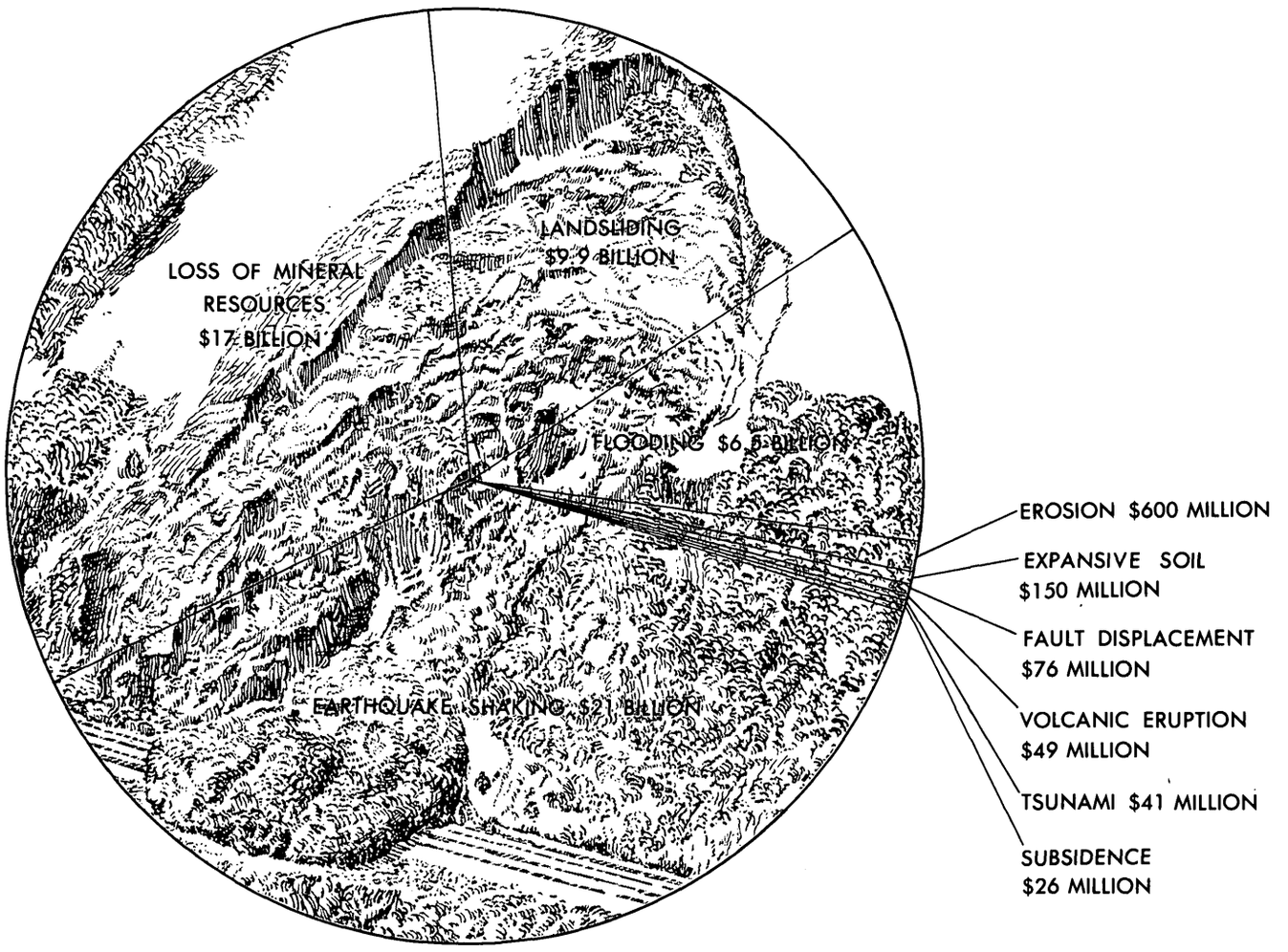


FIGURE 3.—Predicted economic losses from geologic hazards and urbanization in California, 1970 to 2000 (Alfors and others, 1973).

most catastrophic landslides in this country have occurred in nonpopulated areas. However, in recent years, more than 25 people per year have been killed by landslides. The greatest threat to lives seems to be from debris flows triggered by hurricanes in the Eastern United States and by heavy rainfall in southern California.

Reduction of Landslide Hazards and Losses

The reduction of hazards and losses from landslides is both a technical and an administrative problem. In cases where the economics of a major construction activity justify a detailed study, landslides usually can be controlled or avoided. However, in the vast majority of development activity, construction proceeds without recognition or consideration of potential landslide problems.

The steps that need to be taken to reduce the losses from landslides are as follows:

1. Recognition of the areas that have failed in the past and identification of the factors that caused the failures.
2. Quantification of the present conditions and processes that promote landsliding to evaluate present and future landslide activity and to delineate susceptible areas.
3. Dissemination of information to the public and to appropriate agencies in an effective manner that permits decisive use.
4. Regulation of land use in a manner that reduces the hazard.

Geologists, engineers, and planners are involved here in a communication system that begins with research, continues with the education of others who are generally not trained in these fields, and ideally ends with overt social action on the part of an individual, a group, or a governmental organization. As such, a communication system involves people with very different interests and skills and needs to be carefully thought out if it is to achieve its purpose. In practice, this means that the measures available to prevent or to mitigate a hazard must be known in advance to define the kind of information necessary for decisionmaking or for drafting and enforcing legislative actions. Then the geologist must obtain, and present clearly to the right person or group, the geologic data that are appropriate to reach decisions or solutions to the problem. Both the content and the means of communication are critically important because the regulation of land use through ordinances and laws pertaining to geologic hazards is seldom effective unless based on a thorough understanding of the geologic processes involved and on a clear demonstration of the economic and social benefits to be achieved.

An essential tool for rational land use planning is a map that shows where landslides exist or may be expected. Although individual landslides are generally relatively small, from a few feet to almost a mile or two in maximum dimension, they commonly occur in swarms or are dispersed widely in areas having particular geologic, topographic, and climatic characteristics. The combinations of these characteristics that lead to landslides vary greatly in kind and areal extent; hence, texts and maps concerning slope stability problems also vary markedly in content and scale and according to the purpose for which they were made. The size of the area of interest determines the kinds of factors that can be studied and the scales at which results can be shown. For example, both incidence of and susceptibility to slope movements have been shown, for generalized groups of geologic units, at a scale of 1:7,500,000 for the conterminous United States in an overview map prepared by the U.S. Geological Survey. Maps range in scale from smaller than 1:30,000,000 to one to several hundred. At a scale of 1:30,000,000 some generalized aspect of slope stability for a nation the size of the United States can be shown on a page-size map. At a scale of one to several hundred, details of lithology and physical properties of components of small individual landslides, together with stability analyses, can be presented. Although small-scale maps may give an informative overview, the real use of maps for land planning and hazard reduction begins at a scale of about 1:125,000 and intensifies as the scales become larger.

The types of landslide information that can be depicted on maps vary with the scale used. At scales smaller than 1:125,000, the common procedure is to interpret broadly or to infer the slope stability of large regions according to available knowledge of the behavior of geologic formations, or groups, within similar topographic and climatic settings. But at larger scales, and with adequate economic incentive, it becomes possible to do much more. Actual landslides may be shown in nearly their correct positions and sizes, together with the factors of lithology, slope, or rainfall with which they may be associated. The effects of shear zones, faults, and joints; the attitude of weak or water-bearing strata in relation to the direction in which the ground slopes; the possible effects of seismic vibrations; and the impact of man's activities can all be considered in written discussions and shown on maps. In studies of specific sites that warrant thorough exploration, a wealth of geotechnical data on physical properties of materials to considerable depth may be obtained and used for definitive analyses of stability.

At scales larger than about 1:125,000, it is possible to make a significant change in methodology of land-

slide hazard prediction. This involves breaking away from geologic units as the basis for areal prediction of landslide problems and creating new map units of susceptibility based not only on lithology but also on pertinent and mappable factors such as slope, slope aspect, ground and surface water, geologic structures, vegetation, and physical properties. In effect, maps can be added or superposed to yield a new map with the closely defined purpose of classifying the land according to its susceptibility to slope failure.

If warranted, the map units can be quantified, weighted according to their estimated relative importance, and plotted within uniformly sized parcels of ground so that the whole array of information may be processed by computer methods. An early and instructive example of the use of four categories of rock strength and two of slope to produce eight map units of relative stability is provided by a slope-stability map at a scale of 1:19,200 of the San Clemente area, California (Blanc and Cleveland, 1968). In the last 10 years, many more landslide susceptibility maps at various scales and using a variety of factors have been prepared by both governmental organizations and private consultants for areas in the United States.

Among the better known and more successful efforts to translate geologic information on slope stability into land use planning has been the work of the Survey in the San Francisco Bay region. The methodology by which the landslide susceptibility map of San Mateo County has been prepared represents an advanced state of the art. It was prepared by superposing and integrating maps showing geologic units, the distribution of actual landslide deposits, and five categories of slope. Maps of a test area are shown in figure 4 . The original procedure developed by E. E. Brabb, T. H. Nilsen, and their associates at the Survey has been adapted by Newman, Paradis, and Brabb (1978) for more economical processing of data and production of the landslide susceptibility map by computer. The landslide susceptibility map of San Mateo County is unusual in that it has been incorporated into county ordinances which assign upper limits to the number of dwellings per unit area within each of the landslide susceptibility zones.

The intent of much of the geologic work on slope stability directed toward land use planning is to reduce the hazard through avoidance—by not building on areas foreseen to be troublesome or dangerous. But avoidance is not always possible, and it may not always be the best solution where large engineering projects rather than residential construction are involved.

For example, the routes of major highways are commonly dictated by cost of land acquisition and other factors that may outweigh the advantage of choosing one route over another because of better slope stability. Unless stability problems are foreseen to be extremely critical, the highway may be located with the expectation either of having to solve these problems through design or of living with them and providing continued maintenance over the life of the structure, which in the long run would cost less than originally choosing a more stable route.

Large dams that create deep reservoirs often cause landslides on the reservoir banks when the water level rises or falls. To assure complete stability would in many instances be prohibitively expensive, unless lives or valuable property are clearly threatened. Should the potential slides present the possibility of creating waves that might overtop the dam, yet not cause a catastrophic flood, it may be more economical to design the dam to resist overtopping than to try to locate, to evaluate, and to correct the potentially unstable slopes. These approaches to landslide hazard evaluation and reduction require both perceptive geologic insight and a high degree of engineering skill and judgment.

Landslide Hazard Reduction by the City of Los Angeles

The best example of the success of a landslide hazard reduction program in the United States is that enacted by the city of Los Angeles. The experience there was long enough ago and has been documented well enough to permit an evaluation of the program's effectiveness. In an unprecedented series of activities that required cooperation among geologists and engineers working closely with city agencies and elected officials, Los Angeles responded to citizen pressure for protective regulations for the development of hillside land. Development of the basic program spanned the period from 1952 to 1963. Since 1963, the program has been reevaluated and modified several times. Portions of the history of the Los Angeles program to reduce landslide damages are summarized below.

A great deal of grading and construction that had been done during the early post-World War II period, with little or no regulation, created many steep cuts and large poorly compacted fills. The winter of 1951–52 produced more than 26 inches of rainfall in downtown Los Angeles compared to an average of 10 inches during the preceding 7 years. One severe storm during January 1952 produced 7 inches of moisture. The resulting erosion, sedimentation, and landslides caused property damage estimated at $7.5 million (Jahns, 1969).

According to the Mayor's Ad Hoc Landslide Committee, "the citizens of Los Angeles, in conjunction

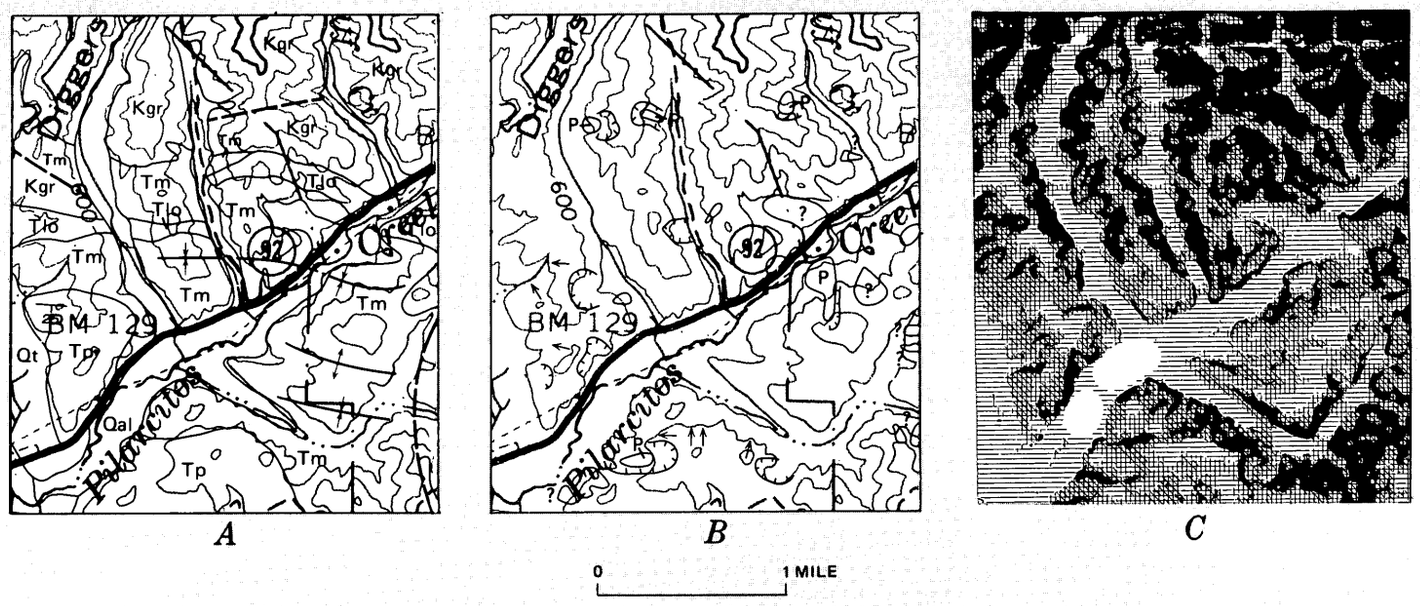


FIGURE 4 .—Materials used for a landslide susceptibility map of San Mateo County, Calif. *A*, Geologic map. *B*, Landslide map. *C*, Slope map. The tones indicate the degree of slope, in which the darker the tone, the greater the slope. These maps are combined and integrated to produce *D*, the landslide susceptibility map in which the higher the roman numeral, the greater the susceptibility. Landslide deposits (L) are shown as a separate and highest category of slope susceptibility (Nilsen and Brabb, 1977).

with the grading industry and professional people in private industry and city government wrote a grading ordinance which was adopted into law on October 17, 1952." This ordinance was based on state-of-the-art practices for large grading projects such as earthen dams and required the expertise of soils engineering and "very limited geology."

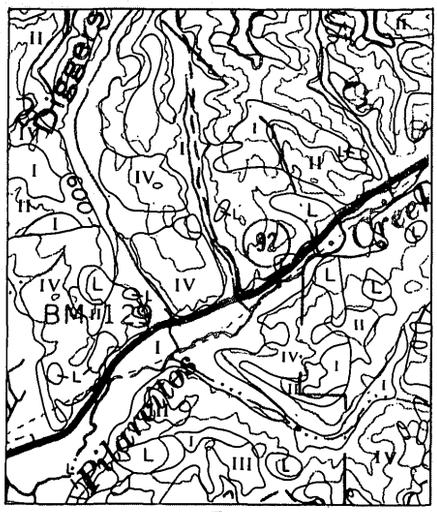
The first real test of the new ordinance occurred in 1956 when, although the total rainfall for the season barely exceeded the long-term average, about 8 inches of rain fell during a 36-hour period. The resulting erosion was massive and led to a change in the ordinance. Compaction of the sloping surface of fills became mandatory. At the same time, in response to special landslide problems, the city government required geologic reports before certain grading permits could be issued.

Another event in 1956 undoubtedly affected the course of future programs to reduce landslide damages. In the Portuguese Bend area of Los Angeles County, a large old landslide was reactivated, causing damge or destruction to more than 150 private residences and associated roads and utilities. Prior to this event, limited insurance coverage was available for landslide damages, and it was all but discontinued immediately following the Portuguese Bend landslide. Also, in the aftermath of this landslide, the concept that many destructive geologic processes are acts of God was questioned and tested in the courts. In succeeding years, the courts have gradually come to the position of applying the concept of strict liability to developers, engineers, and geologists. This concept holds that, in the interest of public welfare, a manufacturer (or in this case a developer, grading contractor, engineer, or geologist) is strictly liable for defects in products or workmanship. Lawsuits against professional geologists and engineers have relied on proving negligence in the investigation, design, or inspection of a grading project.

The next test of the Hillside Grading Regulations of the City of Los Angeles came during the winter of 1957–58. More than 20 inches of rain, nearly 50 percent above normal, fell in the city, causing considerable landslide damage. The Grading Regulations were modified slightly to accommodate some special stability problems within one geologic formation.

At about the same time, the Department of Building and Safety of the City of Los Angeles established an Engineering Geologists Qualification Board to evaluate and to certify the training and experience of engineering geologists wishing to practice their profession in the hillside areas of Los Angeles. This action provided a measure of quality control over the technical community associated with hillside grading. Two years later, the Qualification Board prepared a general guide and checklist of the desired contents of geologic reports submitted to the city.

The winter of 1961–62 provided yet another test of effectiveness of the Grading Regulations. Total rainfall for the season was 19 inches, not much more than the long-term average. However, one storm in



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February 1962 produced about 8 inches of rain. Even though 40,000 new homes had been constructed since the enactment of the Grading Regulations and this storm caused less damage than the storms of a decade earlier, deficiencies in existing regulations again became apparent. Groups were organized to rewrite the Grading Regulations, and, in October 1963, a new ordinance was adopted. The new ordinance provided a more restrictive grading code and geologic and engineering participation in design, construction, and final inspection and certification of the adequacy of a grading project.

The winters of 1968–69 and 1977–78 have provided stern tests of the effectiveness of the regulations. The Department of Building and Safety of the City of Los Angeles conducted a thorough analysis of the damage and slope failures to private property in the hillside areas caused by the storms in 1969, as shown in table 1 . The study compared the distribution of damage to developed sites according to the years the sites were graded. Sites developed before 1952 were without a grading code, and sites developed between 1952 and 1962 were based on the first code and modifications. Sites developed after 1962 had the benefit of the revised Grading Regulations and stringent requirements for engineers and engineering geologists.

Comparing the data for damage to sites constructed after 1963 to those constructed before 1952, the older sites sustained 18 times as much total damage as did the sites developed with stringent controls. Less than 3 percent of the total damage occurred to sites developed under the strong grading regulations. Although the published analysis did not separate landslide damage from the other types of damage, the losses from landslides were apparently reduced at least proportionally.

TABLE 1 .—*Damage associated with destructive storms of 1969 in hillside areas of Los Angeles*

[Adapted from Slosson (1969)]

	Sites developed prior to 1952	Sites developed 1952 to 1962	Sites developed 1963 to 1969
Number of sites constructed	10,000	27,000	11,000
Total damage	$3,300,000	$2,767,000	[1] $182,400
Average damage per site	$330	$100	[2] $7
Percentage of sites damaged	10.4	1.3	0.15

[1] More than $100,000 of the $182,400 occurred to sites that were currently being graded. Even the best of grading projects are susceptible to damage during construction.

[2] If the total damage value is used, the average damage value per site is about $17. The value of $7 per site was obtained by deducting the damages to sites under construction.

The results of the near-record rainstorms in 1977 and 1978 are incomplete. A preliminary analysis of the distribution of damage by the Department of Building and Safety of the City of Los Angeles suggests that more than 93 percent of the landslide damage to sites involved those graded before the Grading Regulations of 1963.

Drafting and adoption of regulations were only part of the entire process, and mention should be made of the other activities essential to the success of the program. Perhaps as important as the creation of regulations is their enforcement. As the regulations were developed and refined, so were the procedures for policing grading projects. The procedures require

FIGURE 5.—Landslides in the Los Angeles area caused by the near-record rainstorms of 1977–78 dramatically showed that hazards have not been eliminated. However, scenes like this would have been much more common without the effective hazard reduction program developed over the past 25 years. (Photograph courtesy of the Los Angeles Times.)

review of plans and construction by several departments and approval at two stages before grading begins. Following grading operations, the site is inspected and an "as built" grading plan and technical reports are submitted for review and approval. If all the reports and plans are acceptable, the city prepares a grading certificate and releases performance bonds. The procedure is not as complex for some other types of development, such as single lots, where questions regarding zoning and easements have already received attention.

Another activity critical to the success of landslide hazard reduction was the accumulation of the necessary scientific information to understand hazardous locations and situations. Intensive programs of geologic and special-purpose mapping were conducted by Federal and State agencies, in some cases in cooperation with the city and county of Los Angeles. A great deal of work was also accomplished by university faculty and students and the various private consulting firms in the area. Local meetings of the Association of Engineering Geologists and the American Society of Civil Engineers provided forums for the exchange of ideas and information. Members of both professional societies served on committees and contributed to the prepartion of the regulations. Other individuals and organizations, such as builders, homeowners' associations, and interested citizens, contributed similarly.

Members of the news media did their part as well. Landslides and related hazards became headline stories. The activities of the groups working on evaluating the problem and preparing the Grading Regulations were treated with in-depth reports that kept the landslide issue before the public even when their hillsides were not sliding.

These appear to have been the ingredients for the successful experiment in Los Angeles. This simplified account does not convey the countless hours spent by many segments of the community in formulating and implementing the program, the range of strategies proposed, and the debate among the various groups concerned. The storms of 1977–78 demonstrated that the program does not completely eliminate damages and hazards and can be further improved. Figure 5, which shows landslide damage in Los Angeles caused by these storms, reveals that not all the problems have been solved. Without the program in Los Angeles, however, losses would have been many times greater, and the efforts of the past 25 years will continue to help both Los Angeles and other communities looking for solutions to landslide hazards.

The experience of Los Angeles in reducing landslide hazards can be summarized into the following generalizations that may be applicable to other areas:

1. Damages and hazards from landslides can be significantly reduced. The technology is available in geology, engineering, construction, and government. Achievement of hazard reduction requires the perception of the necessity and the will to reduce the risk and damages.
2. Opportunities for community responses to landslide reduction programs arise during and immediately after the crises accompanying the hazardous processes and the resulting damages.
3. The development and implementation of the successful landslide hazard reduction program in Los Angeles contained at least three key elements that must be emulated for success in other parts of the United States. These are an able and concerned local government, a solid base of technical information about the hazards and a technical community able to apply and build on the information, and a citizenry that, on the whole, recognizes the need for appropriate regulation.

REFERENCES CITED

Alfors, J. T., Burnett, J. L., and Gay, T. E., Jr., 1973, Urban geology—master plan for California: California Division of Mines and Geology Bulletin 198, 112 p.

Blackburn, Chris, 1978, "Redflag" on Pillar Felt Hastle for Kodiak: Kodiak Daily Mirror, v. 8, no. 235, p. 1.

Blanc, R. P., and Cleveland, G. B., 1968, Natural slope stability as related to geology, San Clemente area, Orange and San Diego Counties, California: California Division of Mines and Geology, Special Report 98, 19 p.

Chassie, R. G., and Goughnor, R. D., 1976, National highway landslide experience: Highway Focus, Federal Highway Administration, v. 8, no. 1, p. 1–9.

Jahns, R. H., 1969, Seventeen years of response by the City of Los Angeles to geologic hazards, *in* Proceedings, Geologic hazards and public problems: Office of Emergency Preparedness, Santa Rosa, California, p. 283–296.

Leighton, F. B., 1976, Urban Landslides—Targets for land-use planning in California, *in* Urban Geomorphology: Geological Society of America, Special Paper 174.

Newman, E. B., Paradis, A. R., and Brabb, E. E., 1978, Feasibility and cost of using a computer to prepare landslide susceptibility maps of the San Francisco Bay region, California: U.S. Geological Survey Bulletin 1443, 27 p.

Nilsen, T. H., and Brabb, E. E., 1977, Slope-stability studies in the San Francisco Bay region, California, *in Coates,* D. R., ed., Landslides: Geological Society of America, Reviews in Engineering Geology, v. 3, p. 235–243.

Slosson, J. E., 1969, The role of engineering geology in urban planning, *in* The Governor's Conference on Environmental Geology: Colorado Geological Survey, Special Publication No. 1, p. 8–15.

Taylor, F. A., and Brabb, E. E., 1972, Map showing distribution and cost by counties of structurally damaging landslides in the San Francisco Bay region, California, winter of 1968–69: U.S. Geological Survey Miscellaneous Field Studies Map MF–327.

The Pronghorn Environmental Impact Statement: An Improved Prototype

By James R. Burns and Linda G. Marcus

INTRODUCTION

A common problem among Federal agencies is a tendency to prepare inordinately long environmental impact statements (EIS's) that fail to focus on real issues, impacts, and alternatives. The problem is more than superficial. It threatens the goals of the National Environmental Policy Act (NEPA) because few decisionmakers will ever read such bulky statements—many hundreds to several thousand pages each—much less get a clear picture of the issues involved. Many such EIS's tend to become justifications for decisions already made rather than aids to decisionmaking. The problem is most pronounced in two types of projects—those that are complex and controversial, where informed decisionmaking is particularly crucial, and those that are ill-conceived and poorly planned, the faults of which tend to be concealed by verbiage.

Much attention and several major studies have been devoted to this problem in the past 2 years, notably by the Council on Environmental Quality (CEQ), the Commission on Federal Paperwork, and the General Accounting Office. Executive Order 11991, requiring CEQ to issue regulations that would make EIS's more useful to decisionmakers and the public, was issued in 1977 with the comment by the President that "We do not want impact statements that are measured by the inch or weighed by the pound."

GEOLOGICAL SURVEY EFFORTS TO IMPROVE THE EIS PROCESS

As early as April 1976, the U.S. Geological Survey began a formal effort to improve its own EIS preparation process. Emphasis was on the internal improvements that would be consistent with current Federal policies and procedures and that would contribute to shortening EIS's, to improving their readability, and to making the process more effective in time, cost, and manpower while maintaining the legal adequacy and acceptability of the statements.

In this effort we searched for the roots of the problem through various facets of the process. These facets included the legal and regulatory background, the use of in-house staff and contractors, the work scheduling practices, the standardized EIS formats, the analytical techniques, and the roles of organizational elements within the Geological Survey.

Two elements of the problem must be accepted as "givens," as challenges requiring more innovative responses. The first is the diversity of needs among EIS users. Decisionmakers and some segments of the public need a clear and concise presentation of the proposal, its reasonable alternatives, the unavoidable impacts, and the principal issues involved. Others, at all levels of government as well as other sectors of the public, need detailed technical information to plan and to review the validity of the conclusions in the EIS.

The second "given" is the diversity of laws, regulations, and adjudications that govern the content of an EIS. NEPA itself is a brief straightforward statement of national policy that has been extensively defined by the courts as a result of litigation. The conditions for approval of a proposed Federal action and the range of alternatives to it are also influenced greatly by two separate bodies of laws and regulations—those dealing with environmental protection and those dealing with the authorities under which the Federal action is proposed. For the Geological Survey, the second category consists chiefly of a series of laws and regulations relating to the leasing and the development of Federal and Indian minerals. These laws and regulations are complex and are changed frequently. For example, since May 1976, there have been six modifications of the regulations governing management of federally owned coal. In addition, the Surface Mining Control and Reclamation Act of 1977 was passed, and regulations are being developed to implement it. With every change, the text for each coal mining EIS in progress had to

be reviewed for compliance, had to be amended as necessary, and had to be reanalyzed for impacts.

Another element of the problem, the selection of persons for the team employed to prepare an EIS, deserves careful scrutiny because important trade-offs are involved. Other factors being equal, persons with previous experience in EIS preparation can generally write a more acceptable EIS manuscript in a shorter length of time than those without prior experience. This premise can readily support proposals for the wider use of career environmental specialists, consultants, and contractors. However, such proposals can lead to reduced NEPA responsiveness by those who are involved in day-to-day project and planning activities. The Geological Survey has relied heavily upon in-house staff for EIS preparation. EIS specialists are chiefly confined to a small core group that manages, guides, and reviews the work. Teams composed principally of people detailed from the Operating Divisions, who collaborate with members of cooperating agencies to prepare the EIS, provide a broad diverse skill resource with flexibility for the changing workload. Many of the team members have not had previous specific experience in EIS preparation, although most have had experience in writing technical reports. The dominant consideration, however, is that EIS involvement promotes the growth of NEPA-oriented viewpoints and values within the operating staff of the Survey. This effect has been widely noted in Federal agencies employing in-house staffs for EIS preparation. Some have felt that it has been more beneficial to planning and to decisionmaking than to the actual direct use of the EIS's themselves. Our quest for improved staffing practices, therefore, has concentrated on better interactions between those with previous EIS experience and those without it rather than on increasing the proportion of EIS specialists involved. The principal trade-off illustrated here is between greater efficiency in achieving short-range goals, as by the use of a more experienced and specialized EIS preparation staff to produce better documents, and greater effectiveness in achieving long-range goals, as by the broader involvement of agency personnel in the NEPA process to produce better planning and decisionmaking.

All of these problem elements discussed above supported the Geological Survey's decision, with the approval of the Department of the Interior, to develop and to demonstrate a prototype for an improved, shorter, more readable EIS. The relationship of the first element, diverse user needs, to this decision is obvious. The second element, involving frequent changes of laws and regulations, demands a short and manageable EIS that can be amended rapidly when such changes occur during the process of preparation. The third element, which greatly affects preparation time requirements and which led to a quest for better interactions between experienced and inexperienced EIS preparers, deserves more extended comment. This will provide insight into the procedural problems attacked during the prototype effort. The scope and content of an EIS become essentially set during the period when the team prepares the preliminary draft statement. For an average Geological Survey EIS, this period accounts for little more than one-quarter of the total critical-path preparation time (which averages slightly more than 1 year); an additional one-quarter of the time is devoted to revisions and to responses to comments; the remainder is spent in initial planning and in external review, hearings, and coordination.

When massive EIS's (averaging 600 to 800 pages each) are the norm, the preliminary draft preparation period mentioned above is so short that writing must proceed almost from the outset; writing, therefore, becomes the vehicle for analysis. This often results in data being incorporated in the manuscript before their significance can be established through a completed analysis. At the end of the period, the manuscript is of unmanageable size, and insufficient time is left to edit it. A shorter EIS is absolutely essential to reduce the writing burden so that detailed preparation planning, analysis, writing, and editing can be put into proper sequence and balance and experienced people can interact at each stage and effectively influence the outcome, including, particularly, the quality of the product.

THE PRONGHORN EIS PROTOTYPE

The Federal action selected for the demonstration of an improved EIS prototype was approval of the mining and reclamation plan proposed by Mobil Oil–Consolidation Coal Co. for the Pronghorn mine in Campbell County, Wyo. The plan proposed surface mining of about 100 million tons of coal at a rate of about 5 million tons annually over 22 years, with reclamation of the area following the progress of mining.

The preparation process for the Pronghorn EIS differed from previous efforts by (1) an extended intensive planning phase that involved all concerned elements of the Geological Survey and the Department of the Interior and lasted for several months, (2) a preliminary draft preparation phase that was conducted in three sequential steps—instruction, data collection and analysis, and writing—and was completed in 2 months, less than one-half the normal time, and (3) an extended period for review and editing, during which it was possible to make major revisions and improvements in key parts of the text.

STANDARD EIS FORMAT

- Description of the proposal.
- Description of the existing environment.
- Environmental impacts.
- Mitigating measures.
- Adverse impacts that cannot be avoided.
- Relationship between short-term uses of man's environment and maintenance and enhancement of long-term productivity.
- Irreversible and irretrievable commitments of resources.
- Alternatives to the proposed action.
- Consultation and coordination with others.

PRONGHORN EIS FORMAT

Part A—Statement of Environmental Impact
Part B—Supporting Analysis and Data

- Description of the proposed Federal action.
- Probable effectiveness of reclamation.
- Analysis of anticipated impacts.
- Alternatives to the proposal.
- Consultation and coordination with others.

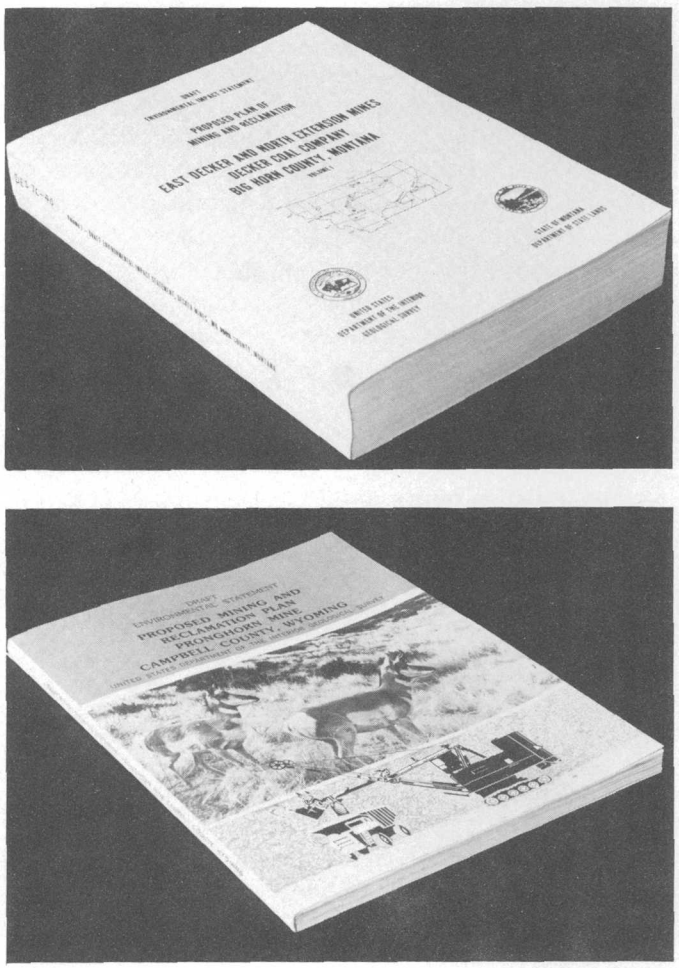


FIGURE 6 .—Comparison of standard EIS format and Pronghorn EIS format.

Persons experienced in the EIS process interacted effectively at each phase and had more influence than usual over the final outcome of the effort.

Figure 6 compares the traditional EIS format with the prototype format of the Pronghorn EIS. The Pronghorn format consists of Part A, Statement of Environmental Impact (31 pages), and Part B, Supporting Analysis and Data (122 pages). Part A is a summary intended for decisionmakers and others who are primarily interested in the salient features and conclusions of the EIS. Part B contains the detailed technical descriptions and analyses of the proposed action, the alternatives to the proposed action, and the impacts for planners and technical reviewers and others of similar needs.

Other significant features of the Pronghorn EIS format are as follows:

- *Proposed action.*—This section combines two formerly separate treatments, one addressing the applicants' proposal and the other addressing the mitigating measures that would be enforced by governmental authority.
- *Mitigating measures.*—The standard chapter on this subject, dealing with special measures to reduce impacts, was eliminated. Measures that will be expressly required are included in the description of the proposal that is then analyzed for impacts. Measures subject to the decisionmaker's discretionary authority are included in the section on alternatives. This eliminates confusion as to the status of individual mitigating measures. It also avoids a previous practice of analyzing impacts before considering required mitigations; this produced unrealistic conclusions.
- *Description of the environment.*—The standard chapter on this subject was eliminated, and necessary background information has been redistributed among other sections. CEQ's guidelines had called for such information only as needed to understand the proposal, its alternatives, and their impacts. This chapter had accounted for 42 percent of the total pages in five recent EIS's prepared by the Survey. It appeared to be the object of most complaints about sheer volume and encyclopedic detail.
- *Effectiveness of reclamation.*—A separate section was established for this subject. Reclamation, a composite of various impacts and mitigating

measures, tends to be fragmented within the standardized departmental EIS's, yet it is a recurring major issue in surface mining proposals. This section reflects an intent for flexibility of format whenever needed to focus on any major issue that might arise in future statements dealing with different kinds of proposals.

- *Environmental impacts.*—The section dealing with this subject is divided into two parts that distinguish onsite impacts from countywide and regional impacts of the proposed action. This promotes a better focus on additional major issues such as social, economic, and community impacts. In the traditional EIS format, three additional chapters had summarized the impact analysis from varying viewpoints, as explicitly required by NEPA. By incorporating these viewpoints in the summary of the Pronghorn EIS, repetition has been reduced.
- *Alternatives.*—This section includes alternatives to the proposed action based on administrative options (for example, approve the proposal, delay approval) and on operational modifications involving additional mitigating measures that the Secretary of the Interior could order. Included are measures that address mitigation of the social and economic energy-related impacts being experienced by Campbell County and the city of Gillette which are beyond the functions and authority of the Department of the Interior. The alternatives are retained in a separate section from the proposed action because the alternatives are not of a type that is amenable to the same depth of description and analysis as the basic proposal. In the Geological Survey's experience, this has generally been true of proposals initiated by nongovernmental applicants, where the principal available alternatives include rejection, deferral, and various modifications of the original proposal.
- *Significance of impacts.*—An attempt has been made to give the reader some perspective on the significance of impact levels. Impacts from the Pronghorn mine have been related to the total impacts of energy-related activities in the area. Supported by quantitative data, qualitative terms defining magnitude and duration of impacts have been introduced to provide further perspective of significance.
- *Readability.*—To make the document easier to read, a double-column format has been used. Tables and figures are used to summarize and highlight key facts. The summary of impacts (Part A) uses interspersed charts for quick access to key facts about each impact. Boldface headings are used liberally to aid judicious skimming. Key conclusions are underscored in Part B.
- *Supporting data.*—Background information of a detailed technical nature has been removed from the EIS. Some of it is available in a corresponding Geological Survey open-file report; the remainder is accessible upon request from task force files.

RESULTS

The draft EIS on the Pronghorn mine was filed with the Environmental Protection Agency in July 1978. At this writing, completion of the final statement and its use in decisionmaking have not yet occurred. Evaluation of the prototype effort at this time is, therefore, preliminary and is based on (1) user reaction during the public and interagency comment period, (2) relationship of the format to CEQ's proposed regulations for implementing procedural provisions of NEPA, and (3) the in-house preparation experience.

Questionnnaires requesting reaction to the new format were sent out with all copies of the EIS, and the majority of the 52 responses received indicated that (1) this EIS is clear and easier to understand, (2) the information presented in Part A of the report was sufficient for readers to understand the proposed action, alternatives, and environmental impacts, and those responding believed it provided a sufficient basis for making a decision, (3) the supporting analysis and data provided in Part B was occasionally used to more fully understand information presented in Part A and was sufficient to answer questions raised in Part A, (4) most readers would like future EIS's to use a summary that covers the proposed action, significant impacts, and alternatives in less than 50 pages and supporting data and analysis provided in a separate section not to exceed 150 pages, and (5) readers were evenly divided as to whether future EIS's should include a separate section for discussing the probable effectiveness of reclamation.

In addition to reaction received on the questionnaire, several of the agencies that formally reviewed the content of the EIS also offered strong support of the abbreviated format. All of those persons who testified at the public hearing held at Gillette (the mayor, the city-county planner, a representative from an environmental group, and the applicant's representative) strongly supported the new format for its brevity and readability. A comment of particular note is that this EIS succeeded to an unusual degree in presenting technical information in such a way as to be understandable to a layman.

CEQ's proposed regulations were published on June 9, 1978,[1] shortly before the Pronghorn statement went to press and did not apply to Pronghorn EIS. The format provisions of those proposed regulations had no direct effect upon the Pronghorn EIS format. Nevertheless, overall objectives of the two appeared to be compatible and were the subject of informal discussion between CEQ and the Geological Survey prior to June 9. Preliminary analyses indicate that the format developed for the Pronghorn EIS would require the following principal adjustments for compliance with CEQ regulations based on the June 9 proposal: (1) expansion of the introduction to Part A into a 5- to 15-page summary of the statement, (2) inclusion of the alternatives in the description of the proposed action and the impact analysis, (3) restoration of a section on description of the environment, and (4) possible elimination of the separate section on the effectiveness of reclamation.

From the in-house preparation experience, the findings of the team that prepared the Pronghorn statement are best expressed by an official of the Bureau of Land Management, which cooperated in the effort and provided staff for the preparation team:

> "The entire team found the new format superior to the traditional ES format. The writers consistently felt much more comfortable with the new format for several important reasons:
>
> 1. Although new, it was much clearer and easier to understand than the traditional format.
> 2. It was more direct and, therefore, did not contain the redundancies in writing that are often required in the traditional format.
> 3. The amount of writing time required under the new format was sharply reduced. This meant two things: first, it freed the writer to spend more time on the quality rather than the quantity of his or her writing. Secondly, it meant that the total length of the project was of a more reasonable duration which made it easier to sustain interest and momentum in the project. This added up to the writer's being able to produce a better product in less time, under more reasonable time schedules, both per section and for the project overall."

This prototype effort per se was aimed primarily at product improvement and not specifically at savings in time or cost. However, as described in the quotation above, the preliminary draft preparation phase was markedly shortened. This is the most manpower-intensive phase of all, hence, the most costly per unit of time. Savings here were balanced by extended planning and review phases in the case of this initial effort, but it is likely that planning and review could be shortened if the prototype format became routine. This might result in some overall savings in time and cost for future EIS's.

In summary, the Pronghorn EIS prototype has gained wide acceptance among users and reviewers as being more responsive than previous EIS's to their various needs; and it makes possible a more efficient and expeditious preparation process. Further evaluation is needed, specifically in its use in final decision-making and in its compliance with CEQ regulations. Results of the study and analysis effort that led to this prototype are expected to be beneficial in further efforts to improve the EIS preparation process.

[1] CEQ's final regulations were subsequently published after this writing on November 29, 1978.

Petroleum Exploration and Environmental Protection in the Alaskan Arctic

By M. E. Britton

INTRODUCTION

Nowhere are the environmental sins of summer more immediately apparent or those of winter emerge so promptly and visibly with the snowmelt of spring than on the treeless tundra. The tundra of Alaska's North Slope, from the crest of the Brooks Range northward to the Chukchi and Beaufort Seas (fig. 7), is a major challenge to the engineer who has a job to do and who must, in some degree, disrupt the environment and to all who insist upon its protection. Nowhere is it more evident that known environmentally compatible engineering practices provide the greatest economy and environmental protection and that the best of protection demands them. Compatibility is achievable in most respects, but it remains lamentable that absolute protection occurs only through no exploration and that any exploration leaves its mark.

Tractor train tows sled-mounted living facilities over winter trails. Large low-ground-pressure tires and sled runners have little effect on the frozen snow-covered ground. Photograph by Robert Mallahan.

On June 1, 1977, the U.S. Geological Survey became responsible for the management of a large petroleum exploration program in the National Petroleum Reserve in Alaska (NPRA), which is located on the North Slope. With this role came the responsibility and the commitment to achieve the exploration goals with the fewest possible adverse effects on environmental values of all selected areas of operation. As will be seen, degradation of local scenic qualities in essentially wilderness country is the least avoidable and most enduring environmental heritage of exploration. There is no satisfactory solution for this effect, only cosmetic procedures which may blur but not eliminate the small and widely scattered blemishes on the natural scene.

Present knowledge of correct protection procedures accrues from the experience of all circumpolar countries with lands within the Arctic (Canada, Greenland, Norway, the United States, and the U.S.S.R.). Much of this knowledge, however, has evolved within NPRA (formerly the Naval Petroleum Reserve No. 4); many Geological Survey personnel were involved, some of whom still provide their expertise for today's exploration program.

Two major developments historically impacted the Reserve. First, the Department of the Navy Oil Exploration of 1944 to 1953 was accomplished with little understanding of environmental protection yet provided the training and experience for today's arctic operations. By present environmental standards, inexcusable errors were made—bulldozed trails became canals, thin gravel roads subsided, heated buildings sagged, and the litter of exploration was carelessly left in place, ultimately to demonstrate the slowness of arctic decay and corrosion to eliminate eyesores.

The second development was the construction of the Distant Early Warning Line of radar stations by the U.S. Air Force. This time, environmental concerns in engineering design were considered, and Survey personnel who had learned their lessons in the Reserve made major contributions to site selection and to the design of arctic-worthy camps, roads, and airstrips which were both functional with low maintenance and protective of the environment. The basic lessons had been learned and heeded, except for abandoned litter.

A third, and by far the largest North Slope development outside NPRA but sharing the same problems, occurred at Prudhoe Bay following the very significant oil and gas discovery in 1968. Although initially resisting the accumulated arctic operational knowledge and, incomprehensibly, repeating the error of bulldozing the first access roads, the industrial complex at Prudhoe Bay eventually became a model of good arctic engineering and, consequently, environmentally sound.

THE NATURE OF THE PROBLEM

NPRA is 37,000 square miles of coastal plain, foothill, and mountain tundra essentially without roads and having airstrips at only a few principal bases. Permafrost is continuous, and fine-grained surficial materials that predominate are rich in pore ice and massive segregated ice, often as polygonal networks of ice wedges. The ground is usually covered with at

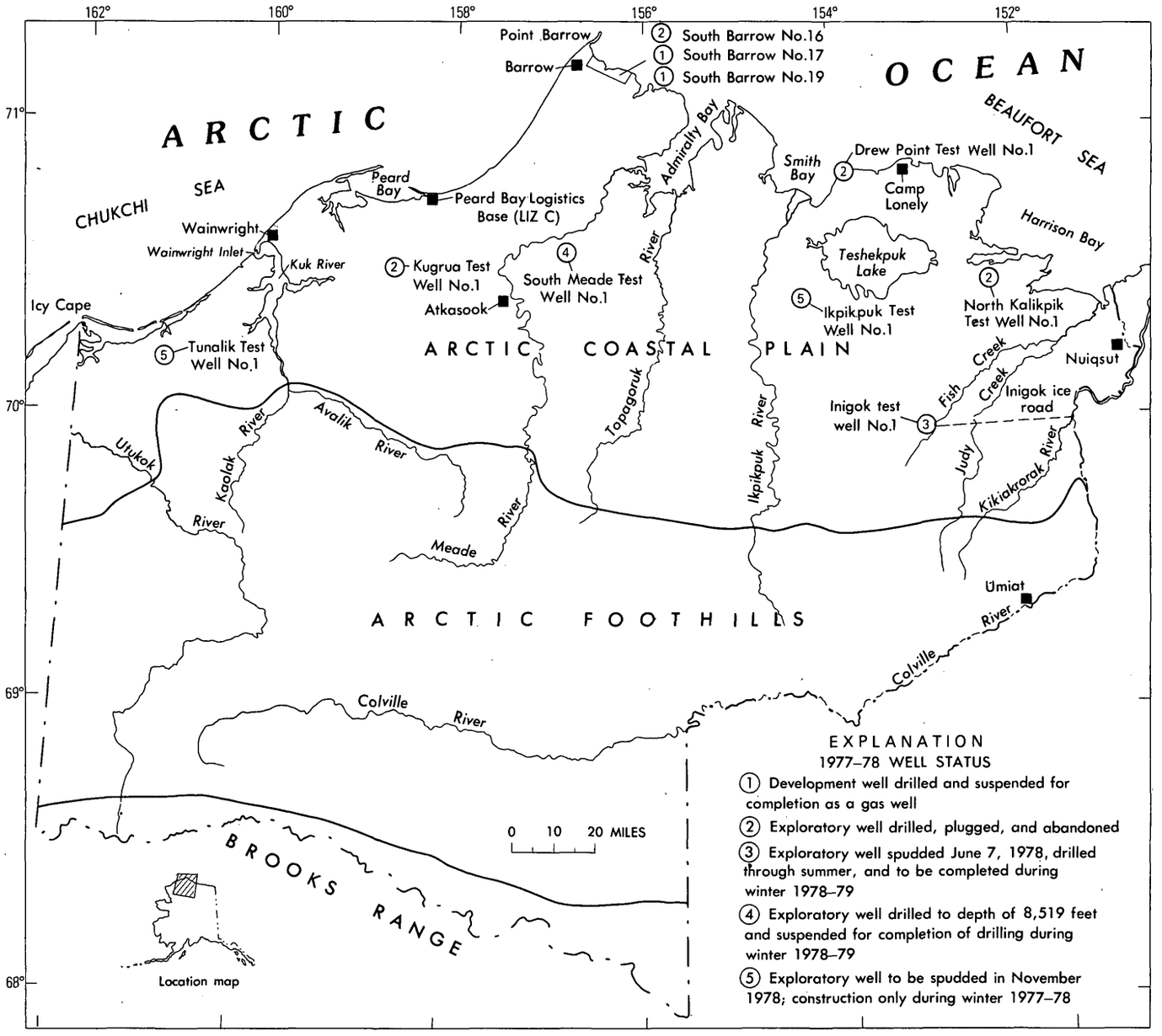


FIGURE 7.—National Petroleum Reserve in Alaska.

Inigok Test Well No. 1, a deep well requiring year-round drilling, is located between two large lakes in an area of ice-wedge polygons with many small ponds. The sand and gravel pad and the diked reserve (mud) pit occupy about 14 acres. The drilling rig and all living and working facilities are confined to the pad; the portable camp living quarters are lined up at the upper margin of the pad. At the right of the reserve pit is the diked membrane-lined fuel storage pit containing two fuel bladders, and, at the lower left, is the flare pit. An all-season sand and gravel road leads from the right side of the pad to the all-season airstrip (not shown). Photograph by Charles Andrews.

least a few inches of organic mat, or peat, an effective thermal insulator. Summer thaw penetrates from about 6 inches to about 18 inches in fine-grained materials and from 5 to 6 feet in better drained sands and rare gravels. Under the thawed zone, referred to as the active layer, lies the permafrost table, which is the upper surface of the permafrost which itself extends downward for hundreds of feet. Ponds and lakes abound on the coastal plain and are surrounded by swamplands in summer.

The tundra is home for the migratory caribou; the Western Arctic Herd calves in the foothills in spring, grazes over the entire tundra in summer, and, for the most part, moves to the mountains in winter. Other mammals include grizzly bear, moose, fox, wolf, wolverine, least weasel, and small rodents. Hundreds of thousands of migratory waterfowl, shorebirds, and songbirds populate the area in summer, but only a few kinds of birds, such as snowy owl, raven, ptarmigan, and gyrfalcon, are winter residents. The endangered migratory peregrine falcon is a summer resident on bluffs, principally along the Colville River. The larger deeper lakes and streams contain fish populations important to Native subsistence, and marine sea mammals, including polar bear, seal, walrus, and whale in spring and autumn migration, are found offshore and are heavily harvested.

Into this pristine land rich in renewable resources, significant for wilderness qualities and for the cultural and economic well-being of Natives, exploration for nonrenewable resources is an intrusion but not a major threat to natural values. In perspective, the area is large, and the exploratory program, although intensive, is relatively small. For example, in fiscal year 1978, seismic reflection surveys covered 1,935 miles, mostly in the foothills, and including 257 miles in offshore bays and lagoons. The 10 drilling sites (fig. 7) were constructed during the 1977–78 winter; drilling was completed at six sites; one well was suspended for continuation in the winter of 1978–79; and on

June 7, 1978, a deep well, Inigok Test Well No. 1, was spudded, and drilling continued through the summer.

Experience has demonstrated that environmental problems stem primarily from construction and overland transportation. The question is, how to transport to remote sites the thousands of tons of machinery, muds, pipe, fuels, and other supplies; construct all needed facilities; and complete drilling, clean up, and restore the site without leaving "footprints," creating erosion and siltation, destroying wildlife habitat, disturbing the behavior of birds and mammals, or interfering with subsistence activities or cultural resources of Natives?

HOW THE ENVIRONMENT IS PROTECTED

Arctic experience uniquely teaches that the rigorous winter is the season of choice for outdoor engineering operations. The cardinal rule at NPRA is to concentrate all potentially disruptive construction work and surface transportation in winter. Summer is the season for activities that produce the least environmental disturbance and that enhance the opportunity for greater protection the following winter. Among these are survey of drilling sites and seismic lines; selection of water sources, ice road routes, and material sites; cultural resource inventory; staking of winter trails; geologic and ecological research; and surface restoration and rehabilitation of previously used sites. Such activities accomplished by personnel operating from aircraft and on foot have few environmental implications beyond minor human presence and noise. An exceptional case is the summer drilling operation at Inigok Test Well No. 1, but, with the construction phase accomplished during the winter, the principal disturbance to wildlife is largely one of noise—that of aircraft on logistics missions.

The Ground Surface

"Save the Surface and You Save All," the slogan of a paint manufacturer, has special pertinence to the tundra, although not a complete answer to all environmental problems. Permafrost preservation is a concomitant goal of all construction and transportation.

In the Arctic, the strength of otherwise unconsolidated surficial materials depends largely upon ice cementation, and the loss of rocklike properties is instantaneous with ice melt. The consequence is loss of mechanical strength, subsidence proportional to the ice-volume loss, destruction of surface, ponding, and the accumulation of a slurry of supersaturated organic and inorganic materials. On slopes, water drainage, mudflows, and downhill creep of soils become sources of siltation to tundra surfaces or water bodies. The active layer depth represents an equilibrium between available heat and the biological and physical properties of the surface and substrate. All possible precautions are taken to avoid disturbing in any way the equilibrium by increasing heat penetration and thaw. Surfaces cannot always be preserved, and it is necessary to examine two cases, one which degrades permafrost and one which does not, although other surface features are lost.

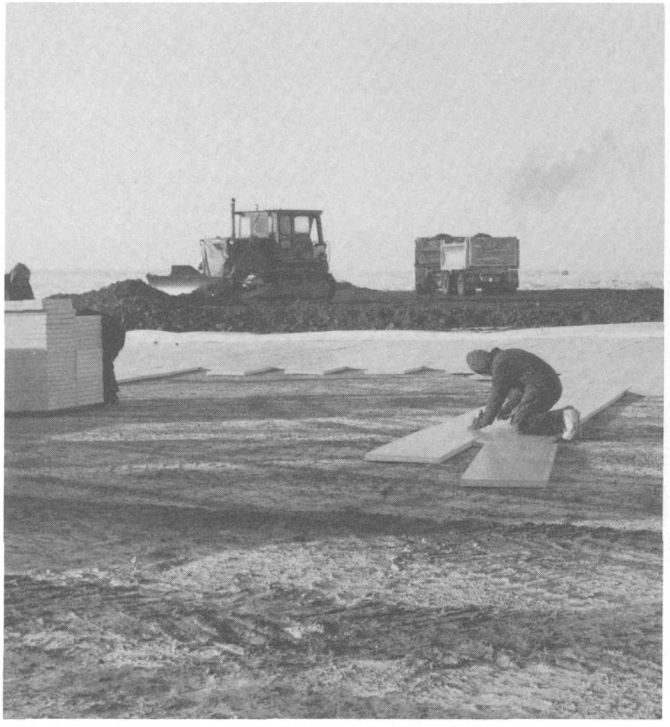
EXCAVATION OF CONSTRUCTION MATERIAL

Material borrow is a surface-destroying process over a few acres at each site. All pad construction requires locally available sand and (or) gravel. Gravels contain little or no ice and are usually stable when thawed but are very scarce at NPRA. In 1978, some gravel was taken from marine beaches at Barrow, Lonely, and Peard Bay and from an old river bar on the delta of the Kikiakrorak River (fig. 7). There is little effect from such borrow because the surfaces are devoid of vegetation and removal is not made below water line. Sands, which are somewhat more plentiful, are the most commonly used. They contain some ice wedges and usually have an active layer 5 to 6 feet thick. Slumping occurs with thaw, but the materials are relatively stable thereafter.

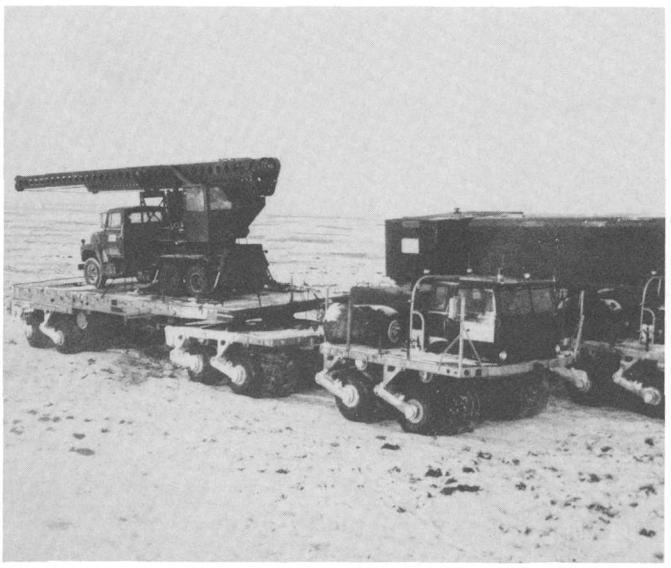
PAD CONSTRUCTION

Sand or sand and gravel pads provide the working and living surfaces at each drilling site and the short local all-season roads and airstrips at the Tunalik and Inigok wellsites. Pads bury all surface features but preserve permafrost. A pad 5 to 6 feet thick laid on top of undisturbed tundra is sufficient to maintain the frozen condition at the latitudes of NPRA, but this is not critical in a single winter's operation, and thinner pads are often used. A pad of proper thickness will contain the wave of summer heat penetration so that the temperature does not rise above 32°F at the permafrost table and melt buried ice. This engineering practice is the secret of all successful road or other enduring pad construction over permafrost. To assure the stability of the two all-season airstrips in the absence of completely satisfactory construction material, special precautions were taken in design. Styrofoam board insulation, 3 inches and 2 inches thick at the Inigok and Tunalik sites, respectively, overlain by a plastic membrane moisture barrier, was laid beneath the top course of 18 inches of gravel. Each 1 inch of such insulation reduces the gravel requirement by about 1 foot. Thin pads, used briefly in winter and abandoned, induce minor thaw and subsidence that result in wetter substrate and more favorable environment for plants, and, therefore, more rapid revegetation.

Ice road 1 foot thick protects the tundra surface under heavy traffic of 20-cubic-yard dump trucks hauling gravel. Photograph by John Schindler.



The all-season airstrip at Tunalik Test Well No. 1 is under construction in March 1978. Building on a subgrade of sandy gravel, styrofoam insulation is laid and is overlain by a sheet plastic moisture barrier. The surface wearing course consists of 18 inches of compacted gravel. Photograph by Husky Oil NPR Operations, Inc.



Soft-tire Rolligons are used for overland transport of cargo on unprepared surfaces of winter trails. Photograph by Husky Oil NPR Operations, Inc.

Construction of the supporting structure of the drilling rig for a deep well, which must be drilled through at least one summer season, requires special protection of frozen ground around the well head. Wooden piling set as much as 40 feet into permafrost provides stable support for the rig, and styrofoam insulation installed in the drill pad retards heat flow to the pad from machinery and heated structures; this is especially important during the summer period of higher ambient air temperatures. Hotter muds from deep wells also require insulated conductor pipe and special thermal design of the cellar (neither shown) to preserve the integrity of the frozen ground immediately around the well. Photograph by Husky Oil NPR Operations, Inc.

ICE AIRSTRIPS

The large numbers of coastal plain lakes are a ready environmental asset used routinely for ice airstrips accommodating all project aircraft, including large C–130 Hercules cargo planes. The strips are economically constructed by removing or dragging and compacting snow, sometimes supplemented by water flooding to hasten ice thickening. The method is highly effective, and the disturbance to tundra surfaces is avoided.

SNOW AND ICE ROADS

Access roads of this type are used for all local winter traffic between drilling sites, airstrips, borrow pits, and lake water sources and, properly used, prevent tundra damage. Snow is compacted over frozen ground and repeatedly flooded with water to build up ice layers. Light traffic requires only a thickness of 3 to 4 inches of ice but at least 12 inches are required for heavy duty, such as gravel haul. One road 37 miles in length was built to enable the transport of 88,571 cubic yards of gravel from the Kikiakrorak River delta to the Inigok all-season airstrip.

OVERLAND WINTER TRAILS

All overland traffic is strictly confined to carefully selected staked trails in winter, whether for heavy-duty freight or seismic parties, and is permitted only after the ground is frozen and snow covered and before the beginning of spring thaw. No bulldozing is allowed except occasionally for snow removal and then only to depths not reaching the organic tundra mat. Vehicles are selected for low-ground-pressure qualities and may be rubber-tired carriers of the Terra-tire or Rolligon type or track-laying tractors towing sleds. Additional tundra protection is achieved by successive tractor trains over the same trail traveling in off-setting tracks. Lake and lagoon ice surfaces are used as much as possible, and their banks are crossed at low approach angles to avoid track or wheel slippage and churning of the surface.

WASTE DISPOSAL

Mobile parties and construction camps utilize incinerator toilets, and filtered disinfected gray wash water is discharged to tundra depressions or small ponds. Drilling camps and the Lonely Base Camp are equipped with sewage treatment plants, and warm sewage effluent, including gray waters, is treated to Environmental Protection Agency–State of Alaska secondary standards and is discharged as mentioned above. Such liquid discharges have no appreciable effect on thaw in winter or summer but may affect vegetation.

During earlier operations in the Reserve, the tundra was left littered with wood and metallic debris. Casual surface dumping today is not only unthinkable but illegal. The solution is effective but costly. All solid wastes are incinerated if burnable. All nonburnable solid wastes, including ashes and excepting drilling muds and cuttings, are hauled back to Lonely, usually by aircraft, for disposal in sanitary landfill approved by the State of Alaska. Drilling muds and cuttings are accumulated in reserve (mud) pits excavated into permafrost as part of the drilling pad. The reserve pit volume is sufficient to contain all drilling muds below the level of the permafrost table; this precludes leakage. Additionally, the pits are diked with sand or gravel as a precaution against any unforeseen volume increases. Disposal is by burial in place, utilizing sand and gravel taken from a portion of the drilling pad at the time of abandonment or the following warm season. Within one winter, the materials are solidly frozen and qualify as permafrost. Surface disposal of muds is practiced in the Barrow Gas Field because the wells are shallow and the mud volumes are small. Disposal causes insignificant thermal problems but does bury small areas of surface, which are indiscernible after a few years.

Vegetation

Plant cover was destroyed during 1977–78 winter drilling season by excavation of 73.4 acres of borrow pits, by burial beneath 163.6 acres of drilling pads, airstrips and related facilities, equipment storage pads, all-season roads, and by mud disposal at Barrow. An additional 88.6 acres of barren beach gravels were utilized by shallow surface removal of construction material in some cases or simply by leveling in the case of a temporary C–130 airstrip at the Peard Bay Logistics Base (LIZ C).

Otherwise, the project has little effect on vegetation as it is protected by snow cover in winter and there is no off-road traffic in summer. Occasionally, woody plants extend above the snow layer where, in a condition of brittleness at low temperature, small branches are broken. Tall willow shrubs, which occur along some rivers, are avoided by vehicles if possible, otherwise attempts are made to follow paths avoiding straight lines.

At times, winter trails and ice roads experience some compaction of the organic mat and minor puddling of water in slight depressions the following warm season. Interestingly, this provides improved growing conditions, and the grasses and sedges respond with greater vigor, forming "green trails" in the duller green of the tundra.

Similar green spots on land and algal blooms in ponds result from the fertilizing effect of discharged sewage effluent. Other "trail scars" may result from mechanical disturbance to sedge tussocks, especially

Caribou of the Western Arctic Herd graze throughout the NPRA in summer. This group exhibits the common reaction of flight to the noise of low-flying aircraft. Photograph by John Schindler.

in the foothills, or exposure of soils, if vehicles unexpectedly encounter thin snow. Compacted snow loses its insulation efficiency in ice roads, and, on occasions when air temperatures are extreme, plants may be damaged or killed. These events have little impact on the vegetation resources, but the scars are visible for 2 or 3 years and degrade the aesthetic quality of the landscape. Tundra fires are rarely seen, but, during the unusually dry summer of 1977, a fire of human origin burned several acres at the Inigok site. Recovery from such fires is rapid.

Wildlife and Their Habitats

Except for accidental oil spills, to be discussed later, operations hold little threat for wildlife. One of the major benefits of winter operations is the avoidance of caribou, except stragglers, and all migratory birds, including waterfowl and the endangered peregrine falcon. Daily burning of garbage diminishes attraction of ravens and mammals and avoids their conflict with workers. Hunting is not permitted within 5 miles of any work site, and all forms of harassment are forbidden.

DESTRUCTION OF HABITAT

Unavoidable habitat destruction was identical with the acreage of vegetation destroyed, as discussed in the section on vegetation. These amounts of land surface, divided among the several drilling sites, are small relative to the resources available. Some bird nesting and small rodent habitat is lost, hunting area of predators is diminished, and grazing area for caribou is reduced slightly.

Borrow pits, especially at Tunalik and Inigok, and airstrip construction on a sandy ridge at the latter of these two sites are destructive of upland habitat used by birds for nesting and feeding. Loss of willows will have some effect on ptarmigan which feed on willow buds. A more direct loss, unfortunate but unavoidable, is destruction of occasional hibernating ground squirrels and their dens. More rarely fox dens are also destroyed. Peregrine falcon habitat is strictly avoided in all seasons.

HUMAN PRESENCE AND NOISE

Animals may be deprived of habitat or exhibit fright reactions as a result of activities of workers and

the noise of surface vehicles, drilling machinery, seismic explosions, and aircraft. In winter, the few animals encountered move away from disturbing noises, ignore them, or, in some cases, as with caribou, may be attracted to them if there is no additional threat to their safety. Any animals displaced by transient noises of overland tractor trains and seismic parties return to normal range and activities when the disturbance has passed. The sounds of seismic explosions in winter are muffled, the detonation being more felt than heard, and have little disturbing effect on the few animals present. Most disturbing to birds and mammals are summer aircraft operations. The only protection is avoidance of highly sensitive areas such as caribou calving grounds, peregrine aeries, principal waterfowl nesting areas, and open leads in pack ice during whale migration. It is inevitable that some displacement of birds will occur as a result of summer air activities at the Inigok airstrip.

Water Resources

Ponds and lakes are the sources of water for domestic uses, well drilling, and ice road construction. Rivers are not used at all in winter, but many could be safely used in summer. Snow melters are often used by seismic parties or in any other case where lake water is not readily available and the cost of fuel is favorable relative to the cost and greater potential of environmental effects of long hauls. The principal concerns are excessive withdrawal of water, siltation, and introduction of oils, which will be discussed later.

WATER WITHDRAWAL

Water requirements are high—ice roads use about 1 to 4 acre-feet per 1 mile, depending on thickness and length of time in use; drilling a medium depth well requires about 5.25 acre-feet; and a deep well requires about 26 acre-feet. Water is readily available for ice roads early in winter and is obtained for this purpose largely from shallow tundra ponds that do not contain fish. Lakes less than 6 feet deep do not contain fish because the lakes freeze to bottom in some years. These are abundant, especially on the coastal plain, and are used until late winter when maximum ice thickness is attained and the water supply is gone. Deep lakes, which are scarce, are always used if conveniently available because there is no threat to fish by water withdrawal. Difficulties arise with lakes that are only a few feet deeper than the maximum depth of freeze and that contain fish. Drawdown of water in such cases holds the threat of killing fish by depletion of oxygen supply. Lakes of sufficient size and of a bottom configuration providing a large acreage of water a few feet deep below maximum ice thickness are selected and readily provide for all water needs and entail only a few inches of drawdown.

If only 1 foot or so of residual water exists beneath the ice and fish are present, withdrawal is restricted, and several source lakes may be used. As a matter of policy, any lake with water present under 6 feet of ice is considered to contain fish even though their presence has not been demonstrated. All water intakes are screened to prevent entry and killing of fish.

SILTATION

Protection against siltation is effected by avoidance of erosion and by control of erosion in the event of occurrence. The principal concern is siltation of fish spawning beds in streams and lakes. Because little activity is associated with streams, the probability of the program causing any problems is small. Excavation of borrow pits in silty sands is a potential threat if near a stream or lake, but such sites are usually avoided or drainage is diverted sufficiently to permit settlement and containment of silts on land. Sand deposits, mainly of eolian origin, contribute considerable silts naturally, and borrowing practices, which reduce slope angles, may even reduce the amount of their downslope transport.

SEISMIC EXPLOSIONS

Fish and spawning beds are protected by prohibiting dynamite shot holes any closer than 300 feet to thermal springs, deeper lakes that do not freeze to bottom, or designated anadromous streams, except where those waters and underlying sediments at the time of shooting are completely frozen. Variances are sometimes obtained from regulatory agencies when surveys require especially critical data. Air guns, or a modification called a mud gun, which employ compressed air as an energy source, are used in offshore marine environments to avoid the harmful effects of dynamite to fish and sea mammals.

Archeological and Historic Sites

Integral parts of the environment are the ancient and modern sites recording the history and culture of arctic man. The exploration program adheres to all Federal and State regulations for preservation of archeological and historic sites. In 1978, a cultural resources survey was conducted by professional archeologists over all areas of operation, and no area was used without official clearance. All identified cultural sites are protected by complete avoidance.

In two cases, Tunalik Test Well No. 1 and South Meade Test Well No. 1, critically needed borrow areas proved to be significant archeological sites. These sites were authorized for excavation and study by professional archeologists, under Federal Antiquities Act permit 77–AK–079. Only the Tunalik bor-

row site was ultimately used, clearance for use being issued following completion of the study.

Scenic and Aesthetic Values

All activities are an intrusion on the natural scene which, except for the long-disturbed coastal fringe of the Reserve, is de facto wilderness. Although observed by few people, many of them consider the active operations a degradation of environmental qualities. At the end of operations, cleanup, abandonment, and rehabilitation, all constructed pads and, to a lesser degree, borrow areas are conspicuous, especially as viewed from the air. Recontouring of sand pads breaks their linearity, and wind action will redistribute sands into dunelike mounds. Gravel airstrips at Inigok and Tunalik must be abandoned without earthworking to avoid exposure of insulation and littering of the tundra by windblown debris. These airstrips will be evident on the landscape into the distant future and perhaps will be permanently visible in configuration even though ultimately covered by vegetation. Alteration of the natural scene is the most serious environmental effect anticipated in the exploration program. Any protection rests with success of rehabilitation procedures, most of which cannot be completely effective. The scars of work sites and any accidental trail scars, described above, are a long-term legacy of exploration, and only natural processes of revegetation and animal repopulation can restore them to a degree of similarity to surrounding tundra. Two to three decades may be required to accomplish the transformation.

ACCIDENTAL FUEL SPILLS

Accidental spills during transport, transfer, and storage of gasoline, jet fuel, and fuel oil; refueling of vehicles and aircraft; and leaks of oils and greases from vehicles are a constant threat prevented only by good equipment and the best management and labor practices. Considering that several million gallons of fuels and oils are used in an annual program, it is inevitable that some spills will occur, usually the result of human error. The potential of spills and leaks at ice airstrips to cause environmental damages to

At a temporary fuel storage facility, two fuel tankers mounted on tracked trailers are blocked above ground level on timbers to facilitate transfer of fuel to truck tanker (left). A wooden containment structure forms an aboveground "pit" which is lined with an impervious plastic membrane to retain any accidental spills or oil leaks. Photograph by Husky Oil NPR Operations, Inc.

lakes is an ever-present danger. No storage of petroleum products is permitted on lake ice at drilling sites, seismic camps, or any other work site. Refueling requires use of containers for nozzle storage and prevention of dripping to the ice.

Avoidance of leaks and spills is the primary goal, followed by alertness to any that do occur and prompt cleanup. Oils on lake ice at low winter temperatures do not spread far and are relatively easy to recover and dispose of by approved methods. Spilled fuel oils not recovered from the ice, as well as any spilled during the summer, are a threat to all biological components of lakes and streams. Toxicity of the more volatile fractions of petroleum are biologically harmful, and heavier fractions have particularly adverse effects on waterfowl by oiling of feathers and loss of flying and feeding capabilities and thermal protection. Spills on water are contained by booms and removed by skimming and using sorbents.

Overland transport of fuels is usually in steel tanks, and, at logistics bases and wellsites, fuels are stored either in tanks or bladders in diked pits, which are lined with an impermeable plastic membrane.

Small spills of a gallon or so on land are usually on a work pad surface and are readily cleaned up. Spills on any land surface are more readily cleaned up in winter as they occur on snow which can be scraped up and the product separated and burned under approved conditions, although gasoline quickly penetrates the snow cover. In summer, any spill or leak reaching the tundra surface is difficult to recover because the spongy surface holds oil as well as any sorbents used to soak it up, and removal by mechanical means is often as destructive to the surface as is the oil. Any large spill on the tundra would kill vegetation and, in summer, would result in thaw and subsidence. The extreme case would occur in the unlikely event of an oil-well blowout which might cover several acres. Protection against such an event is good blowout-prevention equipment, frequently tested for operation, and efficient well-trained crews following prescribed regulations under the surveillance of the Survey Oil and Gas Supervisor.

REHABILITATION AND RESTORATION

There are limited procedures which can mitigate the effects of exploration, but no disturbed site can, of course, be fully restored. The principal concern is to control erosion and, otherwise, to diminish the visual effects and to get the surfaces into a condition where natural processes of revegetation will ultimately restore areas to something near the natural landscape appearance.

Borrow pits, and, to some degree, the drilling pads, are recontoured by bulldozing, then fertilized with mineral nutrients, which are very deficient in the tundra, and seeded with mixtures of perennial agronomic and native grasses found to be effective on the Alyeska Oil Pipeline project. Such revegetation is successful for a time on some sites, but the record is spotty. Because water is deficient in the sandy area of most borrow pits, seedling survival is tenuous. It is expected that repeated fertilization and reseeding will be necessary on some sites before natural revegetation with native species is far advanced. When possible, surface soils and clumps of plants are stockpiled and redistributed to the surface of borrow pits. Some plant parts will survive the procedure and will provide a vegetative means of restoring some native species.

All areas of operation, including ice roads and winter trails, are inspected during the first summer following use to determine the nature of any damage and any requirement for erosion control. Scars on the tundra, in the absence of erosion, are usually left to natural processes of restoration, but, in case of severe surface disturbance, these, too, will be seeded. The slow natural repopulation of disturbed terrain by plants and animals will provide the long-term solution to stabilization and restoration.

ENVIRONMENTAL MONITORING

Protection of environmental values depends upon continuous, close, and effective monitoring and inspection of all exploration activities to assure compliance with all applicable laws, regulations, and stipulations. This role is shared between the Geological Survey and the Bureau of Land Management (BLM), which has the overall surface management responsibility of NPRA.

The two bureaus have established their individual and mutual responsibilities for management, including environmental protection, by agreement to terms of a Memorandum of Understanding (MOU) with Cooperative Procedures of January 18, 1977 ("Federal Register," v. 42, no. 16, January 25, 1977, p. 4542–4546). The Survey is solely responsible for all petroleum operations conducted within areas of operation described in each Annual Plan of Operations, including the enforcement of the surface protection and rehabilitation requirements as defined in the MOU.

Monitoring is accomplished by the following groups of professional environmentalists: BLM, the Survey's Office of NPRA, and the Survey's prime contractor, Husky Oil NPR Operations, Inc. The independent but cooperative diligence of highly knowledgeable arctic personnel in this three-tiered hierarchy of inspection has assured the setting and the accomplishment of the highest of environmental standards.

SUMMARY

The assessment of petroleum resources at NPRA pits the potential rewards of fossil energy discovery against the certainty of some degree of disruption of environmental values. This classic conflict of values constitutes a dilemma to the Department of the Interior, mandated by the Congress to both conduct a petroleum assessment and protect environmental values. The twin goals are achievable only by acceptance of some inevitable environmental cost. These costs are kept to minimal values by procedures designed to protect the specific environmental attributes of each area of operations. Based on the history of previous operations and the first 18 months of the current program, most environmental effects of the assessment were both predicted and found to be transient and minor and no threat to any environmental systems or to their physical and biological components. The only unavoidable cost demonstrated is that of tundra scarring and resultant degradation of visual qualities of wilderness. These effects may persist for a few decades at scattered local sites.

Track-laying water tanker sprinkles water to build an additional layer of ice on an ice road. Photograph by John Schindler.

Missions, Organization, and Budget

On March 3, 1979, the U.S. Geological Survey will celebrate the one-hundredth anniversary of its establishment by Act of Congress. The Survey was originally charged with responsibility for the "classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain," but the evolution of the earth sciences, the need to carefully manage the Nation's nonrenewable resources and to find new sources of scarce energy and mineral commodities, and mounting concern regarding the impact of man on the Nation's environment have added numerous other duties including topographic mapping, chemical and physical research, stream-gaging and water resource assessments, and supervision of mineral exploration and development activities on Federal and Indian lands.

The most recently added responsibility is the exploration program of the National Petroleum Reserve in Alaska, transferred from the Department of the Navy to the Department of the Interior in June 1977 under the Naval Petroleum Reserves Production Act of 1976 (Public Law 94–258). Under the Act, Congress also charged the Department of the Interior with the responsibility for operating the South Barrow gas field as a source of energy for the village of Barrow and several Federal installations including the Naval Arctic Research Laboratory. This responsibility for the operation of the gas field was assigned by the Secretary to the Geological Survey.

In general, the Survey's activities are oriented toward two basic missions, scientific and regulatory. The first of these is to collect, to analyze, and to publish information about the Nation's energy, mineral, land, and water resources; to conduct research to determine the geological structure of the United States; and to develop an understanding of Earth processes and history. The second mission is to classify Federal lands as to their water and mineral potential and to supervise the activities of lessees who explore for and develop the mineral resources of Federal and Indian lands, including the Outer Continental Shelf (OCS). Both missions and their supporting activities are directed towards the goal of assuring that the Nation's mineral resources are identified, conserved, and developed in an orderly, timely, and diligent fashion; that the American people receive a fair return on the value of their leased resources; and that mineral exploration and production activities on Federal and Indian lands are conducted with due regard for the interests of the communities directly affected and with minimum damage to other resource and environmental values.

◀ Sheet joints in granitic rocks, Sierra Nevada, Calif.

ORGANIZATION

The Geological Survey is headquartered at Reston, Va., and maintains a nationwide organization consisting of three Regions and more than 160 offices located throughout the United States. The Survey is organized into four program divisions, two major offices, and three support divisions, each reporting to the Director of the Survey as shown in the diagram appearing on pages 170 and 171 in the section entitled "Organizational and Statistical Data."

Program Divisions

- The Topographic Division produces maps delineating the physical features of land areas in the United States, its outlying areas, and Antarctica. The Division also collects and distributes photographs and space images, maps and charts, geodetic data, and related cartographic information through the National Cartographic Information Center.
- The Geologic Division conducts research on geologic processes and the Earth's history. The Division also studies the composition and structure of the rocks and materials that lie on or beneath the Earth's surface; identifies potential energy and mineral resources, including those of the OCS; and develops and distributes knowledge about natural hazards such as earthquakes, volcanic eruptions, and land subsidence.
- The Water Resources Division assesses the quantity and quality of the Nation's water supply, develops the knowledge necessary to predict the environmental consequences of alternative plans for developing water resources, coordinates Federal water-data acquisition activities, collects and distributes information about the availability of water data through the National Water Data Exchange, and develops and distributes information about hydrologic extremes including floods and droughts.

- The Conservation Division classifies the public lands with respect to leasable mineral and waterpower sites and supervises exploration and development authorized under leases and permits on Federal and Indian lands and on the OCS.

Major Offices

- The Land Information and Analysis Office coordinates and administers certain interrelated interdisciplinary programs of the Survey and other bureaus of the Department of the Interior wtih the objective of interpreting and displaying resource information in ways that are readily accessible and understandable to a wide range of potential users, particularly land use planners and decisionmakers.
- The Office of the National Petroleum Reserve in Alaska (NPRA) manages, for the Department of the Interior, the oil exploration program in the Reserve as mandated by Public Law 94–258. It supervises and oversees the activities of the contract operator to ensure efficient and environmentally sound activities and the continued supply of natural gas to the village of Barrow and to the nearby Federal installations.

Support Divisions

- The Administrative Division supports the varied scientific and engineering programs of the Survey through its management analysis, accounting, budgeting, personnel, contracting, property, and supply services.
- The Computer Center Division provides computation, data processing, systems analysis, and design services to all elements of the Survey.
- The Publications Division prints and distributes maps, edits scientific and technical manuscripts, prepares illustrations and visual aids, disseminates general Survey program and publications information, and sells Survey book publications as an authorized sales agent of the Superintendent of Documents.

A number of Assistant Directorships have been established to coordinate the activities and relations among the Divisions and the three Regional Offices and to render staff services to the Director and Associate Director in certain specified areas such as program analysis, land resources, energy, mineral and water management, geologic engineering, and regulation.

The Geological Survey's field organization is made up of Regional Offices at Reston, Va., Denver, Colo., and Menlo Park, Calif., and a network of field and special-purpose offices. These offices coordinate and administer the work of the Survey's widely dispersed activities. The Water Resources Division, for example, has District Offices in 45 of the 50 States. The Conservation Division maintains 73 Area and District Offices close to its areas of work on the public lands and adjacent to areas of petroleum development on the OCS. A directory of the Survey's National Center and selected field offices appears on page 172.

A WORD OR TWO ABOUT PROGRAMS AND MONEY

The word "programs" as used in Government circles has been integrated to denote almost any size or level of activity from the multibillion dollar effort that placed a man on the Moon to the study of the

TABLE 2.—*Participation of Survey organizational units in areas of study included in the fiscal year 1978 budget*

Area of study	Topographic Division	Geologic Division	Water Resources Division	Conservation Division	Land Information and Analysis Office	Office of the Director and Administrative Division	National Petroleum Reserve in Alaska
OCS oil and gas	--	X	--	X	--	--	--
Onshore oil and gas	--	X	--	X	--	--	--
Coal	--	X	X	X	--	--	--
Uranium, geothermal, and oil shale	--	X	X	X	--	--	--
Mineral resources	--	X	--	X	--	--	--
Land resource investigations	--	X	--	--	X	--	--
Geologic hazards	--	X	--	--	--	--	--
Water-data collection, analysis, and research	--	--	X	X	--	--	--
National mapping program	X	--	--	--	X	--	--
Earth Resources Observation Systems	--	--	--	--	X	--	--
Environmental Impact Analysis	--	--	--	--	X	--	--
General administration	--	--	--	--	--	X	--
National Petroleum Reserve in Alaska	--	--	--	--	--	--	X

behavior of some small organism in a one-man laboratory. This ambiguity is not particularly helpful to those who must classify large numbers of such activities according to their varying size and complexity. Predictably, a hierarchy of distinctive terms has been developed to aid in this task.

In descending order, *Activity, Subactivity, Program Element,* and *Program Subelement* are used to describe various levels of effort for budgeting purposes. Thus, under the *Activity* "Geological and Mineral Resource Surveys and Mapping" appears a *Subactivity* identified as "Land Resource Surveys." Under "Land Resource Surveys" are a number of *Program Elements,* one of which is "Earthquake Hazards Reduction," which in turn is comprised of *Program Subelements,* including one designated "Hazards Delineation and Evaluation."

The structure of the Geological Survey's budget closely parallels that of its organization, with each of the program divisions being responsible for administering a particular budget activity and its components as described above. Two support-related activities, "General Administration" and "Facilities," fund the Office of the Director and the operation of the National Center complex at Reston. Support services provided by the Administrative Division are financed through assessments to the program divisions. The Computer Center and Publications Divisions are financed by direct user charges in return for services rendered. The relationships between the Survey's organization and budget activities are shown in tables 2 and 3.

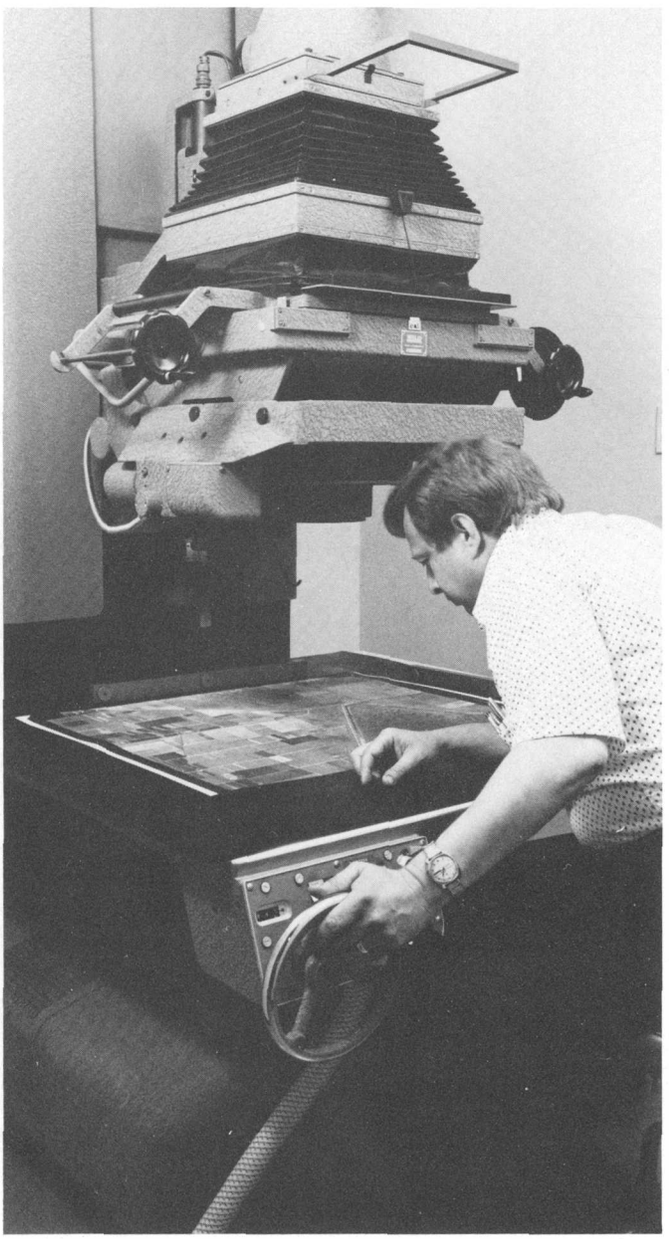
The Survey and its activities are supported directly through annual congressional appropriations and indirectly through reimbursements from other fund sources, both Federal and non-Federal. Currently, direct support is provided by two appropriations, "Exploration of the National Petroleum Reserve in Alaska," which funds the work being done in the National Petroleum Reserve, and "Surveys, Investigations, and Research," which supports all other activities of the Survey.

The direct funding of the Survey is supplemented by reimbursements from the Federal agencies, States, local communities, foreign countries, international organizations, and other entities, both public and private, for work performed of particular interest to those sources but also contributing to the performance of the Survey's missions. A list of agencies and organizations with which the Survey has formal agreements for reimbursable work in fiscal year 1978 can be found beginning on page 179.

A large portion of the work performed by the Water Resources Division under Federal-State cooperative programs is carried on under long-standing arrangements with State, county, or municipal agencies.

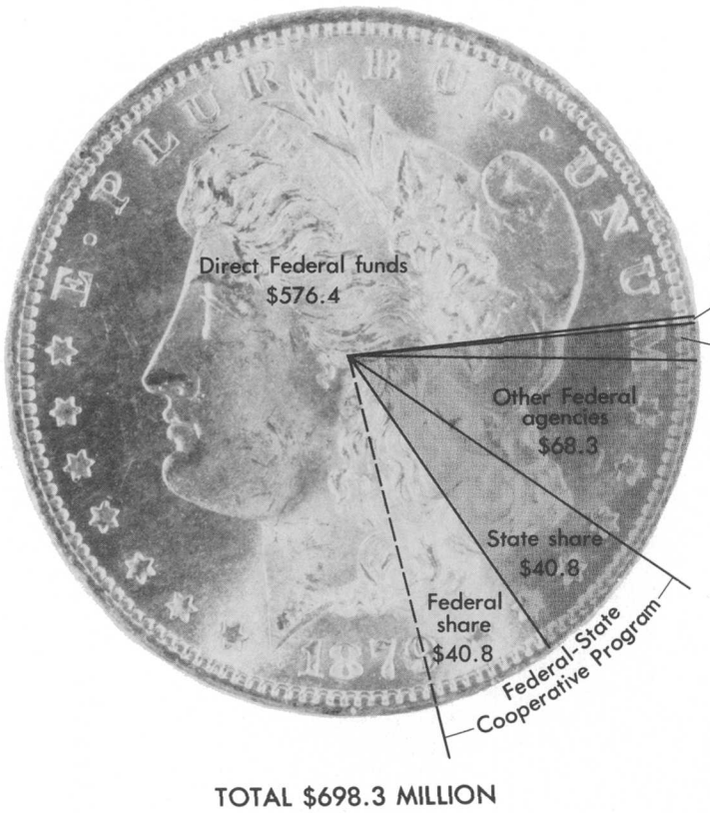
Funding may vary according to the type of investigation within the stipulation that federally appropriated funds may not be used to finance more than one-half of the cost of topographic mapping or water resource investigations. In the case of the latter, a dollar limitation is also imposed within each annual appropriation. Cooperative programs undertaken for geologic surveys and investigations are not subject to specific dollar limits or to the general 50-percent matching ceiling.

Work performed by the Survey for other agencies and organizations is usually on a fully reimbursable basis.



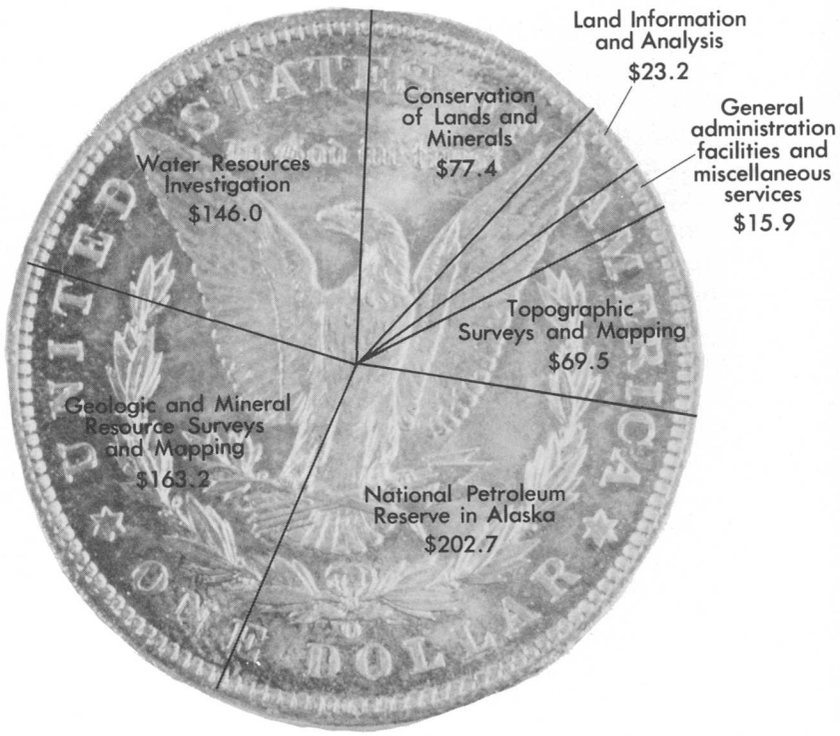
Producing an orthophotograph.

U.S. GEOLOGICAL SURVEY BUDGET



TOTAL $698.3 MILLION

SOURCE OF FUNDS



USE OF FUNDS

BUDGET

Total obligations incurred by the Geological Survey in fiscal year 1978 were $698 million, an increase of $265 million over the preceding year. By far the largest part of the increase resulted from the Survey's first full year of funding of the work being undertaken on the NPRA under the appropriation for "Exploration of the National Petroleum Reserve in Alaska," which totaled over $202 million compared to $9 million for this activity during fiscal year 1977. Obligations for "Surveys, Investigations, and Research" were $374 million, up $54 million from the previous year, which was due principally to a greatly expanded effort in the Earthquake Hazards Reduction Program, continued expansion of the National Mapping Program and modernization of mapmaking techniques, and other program increases in the areas of Water Resources Investigations and Conservation of Lands and Minerals.

Reimbursable programs provided $122 million from fund sources other than direct appropriations, an increase of $8 million over fiscal year 1977. These

funds constituted about 25 percent of total funds obligated for activities other than those related to the National Petroleum Reserve. Funds received from States, counties, and municipalities under the Federal-State Cooperative Program totaled over $41 million, about $1 million more than was received in fiscal year 1977.

A 10-year comparative analysis of obligations incurred under direct and reimbursable program activities is presented in figure 8.

Just as it performs services within its own field of expertise for other agencies under reimbursable agreements, the Survey relies upon outside sources for the accomplishment of an increasingly large portion of its burgeoning workload. Funds obligated for grants and contractual services have risen from less than $25 million in fiscal year 1973 to $112 million in fiscal year 1978, a 348-percent increase in 5 years. The $203 million obligated under "Exploration of the National Petroleum Reserve in Alaska" was almost entirely for contractual services.

Table 3 shows a comparison of obligations in fiscal years 1977 and 1978 by major budget activity, and figure 9 depicts the annual obligations incurred by each activity for the period 1968 to 1978.

TABLE 3.—*U.S. Geological Survey obligations for fiscal years 1977 and 1978*

[Dollars in thousands]

Activity	Fiscal year 1977	Fiscal year 1978
Total	**$433,403**	**$698,272**
Direct program	319,460	576,393
Reimbursable program	113,943	121,879
Alaska Pipeline Related Investigations	**317**	**272**
Topographic Surveys and Mapping	**57,073**	**69,520**
Direct program	50,311	61,356
Reimbursable program	6,762	8,164
Geologic and Mineral Resource Surveys and Mapping	**130,269**	**163,193**
Direct program	100,007	123,830
Reimbursable program	30,262	39,363
Water Resources Investigations	**131,509**	**146,014**
Direct program	68,555	78,487
Reimbursable program	62,954	67,527
Conservation of Lands and Minerals	**67,427**	**77,409**
Direct program	67,239	77,299
Reimbursable program	188	110
Land Information and Analysis	**23,476**	**23,226**
Direct program	17,698	18,132
Reimbursable program	5,778	5,094
General administration	**3,760**	**3,650**
Facilities	**9,494**	**10,769**
Miscellaneous services to other accounts	**924**	**1,515**
National Petroleum Reserve in Alaska	**9,154**	**202,704**
Direct program	2,079	202,598
Allocation transfer	7,063	106

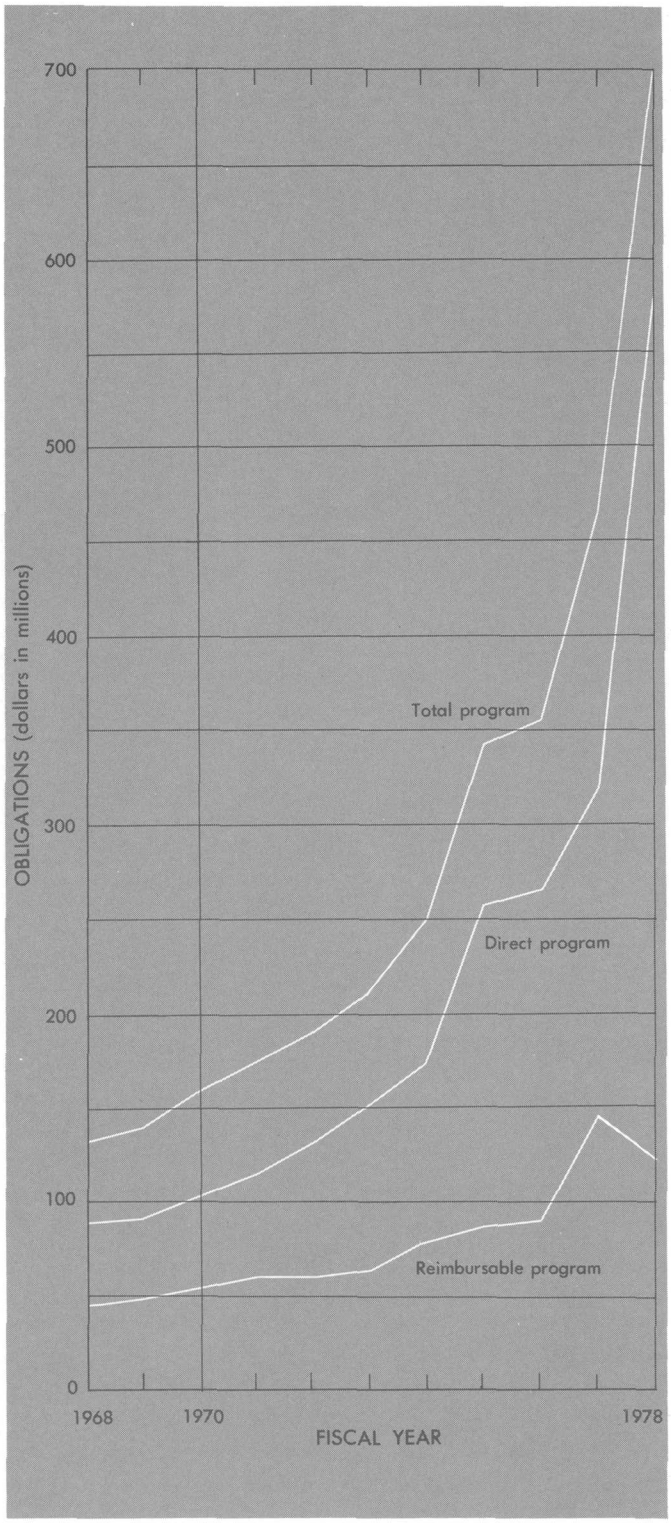


FIGURE 8.—U.S. Geological Survey budget for fiscal years 1968 to 1978, by source of funds.

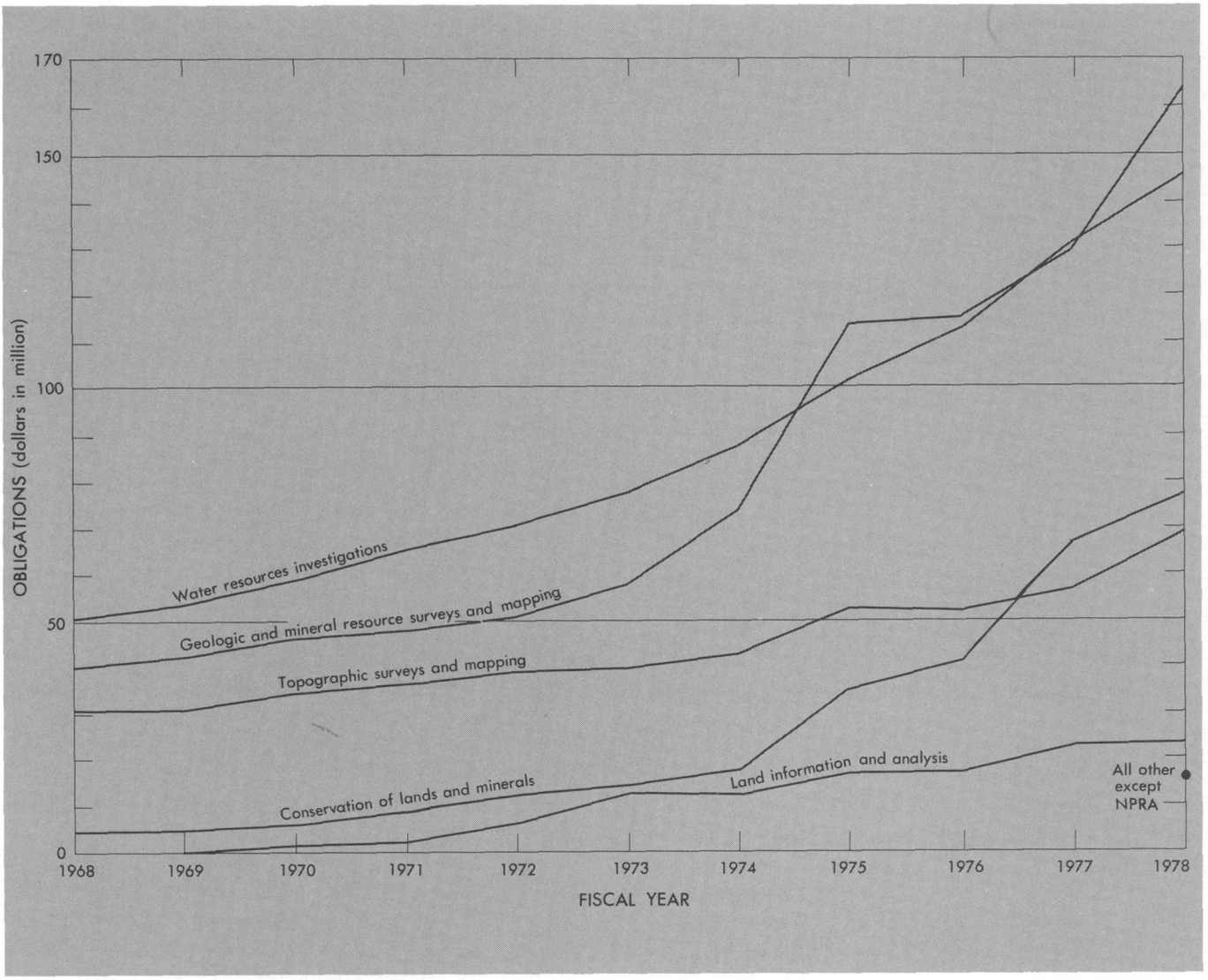


FIGURE 9 .—U.S. Geological Survey budget for fiscal years 1968 to 1978, by activity.

PERSONNEL

Although the workload of the Survey has grown dramatically during the past 5 years, its permanent employment has risen very little from 8,089 at the end of fiscal year 1973 to 9,587 at the end of fiscal year 1978, an increase of 18.5 percent. The increased responsibilities pursuant to the scientific mission have been accomplished with an essentially level full-time personnel work force; virtually all of the increases in full-time personnel have been directed to the rapid increases in the regulatory mission as energy exploration and development expands on Federal lands. Although much of the program increases have been "contracted out" as described in the preceding section, a substantial share of the additional work is being performed by the Survey's other-than-permanent employees, the number of which has doubled since fiscal year 1973, as shown in figure 10. The Survey has profited greatly from its historic relationship with this group, which has given it access to eminent specialists in many fields and afforded it great flexibility in meeting surges in the workload. The arrangement also has unique advantages in bringing the academic community into close and continuing contact with Government on a personal level.

Scientists, engineers, and other professional people comprise roughly one-half of the Survey's total permanent staff, and technical specialists account for an additional 24 percent. Hydrologists and geologists predominate among the professional corps, 9 percent of whom have doctoral degrees. These and other aspects of the Survey's permanent work force are presented graphically in figure 11. Staff distribution among the several Divisions is shown in figure 12.

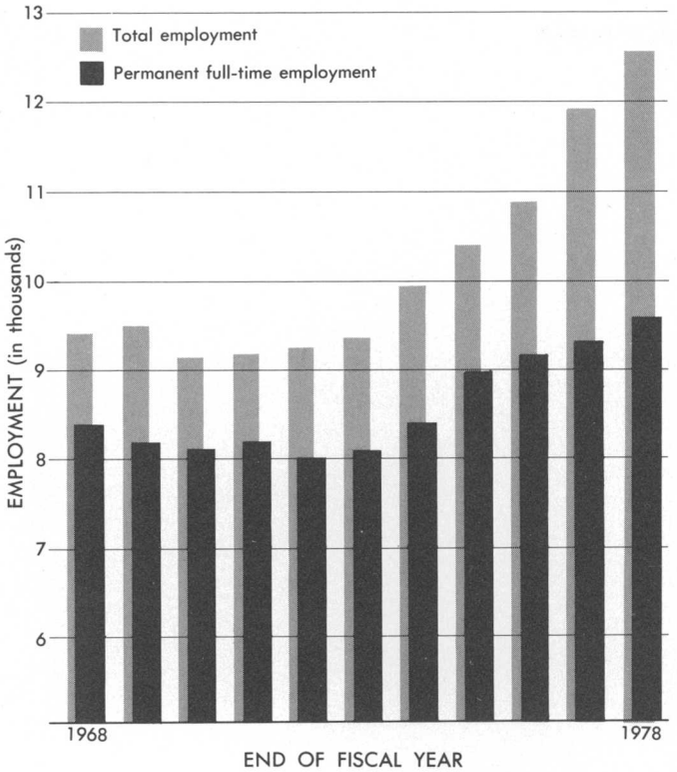


FIGURE 10.—U.S. Geological Survey end-of-year employment for fiscal years 1968 to 1978.

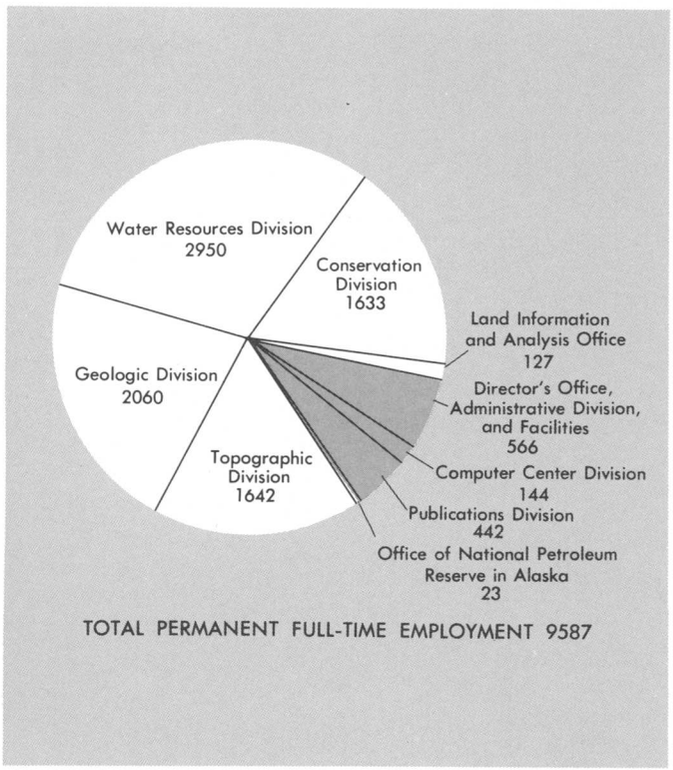


FIGURE 11.—Distribution of permanent full-time U.S. Geological Survey employees as of the end of fiscal year 1978, by organizational unit.

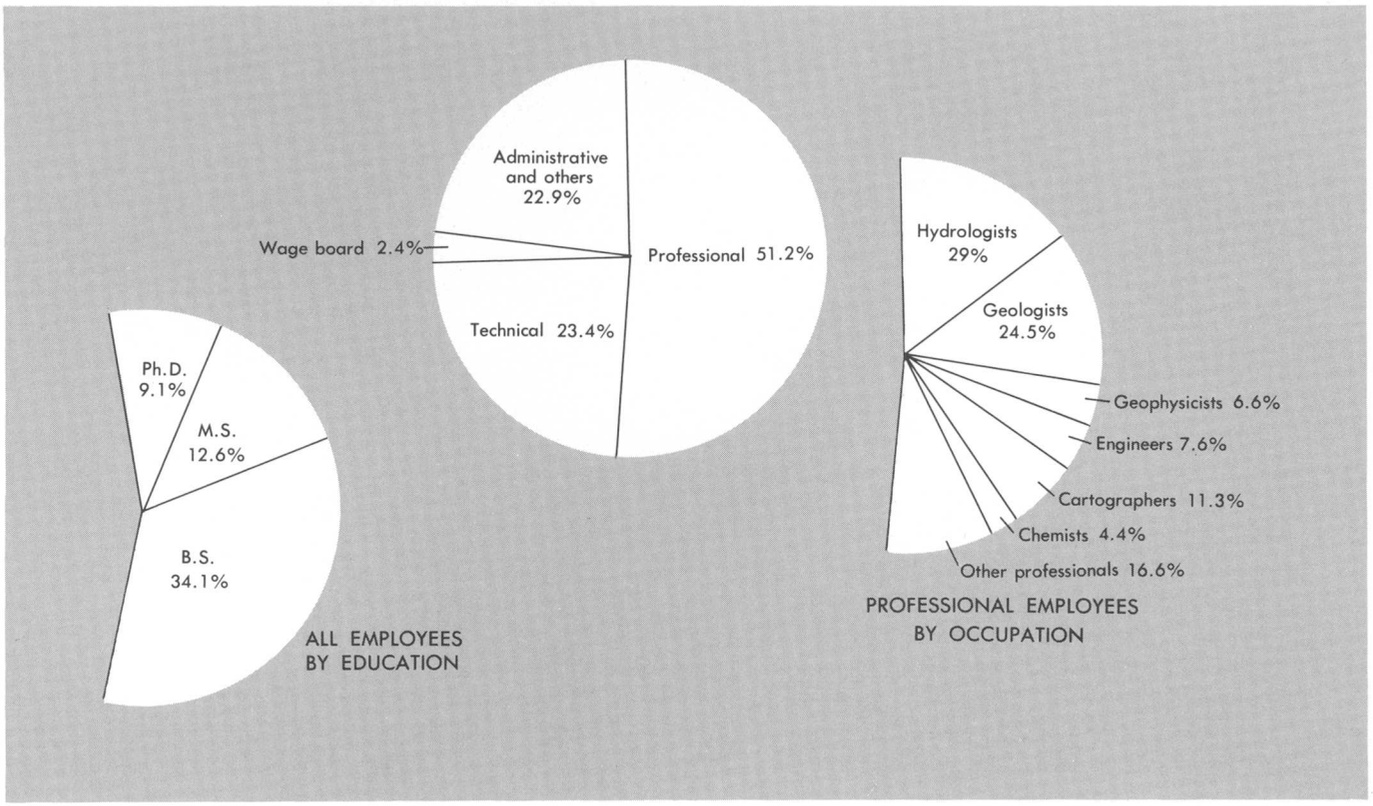
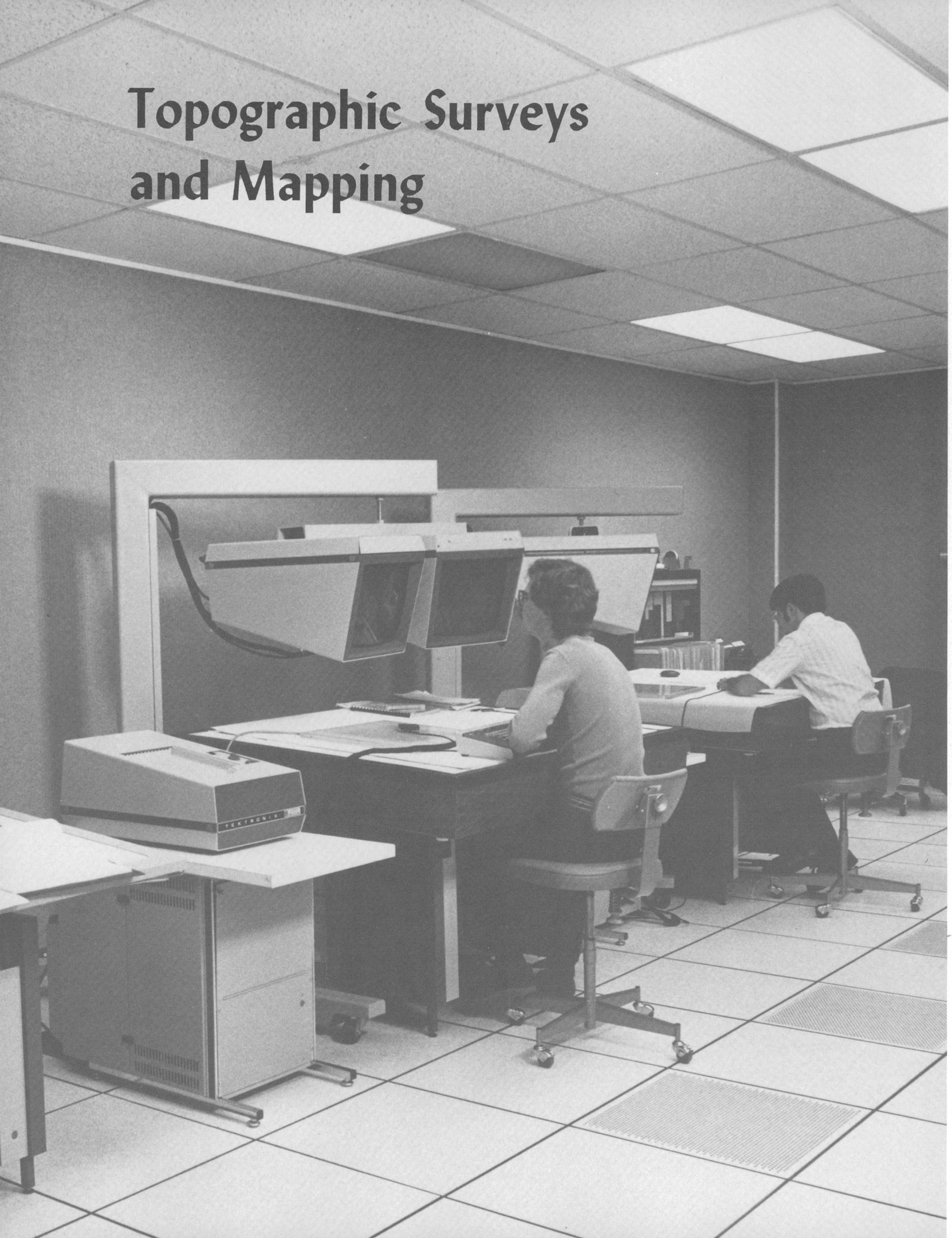


FIGURE 12 .—Permanent full-time U.S. Geological Survey employees, by type.

Topographic Surveys and Mapping



INTRODUCTION

Topographic maps at various scales illustrating detailed and precisely referenced information about natural and manmade features on the Earth's surface continue to be the most important products of the National Mapping Program. These maps provide basic cartographic information needed by most Federal, State, and local government agencies in dealing with key issues ranging from energy production to conservation, from preparing environmental impact statements to developing social alternatives, and from locating commercial facilities to designing public works.

The 7.5-minute topographic map series is the primary map series produced under the National Mapping Program. This series is not only the most popular but also serves as source material for a variety of smaller scale products, including the 1:50,000-, 1:100,000-, and 1:250,000-scale maps. Published 7.5-minute maps are available for 71 percent of the country (fig. 13), and manuscript materials are available for an additional 7 percent. Photoimage products at the same scale, known as orthophotoquads, are available for most of the areas unmapped in the conterminous United States at 1:24,000 scale (fig. 14). In Alaska, the 1:63,360-scale series has been standard, although most new mapping will be prepared at 1:50,000 scale and will be used in much the same manner as the 7.5-minute series in other States.

For a basic map series to retain value, it must be periodically reviewed and the cultural information revised and updated as needed. Approximately 4,000 maps are reviewed and 1,600 revised maps are completed annually. The need for revision is expected to grow due to the dynamic nature of society. Revision of the 7.5-minute maps occurs when a comparison of published maps to recent aerial photographs reveals significant change. Although most revisions are photorevisions, having new planimetric map data overprinted in purple, increased emphasis is being placed on field review of the changes which are then printed in standard colors.

In addition to maps, the National Mapping Program is also starting production of cartographic data in computer-readable form. These data will be used in computer-based resource information and management systems to evaluate alternative management plans and to study the effects of different policies. The Geological Survey is developing production capabilities and techniques and is acquiring sophisticated new equipment.

In response to the Metric Conversion Act of 1975, plans are being implemented to convert gradually to metric scales and units. Individual plans for conversion are being developed with each State. Currently, nearly 1,700 7.5-minute quadrangle maps in 19 States are being prepared in metric units. A cooperative mapping program has begun with the Commonwealth of Massachusetts to produce new metric maps of the entire State. This 8- to 10-year program will make Massachusetts the first State to convert its mapping program entirely to the metric system. All 1:50,000- and 1:100,000-scale quadrangle maps and some of the county maps are being completed as metric maps, and recompilations of 1:250,000-scale maps will be in metric units.

COORDINATION OF MAPPING

The Geological Survey has been given the responsibility for coordinating domestic mapping activities by Circular A–16 of the Office of Management and Budget. Additions and changes to the National Mapping Program are made largely on the basis of national priorities developed through evaluation of the requirements stated by Federal agencies, State Mapping Advisory Committees, and other State and local agencies.

In fiscal year 1978, the Survey received 39,473 requests for 25,261 7.5-minute quadrangles of mapping and revision from 25 Federal agencies. The Survey also received hundreds of requests for intermediate-scale maps, 1:250,000-scale maps, orthophotoquads, and digital cartographic data.

State Mapping Advisory Committees (SMAC) have been formed in 23 States to determine State mapping requirements, to direct State cooperative mapping programs with the Survey, and to stay abreast of mapping developments and to report them to State map users. SMAC recommendations are given equal weight with Federal agency requirements in development of the Federal programs.

During fiscal year 1978, two regional mapping conferences were held to review the policies and long-range plans of the National Mapping Program and to

◀ Digital map data collected with two- and three-axis systems can be interactively edited and revised on the Digital Data Editing System. Each editing station consists of a large graphic digitizing table, a "menu" tablet for mode control, a keyboard for entering alphanumeric and function data, and dual display screens. The editing stations are interactively interfaced to the control computer to reformat data, to add or to delete points and lines, to change the position of data, to add or to revise descriptive header information, or to collect and to digitize new data. Current editing systems have three stations each; however, up to eight stations can be simultaneously operated per system when expanded capacity is needed.

provide an opportunity for the States to discuss their long-range mapping needs.

Additionally in fiscal year 1978, 38 States and Puerto Rico with cost-sharing cooperative mapping agreements participated directly in selecting areas to be mapped in their States.

Accomplishments for fiscal year 1978 include the following:

- Publication of 2,678 new and revised maps, ranging in scale from 1:24,000 to 1:250,000. In addition, about 4,467 orthophotoquads were produced and are available in diazo or photocopy form. Initial 1:24,000-scale topographic map coverage of Florida and West Virginia was completed during fiscal year 1978 as a result of cooperative efforts with the States.
- Completion of 452 intermediate-scale maps to meet special needs of Federal and State agencies (fig. 15). These included 204 1:100,000-scale quadrangles, 162 county maps for the Soil Conservation Service and State cooperators, and 86 1:50,000-scale quadrangles for the Defense Mapping Agency.

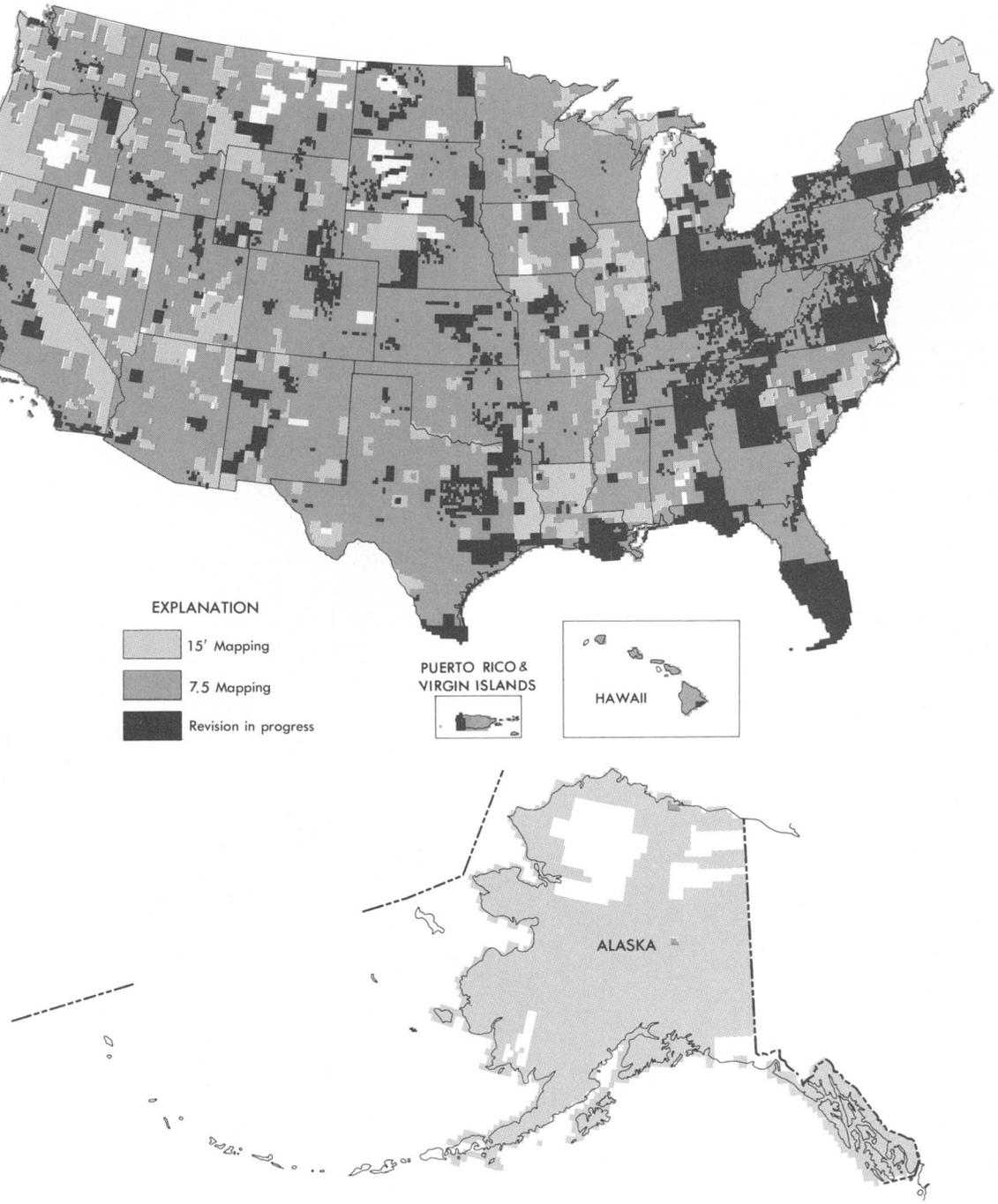


FIGURE 13.—Status of standard topographic mapping and revision.

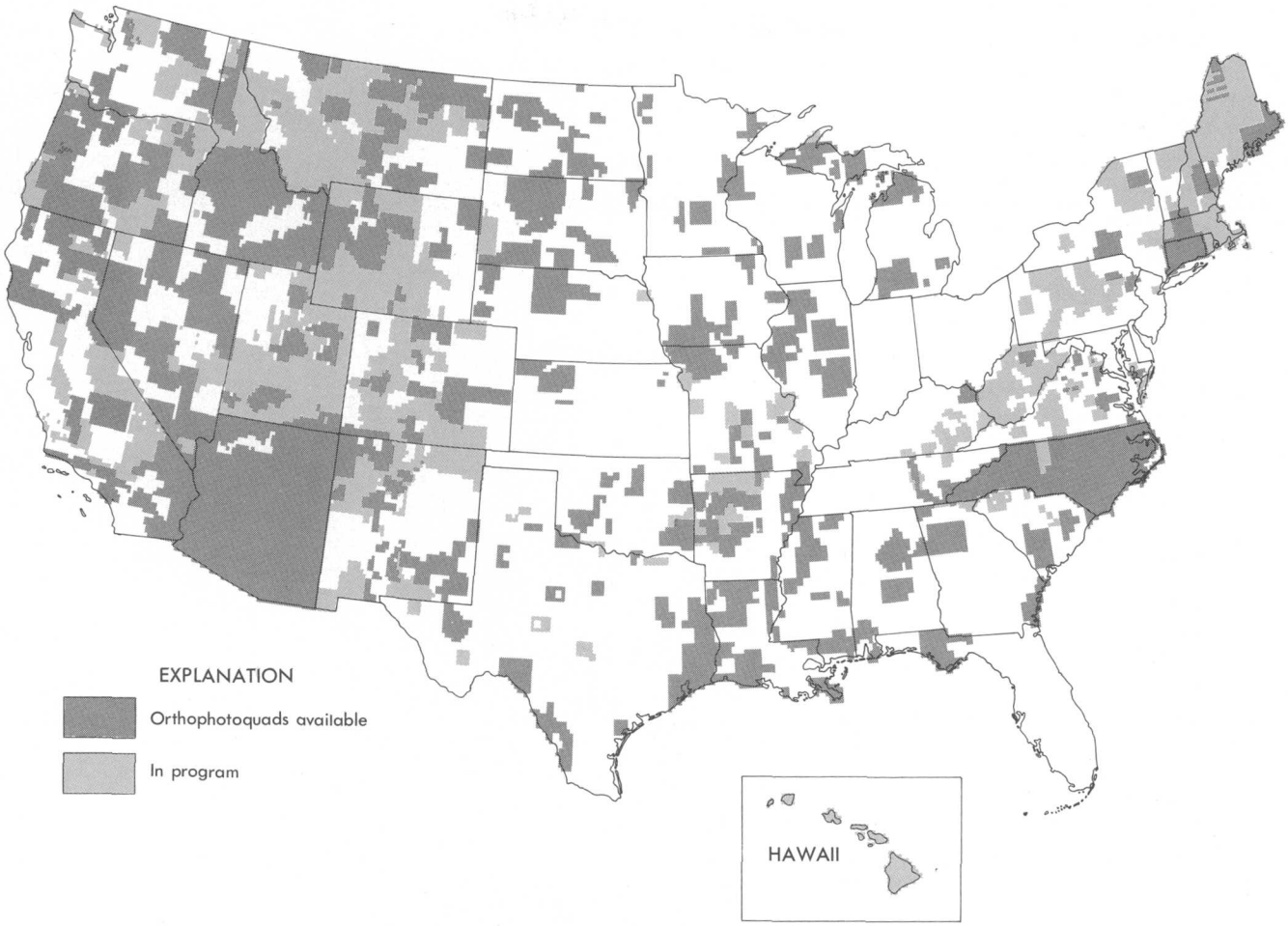


FIGURE 14.—Status of orthophotoquad production.

- Production of two experimental maps in the proposed new format for 1:25,000-scale metric maps—7.5 minutes of latitude by 15 minutes of longitude. The new maps, Saranac Lake and Lake Placid (fig. 16), N.Y., were prepared in conjunction with new mapping of the site for the 1980 Winter Olympics.
- Publication of 18 simulated natural color photoimage maps at 1:25,000 scale of the U.S.–Canadian border from St. Regis to East Richford, N.Y., as part of a cooperative project with the U.S. Customs Service.
- Completion of a data base containing over 1,700 7.5-minute quadrangles of digital elevation model data as part of the Digital Cartographic Applications Project. In addition, several digital data pilot production projects were started with the Bureau of Land Management (BLM), the Forest Service, the Department of Energy, the Census Bureau, and the State of Idaho.
- Experimentation in preparing 1:250,000-scale maps by combining reduced 1:100,000-scale map material with space imagery has resulted in a space-imagery edition of the Wenatchee, Wash., quadrangle. Photomechanical equipment restored photoreduced 1:100,000-scale-map line weights and generated thematic data from Landsat imagery, which also provides a striking appearance of natural relief shading.
- User evaluation of 22 folded maps as a new element of the National Mapping Program. The folded maps, complete with transparent plastic jackets, were for high-interest recreation areas and are designed to meet the needs of the outdoor general map users.
- Agreements with the States of Minnesota, North Dakota, Pennsylvania, Tennessee, and West Virginia to establish State-operated information centers for collecting and distributing cartographic data in affiliation with the National Cartographic Information Center. This brings the total of State affiliates to 10.
- Contracting for 413,075 square miles of aerial photographic coverage as an addition to the national aerial photograph data base.
- Publication of the first of a series of U.S.–Mexico 1:24,000-scale border maps. Through agreement

with DETENAL, the Mexican mapping agency, mapping projects along the border are coordinated so that territory on both sides can be depicted completely. DETENAL is publishing its border series at 1:50,000 scale.

- Completion of a cooperative mapping program with the State of North Carolina to produce 1:24,000-scale orthophotoquads for the entire State. To date, this is the largest cooperatively funded orthophotoquad program.
- Hosting a conference of Federal agency representatives to consider the requirements and funding for a cyclic national high-altitude aerial photography program.
- Completion of microfilming of all Geological Survey topographic maps published to date. Copies on 35-mm roll microfilm are now available.
- Production of a family of maps along the Georgia coast in cooperation with the State and in support of programs and studies of the near offshore and Outer Continental Shelf (OCS) areas. The maps are published at 1:24,000, 1:100,000, and 1:250,000 scales. The 1:24,000-scale map is a standard orthophotomap with bathymetric contours and shows mean low-water and mean high-water lines. The 1:100,000- and 1:250,000-scale maps also have bathymetric contours and mean low-water and mean high-water lines, plus BLM's offshore protraction diagram.

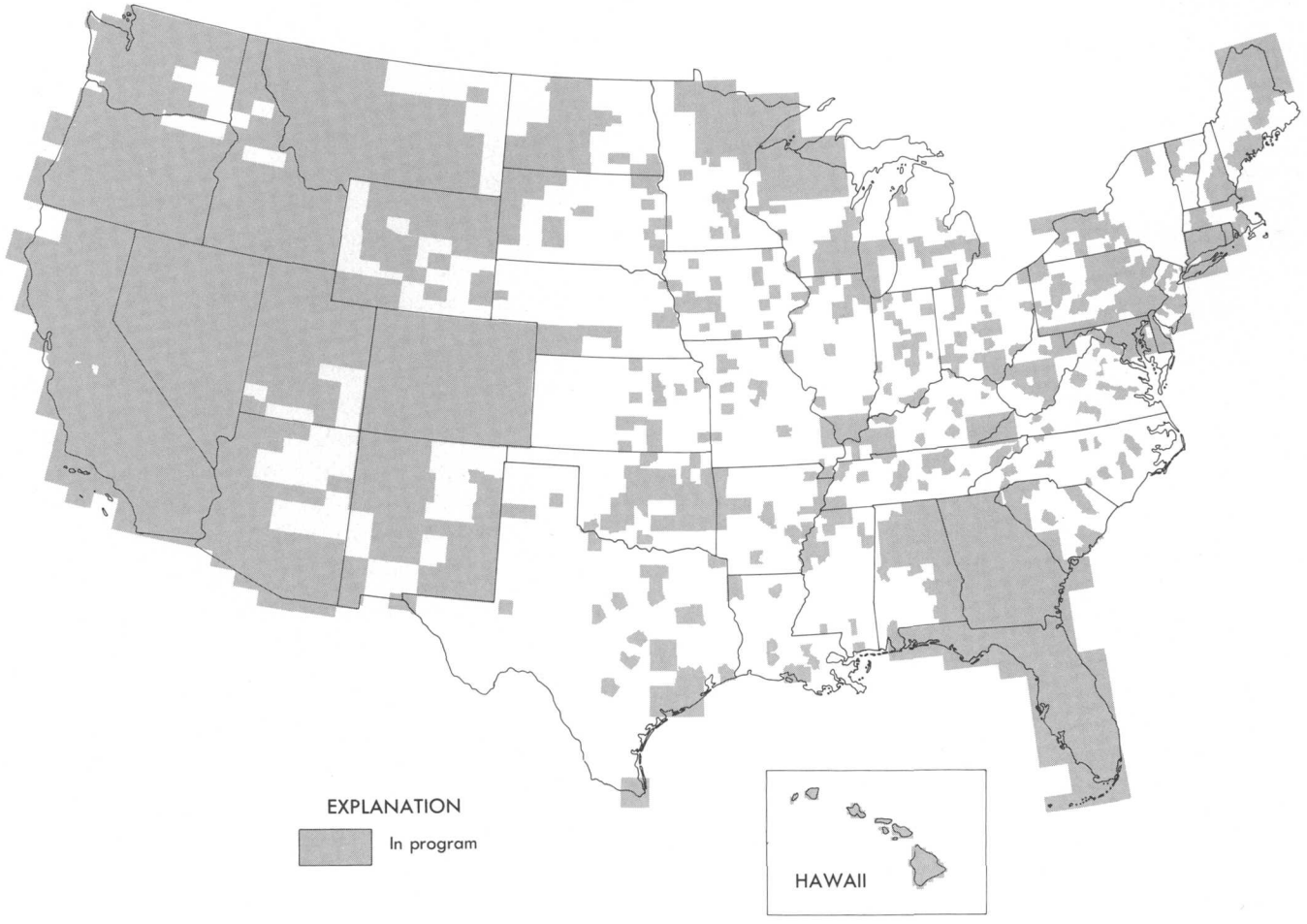


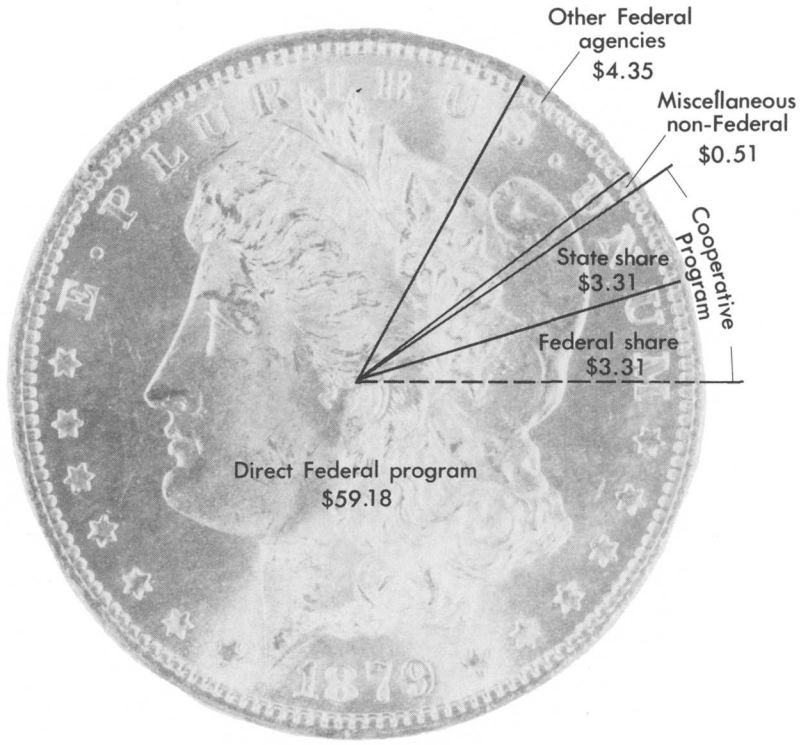
FIGURE 15.—Status of the Intermediate-Scale Mapping Program.

Mapping production for fiscal year 1978

[Data in square miles]

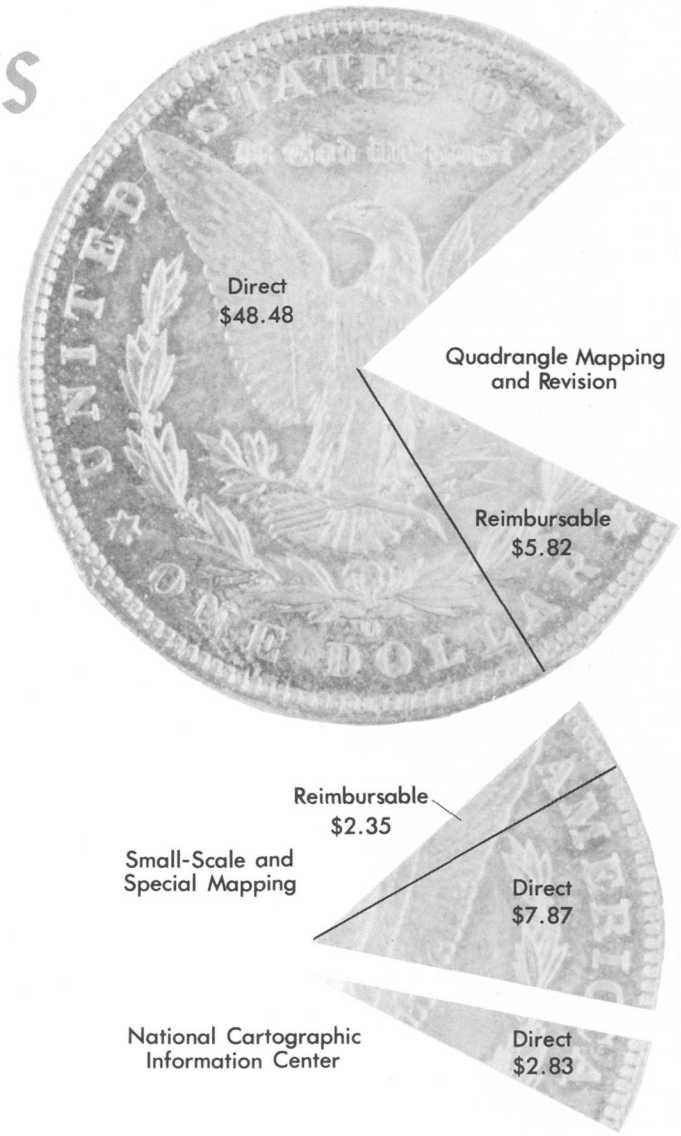
	1:24,000-scale topographic	1:24,000-scale orthophotoquads	1:24,000-scale revisions	Intermediate scale
Alabama	996	-----	1,581	4,135
Alaska	509	-----	36	-----
Arizona	3,392	-----	667	29,468
Arkansas	1,547	7,015	953	4,143
California	3,341	34,252	3,455	59,690
Colorado	2,122	4,631	3,801	17,481
Connecticut	-----	-----	76	1,011
Delaware	-----	-----	-----	-----
District of Columbia	-----	-----	-----	-----
Florida	-----	-----	2,509	1,061
Georgia	235	-----	319	7,021
Hawaii	-----	-----	-----	-----
Idaho	966	35,352	1,582	35,943
Illinois	1,733	2,476	2,396	2,346
Indiana	-----	-----	347	2,406
Iowa	3,714	-----	34	4,076
Kansas	2,266	92	6,923	11,493
Kentucky	-----	1,100	6,091	2,952
Louisiana	1,141	2,201	403	971
Maine	152	2,980	444	-----
Maryland	-----	-----	826	2,293
Massachusetts	-----	-----	2,331	-----
Michigan	1,459	3,517	257	4,772
Minnesota	2,113	2,935	119	19,348
Mississippi	1,617	-----	349	1,104
Missouri	1,168	-----	4,445	3,628
Montana	3,426	16,323	1,660	28,080
Nebraska	1,203	2,201	1,280	1,958
Nevada	427	21,413	255	50,110
New Hampshire	-----	-----	85	-----
New Jersey	-----	275	-----	796
New Mexico	2,686	9,767	1,719	21,600
New York	645	2,935	4,286	1,546
North Carolina	1,011	17,284	1,768	2,139
North Dakota	2,004	-----	465	3,242
Ohio	-----	-----	3,065	2,044
Oklahoma	607	3,943	1,239	2,364
Oregon	1,524	24,898	452	29,222
Pennsylvania	-----	6,007	4,989	973
Rhode Island	-----	1,055	-----	-----
South Carolina	1,037	1,055	891	1,351
South Dakota	2,778	5,227	2,865	4,250
Tennessee	-----	1,421	-----	-----
Texas	5,889	9,721	9,965	8,938
Utah	1,001	13,114	2,613	3,876
Vermont	37	-----	-----	-----
Virginia	-----	-----	7,131	2,187
Washington	824	5,640	950	17,800
West Virginia	-----	1,880	5,095	2,251
Wisconsin	2,271	1,100	107	8,758
Wyoming	1,018	12,839	7,873	7,880
Guam	-----	-----	-----	-----
Puerto Rico	-----	-----	-----	-----
Samoa	-----	-----	-----	-----
Virgin Islands	-----	-----	-----	-----

TOPOGRAPHIC SURVEYS AND MAPPING



TOTAL $67.35 MILLION

SOURCE OF FUNDS



USE OF FUNDS

BUDGET AND PERSONNEL

The Topographic Surveys and Mapping budget comprises the following subactivities:

1. Quadrangle mapping and revision, including production and revision of 7.5-minute maps at 1:24,000 scale in customary units and 1:25,000 scale in metric units for the conterminous United States, Hawaii, and developing areas in Alaska, and maps at 1:63,360 scale (inch-pound units) and 1:50,000 scale (metric units) for Alaska.
2. Small-scale and special mapping, including preparation of other maps and map products from the intermediate-scale series to the small-scale U.S. base maps.
3. The National Cartographic Information Center for acquisition and dissemination of information about available cartographic data.

For fiscal year 1978, Topographic Surveys and Mapping obligations amounted to $67.3 million (table 4). Included are funds from 38 States, which, when matched by Federal funds, amounted to $6.6 million for cooperative mapping. The cooperative projects mutually benefit the State and national programs by ensuring the completion of map coverage sooner than would otherwise be possible.

TABLE 4.—*Topographic Surveys and Mapping activity obligations for fiscal years 1977 and 1978, by program*

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Program	Fiscal year 1977	Fiscal year 1978
Total	**$57.07**	**$67.35**
Quadrangle Mapping and Revision	**47.51**	**54.30**
Direct programs	42.39	48.48
Reimbursable programs	5.12	5.81
States, counties, and municipalities	2.73	2.80
Miscellaneous non-Federal	.45	1.67
Other Federal agencies	1.94	1.34
Small-Scale and Special Mapping	**6.92**	**10.22**
Direct programs	5.28	7.86
Reimbursable programs	1.64	2.36
State, counties, and municipalities	.54	.52
Miscellaneous non-Federal	.15	.32
Other Federal agencies	.95	1.52
National Cartographic Information Center	**2.64**	**2.83**
Direct programs	2.64	2.83

The National Mapping Program in the Geological Survey was carried out through a combination of in-house efforts and contracts. The in-house effort involved about 1,630 career employees, many with special training in cartography, data processing, engineering, photographic technology, and the physical sciences. About 250 additional employees, many on work-study programs, served as temporary aids.

QUADRANGLE MAPPING AND REVISION

Aerial photographs of the land surface are essential to the mapping process. In fiscal year 1978, the Survey contracted for 413,075 square miles of aerial photography. Photographs of about three-fourths of the area were taken from altitudes higher than the 39,000 feet primarily for use in photoinspection and photorevision of published maps.

Field control surveys are needed to show map features in correct relationship to each other and to the Earth's surface. Horizontal ground control establishes and maintains correct scale, position, and orientation of the map. Vertical control governs the contours and spot elevations that show the shape of the terrain. These data are used to prepare the map base, the framework on which map detail is compiled. During fiscal year 1978, 53,950 square miles of horizontal control and 65,950 square miles of vertical control were established.

During fiscal year 1978, 1,083 new standard topographic maps were published, covering 61,467 square miles as shown in figure 13; most of the maps were in the 7.5-minute 1:24,000-scale series (1:63,360-scale series in Alaska). West Virginia and Florida became the 12th and 13th States to have complete published topographic map coverage at 1:24,000 scale. In addition to being used directly at the published scales, these map series are also used to prepare smaller scale and special maps.

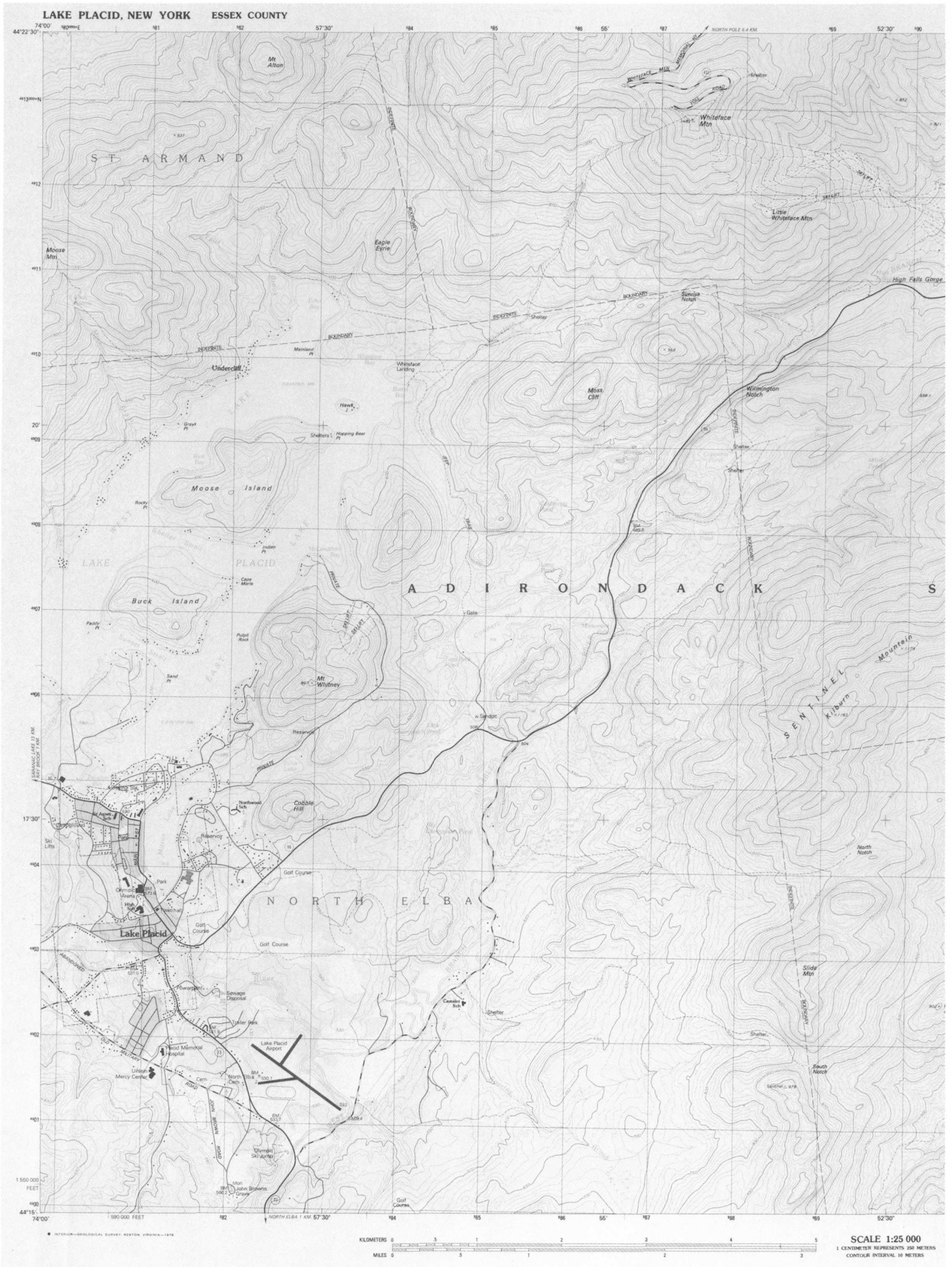
As national coverage in the 7.5-minute series increases, the revision mapping workload increases. The need for revision of individual maps is determined by the amount of change detected in comparing the published maps with current aerial photographs. Maps are reviewed cyclically with emphasis on urban areas, coastal zones, airports, major transportation corridors, and other areas of high national interest. During the last year, 4,897 7.5-minute maps were reviewed, and 1,322 revised maps were published.

Orthophotographs are produced by processing aerial photographs to correct image displacement caused by camera tilt and terrain variations. In a standard quadrangle format with grid and name information superimposed, the orthophotograph is called an orthophotoquad, which has many applications as a map substitute or as a companion product to a published line map (fig. 17). In 1978, 4,467 orthophotoquads were prepared; printed stock is available for a small percentage of these, with the majority available in nonlithographic form (fig. 14) on request to the regional mapping centers.

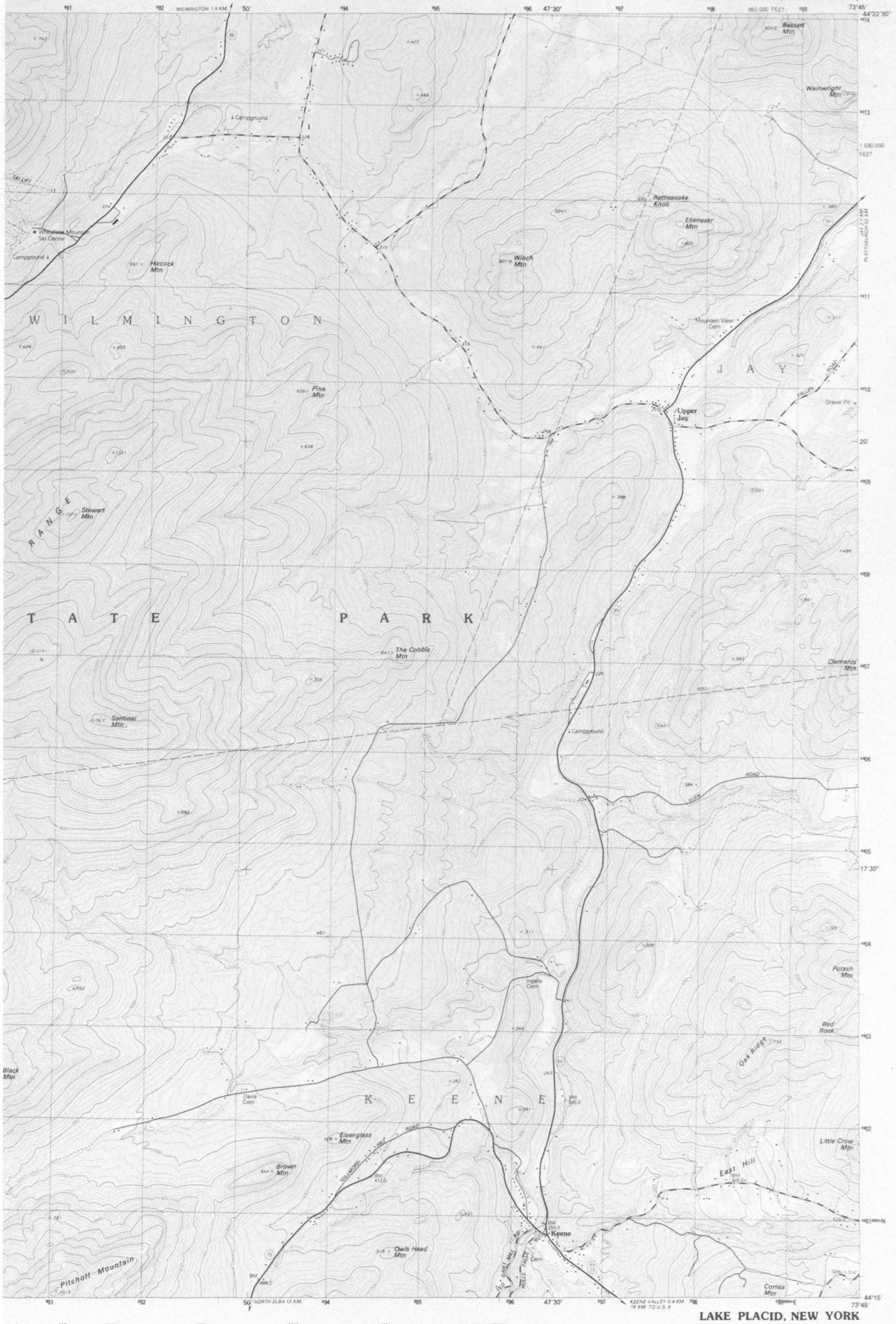
SMALL-SCALE AND SPECIAL MAPPING

To meet the need for basic map data at various levels of detail and at scales between 1:24,000 and 1:250,000, the intermediate-scale map series was introduced in 1975. These maps are prepared to have up to 25 feature-separation drawings, any combination of which can be used to produce a special map

FIGURE 16.—The Lake Placid, N.Y., quadrangle is one of a series of metric topographic maps prepared in a new format by the U.S. Geological Survey. All map elements—grid, contours, elevations, distances, and bathymetry—are in the metric system. ▶


LAKE PLACID, NEW YORK ESSEX COUNTY
ST ARMAND
NORTH ELBA
LAKE PLACID
A D I R O N D A C K S
Mt Alton
Whiteface Mtn
Little Whiteface Mtn
Eagle Eyrie
Moose Mtn.
High Falls Gorge
Sunrise Notch
Undercliff
Whiteface Landing
Moss Cliff
Wilmington Notch
Hawk
Moose Island
Buck Island
Mt Whitney
Cobble Hill
Sentinel Mountain
Kiburn
North Notch
Slide Mtn
South Notch
Lake Placid
Lake Placid Airport
Golf Course
Olympic Ski Jumps
Mon John Browns Grave
Uihlein Mercy Center
Saranac Lake 13 KM
Bay Brook 7 KM
North Elba 1 KM
KILOMETERS
MILES
SCALE 1:25 000
1 CENTIMETER REPRESENTS 250 METERS
CONTOUR INTERVAL 10 METERS

7.5X15 MINUTE SERIES (TOPOGRAPHIC)



0 500 1000 2000 3000 4000 5000 METERS

0 1000 2000 4000 6000 8000 10 000 12 000 14 000 16 000 FEET

LAKE PLACID, NEW YORK
4473-231-T25
1978

1:25 000-scale *metric* topographic map of

Lake Placid

NEW YORK

SHOWING

- Contours and elevations in meters
- Highways, roads and other manmade structures
- Water features
- Woodland areas
- Geographic names

GEOLOGICAL SURVEY

1978

Produced by the United States Geological Survey

Control by USGS and NOS/NOAA

Compiled by photogrammetric methods from aerial photographs taken 1976. Field checked 1976
Map edited 1978

Projection and 1000-meter grid, zone 18: Universal Transverse Mercator
10,000-foot grid ticks based on New York coordinate system, east zone. 1927 North American datum

To place on the predicted North American datum 1983 move the projection lines 2 meters south and 32 meters west as shown by dashed corner ticks

This area also covered by 1:25 000-scale orthophotoquad

CONTOUR INTERVAL 10 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

CONTROL ELEVATIONS SHOWN TO THE NEAREST 0.1 METER
OTHER ELEVATIONS SHOWN TO THE NEAREST METER

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS

CONVERSION TABLE

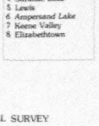
Meters	Feet
1	3.2808
2	6.5617
3	9.8425
4	13.1234
5	16.4042
6	19.6850
7	22.9659
8	26.2467
9	29.5276
10	32.8084

To convert meters to feet multiply by 3.2808
To convert feet to meters multiply by 0.3048

DECLINATION DIAGRAM

UTM grid convergence (GN) and 1978 magnetic declination (MN) at center of map
Diagram is approximate

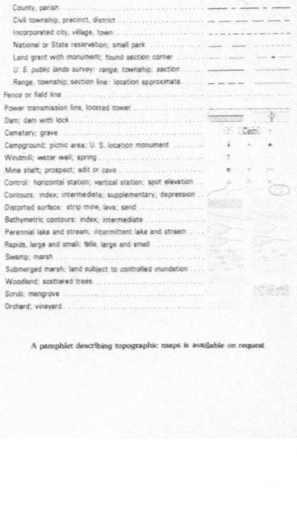
ADJOINING MAPS



1 Bloomingdale
2 Wilmington
3 Au Sable Forks
4 Saranac Lake
5 Lewis
6 Ampersand Lake
7 Keene Valley
8 Elizabethtown

FOR SALE BY U. S. GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

Topographic Map Symbols



A pamphlet describing topographic maps is available on request


TUNICA

FIGURE 17.—Landform details west of Tunica, Miss., appear on the orthophotoquad Clayton NW, Miss.-Ark. Orthophotoquads—uniform-scale photoimages in quadrangle format having a minimum of added cultural and political information—allow the user to interpret detail information for himself. The aerial photographs used for orthophotoquads are processed to remove any scale distortion caused by tilt of the aerial cameras and by terrain relief; thus, all features are shown correct in scale and relative position.

with a desired level of content (fig. 18). The feature symbolization has been specially designed to facilitate digitization. By the end of fiscal year 1978, intermediate-scale maps for about one-third of the conterminous United States were either completed or in progress with priority given to completing maps for Federal and State agencies.

Under the joint Geological Survey–Defense Mapping Agency agreement to produce 15-minute maps at 1:50,000 scale that began in fiscal year 1978, the Survey completed 86 metric topographic maps during the first year. The total program goal is for the completion of about 2,100 maps. The maps will be prepared in accordance with jointly prepared specifications and will produce map materials that can be used directly in the preparation of other intermediate-scale maps.

The 1:250,000-scale topographic map series provides the largest scale complete coverage available for the United States (fig. 19) and is thus valuable to many Federal and State agencies. The maps are also used by the Survey for preparing State base maps, various geologic maps, and special-purpose maps, such as those showing land use and land cover information. During fiscal year 1978, 50 revisions were published. Terrain data digitized from the contours on the 1:250,000-scale maps are available on magnetic tape from the National Cartographic Information Center.

The joint Geological Survey–National Ocean Survey Program for the preparation of topographic-bathymetric maps (fig. 20) continues and involves 90 maps at 1:24,000, 1:100,000, and 1:250,000 scales; 6 of these maps have been published, and an additional 84 are in preparation. In fiscal year 1979, 70 additional maps are planned for inclusion in the program.

During 1978, three National Park Service maps were included in the program as new 1:50,000-scale metric topographic maps. These maps are designed to be folded and placed in pocket-size plastic jackets. An additional six maps will be added to the Park Map Revision Program during fiscal year 1979.

Eighteen experimental simulated natural color photoimage maps at 1:25,000 scale were published to provide new map coverage of the U.S.–Canadian border from St. Regis to East Richford, N.Y., as part of a cooperative project with the U.S. Customs Service (see box, p. 62).

NATIONAL CARTOGRAPHIC INFORMATION CENTER

The National Cartographic Information Center (NCIC) collects and distributes information concerning the availability of cartographic data for the United States. In fiscal year 1978, affiliate agreements were signed with seven more State agencies. The new affiliates are the West Virginia Cartographic Center, the Minnesota Land Management Information Center, the North Dakota Regional Environmental Assessment Program, the North Dakota State Water Commission, the Louisiana Department of Urban and Community Affairs, the Pennsylvania Department of Environmental Resources, and the Tennessee Division of Geology.

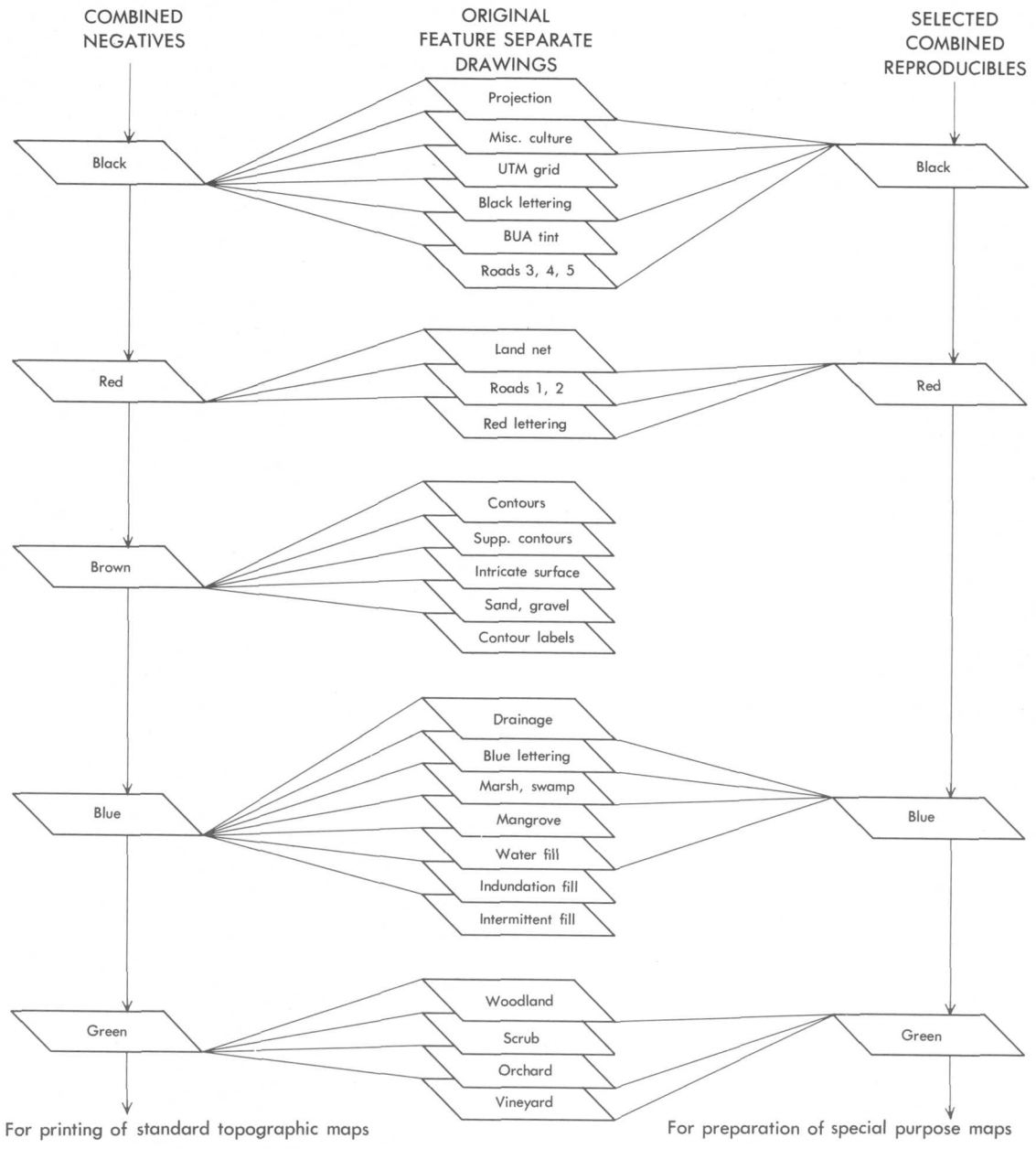
Over 50 organizations now submit data for inclusion in the NCIC Aerial Photography Summary Record System. City, State, and private industry, as well as Federal agencies, have contributed over 2,000,000 records covering all areas of the country.

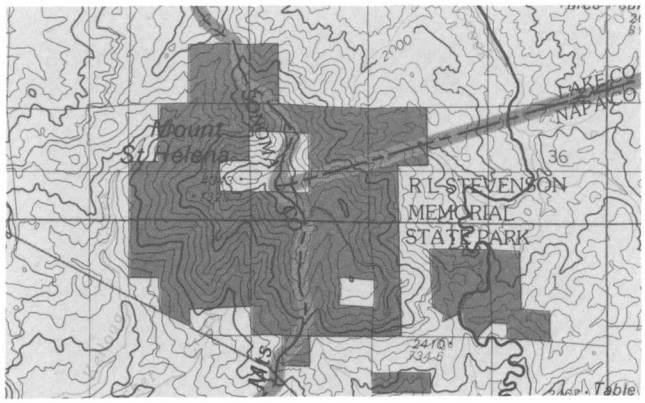
NCIC has completed the systems design and programing of the Cartographic Catalog (CC) and the Map and Chart Information System (MCIS). The CC consists of descriptive records of any cartographic product in the NCIC information systems. The information is arranged by place name or geographic coordinates. The first edition of the catalog, containing 14,000 Library of Congress records, was recently produced.

The MCIS was programed in fiscal year 1978 and is expected to be operational in fiscal year 1979. This system will contain information about the Nation's historic and current maps and charts. It will accommodate batch inquiries from remote terminals located at the regional and State NCIC offices. Many of the complete sets of maps in the system will be available on 35-mm roll microfilm (fig. 21). Currently, over 120,000 maps are contained on 275 rolls of microfilm. They are arranged by State and then alphabetically by map name.

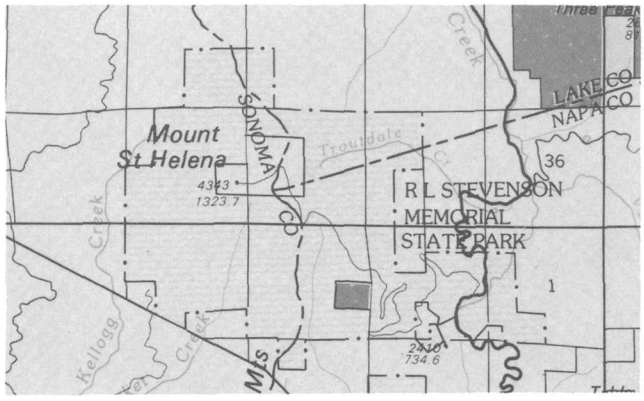
INTERNATIONAL COOPERATION

Survey employees provided training in mapping and cartography to foreign participants from Mali, Lesotho, France, Saudi Arabia, and Trinidad and Tobago and to Inter-American Geodetic Survey employees from Panama. In addition, seminars and workshops on mapping requirements and on the preparation of cartographic Landsat products were conducted by request at selected locations in Latin America.





STANDARD TOPOGRAPHIC MAP



SPECIAL PURPOSE MAP

FIGURE 18.—Intermediate-scale topographic maps are compiled with 13 to 25 feature separates, depending on the variety of detail within the mapped area. Conventionally, map reproducibles are prepared under a color-separation system in which one drawing is prepared for each group of features to be printed in the same color on the map. The innovative feature-separation system subdivides the major components of the map into classes for which separate master drawings are prepared. This system provides flexibility in that it enables users preparing maps for special purposes to obtain copies of the master drawings of only the map elements needed. For example, the special-purpose map shown contains only 14 of the 25 feature separates prepared for the standard topographic map.

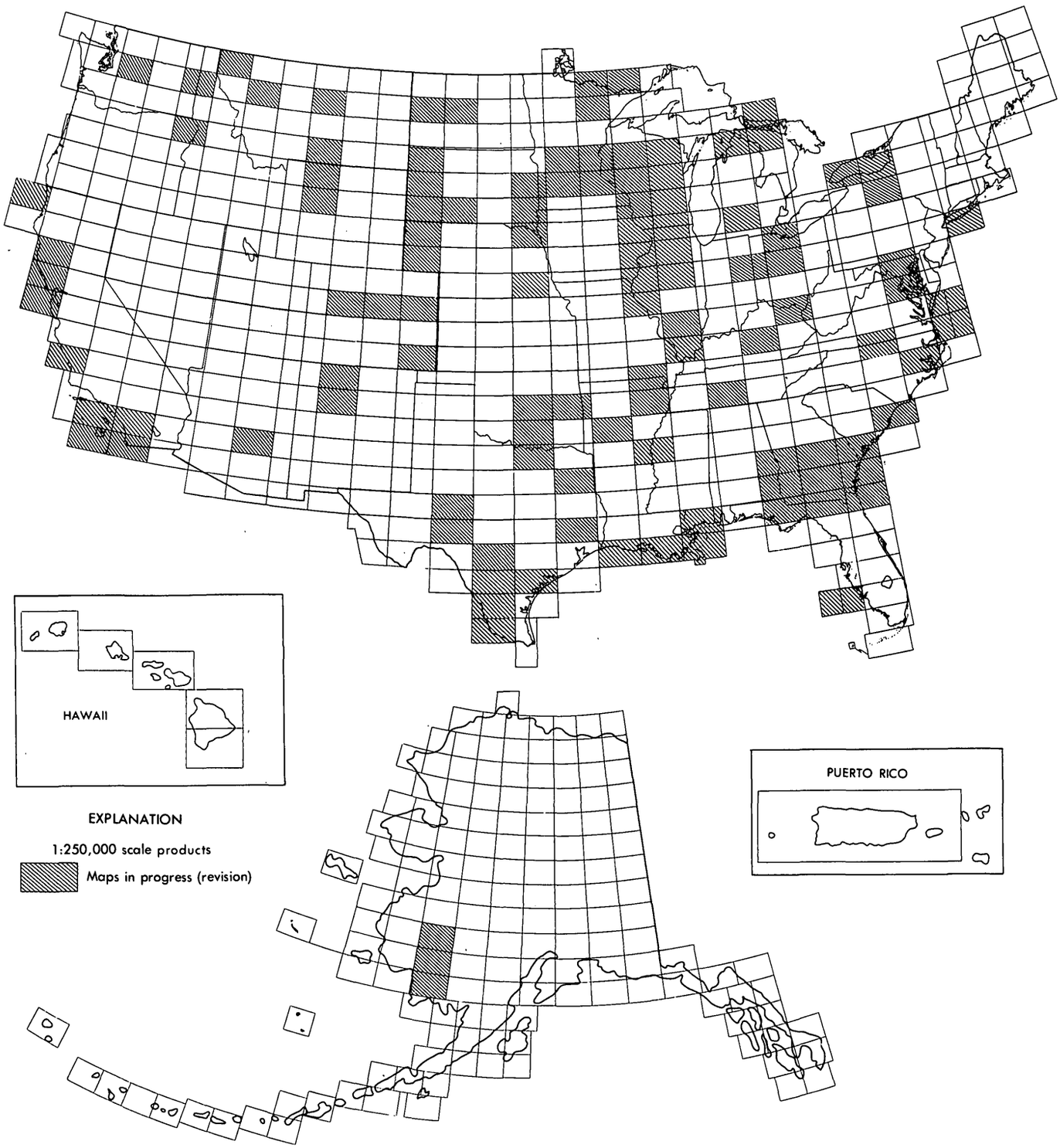


FIGURE 19.—Status of 1:250,000-scale mapping revision.


Tompkins
Horry
Poplar Forks
Allen
Knotty Branch
Maple Crossroads
Shell
Hammond
Red Bluff
Big Swamp
Jordanville
Homewood
Lundy Crossroads
Juniper Bay
Mary
White Oak
Conway
Burgan
Pee Dee Crossroads
Forney
Cedar Grove
Conway Horry Co
Grissett
Powerplant
Waccamaw River
Nixonville
Hand
Grahamville
Sand Ridge
Red Hill
Brownway
Hunting Swamp
Pee Dee River
Woodbury
Dongola
Toddville
Jaluco
Pine Island
Ocean Forest
Outland
Williams Hill
Gilbert Crossroads
Bucksville
Myrtle Beach
Center Crossroads
Klondike
Stalvey
Socastee
Myrtle Beach AFB
Petersfield
Javika
MYRTLE BEACH AFB
MYRTLE BEACH ST PK
Bucksport
Allentown
Yauhannah
Bull Island Creek
Lakewood
Carvers Bay
Burgess
Surfside Beach
HORRY CO
GEORGETOWN CO
St Pauls
Garden City Beach
Sandy Island
Wachesaw Log
Sunny Side
Murrells Inlet
Plantersville
Annieville
Dunbar
Post Foot
Mt Rena
Brookgreen
Gilliard
Chicora Wood Plantation
HUNTINGTON BEACH STATE PARK
Springwood Plantation
Oatland
Jackson
Georgeville
Litchfield Beach
Greenfield Plantation
Anne
Rarkersville
Fraserville
Beneventum Plantation
Nightingale Plantation
Pawleys Island
Marysville
Simmonsville
Kensington
Arcadia Plantation
Debidue Beach
Georgetown
Plant
Moyd
Maryville
Powerplant
Georgetown County
Friendfield
Strawberry
Hobcaw Plantation
Clambank
North Inlet
Frazier Pt
INTRACOASTAL WATERWAY
BLACK RIVER
PEE DEE RIVER
WACCAMAW RIVER
SEABOARD COAST LINE
MARION COUNTY
GEORGETOWN COUNTY
ATLANTA

FIGURE 20.—In addition to the normal topography and bathymetry on 1:250,000-scale quadrangle maps, this map of the Georgetown, S.C.-N.C., quadrangle (partly shown) also contains offshore protraction survey data compiled by the Bureau of Land Management.

The fifth extension of the agreement between Saudi Arabia and the Geological Survey was approved. In support of this agreement, two cartographers continued to provide surveying and mapping capabilities for the Survey's mission in that country. A newly acquired Doppler satellite positioning system will help provide mapping control, especially for the 1:250,000-scale Landsat image base map project.

In March, the First Pan-American Symposium on Automation in Cartography was held in Washington, D.C., by the U.S. National Section, Commission on Cartography, Pan-American Institute of Geography and History. Representatives from 18 Western Hemisphere nations attended the symposium, which was cosponsored by the Geological Survey, the Defense Mapping Agency, and the National Ocean Survey.

Fieldwork in Mexico was completed for a horizontal control network established for a crustal strain and subsidence study in a border area of geothermal activity. This is an ongoing cooperative project between the Geological Survey, the Department of Energy, and Mexico's Comisión Federal de Electricidad.

Fiscal year 1978 marked the 21st consecutive year that the Survey provided surveying and cartographic support to the U.S. Antarctic Research Program sponsored by the National Science Foundation (fig. 22). Nine cartographers participated in four separate expeditions to conduct ground surveys, to provide

FIGURE 21.—Currently, over 120,000 maps, including all U.S. Geological Survey topographic maps, are available for inspection on the 35-mm microfilm system at the National Cartographic Information Center.

Color Image Maps From Black and White Aerial Photographs —A Little Scientific Magic

The idea for producing color image maps by combining and assigning colors to the visible and infrared spectral bands of black-and-white aerial film came as a direct result of the Geological Survey's success in using a similar technique to produce 1:500,000-scale satellite image maps from two or more bands of imagery recorded by the Landsat multispectral scanner (MSS). The cover of this Yearbook shows the Lower Chesapeake Bay in such a satellite image. Experiments indicated that MSS Bands 5 and 7 are sufficient to portray the major themes of vegetation, water, and culture. Therefore, if two aerial camera films were filtered to have spectral responses similar to MSS Bands 5 and 7 and were simultaneously exposed, it should be possible to rectify, to register, and to print a 1:24,000-scale color image map in a rendition similar to that of color infrared film. The resulting map should overcome the weaknesses of high-altitude color photographs—poor contrast and color rendition due to atmospheric scattering of the shorter visible wavelengths, particularly the blue and the violet. In addition, most mapping organizations are not equipped to process color images. Virtually no equipment changes would be needed to produce color image maps from black-and-white film.

The first experimental color composite was produced in 1975 from imagery of the Livingston, Tex., area taken at 40,000 feet from a plane equipped with two mapping cameras—one containing black-and-white panchromatic film and other containing black-and-white infrared film. After exposure, the two films were independently rectified to remove errors caused by the cameras not being perfectly perpendicular to the ground. Printing plates made from the two rectified negatives simulate the dye layers in color infrared film and thereby achieve a color infrared response in the final printing.

After experimenting with other simulated color infrared projects, the Survey produced a simulated natural color composite of an area along our northern border. The resulting map exhibits sharper tonal contrast and better resolution than equivalent high-altitude natural color or color infrared photographs. Color image maps make excellent companion maps to corresponding line maps and could eventually be incorporated into the Survey orthophotomapping program.

Doppler satellite point positioning, and to operate satellite tracking and seismological equipment. One of the expeditions was a cooperative project with the British Antarctic Survey to obtain map control for Landsat satellite image maps in Western Antarctica using the Doppler satellite equipment.

RESEARCH AND DEVELOPMENT

Metric Quadrangle Maps

The Saranac Lake, N.Y., quadrangle is the first of a series of metric topographic maps being prepared in a new format proposed by the Survey, 7.5 minutes of latitude by 15 minutes of longitude at 1:25,000 scale. The map contains newly designed symbols and has a redesigned border. In addition to traditional data, such as the credit legend, bar scale, contour interval, and declination diagram, the border contains a legend explaining topographic map symbols, a metric–inch-pound unit conversion table, and other data pertinent to metric mapping. All map elements—grid, contours, elevations, distances, and bathymetry—are in the metric system. The 1:25,000-scale metric series is printed on the same size paper and uses the same feature-separate sequence as the 1:100,000-scale metric series.

Digital Cartographic Data Index

The file of digital cartographic data has been increased to over 3,000 files of 7.5-minute digital elevation model data from the Gestalt Photo Mapper II. This instrument differentially rectifies a stereopair of aerial photographs electronically to remove image displacements caused by camera tilt and terrain variations, records the elevation information in digital format, and produces an orthophotograph.

Data files may be digital elevation models, consisting of a sampled array of elevations for a number of ground positions, or digital line graphs, which are line map information in digital form. An algorithm has been developed for transforming digital elevation model data into digital line graph data.

Mapping Short-Term Phenomena

Landsat images that show the maximum extent of ice coverage on the Chesapeake Bay, Potomac River, and Washington, D.C., vicinity on February 7 and 8, 1977, were processed as a 1:500,000-scale color image map. A portion of the February 7 image showing the mouth of the Chesapeake Bay is on the front cover of this Yearbook. The images were digitally en-

hanced at the Earth Resources Observation Systems Data Center, Sioux Falls, S. Dak., to emphasize ice distribution. Comparison of the two images demonstrates Landsat capability to record temporal phenomena of general interest for historical purposes.

1-Meter Contour Interval Mapping

Metric maps of some areas of the country, primarily in the coastal zones, require a 1-meter contour interval to properly depict the hypsographic features.

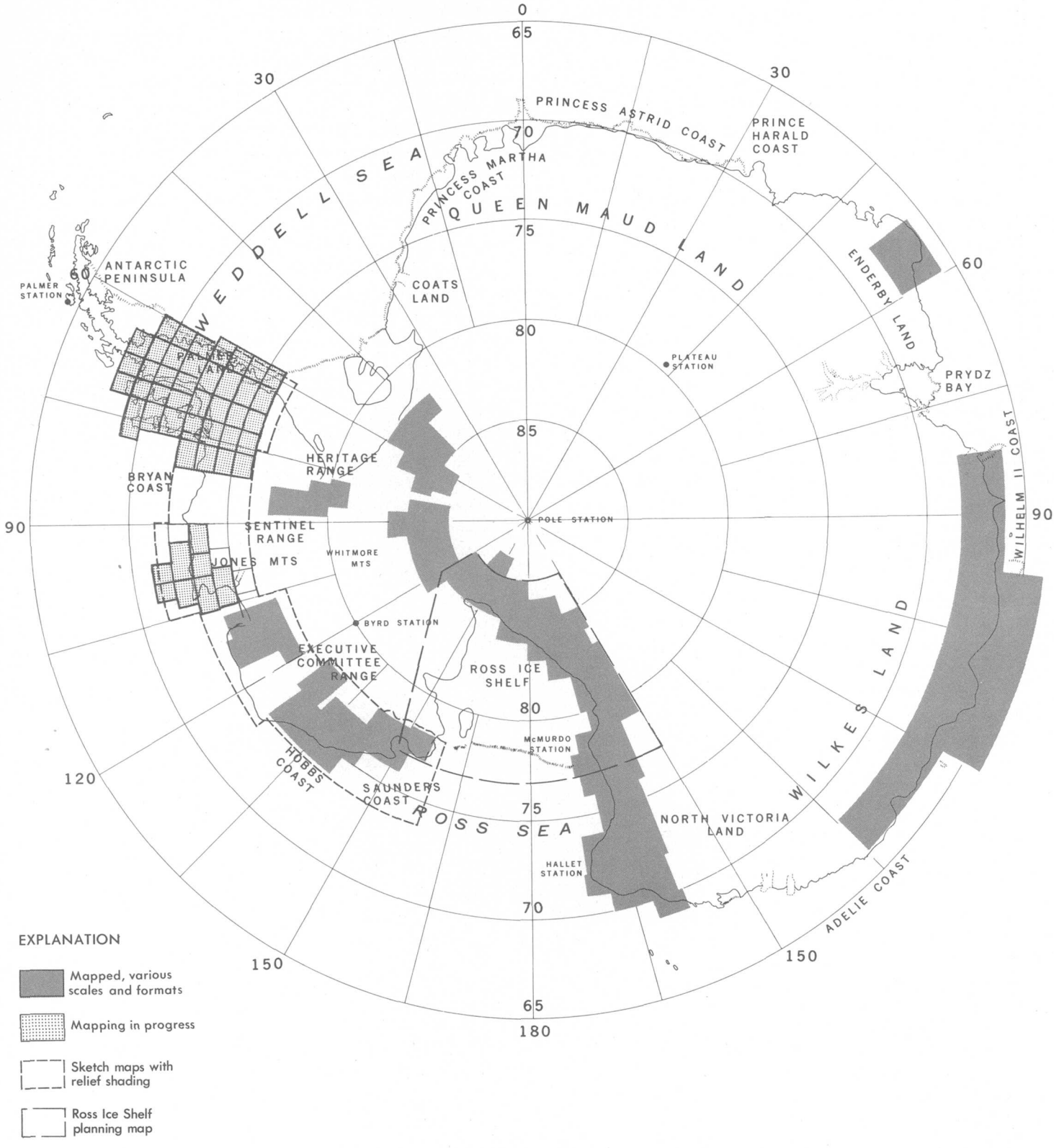


FIGURE 22.—Status of mapping in Antarctica.

Digital Base Map of Idaho
—The State Goes on Tape

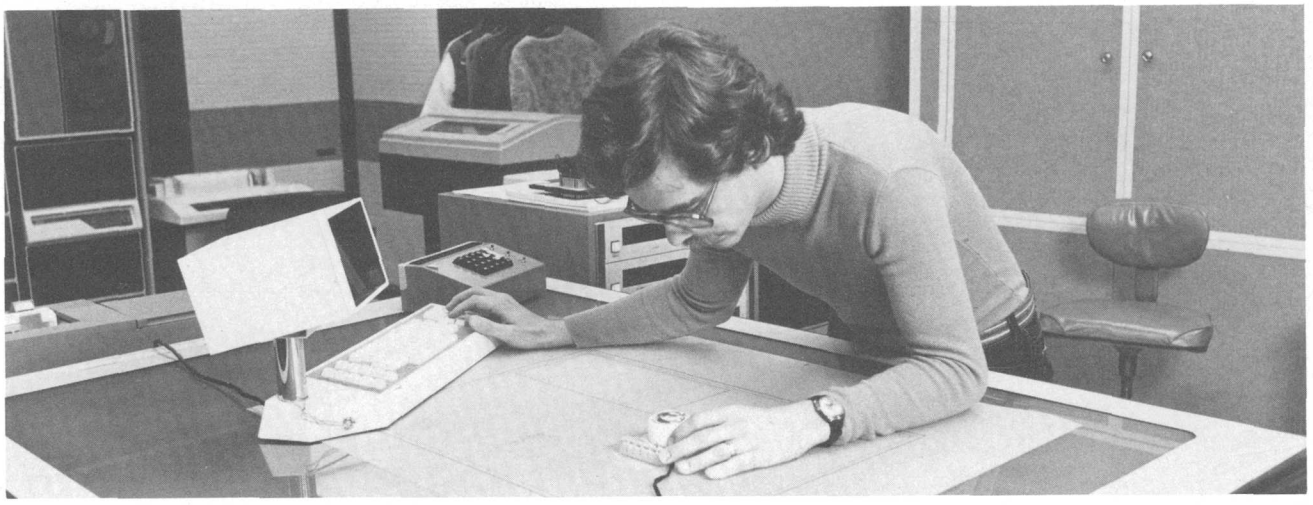
The Geological Survey has converted the standard published Idaho State Base Map at 1:500,000 scale from graphic analog information to digital data for computer processing. State boundaries, drainage, transportation, population centers, and public land surveys were digitized.

The Department of Commerce and the Department of Energy need digital cartographic data at 1:500,000-scale for 16 Western States to prepare a series of State and regional maps showing geothermal resources and tectonic information, such as ancient volcanoes, earthquake epicenters, and major faults. These graphics will serve as planning aids for exploiting geothermal occurrences. Because various map scales and projections are involved, the thematic and the cartographic data have to be in digital form.

The State of Idaho was chosen to begin the project. Duplicate positives of the original map separation plates were prepared, and, on these positives, each map feature was given an identifying number and a rank or classification. For example, every boundary received an individual number and a code that classified it as a State, county, or specific type of Federal reservation. A digitizer converted the analog map information to digital form—the operator entered the identifying data by keyboard and then traced the feature with the cursor to record the feature as a series of points measured from the lower left corner of the map. These data were computer processed for preliminary correction and then automatically plotted for comparison with the original map. Errors were corrected on a Digital Data Edit System (DDES)—poor alinements, faulty junctions, wrong identifiers, and other mistakes were all quickly displayed and corrected, and the amended versions shown again on the viewing screen of the system. The final step was to transform all the data from recorded digitizer x and y coordinates into geographic latitude and longitude coordinates.

An interesting associated effort was a project to correct the geometry of the base map. For many technical reasons, maps, especially older ones such as that for Idaho, do not meet current standards for accuracy. Manual repositioning of the map content is time consuming and expensive. However, once the information is in digital form, it can be adjusted much more easily. For example, 37 critical control points from 1:24,000-scale sources were compared with the same points on the 1:500,000-scale base map. Measured deviations were fed into an elastic body-fit program on the DDES, which in turn repositioned the digital map data. These new data were then tested against other control points and plotted back at larger scales for checking. The result was a new cartographic data file that meets National Map Accuracy Standards.

What future applications lie beyond this Idaho pilot project? By expressing the data in latitude-longitude form and adjusting for accuracy, the Idaho information can be merged with similar data in adjacent States. Work has already begun on Utah, and planning for other Western States is underway. A future possibility is a National Cartographic Data Base that can be used to selectively generate maps of States and regions at 1:500,000 scale and smaller. Secondary applications might be sorting, computation, or analysis based on administrative areas or linear networks, such as streams or transportation. Supplementary indexes to the map features appended to these files will enhance nongraphic applications.



To determine the time and cost of producing 1-meter contours, two projects are being compiled by different methods. The Nanticoke, Md., project, consisting of six 7.5-minute quadrangles, is being compiled by field surveying methods; the Golden Hill, Md., project consisting of four 7.5-minute quadrangles, is being compiled by photogrammetric methods using photographs taken with a camera 5.9-inch focal length at a flight height of 5,000 feet. The areas selected are representative of the general landform types that require 1-meter contours, that is, primarily tidal marshes and low-lying farmland.

Dual-Use Maps

The Geological Survey has prepared experimental dual-use maps of Washington, D.C., metropolitan area for the blind and the normally sighted (fig. 23). One edition has the multicolor normal visual image combined with limited tactual symbols in relief; another has a large-type reverse image combined with tactual symbols. A reversal image, white on a dark background, significantly increases the legibility and readability of graphics or text for individuals with impaired vision. The size of braille characters make it impossible to use full names on a braille map; however, abbreviations of names rather than abstract braille symbols were used to reduce the necessity for referring to the key, also in braille and in large reversal type. Both maps are preprinted on plastic sheets before being vacuum-formed to emboss the tactual information.

Digital Pilot Projects

To fulfill specific requests for digital cartographic data, to evaluate user application, and to refine data formats, nine pilot production projects covering various parts of the country are in progress. Examples of the projects are 33 7.5-minute quadrangles in Kentucky, Montana, Virginia, West Virginia, and Wyoming that were digitized to support the National Coal Resource Data Bank and 400 quadrangles in southeastern California that were digitized to support a land management plan for the BLM California Desert Planning Staff. Several categories of data are being digitized at 1:500,000 scale for the State of Idaho to support geothermal energy evaluations; a special research activity associated with this project is the investigation of the use of control points from large-scale materials to improve the positional accuracy of the digital data files.

Comparison of Landsat Image Products

Information content of Landsat cartographic products has been studied with respect to image enhancement techniques. Landmarks chosen from Geological Survey topographic quadrangle maps of northern Virginia were compared with the corresponding points on four differently processed color images of the Upper Chesapeake Bay. The original Landsat image was recorded in 1972. The variations in detectability of selected features on the small-scale images indicate that enhancement materially increased the informational content of the images. Edge enhancement, although it causes anomalies, further increases the interpretability of cultural and natural features that have continuous edges. An unexpected finding is that one-dimensional edge enhancement approaches the results obtained by two-dimensional edge enhancement.

Scribing From Digital Data

Digitized stereomodels of the Packwood SE, Iowa, 7.5-minute quadrangle are being processed to investigate the feasibility of obtaining final scribed drawings from a digitized photogrammetric system. Computer programs that transform the independent digitized stereomodel data into a format that can be manipulated by the Digital Data Edit System have been written. The editing system interactively smooths the linear information to final tolerences before the feature-separate drawings are scribed by an automatic plotter.

Camera Calibration Data Bank

The camera calibration data bank now contains calibration measurements for over 400 camera-magazine combinations; 157 are suitable for fully analytical aerotriangulation. Additional information in the data bank this year is the platen identification required on all magazines used on Survey aerial photography contracts. The platen number appears in all camera exposures. The data bank also contains information on fiducial-mark coordinates, radial lens distortion correction tables, focal length, lens type and number, nominal focal length code, camera owner, manufacturer, camera number, magazine or platen number, calibration date, and model-flatness test results.

Space Oblique Mercator Projection

Imagery from Landsat and other Earth-viewing satellites in near-polar orbits can now be prepared on a Space Oblique Mercator projection that makes it possible to print the images on a mathematically defined format. These satellites generate a narrow 299-mile-wide strip of imagery in an oblique spiral around the Earth. The Space Oblique Mercator projection is a cylinder that moves to maintain contact with the satellite ground track on a rotating Earth.

The groundtrack serves as the "Equator" of the projection, which is conformal within a few degrees of the track. Two sets of equations have been formulated—one set treats the general case of any polar-orbiting satellite, and the other set is specifically applied to Landsat.

Aerial Profiling of Terrain

Fabrication of the Aerial Profiling of Terrain surveying system to be used in light aircraft has begun. A three-coordinate scheme of reference with an accuracy of 0.5 foot vertically and 2 feet horizontally is provided by an inertial navigation subsystem using a laser unit for air-borne calibration. The ground profile is determined by a laser altimeter whose readings are related to aircraft position by computer. Design of the system was prompted by a need for obtaining terrain profiles for flood-plain delineation; other field applications include establishing survey points for the control of new maps or for evaluating the accuracy of old maps.

FIGURE 23.—Dual-use maps of the Washington, D.C., metropolitan area have been prepared for the blind and the normally sighted by the U.S. Geological Survey.

Digital Cartographic Software Development

Development of cartographic software includes file management to track digital data in production, resampling, and reformatting data derived from different sources, batch editing to verify data, and graphic composition to prepare data for plotting. Emphasis has been on developing the Unified Cartographic Line Graph Encoding System to produce topologically encoded data by automatically editing and verifying raw data from manual digitizers based on topological characteristics.

Resolution Measurements: Bar Vs. Star Targets

In the past, aerial camera lens resolution usually has been determined in a laboratory under ideal conditions. To obtain real-world data, permanent resolution targets, standard bar and Siemens star, were painted on the roof of the Survey's National Center to measure resolution obtained under operational conditions. A low contrast ratio of 2.5:1, which approximates the contract normally obtained in photographs used for mapping, was selected.

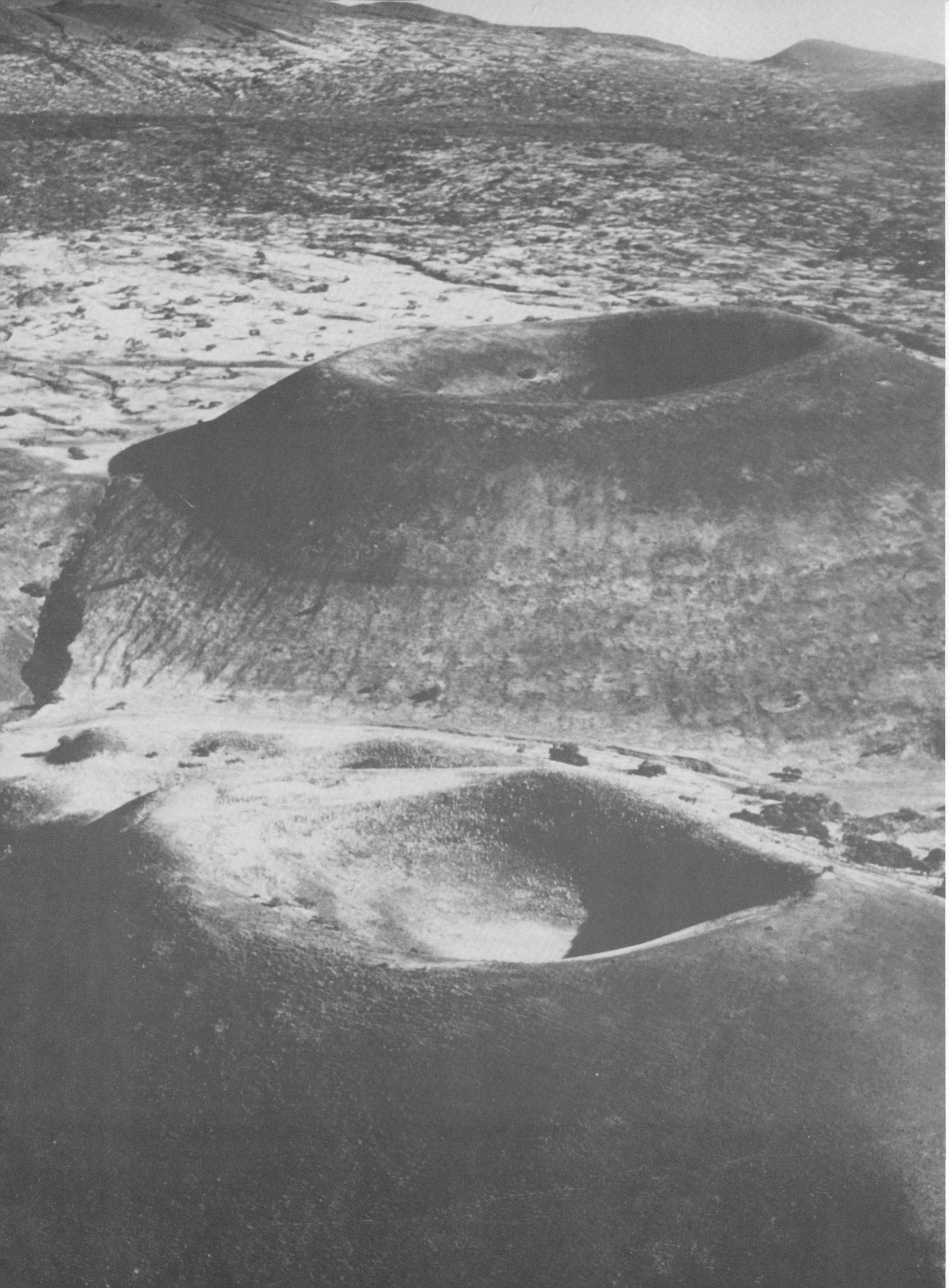
National Geodetic Datum Changes

The National Ocean Survey is readjusting the national horizontal control network and redefining the national horizontal datum based on satellite and other recently obtained data. Completion of the adjustment work, the datum definition, and the formal adoption are anticipated in 1983. To make the new geodetic data available to users, the Geological Survey is planning to show the predicted effect of the datum change on new maps by graticule ticks at the map corners and by a note in the credit legend.

Voice Data Entry of Geographic Names Information

The Voice Data Entry Terminal System, a voice recognition system having a tape-recorded vocabulary for reference, has been programed to compile updated entries to the Geographic Names Information System file. By speaking the 5 digits of the GEONAME record number and 13 digits of the geographic coordinates, the operator records a complete computer-compatible update entry on a separate magnetic tape.

Final preparation of a contour-line scribe sheet used in the production of a U.S. Geological Survey topographic map.



Geologic and Mineral Resource Surveys and Mapping

INTRODUCTION

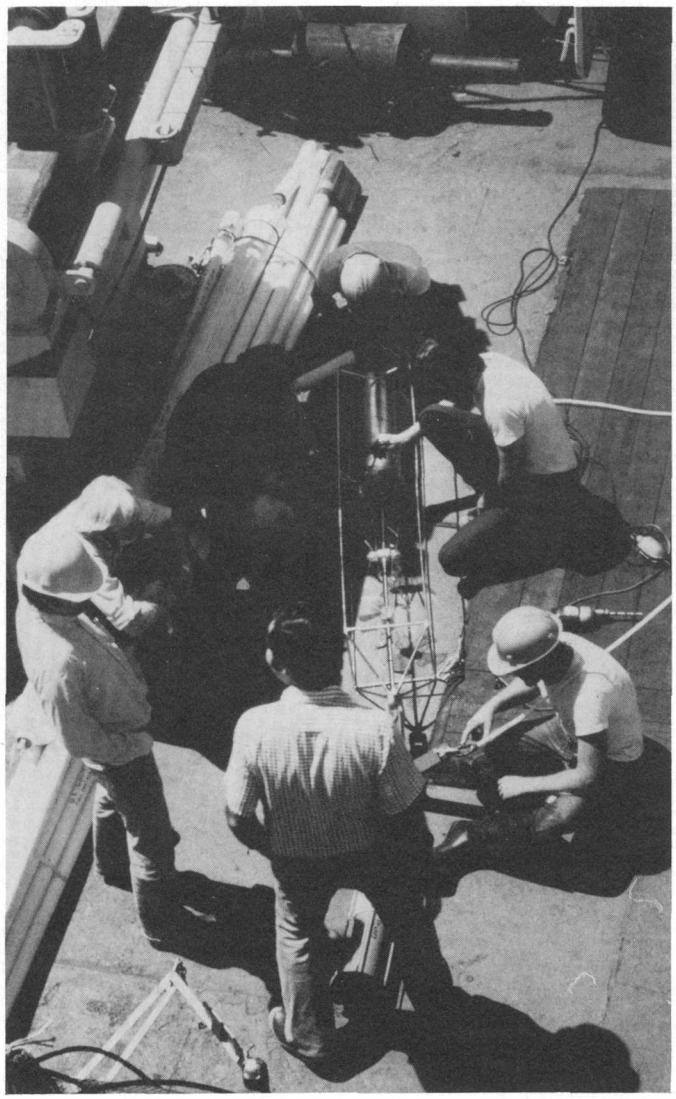
Geologic research and investigation of the Nation's resources and of the geologic processes that formed the composition and structure of the Earth are conducted by the Geologic Division. These activities provide data on the distribution, quality, and quantity of energy, mineral, and land resources required for their wise use and management. Geologic, geochemical, and geophysical data are collected, analyzed, and disseminated to the public and other Government agencies to assist in mitigating hazards caused by such phenomena as earthquakes, volcanic eruptions, and landslides; such data also help efforts to minimize damage to the environment. Four subactivities carry out the programs of the Geologic Division's basic mission. These are Land Resource Surveys, Mineral Resource Surveys, Energy Resource Surveys, and Offshore Geologic Surveys.

Land Resource Surveys provide basic data and interpretive analysis in the form of geologic, geophysical, and geochemical maps and reports. Other programs involve research on earthquake and volcano hazards; environmental aspects of energy development, especially as it affects coal exploitation; and nuclear reactor safety. Research on geologic processes and historical geologic events that develops knowledge necessary in implementing these programs is continually conducted.

Mineral Resource Surveys provide information on metallic and nonmetallic resources. Areas of emphasis include Alaska, Wilderness Areas, other public lands, and Indian lands. Data are also collected that allow a better understanding of fundamental geologic process in mineral formation.

Energy Resource Surveys provide current assessments of the Nation's energy resources. The distribution, quantity, and quality of coal, oil and gas, oil shale, uranium and thorium, and geothermal resources are continually studied so that updated information on these resources is always available.

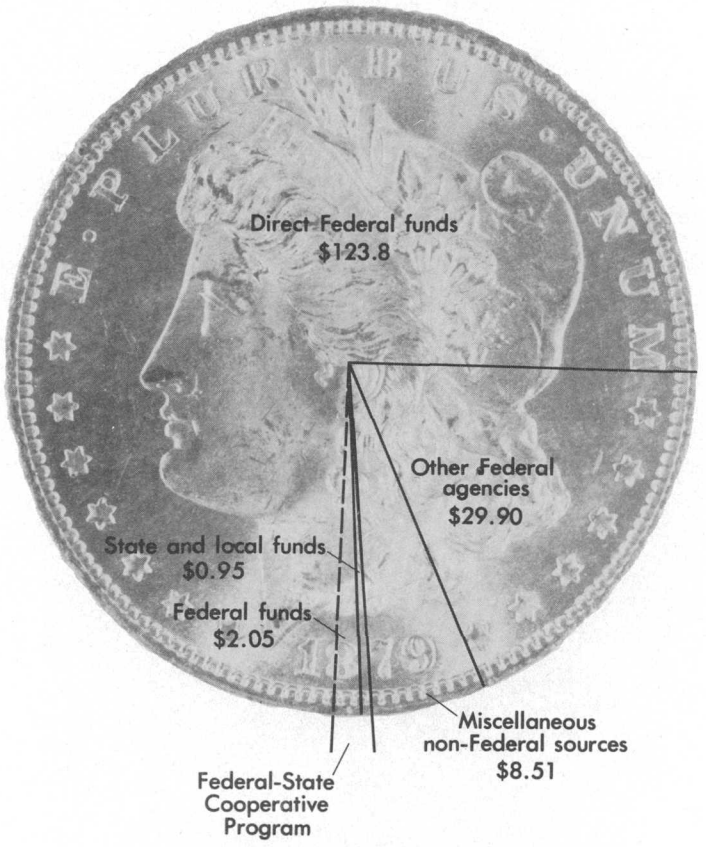
Offshore Geologic Surveys investigate the continental margins of the United States and its territories for assessment of potential mineral and energy resources. Studies are made to evaluate environmental hazards posed in the siting of offshore drilling platforms and pipelines.



Launch preparation of a current and transmissometer mooring system, which is used to estimate the sediment flux above the sea floor. The long white tubes are PVC spar sections that provide buoyancy to hold the instruments vertical while in the sea water.

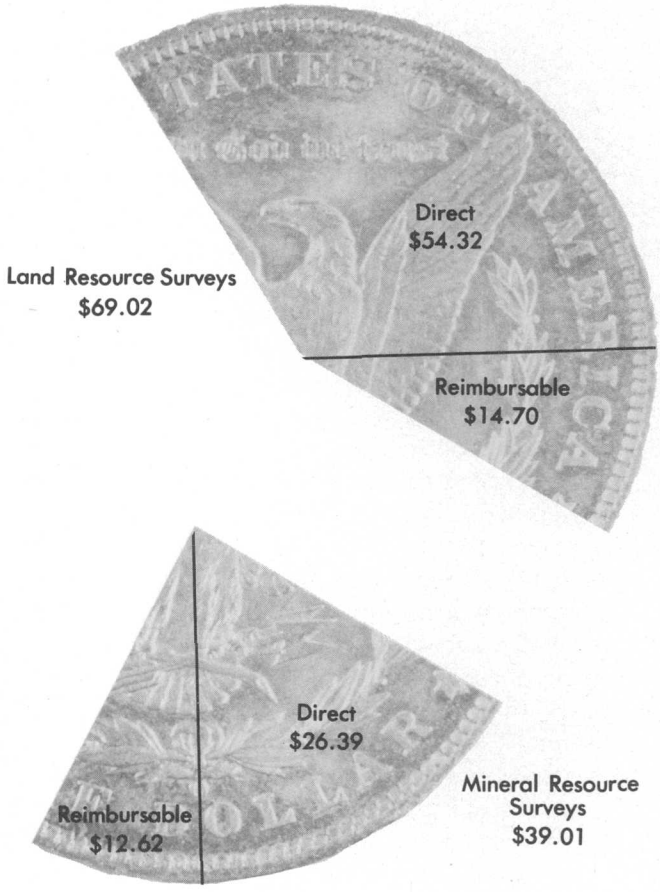
◀ Cinder cones on the slope of Mauna Kea, the highest (13,784 feet) of the five volcanoes that form the island of Hawaii. Radiocarbon dates indicate that Mauna Kea last erupted 4,000 years before present.

GEOLOGIC AND MINERAL RESOURCE SURVEYS AND MAPPING



TOTAL $163.2 MILLION

SOURCE OF FUNDS



USE OF FUNDS

BUDGET AND PERSONNEL

In fiscal year 1978, obligations of the Geologic and Mineral Resources Surveys and Mapping activity were $123.8 million. This amount was supplemented by approximately $1.0 million from 13 States and $38.4 million from other Federal agencies and non-Federal sources (table 5).

At the end of fiscal year 1978, the Geologic Division had 2,060 permanent full-time employees and 1,113 temporary or part-time employees.

TABLE 5.—*Geologic and Mineral Resource Surveys and Mapping activity obligations for fiscal year 1977 and 1978, by program*

[Dollars in millions]

Program	Fiscal year 1977	Fiscal year 1978
Total	**$130.20**	**$163.19**
Land Resource Surveys	**50.53**	**69.02**
Direct programs	35.20	54.32
Earthquake hazards	11.88	30.84
Volcano hazards	.69	1.07
Environmental aspects of energy	6.61	7.32
Arctic environmental studies	.45	.46
Engineering geology	1.29	1.26
Regional mapping and analysis	14.28	13.37
Regional geology Geophysical surveys Geochemical surveys	8.86	7.94
Dating and correlation	4.11	4.48
Geologic processes	1.31	.95
Reimbursable programs	15.33	14.70
States, counties, and municipalities	1.08	.48
Miscellaneous non-Federal sources	.26	.09
Other Federal agencies	13.99	14.13
Mineral Resource Surveys	**31.70**	**39.01**
Direct programs	23.76	26.39
Mineral resource assessment	7.92	11.80
Wilderness areas	1.35	2.81
Alaska	4.44	4.83
Conterminous States	1.91	3.94
Mineral Discovery Loan Program	.22	.22
Mineral commodities assessment	2.37	2.31
Critical commodities	1.73	1.72
Minerals for energy production	.64	.59
Mineral information system and analysis	2.14	1.95
Resources processes technology	5.87	5.95
Resource techniques in geochemistry and geophysics	5.46	4.38
Reimbursable programs	7.94	12.62
States, counties, and municipalities	.20	.30
Miscellaneous non-Federal sources	6.17	8.42
Other Federal agencies	1.57	3.90
Energy Resources Surveys	**29.02**	**34.55**
Direct programs	26.25	27.83
Coal	3.19	4.89
Oil and gas	5.59	5.69
Oil shale	1.02	.62
Uranium and thorium	5.36	5.17
Geothermal energy	9.61	9.76
Energy Resource Data System	1.48	1.70
Reimbursable programs	2.77	6.72
States, counties, and municipalities	.03	.02
Miscellaneous non-Federal sources	.01	----
Other Federal agencies	2.73	6.70
Offshore Geologic Surveys	**18.95**	**20.61**
Direct programs	14.80	15.29
Oil and gas resource appraisal	9.23	9.77
Environmental investigations	4.25	4.23
Marine geology investigations	1.32	1.29
Reimbursable programs	4.15	5.32
States, counties, and municipalities	.09	.15
Miscellaneous non-Federal sources	----	----
Other Federal agencies	4.06	5.17

LAND RESOURCE SURVEYS

Earthquake Hazards Program

The goal of earthquake hazards research is to reduce the risks to life and property from future earthquakes in the United States. The enactment of the Earthquake Hazards Reduction Act of 1977 increased the scope and intensity of Geological Survey research in (1) fundamental earthquake studies, (2) earthquake prediction, (3) earthquake hazards assessment, (4) induced seismicity, and (5) engineering seismology.

Some of the accomplishments and activities for fiscal year 1978 were as follows:

- *National Earthquake Information Service.*—In 1977, more than 40 earthquakes in the world caused fatalities, injuries, and damage. These included the earthquake in Romania on March 4 that killed at least 1,500, injured 10,100, and caused extensive damage in the Bucharest area. The earthquake was felt from Rome to Moscow and from Turkey to Finland. In the United States, 30 States were affected by earthquakes, including 21 damaging earthquakes of intensity VI or greater on the Modified Mercalli Intensity Scale as shown below.

Felt Earthquakes by State, 1977

State	Number
Alabama	1
Alaska	57
Arizona	4
Arkansas	1
California	103
Colorado	3
Delaware	1
Georgia	1
Hawaii	158
Idaho	2
Illinois	1
Maine	1
Massachusetts	2
Mississippi	1
Missouri	1
Montana	18
Nevada	4
New Hampshire	1
New Mexico	2
New York	2
North Carolina	1
Ohio	1
Oregon	2
South Carolina	4
Tennessee	1
Texas	2
Utah	6
Virginia	1
Washington	4
Wyoming	18
Total	404

Damaging Earthquakes in the United States, 1977

[Intensity VI or greater]

Date	Location	Magnitude
Jan. 3	Appleton, Mo	3.6
Jan. 8	Bay area, Calif	4.6
Feb. 9	Price, Utah	4.0
Feb. 22	Nevada (southeast of Tahoe)	5.0
Mar. 5	Farmingdale, N. Mex	4.5
Mar. 11	Harrison, Mont	4.8
June 2	Mena, Ark	4.0
June 17	Celina, Ohio	3.2
June 21	Bay area, Calif	4.7
Aug. 12	San Fernando vicinity, Calif	4.4
Sept. 5	Fairfield area, Calif	3.7
Sept. 24	San Fernando vicinity, Calif	4.2
Sept. 30	Northeastern	5.0
Oct. 19	Hebgen Lake, Mont	4.7
Oct. 21	Brawley, Calif	4.0 (swarm)
Nov. 4	Andreanof Islands, Aleutian Islands	6.6
Nov. 13	Brawley, Calif	4.3 (swarm; others at 4.0)
Nov. 22	Willits, Calif	4.5–5.0
Nov. 27	Idaho (near Cascade)	4.5
Dec. 15	Carmel Valley, Calif	2.9
Dec. 25	New Hampshire (Concord)	3.2

- *National Strong-Motion Network.*—U.S. earthquakes produced strong ground motions that were recorded at 166 accelerograph stations of the National Strong-Motion Network in 1977. (Strong-motion records are of vital interest to engineers in the field of earthquake-resistant design and construction.) A large percentage of these records were obtained from the Brawley, Calif., earthquake swarms of October 20 to 30 and November 11 to 14, 1977. Twenty-four of the records showed accelerations greater than 10 percent of gravity. The maximum acceleration recorded was 0.50 g and was caused by a magnitude 3.9 event on November 14.
- *Destructive foreign earthquakes.*—Investigations following the March 1977 Romanian and November 1977 Argentine earthquakes provided important information about the damage distribution for a large earthquake. The Argentine earthquake showed that extensive liquefaction (temporary transformation of cohesionless soil into a fluid mass) occurred over an area of about 7,722 square miles at distances of up to 124 miles from the epicenter. An international symposium was convened in Guatemala, 2 years after the magnitude 7.5 earthquake of February 4, 1976. The conference focused on the lessons learned from the experience. Important lessons about earthquake-resistant design and human behavior will be the basis for hazard mitigation measures,

disaster response activities, and reconstruction practices that can be applied in similar experiences following a destructive earthquake.

- *Relocation of earthquake epicenters in the Eastern United States.*—More than 100 instrumentally recorded past earthquakes in the United States east of 85° W. longitude were relocated by a newly refined method to provide improved relative hypocenter locations. In the Charleston, S.C., area, the relocated epicenters show that east-west trends suggested by previously published data are probably not correct. The distribution of the relocated epicenters correlates closely with the two most prominent zones of microearthquake activity defined by the South Carolina seismic network. The epicenters correlate with a zone of mafic intrusives inferred from gravity and aeromagnetic data.
- *Earthquake hazards in the Mississippi Valley area.*—An 853-foot trench across Reelfoot scarp in northwestern Tennessee provided new insight into the tectonic and seismic history of the area. The structural and stratigraphic relations observed in the trench suggest that the upper Mississippi embayment experienced at least two major earthquakes prior to the 1811–12 New Madrid earthquakes. Seismic reflection lines acquired in the area show a vertical offset in subsurface reflecting horizons at depth beneath part of Reelfoot scarp, showing it to follow a fault at depth in bedrock. The coincidence of contemporary earthquake activity in the vicinity of the Reelfoot scarp suggests that stresses active in the embayment today are similar to those that produced the 1811–12 New Madrid and earlier high-intensity earthquakes.
- *Earthquake prediction.*—A variety of monitoring networks ranging from continuously recording seismograph and tiltmeter stations to periodically occupied leveling and trilateration figures are being maintained and augmented along the San Andreas fault system in central and southern California. These networks are intended to provide a long-term stable data base against which any premonitory anomalies preceding moderate and large earthquakes can be reliably recognized, as well as a continuing flow of high-quality data in support of specific studies of fault-zone properties and the physical processes leading to earthquakes. Field work was started this summer on an intensive multifaceted study of fault-zone properties in a creeping section of the San Andreas fault near Dry Lake, 30 miles south of Hollister.

A massive effort to obtain a "stop-action" configuration for the area of the southern California uplift was undertaken in early 1978. Under the general supervision of the National Geodetic Survey, but funded primarily by the Geological Survey, more than 2,858 miles of first-order leveling and gravity survey was completed in less than 4 months, in spite of delays caused by an exceptional sequence of severe storms. The configuration provided by this general releveling will serve as a long-term standard datum for comparison with archival survey data in testing models of the formation and evolution of the uplift and in assessing its implications for the potential of a large earthquake.

No large earthquakes have yet occurred within any of the concentrated networks in the conterminous United States. For this reason, the magnitude 6.8 earthquake that occurred on January 14, 1978, in the intensively monitored Izu-Oshima region of Japan is of particular interest. Although this earthquake was not specifically predicted by Japanese geophysicists, it occurred on the edge of a regional topographic uplift of 6 inches first recognized in 1976. In addition to a remarkable foreshock sequence, this earthquake was preceded, by several weeks, by notable anomalies in volume strain and random emission, as well as a variety of other less clear but suggestive anomalies. Also of interest was a magnitude 6.5 earthquake that occurred late in

Geodolite survey for fault monitoring.

1977 within a seismic network maintained on Adak Island, Alaska. The local earthquake activity preceding the main shock showed several distinctive patterns that may prove to be premonitory to other moderate-to-large Aleutian earthquakes.

- *Production of seismicity maps for each State.*—A 1978 map showing the distribution, maximum intensity, and year of occurrence of historic earthquakes in the State of Maine is the first map in a series. Maps for each of the other States will follow, some of which are cooperative efforts with the States.
- *Ground response in urban areas.*—Portable seismograph systems were deployed at 125 selected locations in the greater Los Angeles, Calif., area and at 37 locations in the Salt Lake City–Provo, Utah, area. Ground motions were recorded at each location from Nevada Test Site nuclear explosions. The ground-motion records from these events are being used to produce preliminary ground-response maps, an important part of the assessment of the earthquake hazards for each area.
- *Analysis of strong ground-motion data.*—In the 90 days following the August 1975 Oroville, Calif., earthquake, a unique set of 313 strong-motion accelerograms were obtained. Most of these records were obtained at hypocentral distances of 24 miles or less, a distance range for which very few strong-motion accelerograms had previously been available. Analysis of these data has shown that peak acceleration increases fairly rapidly with magnitudes up to 5 but appears to remain constant above that. These data reinforce the suggestion that peak particle acceleration alone is a poor measure of earthquake source strength and a poor parameter with which to scale ground motion for certain engineering design applications. In those applications, peak particle velocity appears to be a more appropriate parameter for estimating the increase of ground motion with the increase of earthquake size.
- *Field studies of fault zones.*—Field studies of fault scarps in alluvium in western Utah have disclosed a systematic relationship between scarp height, slope angle, and age. For scarps of a given age, the slope angle of the scarp is proportional to the logarithm of the scarp height, and slope angle decreases with estimated age for scarps of a given height. Although the ages for the scarps studied are only approximately known, the procedure provides a means of ranking scarps according to relative geomorphic age within a general age framework for scarps between several thousand and several hundred thousand years old, thereby yielding important information on prehistoric earthquake recurrences.
- *State-of-the-art workshops.*—Six workshops were held to enhance communications between Survey and non-Survey personnel working on the Earthquake Hazards Reduction Program, to improve interdisciplinary communications among investigators working on several aspects of the program, and to improve public education about the consequences and potential for mitigation of earthquake hazards. The subjects of the workshops include (1) abnormal animal behavior prior to earthquakes, (2) experimental studies of rock friction with application to earthquake prediction, (3) fault mechanics and its relation to earthquake prediction, (4) the use of volunteers in the Earthquake Hazards Reduction Program, (5) seismic gaps and earthquake prediction, and (6) communicating earthquake hazard reduction information. Proceedings were published following each workshop.

Volcano Hazards Program

The primary objective of the Volcano Hazards Program is to mitigate the hazards posed by the active volcanoes in Hawaii, the Cascade Range (Washington, Oregon, and California), and the Alaska Range. Intensive monitoring of Hawaii's Mauna Loa and Kilauea, two of the world's most active volcanoes, has been the principal focus of the program, but, beginning in fiscal year 1979, increased emphasis will be placed on the Cascade volcanoes.

Accomplishments for fiscal year 1978 include the following:

- Upgrading and expansion of monitoring networks on Mauna Loa indicated a retardation of the rate of summit inflation from earlier rates.
- Measurement of a triangle linking Mauna Kea, Mauna Loa, and Hualalai Volcanoes showed a decrease in distance between the volcanoes; this decrease is related to the slowed inflation rate of Mauna Loa.
- Continuation of active participation with Hawaii State and county officials and Federal agencies on contingency planning and lava-diversion studies in anticipation of a Mauna Loa eruption, which might pose a threat to Hilo, the largest population center on the island of Hawaii.
- Initiation of a program of systematic monitoring of the chemical composition of volcanic gases to try to evaluate the utility of detecting chemical changes as premonitory signals of impending eruptive activity.

- In response to a Department of State request, preparation of a map of the potential volcanic hazards from Cotopaxi Volcano, Ecuador, as part of the program to provide technical assistance to foreign countries.

Environmental Aspects of Energy Program

The Environmental Aspects of Energy Program is directed to the study, interpretation, and distribution of geologic, hydrologic, geophysical, geochemical, and other information that will assist in the analysis and resolution of environmental problems related to energy development and to the planning, siting, and construction of energy-related facilities.

ENERGY LANDS PROGRAM

Present and near future development of coal and oil shale resources, chiefly through surface mining, has a major potential for negative impact on the environment in many areas across the country. The Energy Lands Program is designed to assess existing baseline knowledge of environments in the coal and oil shale resource areas to predict changes that may occur during mining and development, to monitor changes as they occur, and to suggest means of mitigating negative impacts of energy development on the environment. Types of studies underway include bedrock and surficial geologic mapping, engineering geologic investigations, geochemistry of surface materials and plants, climatic conditions as they affect rehabilitation potential of mined lands, and feasibility of surface and underground mining. The purpose common to all studies in the Energy Lands Program is to provide timely earth science information pertinent to environmental preservation to managers, policymakers, engineers, scientists, planners, and others to contribute to the orderly and safe development of the energy resources of the Nation.

Accomplishments of the program during fiscal year 1978 include the following:

- Completion of a map of the power-generating plants of the United States showing location (built, in construction, planned); type of plant (fossil fuel, nuclear); type of fuel (coal, oil, gas, nuclear); SO_2 content, if fossil fuel; and type of scrubbing plant, startup date, and capacity.
- Completion of mapping of the surficial geology of 40 7.5-minute quadrangles in the eastern Powder River Basin, Wyo. Each quadrangle notes information in regard to alluvial valley floors in the area, a major consideration in surface mining of western coal.
- Publication of reports on surface effects of subsidence into underground mine openings in the Powder River Basin and for an unnamed basin including parts of Utah and Colorado. These studies are essential to planning for underground mining, and in situ gasification of coal and of oil shale.
- Preparation, in cooperation with other programs in the Survey, of a folio (1:100,000 scale) of the Recluse quadrangle, Wyoming, showing bedrock, surficial geology, engineering geology, climatology, coal geology, land use, and land cover maps as well as derivative environmental maps. The folio illustrates types of information essential to wise coal resource development in the West.

REACTOR SAFETY PROGRAM

Expanding demand for electrical power and growing constraints on petroleum availability will probably lead to an increased reliance on nuclear power reactors as a major source of electrical power in the near future. The Reactor Safety Program is designed to identify and improve upon our understanding of geologic processes such as fault movement, failure of foundation materials, and volcanic eruption that may be hazardous to nuclear power reactors. The program seeks to determine the geographic distribution and expected frequency and severity of these processes to help expedite the safe siting, design, and licensing of civilian nuclear power reactors in the United States.

Beyond the study of problems encountered in specific licensing applications, the program focus is on the study of regional geologic settings, on the constraints they impose on reactor siting, and on the development of techniques and an understanding of processes necessary to regional study and site evaluation.

Accomplishments of the program during fiscal year 1978 include the following:

- Recognition, in addition to a previously recognized seismic zone, of a second potential seismic source for the 1886 Charleston, S.C., earthquake.
- Recognition that active faults do exist in the Peninsular Range of southern California, an area previously thought to be tectonically stable and suitable for reactor sites.
- Major revision of the tectonic model of the Puget Sound area resulting from recent field work which could affect major energy facility siting.
- Continued study and application of the new amino acid dating technique that has resulted in improved age dating of tectonic events along the Pacific coast of the United States.

NATIONAL ENVIRONMENTAL OVERVIEW PROGRAM

Maps (1:7,500,000 and 1:1,000,000 scale) are being prepared that summarize many of the characteristics and the distribution of geologic processes and earth materials. These will be useful in an understanding of national environmental problems and will serve as a technical data base for decisionmaking in land, energy, and mineral resource management. The maps will be synoptic land resource inventories that will show extent of, and predict the recurrence of, certain geologic processes and events that may constrain safe land utilization and energy and mineral resource development. The following maps have been recently completed in preliminary form:

- Limestone resource map.
- Solution mining subsidence.
- Quaternary dating applications.
- Lithologic map of the United States.
- Quaternary geologic map of the Chicago, Ill., area (showing distribution of surficial materials).
- Quaternary geologic map of the Minneapolis, Minn., area (showing distribution of surficial materials).

Arctic Environmental Studies Program

The arctic and subarctic regions of Alaska pose special problems for the development of natural resources, transportation systems, and urban development, primarily because of the unusual environmental conditions of permafrost (perennially frozen ground). Ice-rich permafrost soils undergo a change in volume when thawed resulting in severe damage to buildings and other engineering structures. Because of the unique geologic-environmental conditions that exist in the northern regions, geotechnical data are especially important to determine the proper engineering techniques and procedures to use, not only to minimize disruption of the natural environment but also to provide economical and safe methods of design.

Major accomplishments of the program during fiscal year 1978 include the following:

- Continuation of the engineering-geologic mapping of the Tanana Valley transportation-development corridor between Fairbanks and the Canadian border.
- Continuation of the compilation of engineering-geologic maps of the Arctic Coastal Plain between Prudhoe Bay and the Canadian border, which includes the northern part of the Arctic National Wildlife Range.
- Continuation of surficial-environmental geologic mapping of the central Brooks Range, which includes several transportation corridors across the Brooks Range from the energy-rich Arctic North Slope.
- Completion of a 3-year study of the seismicity of northeastern Alaska, demonstrating that this large region is subject to earthquakes although it was previously considered to be essentially aseismic.
- Completion of a series of preliminary engineering-geologic strip maps of the route of the proposed Alaska Highway gas pipeline between Fairbanks and the Canadian border.
- Continuation of the exchange program with Soviet scientists and engineers concerned with pipelines, permafrost, and environmental protection.

Engineering Geology Program

The Engineering Geology Program is focused primarily on geologic processes and the behavior of earth materials as they affect the works of man and on the application of geologic knowledge to increase the safety, efficiency, and economy of design of structures and other engineering works. A major aspect of this program is the study of the areal and geologic distribution of geologic processes (that is, hazards) that are of major engineering significance (landslides, mudflows, floods, catastrophic erosion, failure of foundation materials because of subsidence, collapse, or liquefaction; earthquake shaking; and volcanic eruption) and the influence of physical and chemical properties and the environment on the causes, rates, and effects of these geologic hazards.

Major accomplishments of the program during fiscal year 1978 include the following:

- Completion of a major study on the classification, analysis, and control of landslides; to be published by the National Academy of Sciences.
- Recognition and mapping of a fault, the Ventura fault, within the metropolitan limits of Ventura, Calif., a probable source of seismic activity and Holocene movement.
- Completion of aerial photographic studies of landslides and slopes susceptable to landslides for a major part of the Appalachian region.
- Evaluation of instrumentation techniques used to identify subsurface features that affect slope stability.
- Participation in a study of the causes of failure of the Kelly Barnes Dam, Toccoa, Ga.
- Completion of studies and compilation of thermal properties of rocks, information that is critical to an estimation of geothermal resources and the thermal regime around radioactive waste repositories.

Regional Mapping and Analysis Program (Geologic Framework)

This fundamental program is designed to expand and to develop knowledge of the geologic framework of the Nation. Products of the program are basic to geologic work throughout the Geological Survey and are widely used by other Federal and State agencies and the public. This program is comprised of (1) surveys to determine the distribution and properties of earth materials, (2) studies to determine the absolute and relative ages of those materials, and (3) studies of geologic processes responsible for the formation, modification, and distribution of materials within or at the surface of the Earth.

GEOLOGIC MAPPING

Geologic mapping activities are determined by present and impending environmental and resource problems, by needs of other Federal and State agencies, and by the need to expand the basic knowledge of the Nation's rocks and surficial materials to meet mission program needs. Relations between the environment and the incidence of disease, geologic factors controlling food production, climate changes and their possible effects on the use of and demand for the Nation's resources, the management of radioactive wastes, and the development of alternate energy sources are among the diverse and complex problems that will rely, in the near future, on knowledge of the Nation's geologic framework. By means of cooperative agreements with several States, the Survey is also involved in Statewide mapping programs.

Major accomplishments for fiscal year 1978 include the following:

- Radiometric age determinations for some basalt rift systems in the Snake River Plain, Idaho, indicate eruption-recurrence intervals of 3,000 years. Some systems, however, may show an even shorter eruption interval.
- The cooperative program of detailed geologic mapping of the entire State of Kentucky was brought to a successful close. The program extended over nearly two decades and involved 1:24,000-scale geologic mapping of 707 quadrangles. Major results will be presented in a series of summary reports and in a new State geologic map at a scale of 1:250,000. The Kentucky Geological Survey estimates that the value of the maps to the State is nearly 51 times the $32 million cost of the program.
- Geologic mapping of western Montana has led to a better definition of both the geometry and the genesis of a part of the Cordillera thrust belt. New data indicate that a major block of this belt last moved between 81 and 77 million years ago. The thrust belt of Montana is a major potential source of petroleum.
- The cooperative mapping program with Massachusetts indicates that eastern Massachusetts, Rhode Island, and part of Connecticut (a sliver of the ancient African continental plate) were left sutured to the North American plate along a zone through central Massachusetts when the African and North American plates split 200 million years ago. This most recent split led to the formation of the present Atlantic Ocean.
- Ongoing studies indicate that the rate of uplift and the rate of erosion and weathering of the southeastern Piedmont are alike, 33 feet per million years, and that they have been in balance for about the last 200 million years.

GEOPHYSICAL SURVEYS

Applied and theoretical studies of potential field geophysical data, such as gravity and magnetic data, contribute fundamentally to our knowledge about the characteristics of rocks and structures beneath the Earth's surface. This research is multipurpose and provides a foundation upon which future research dedicated to mineral and energy resources and geologic hazards can be built.

Some of the activities and accomplishments of this program for fiscal year 1978 were as follows:

- Development and successful testing of a new method for determining from a continuous record of magnetic anomalies the depths to the tops of the magnetic rocks causing these anomalies using the maximum entropy power spectrum of the profile data.
- Development of the theory for a generalized approach to the inversion of magnetic and gravity data and reduction and treatment of irregularly distributed data.
- Interpretation of magnetic anomalies over the United States from satellite data which indicates that the most salient anomaly gradients are associated with lateral contrasts of oceanic and continental crust and intercontinental variations in remanent magnetization and crustal thickness due primarily to changes in regional temperature gradients.
- Compilation and interpretation of regional geophysical data in New Mexico which show that the Rio Grande rift encompasses uplifts of the Southern Rocky Mountains in a terrain of en echelon faults which are alined with structural cracks in the basement.

GEOCHEMICAL SURVEYS

The distribution and abundance of chemical elements in rocks, soils, stream sediments, and vegetation provide a basis for appraising the impact of these factors on the economic, environmental, and health interests of the Nation.

Major accomplishments for fiscal year 1978 include the following:

- Geochemical baselines which are used to measure or monitor changes in the environment have been established for 36 regional landscape units spread throughout the energy region of the northern Great Plains; the Powder River, Big Horn, and Wind River Basins; the oil shale region of Colorado and Utah; and the San Juan Basin.
- Chemical data on a variety of plants which include crested wheatgrass, sweetclover, alfalfa, and wheat indicate that coal mine spoils, even with considerable topsoiling, can change the level of many elements to an appreciable degree. Some of these effects are nutritionally beneficial in terms of required concentrations of essential elements in animal forage; others—in particular, the ratio of copper to molybdenum—may induce mineral imbalances in livestock.
- Statistical analysis of concentrations of major, minor, and trace elements in surface sediments in the St. George Basin on the Outer Continental Shelf (OCS), southern Bering Sea, indicates three source areas of sediment—a dominant felsic component from the northern Bering Sea derived from the Yukon and Kuskokwim Rivers, andesitic components from the Aleutian Islands, and a local basaltic component derived from the Pribilof components from the Aleutian Islands, and a local basaltic component derived from the Pribilof Islands. Sediment distribution is further modified by ponding of finer grained, higher organic sediments in the center of the St. George Basin. This information provides a baseline with which to measure future variations that may result from offshore economic exploration and development.

DATING AND CORRELATION—PALEONTOLOGY AND STRATIGRAPHY PROGRAM

The study of life based on fossils, paleontology, and the study of the sedimentary rocks that enclose those fossils, stratigraphy, are essential to an understanding of the geologic history of the Earth, and geologic history is basic to a thorough understanding of the Nation's geologic framework. Paleontologic and stratigraphic information makes possible the relative dating and correlation of geologic deposits, the interpretations of environments in which previous life forms existed, and the assessment of changes in life forms through time. Results of this program are critical to major programs throughout the Survey, and they enable the Survey to respond to both present and future problems requiring a knowledge of the history of geologic events.

Highlights of the Paleontology and Stratigraphy Program in fiscal year 1978 were as follows:

- Biostratigraphic studies in combination with new techniques of absolute age dating have established a more precise correlation of deformed shoreline deposits along the Atlantic Coastal Plain. A better understanding of the deformational history of the area is critical to an assessment of earthquake hazards to the siting of nuclear reactors in the area.
- Recent studies indicate that vertebrate animals existed at least 512 million years ago, that is, 40 million years earlier than previously believed. Study of these fossils provides new knowledge on the anatomy, ecology, and evolution of the vertebrates, as well as new tools for correlation, dating, and paleogeographic reconstructions of ancient seas and landmasses.
- Study of fossils and the magnetic properties of the enclosing rocks indicates that some of the continental margin between Oregon and Alaska is composed of blocks of material formed near an ancient equator and moved 30° to 60° northward before being joined to what is now North America. A better understanding of these blocks is of great economic importance because some of these transported rocks in the Wrangell Mountains of Alaska contain rich copper deposits.
- Study of conodonts and brachiopods indicates that the Phosphoria Formation, a major source of fertilizer raw materials, can be extended into areas where it was not thought to exist. The fossil forms indicate that thicker phosphatic parts of the formation were deposited in small depressions on the shelflike margin of an ancient sea.
- Studies of 85- to 100-million-year-old pollen and other fossils in Texas have been used to establish a more precise biostratigraphy of rocks containing only the pollen fossils in the Atlantic Continental Shelf. This biostratigraphy will aid in the exploration for petroleum on the Atlantic Continental Shelf.

DATING AND CORRELATION—ISOTOPE GEOLOGY PROGRAM

The Isotope Geology Program investigates, develops, and utilizes methods for determining ages of rocks and minerals, geochemical methods for study-

ing geologic processes, and neutron activation methods of field chemical analysis for mineral exploration. This work provides the basic data necessary for understanding Earth history and the geologic processes that have been active in shaping the Earth for the last 4.5 billion years and for solving a great variety of problems, ranging from mineral exploration to nuclear plant site evaluation, in which knowledge of the age of rocks or geologic events is essential.

Highlights of the program during fiscal year 1978 include the following:

- Establishment of a volunteer and paid sampler network is providing well water samples from the Yellowstone National Park and the San Andreas fault areas for the determination of the helium contents to assess its use as a geochemical precursor of earthquakes.
- Operation of the argon mass spectrometer that will be unique when it is functioning on all five collectors; it is now operating on three collectors. Even at this stage, measurement of accurate potassium-argon ages is permitted even when only 1 to 2 percent of the argon measured has been contributed by the radioactive decay of the parent potassium. This improvement has permitted undertaking the assessments of volcanic hazards at the candidate nuclear waste disposal sites in Idaho.
- Discovery that the isotopic composition of lead in Mesozoic and Cenozoic ore deposits is related to igneous activity in the Western United States correlates with the maximum production expected of the deposit. A new method of assessing the economic potential of these deposits is thus provided.

GEOLOGIC PROCESSES

Studies of geologic processes are made because they are fundamental to understanding the origin of mineral and energy resources and because many of these processes bear directly on health and the environment. Current studies include the thermodynamic properties of uranium compounds as related to the solution mining of uranium and the disposal of radioactive wastes, the occurrence and characterization of asbestiform minerals and their application to future public health legislation, the mechanism of volcanic eruptions, and the gas monitoring of volcanoes as a possible means to predict eruptions.

Activities and accomplishments for fiscal year 1978 include the following:

- Development of a comprehensive program of research on radioactive waste disposal, including investigations of potassium chloride, calcium chloride, calcium sulfate, and magnesium chloride systems.
- Completion of studies of the detailed crystal structure of copper sulfate ores. Results of this research will aid in exploration for new copper resources.
- Clarification of the health hazards caused by different fibrous minerals. Crocidolite is apparently a major health hazard, but not all fibrous minerals are equally hazardous.

MINERAL RESOURCE SURVEYS

Mineral Land Assessments

ALASKA

Mineral resource studies in Alaska constitute a long-range program designed to provide a systematic assessment of all potentially mineralized land in the State. The accumulated information and data are published in folios consisting of geologic, geophysical, geochemical, and Landsat image maps. All the maps, each of which is accompanied by a text, are used as building blocks to produce a map that outlines areas with mineral resource potential. Within areas for which there is adequate information on mineral deposit types, a quantitative probabilistic estimate of the mineral resources is made.

Highlights of the program during fiscal year 1978 include the following:

- Open-file release of a mineral resource assessment at a scale of 1:1,000,000 of the main body of Alaska for use by the Department of the Interior and Congress in making decisions on classification and allocation of Alaska's public lands.
- Completion of detailed resource assessment studies in the McCarthy mining district. Similar studies were underway in two other districts in Alaska.
- Publication of mineral resource assessments in seven quadrangles at a scale of 1:250,000. Fieldwork was carried out in nine other quadrangles.

CONTERMINOUS STATES

Areas that have a high proportion of public land and a high potential for mineral resources are receiving comprehensive systematic study. Geologic, geochemical, and geophysical studies are combined to produce maps at a scale of 1:250,000. These integrated studies are the basis for mineral resource assessments that provide information on present and potential mineral supplies. Data from these assessments are an important consideration for land use planning by Federal, State, and local governments.

Major accomplishments for fiscal year 1978 include the following:

- The Atlantic Coastal Plain of South Carolina has been surveyed with airborne radioactivity detectors. Ground checks of areas with anomalous radioactivity show that a few are caused by heavy mineral concentration in Pleistocene beach sands; five were found that contain an estimated 2 million tons of possible economic grade. Other areas of anomalous radioactivity are associated with phosphate deposits that contain traces of uranium. Recognition of these deposits extends the area of potential phosphate resources far beyond previously known deposits.
- Geological and geophysical work in the Iron Mountain 2° quadrangle, Wisconsin and upper Michigan, indicated the presence of a swarm of igneous dikes that extend at least 19 miles beyond their last surface exposure. The area, deeply covered by glacial deposits, is a significant extension of rocks that have a high potential for copper or nickel deposits.
- Careful scrutiny of mineralized rocks in the Canon City area of Oregon succeeded in identifying the origins of its copper and gold veins. Although they occur in the same groups of rocks, they were found to be formed by two different episodes of mineralization. Successful prospecting, therefore, requires different approaches for the two types of deposits.

WILDERNESS AREAS

The United States contains many millions of acres that have not been developed or otherwise changed as a result of man's use. Some of that land is being classified as wilderness and will be permanently closed to future mineral exploration. Prudent selection of areas for such withdrawal requires knowledge of potential resources that they may contain. The Survey, in cooperation with the Bureau of Mines, has completed appraisals of the mineral resource potential of about 18.5 million acres of land proposed for wilderness.

Accomplishments during fiscal year 1978 include the following:

- Publication of mineral resource assessments for eight areas comprising about 2 million acres. They are as follows:
  1. Jarbidge, Nev.
  2. Cabinet Mountains, Mont.
  3. Snow Mountain, Calif.
  4. Cranberry, W. Va.
  5. Elkhorn, Mont.
  6. Bob Marshall, Mont.
  7. Rock Creek Canyon, Mich.
  8. Sturgeon River, Mich.
- Five of the above areas have potential for mineral resources. They are as follows:
  1. Jarbidge, Nev. The central and east-central part of the area has a high potential for barite.
  2. Cabinet Mountains, Mont. The southern part of the area has a potential for large deposits of copper and silver.
  3. Bob Marshall, Mont. The east half of the area has a high potential for natural gas.
  4. Elkhorn, Mont. The northwest side of the area has a potential for molybdenum; the south has a potential for molybdenum and copper.
  5. Cranberry, W. Va. Approximately 116 million tons of coal are present in seams thick enough and close enough to the surface to allow economic recovery.
- No significant mineral resource potential is known in the Rock River Canyon, Sturgeon River, and Snow Mountain areas.

INDIAN LANDS

Phase I studies on Indian lands consist of the review and evaluation of existing information and recommendation of further work where needed. These studies, done jointly by the Geological Survey and the Bureau of Mines, were completed on 13 reservations or groups of reservations, with a total area of 1.6 million acres in fiscal year 1978.

Phase II studies involve reconnaissance geologic mapping and geophysical and geochemical studies by the Geological Survey. In fiscal year 1978, Phase II studies were continued on the Papago Indian Reservation, Ariz., the Fort Belknap and Flathead Reservations, Mont., and the Pine Ridge Reservation, S. Dak., a total of 7.5 million acres. New projects were started on eight Indian reservations; they were Acoma, N. Mex., Blackfeet, Fort Peck, and Crow Reservations, Mont., Wind River, Wyo., Rosebud, S. Dak., and the Mole Lake and Lac du Flambeau Reservations, Wis. Total area involved in the new projects is 6.6 million acres.

Noteworthy results of Phase II studies include the completion of six 15-minute quadrangle geologic maps on the Papago Reservation, Ariz., and the delineation of a drilling program for geothermal energy on the Flathead Reservation, Mont.

Resource Information and Analysis

The minerals and metals most important to national and world economy are studied by commodity

specialists, who collect worldwide data on geologic occurrences and on the current and potential future sources. They maintain data on the origin and distribution of important mineral commodities and evaluate the significance of new discoveries and newly recognized processes in ore formations and apply them to assess the potential for mineral resources in areas under study.

Data on worldwide mineral supplies are stored in computer data banks, where they can be used by commodity specialists and others to supply information on which to base land use decisions and national mineral policy decisions. New computer programs are developed to evaluate current information and to estimate future supplies.

Major accomplishments of these interrelated fields in fiscal year 1978 include the following:

- Detailed studies in northern New York State resulted in the recognition of a very large body of high-calcium marble, within about 25 miles of the St. Lawrence Seaway. Utilization of material from that deposit as a flux in iron and steel making could result in significant savings in transportation costs compared with sources now in use.
- An evaluation of the fluorine provinces of the United States show that fluorspar occurs mostly in the Rocky Mountains, Appalachia, and the midcontinent. Fifty-five percent of known fluorspar reserves are in Illinois and Kentucky. Additional very large resources of fluorine are in phosphate rock, where the fluorine content is too low to permit economic recovery of itself but which may be recovered from the processing of phosphate rock for fertilizer. Major phosphate deposits are in Florida, Idaho, North Carolina, Tennessee, and Utah.
- Examination of data on past and current world sources and world consumption of chromite indicates that projected world demand for the period 1976 to 2000 will be double the total world production prior to 1976. By the year 2000, world markets will be dominated by the immense chromite resources of South Africa and Rhodesia.
- Consideration of known geologic environments that contain major deposits of lead and zinc throughout the world indicates that a significant potential exists for undiscovered deposits in buried shale sequences in the Eastern and Central United States. Detailed understanding of the geologic history of these concealed rocks can lead to the definition of favorable target areas with a high potential for new deposits.
- A computer program, using weighted aggregates of observed characteristics including lithology, structure, magnetic intensity, and reflectance, was developed to provide a quantitative assessment of the resource potential of a mineralized area. The program has an important application in the assessment of the resource potential of large remote regions.
- Analysis of petroleum production and petroleum discovery rates in free world countries outside the United States and Canada shows that peak production for those countries will occur in the 1990's. Peak production for the world as a whole will occur earlier.
- A worldwide computer network was established to provide information and methods for resource assessments and analysis. One hundred forty-one geologists in 10 countries made extensive use of the network to share resource information, to disseminate scientific information, and to consider policy issues.
- International standards for resource assessment methods, primarily for developing countries, were developed and accepted by more than 40 countries. This provides the first opportunity to conduct resource assessments and studies in a uniform format useful to all nations involved.

Resources Processes

Assessment of mineral resources is greatly facilitated by the understanding of the processes responsible for their formation. A variety of field and laboratory studies, including the study of mining districts, detailed studies of ores, and experimental work on the physical and chemical properties of minerals and rocks, contribute to such understanding.

Resource processes under study in fiscal year 1978 provided the following results:

- Molybdenum deposits in the Battle Mountain district, Nevada, are related to a group of small quartz monzonite intrusives. Emplacement of both the intrusives and the molybdenum was controlled by jointing. Two sets of joints striking north and N. 70° W. controlled igneous rock emplacement; the ore veins are mostly in the N. 70° W. set, but a N. 45° E. set was important as conduits for mineralization. Much of the ore is associated with intense potassic alteration. Fluid inclusion study suggests molybdenite deposition from moderately saline solutions at temperatures of 300° to 400°C.
- Mapping, microscope studies, examination of fluid inclusions, and extensive chemical and microprobe analyses of the porphyry copper deposit at Ray, Ariz., were used to test theories on the

origin of the deposit. Earlier models of ore genesis were found to be inadequate. The Ray deposit appears to have formed from sulfides that remained below the porphyry until the intrusive had cooled enough to allow circulation of late magnetic metal-bearing water. Regional structures appear to exercise important controls on the localization of ore.

- Chemical composition and properties of radioactive ground water and spring water in the Southwestern United States are controlled by a complex group of factors. Multivariate analyses of analytical data revealed that nine identifiable characteristics controlled the properties of the water. Differences in the properties of the water were a function of the variations in the intensity of the nine processes at various springs and in various geologic environments. Properties of radioactive water are controlled by (1) total dissolved solids, (2) true alkalinity, (3) temperature, and (4) uranium-iron concentration. The composition of precipitates from the waters are determined by (1) contamination by migrating salts, (2) manganese precipitation, (3) iron-arsenic-beryllium precipitation, (4) heavy metal precipitation, and (5) barium-radon precipitation. Computed intensity levels allow the scoring of intensity levels of each process that affected a particular water or precipitate sample.
- Detailed studies in the Duluth Complex, Minn., provided a basis for understanding the patterns of the large number of faults that cut these rocks. Interpretation of the pattern is important in evaluating the continuity of the nickel-copper deposits that occur in the complex.

Geochemical and Geophysical Techniques in Resource Assessments

As the supply of near-surface easily found mineral resources dwindles, detection of concealed deposits becomes increasingly important. Development of new geochemical and geophysical techniques and of new ways to interpret these and other sort of geologic information are major needs. Survey efforts in this direction include not only conception and design but also the testing of the new equipment and techniques in resource assessment and their incorporation into further assessment work as successful developments occur.

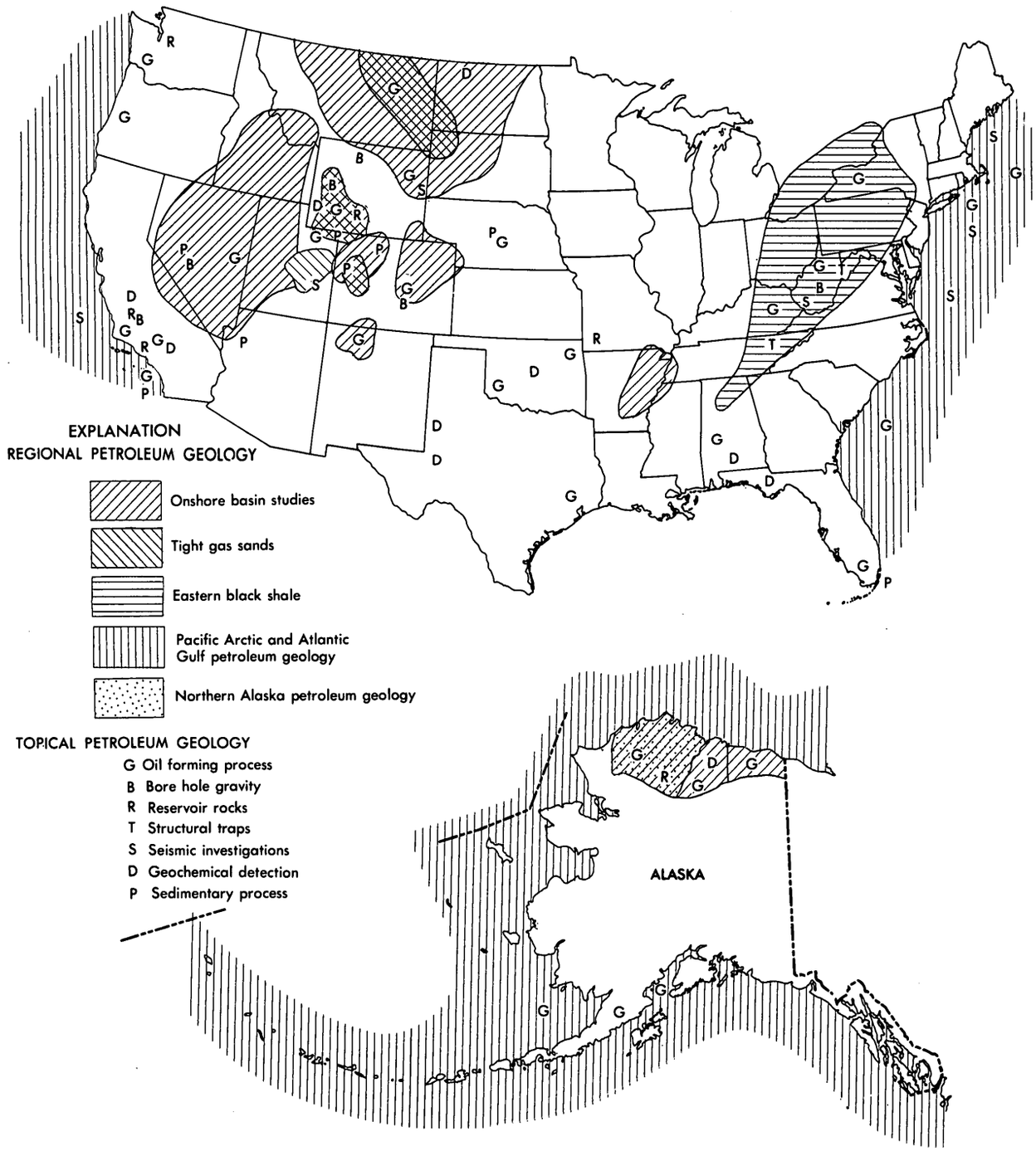
Important results in fiscal year 1978 include the following:

- Drill core samples of "barren" carbonate rocks from the Rolla 2° quadrangle, Missouri, were examined to identify possible geochemical guides to mineral deposits. The samples, all from areas outside of known ore bodies, were found to contain two suites of trace elements. The first suite is present in all samples tested and is considered to be part of the original rock unit. The second, found in a few of the samples, includes lead, zinc, copper, molybdenum, nickel, cobalt, silver, arsenic, antimony, and tin. Metals of this suite were undetectable in most whole rock samples but were readily detected in their insoluble residues. That group of metals, which was introduced after the rocks were formed, is the same group found in rocks within known mineralized areas. Examination of insoluble residues of appropriate rock units thus becomes a potential guide to previously undetected deposits.
- Analyses of core samples from the Boulder Basin, Idaho, revealed the close association of mercury with the ores highest in gold and silver. The association suggests that mercury may be a useful pathfinder element in future exploration.
- Geochemical exploration in northern Sonora, Mexico, in cooperation with the Consejo de Recursos Minerales of Mexico, found that certain stream sediments and panned concentrates were high in rare-earth elements. The anomalous samples, which also contain thorium, delineate a southwest-trending belt about 28 miles wide and 112 miles long, extending across several mountain ranges. The thorium mineral was identified as thorite.
- Reconnaissance geochemical studies in the National Petroleum Reserve in Alaska (NPRA) and the adjoining Brooks Range found evidence for five types of mineralization: (1) barium in concretionary or bedded deposits, (2) zinc, silver, and barium in massive sulfides, (3) lead, silver, and zinc in deposits of unknown type, (4) arsenic, lead, and silver in deposits of unknown type, and (5) chromium and associated elements related to ultramafic rocks similar to those known south of the NPRA. The barite potential is of particular interest as a local source of drilling mud if the NPRA becomes a significant source of petroleum in the future.
- A pilot study in the Medicine Bow Mountains, Wyo., found highly radioactive ground water. Radioactivity, caused by radon gas, was much higher than could be accounted for by the uranium in exposed rocks. The results indicate a strong likelihood of significant uranium concentrations in Precambrian conglomerates, the geologic environment that contains the great gold-uranium deposits of South Africa.

ENERGY RESOURCE SURVEYS

Oil and Gas

The Oil and Gas Resource Investigations Program, which includes regional and topical petroleum-related geologic studies, provides Government and the public with credible and reliable assessments of the Nation's undiscovered oil and gas resources, both onshore and offshore. These research investigations involve the collection and analysis of geologic, geophysical, and geochemical data, leading to the development of concepts concerning the origin, migration, entrapment, and detection of oil and gas that are needed to support the resource appraisal efforts. Resource appraisal techniques and methodology are continually refined to make reliable estimates of undiscovered resources or to update previous estimates. Computerized data systems are being developed to organize petroleum-related geologic data and resource information so that they can be retrieved rapidly and applied to petroleum-related investigations.



Location of regional petroleum geologic studies and topical investigations.

Fiscal year 1978 accomplishments and activities include the following:

- Publication of a comprehensive report on the geologic and geophysical data obtained from the Continental Offshore Stratigraphic Test (COST) GE–1 well that was drilled in the southeast Georgia embayment, 74 miles east of Jacksonville, Fla.
- Publication of a report on the geologic setting, sediments, environmental conditions, and petroleum potential of the Mid-Atlantic OCS and Slope.
- Completion of a detailed report on oil and gas resource estimates, including appraisals by major stratigraphic units, historical frequency distributions by sizes of fields, distributions by depth of occurrence for the known fields, and estimates of the number and probability distributions for the sizes of the undiscovered fields in each of the major stratigraphic units for the Permian basins in west Texas and New Mexico and offshore Gulf of Mexico, Tex. and La.
- Continuation of research on characterization studies (stratigraphic, structural, geochemical, paleontologic, mineralogic, geophysical, and resource appraisal) of the tight gas sands in the Uinta, Piceance, and Green River Basins, the northern Great Plains area, and the black shales and related rocks of Middle and Late Devonian age in the Appalachian Basin for the Department of Energy.
- Publication of a report on the petroleum geology of the West Siberian Basin and a detailed description of the Samotlor oil field, U.S.S.R.

Coal

The Geological Survey conducts a program to assess and classify the Nation's coal resources on the basis of their geographic and geologic distribution, physical and chemical characteristics, and availability for mining. The program involves geologic mapping, core drilling, stratigraphic and petrographic studies, chemical analyses of samples, and geophysical and biochemical investigations, as well as research on the organic and nonorganic (mineral) constituents of coal, coal depositional environments, and coal diagenesis. The data obtained from these investigations are incorporated in the computerized National Coal Resources Data System (NCRDS), which now contains approximately 92,000 records.

The following activities and accomplishments were highlights in fiscal year 1978:

- Mapping, sampling, and assessing of the low-sulfur coal resources in areas totaling about 580 square miles in Colorado, Montana, Virginia, West Virginia, and Wyoming. A reassessment was made of low-sulfur coal on Federal lands in Wyoming, Montana, and Colorado, totaling about 957 square miles.
- Determination of 110 million short tons of coal resources in nine beds within the 57-square-mile area proposed for the Cranberry Wilderness area in the Monongahela National Forest, Webster and Pocahontas Counties, W. Va.
- Preparation of 15 reports on the geology, quantity, and quality of coal resources; mining methods and potential development; and environmental hazards of mining federally owned coal in the Western United States, where production is anticipated and for which environmental impact statements and reclamation will be required.
- Participation in the International Energy Agency and cooperation with other North American and European coal-producing countries in the development of a World Coal Resource and Reserve Data System for the assessment of world coal resources and an international lexicon of coal-resource and reserve terminology.
- Collection of 1,000 samples of coal and related rock for chemical analysis in cooperation with 20 State geological surveys. The analysis to date of more than 5,600 samples shows that coal from the Powder River region of Wyoming and Montana contains the lowest average amounts of many minor elements. In general, coal from the Interior province contains the highest average amount of these elements, and coal from the Appalachian province contains an intermediate amount.

Oil Shale

Field and laboratory studies of the Green River Formation in Colorado and Utah are conducted to determine the geologic setting and physical and chemical characteristics of oil shale. This work ultimately will lead to an assessment of the oil shale resources of the United States.

During fiscal year 1978, the following tasks were completed:

- Detailed geologic mapping of 58 square miles in the Piceance Creek Basin, Colo., and Uinta Basin, Utah.
- Measurement and analysis of 16 stratigraphic sections, totaling 2.4 miles.
- Drilling and logging 15 core holes, for a total of 0.7 mile.
- Analysis of 200 samples for oil yield, 400 samples for acid-extractable alumina, and 360 samples for chemical composition.

- Input of 10,000 data items from 10 core holes to the oil shale resource data file.

Uranium and Thorium

A better understanding of the occurrence of uranium and thorium in the United States is the basic objective of the Uranium-Thorium Resource Investigations Program. To attain this goal, geologic, geochemical, and geophysical studies are conducted on a broad range of problems concerning the origin, migration, and deposition of uranium and thorium. The program also includes research on resource assessment methodology, which will lead to more reliable estimates of domestic uranium and thorium resources.

Among the program accomplishments and activities for fiscal year 1978 are the following:

- Participation in the National Uranium Resource Evaluation (NURE) Program being conducted by the Department of Energy. The favorability for uranium resources in 42 2° quadrangles is to be evaluated in 3 years. Preliminary studies of 38 quadrangles were completed during fiscal year 1978.
- Development of a facies model that explains and predicts uranium occurrences in the Powder River Basin, Wyo. The model uses information from surface and subsurface geologic and geophysical surveys and remote sensing data from satellite and high-flying aircraft.
- Identification of potential sources of uranium in four two-mica granite plutons in northeastern Washington and northern Idaho. The mineralogy, high uranium content, and thorium-uranium ratios are analogous to similar granites in important French mining districts.
- Demonstration of the effectiveness of a low-cost high-quality plastic scintillation detector for airborne spectrogamma ray surveys. The use of this detector by private industry should reduce the cost and increase the coverage of aerorad surveys in the United States.
- Preparation of an estimate of the reserves and probable potential thorium resources in the higher grade and better known deposits in the United States for the Department of Energy. Principal areas include high-grade veins in the Western States; low-grade disseminated deposits in Illinois, Wyoming, and Colorado; low-grade massive carbonatites in Colorado and California; and very low grade stream placers in the Carolinas.
- Continuation of research on electrical resistivity and induced polarization surface and borehole surveys for detecting anomalous concentrations of sulfide and clay minerals in the vicinity of uranium deposits. The success of this research has encouraged private industry to include resistivity and induced polarization surveys in four major exploration programs over the past year.

Geothermal Energy

A number of areas that have promise as sources of geothermal energy have been identified, and other areas of possible geothermal energy are under study. The Geothermal Energy Investigations Program is also developing a scientific basis for more accurate assessment and exploration techniques; this effort complements the technologic research program of the Department of Energy.

Some significant results and accomplishments for fiscal year 1978 include the following:

- Discovering a large low-velocity seismic anomaly beneath The Geysers—Clear Lake geothermal area in northern California. This anomaly is probably the heat source responsible for the geothermal system.
- Discovering that the "Battle Mountain High," a region of high heat flow previously known only in north-central Nevada, probably extends northeast into Utah and Idaho and west almost to California. This indicates that a zone of exceptionally high heat flow extends almost continuously for 621 miles from the vicinity of Steamboat Springs, Nev., to Yellowstone National Park, Wyo.
- Determining that the solubility of quartz in water at high temperature and pressure is of major importance to maintaining permeability in a geothermal reservoir. Heating water above 340°C at a depth of 1.2 miles will cause a decrease in the solubility of quartz. Decreased permeability due to quartz precipitation imposes an upper limit on the temperature attained by dilute water circulating into a geothermal system.
- Finding that reservoir temperature at Cerro Prieto geothermal field has decreased as pressure declined with production. Temperature decreases since 1970 may exceed 30°C and may make reinjection of separated water a necessity.
- Recognition of the following distinct patterns of organic gases in geothermal fluids: (1) a volcanic pattern with relatively little total hydrocarbons, (2) a volcanic-geothermal pattern with more total hydrocarbons, and (3) a sedimentary-geothermal pattern characterized by a relatively large amount of total hydrocarbons.
- Conducting a major multidisciplinary study of the Snake River Plain in Idaho to determine the geothermal potential of this region. Seismic,

magnetic, gravity, and electromagnetic surveys were made in conjunction with geologic and hydrologic studies.

OFFSHORE GEOLOGIC SURVEYS

Oil and Gas Resource Appraisal

The assessment of offshore oil and gas resources involves a study of the rocks beneath the Continental Shelf, using a variety of geophysical and geologic equipment. At sea, the prime geophysical tool is the common-depth-point seismic reflection system. Using compressed air as an energy source, sound waves are reflected off rock layers thousands of feet below the sea floor. The returning acoustic signals are recorded onboard the ship. Simultaneously, magnetic and gravity measurements are taken; these aid in interpreting the crustal structure.

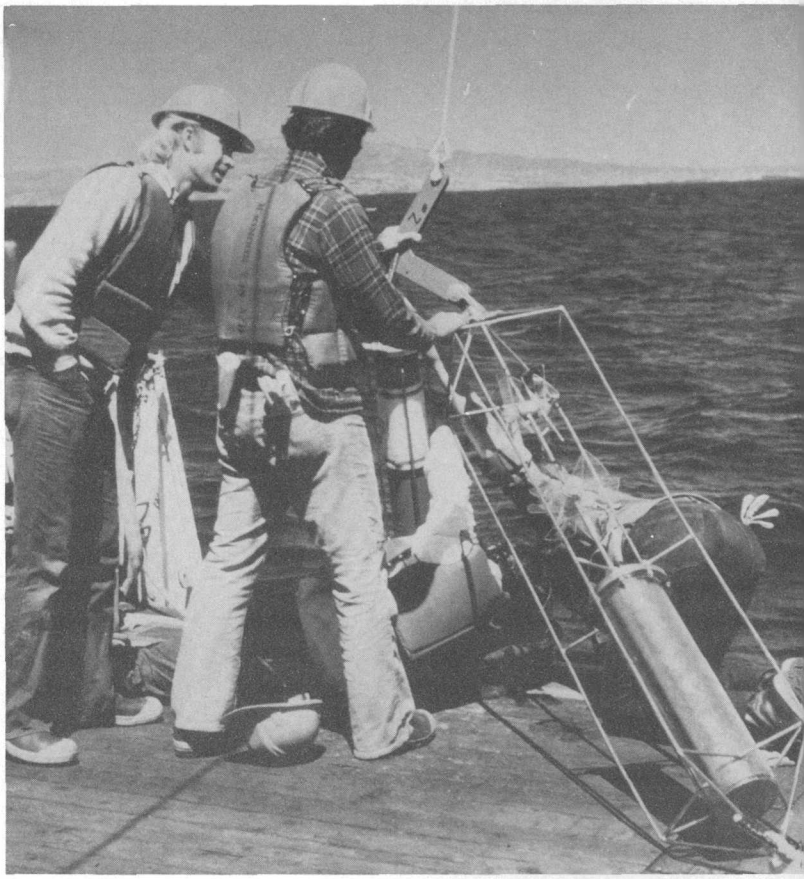
The final interpretation integrates all of these data with geologic knowledge gained by directly sampling the sediments and rocks that constitute the sea floor. Deep stratigraphic cores provide the most satisfactory samples for calibrating the geophysical data and for chemical analyses of hydrocarbon generation, maturation, migration, and accumulation. Because deep coring is costly, this type of sampling is generally limited to sites where petroleum exploration is being conducted by private companies. In other areas, samples are dredged from rocks exposed in the walls of submarine canyons or other sea floor outcrops. Wells and outcrops from nearby coastal areas also provide samples to aid in the interpretation.

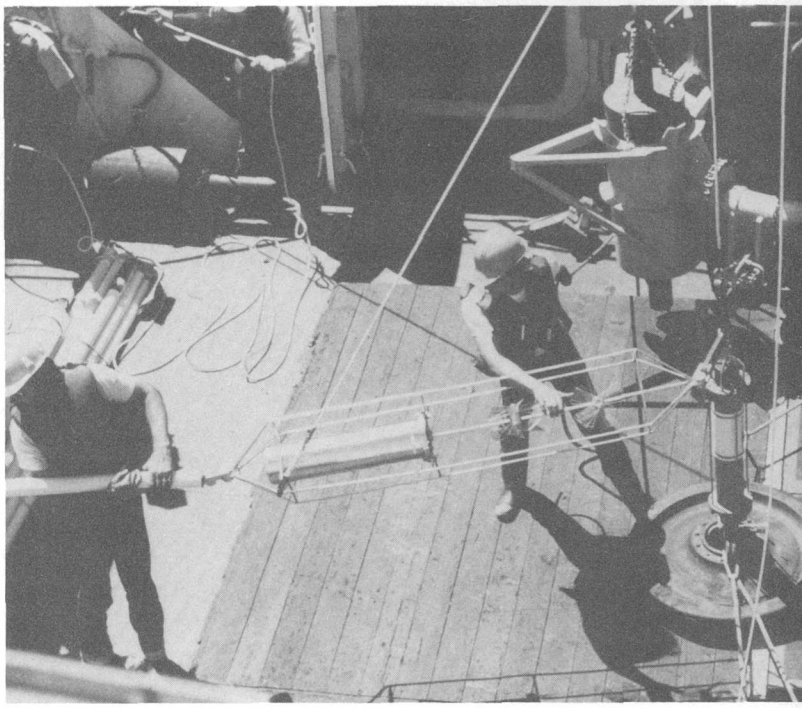
Major activities and accomplishments in fiscal year 1978 include the following:

- In the Beaufort Sea off northern Alaska, the *R/V Samuel P. Lee* mapped major geologic structures which may contain oil and gas resources.
- A submarine gas seep in Norton Sound, Alaska, was found to contain types of gases that are of commercial interest.
- A synthesis of all geophysical and geologic data on the Atlantic OCS has been enhanced with 3,169 miles of newly acquired geophysical data.

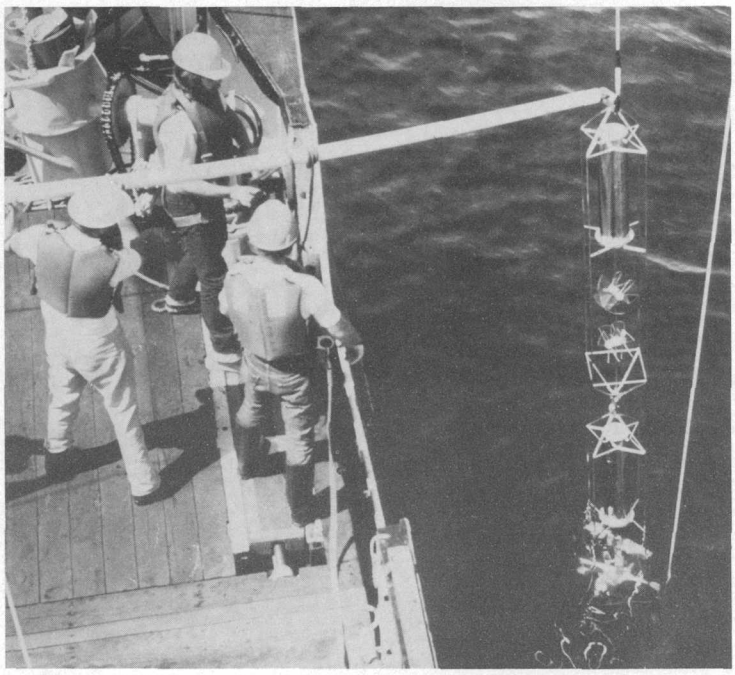
Environmental Investigations

Marine geologic features and processes, including active faulting, unstable sediment masses, and excessive underwater erosion, are hazardous to offshore structures such as drilling platforms and pipelines. Field studies (see below) are conducted to identify safe and hazardous areas within each lease sale area. The information developed from these investigations is used in the departmental leasing decision process.





Sequence showing launch and retrieval of current and transmissometer mooring system. This page: Two scientists discussing whether the unit will "fly" (above); anchor, acoustic release, new fan-type current meter, and span buoy being attached (below). Next page: Retrieval of system (above); checking out the instrument package (below); two scientists taking 1 of 125 suspended sediment samples (right).



port the Bureau of Land Management's environmental baseline study program.

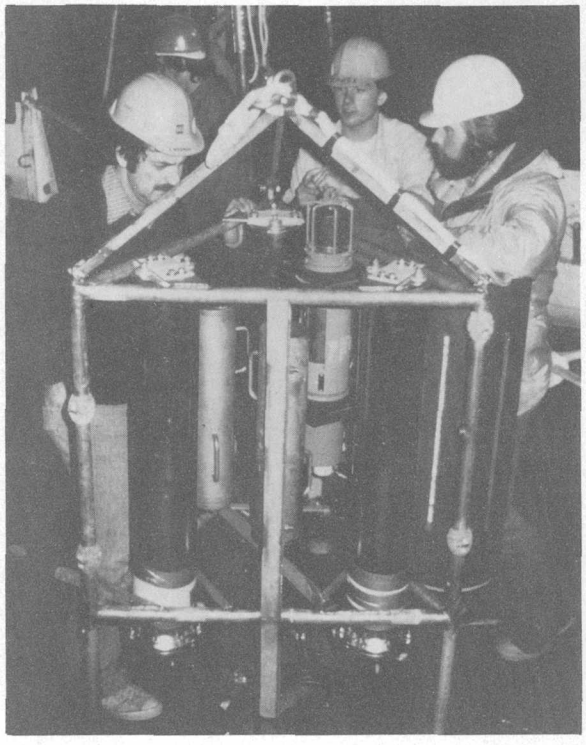
- A profiling and sampling program on the Yukon Delta of Alaska was begun to gather data on sediment movement across the delta region and to identify areas of unstable sediments on the delta front slope.

Marine Geology Investigations

This program consists of marine research and support activities specifically directed toward OCS oil and gas development. Current research includes geochemical studies of manganese nodules and the development of deep-towed instruments to map the distribution of manganese nodules, coastal zone studies, and engineering properties of sea floor sediments.

Fiscal year 1978 highlights include the following:

- Compilation of a series of charts covering the Alaskan and northeastern Pacific Continental Shelves which show sea floor topography, tracklines with high-resolution geophysical data, tracklines of single and multichannel seismic data, sample localities, and subsurface geologic structures.



Activities and highlights for fiscal year 1978 include the following:

- Field studies were conducted in the North, South, and Mid-Atlantic OCS areas; in the central and western Gulf of Mexico; off the southern California coast; and in the Gulf of Alaska and the Bering Sea.
- Geophysical data and sea floor samples were collected in the Pacific and Alaskan OCS areas to identify potential geologic hazards to offshore oil and gas resource development and to support the Bureau of Land Management's environmental baseline study program.
- Discovery and mapping of sand resources offshore St. Thomas, Virgin Islands, where onshore resources are virtually unavailable. Other coastal and nearshore investigations were conducted in Alaska, Oregon, California, Texas, Puerto Rico, and Massachusetts.

ASTROGEOLOGY

Study of geologic processes, materials, and histories of the Moon and other planets and their satellites continued in fiscal year 1978 under funding from the National Aeronautics and Space Administration. As in the previous fiscal year, emphasis has continued to shift away from the study of the Moon to the study of other planets, as the last of the lunar projects ended and a new 5-year Mars data analysis program was begun. The Viking mission returned a vast amount of data on Mars, including about 50,000 pictures. The Astrogeology Program was expanded to take advantage of this mass of information, with the hope of a better understanding of this geologically diverse planet. Support was also provided for the Pioneer mission to Venus and the Voyager and Galileo missions to the outer planets.

INTERNATIONAL ACTIVITIES

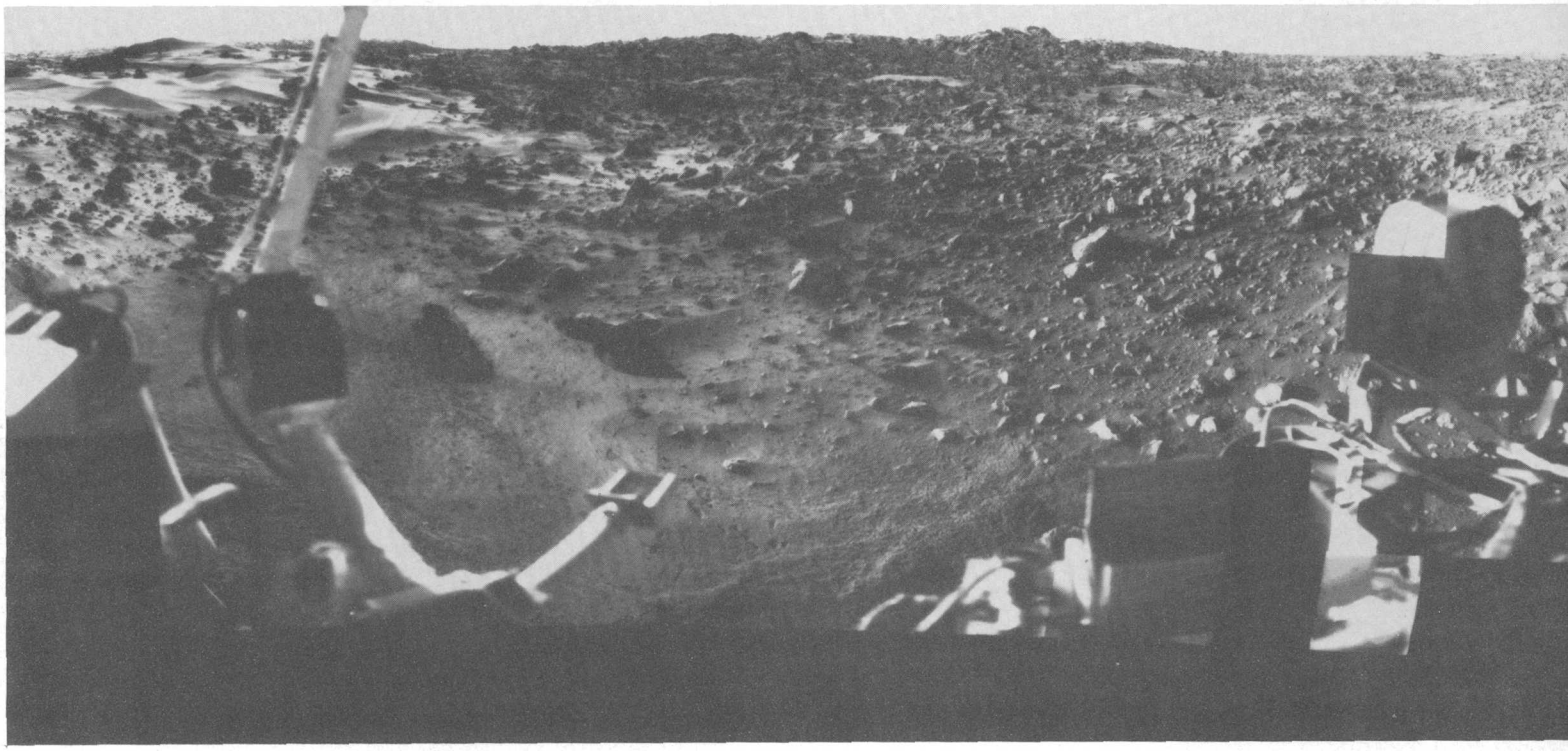
Although the Geological Survey's primary responsibilities are for Earth resources surveys, investigations, and research within the territorial limits of the United States, it has long been involved in activities abroad, both on behalf of other U.S. agencies and programs and in the extension of its own research into foreign areas. In recent years, the scope of these activities has increased to support the growing interests of other Federal agencies and the growing needs for research abroad on earth science problems of concern to the United States.

The Survey's international activities may be classified in the following principal categories:

1. Scientific and technical assistance to other agencies, governments, and international organizations.
2. Cooperative research on subjects of mutual interest to the Survey and counterpart agencies.
3. Representation and participation in international commissions, working groups, and meetings.
4. Training and information exchange.

Scientific and technical assistance and training activities are authorized by the Agency for International Development (AID) under the Foreign Assistance Act and are conducted with funds transferred from other agencies or governments. The other international activities are conducted, in part, to support the Survey's own domestic program objectives.

All Survey divisions and elements of the Land Information and Analysis Office (LIA), including the Earth Resources Observations Systems (EROS) Program, the Environmental Impact Analysis Program, the Geography Program, and the Land Resource Data Applications Program, are involved in the Survey's international activities. Most scientific, technical, and



Computer mosaic of high-resolution Viking 1 Lander pictures, which were taken in the early morning of August 3, 1976, and cover about 167°. The drifts of fine-grained material (left) are about 50 to 100 feet from the spacecraft. The blocks (near center) are about 250 feet from the spacecraft. Computer mosaicking was done by the Jet Propulsion Laboratory, Pasadena, Calif. Photograph by the National Aeronautics and Space Administration.

administrative personnel who participate in these activities are drawn from the staffs of these organizational units and return to domestic operations following their international assignments.

Coordination of Survey international activities is achieved through the International Activities Committee, which consists of representatives of the divisions and LIA. Administrative, managerial, and logistical functions are performed by the Office of International Geology, which operates within the Geologic Division.

Results of the Survey's international activities are made available in Geological Survey publications and those of sponsoring U.S. agencies, in publications of counterpart and cooperating agencies in the host countries and of professional societies, and in the proceedings of international organizations and commissions.

The range of subjects and countries involved is indicated by fiscal year 1978 reports on recent and projected changes in the level of the Red Sea and their influence on mineral production; studies of rock types and geologic structures in Brazil, the Libyan Arab Republic, the Yemen Arab Republic, Saudi Arabia, Colombia, and Liberia; ground-water conditions in Cambodia, Egypt, and Kenya; the geologic conditions pertinent to engineering planning for the new Federal Capital Territory of Nigeria; volcanic hazards of Cotopaxi, Ecuador; and copper prospects, gabbro, and the geochronology and radioactive mineralogy of rocks of the Arabian Shield. A tectonic map of the circum-Pacific region, one of a series being produced by cooperative international effort, was published, as was a report presenting the technical papers of a Central Treaty Organization (CENTO) workshop on remote sensing.

Scientific and Technical Assistance

During fiscal year 1978, scientific and technical assistance activities, which range in length from a few weeks to many years, cover virtually all subjects with which the Geological Survey's domestic program is involved. They vary in scope from consultation on specific techniques, problems, or resources to multifaceted programs involving many disciplines that aim toward developing or strengthening Earth resources institutions and programs.

During fiscal year 1978, in support of the Department of Energy, a new program to assist developing countries in identifying and evaluating their options for future development and use of their energy resources was undertaken. In this program, existing information on indigenous energy resources is compiled and evaluated jointly with host-country scientists to determine the status of known resources and possibilities for the discovery of additional resources. The Bureau of Mines, the Bureau of Reclamation, and the Argonne National Laboratories also cooperate with the Geological Survey in the program, providing information on production of raw materials essential to energy industries, on hydropower development, and on the applicability of solar, wind, and biomass energy technology. This information is then analyzed in cooperation with host-country agencies to determine the options available for meeting future energy requirements. Such studies were carried out in Egypt and Peru in 1978.

The fifth extension of an agreement between the U.S. Geological Survey and the Directorate General for Mineral Resources (DGMR), Ministry of Petroleum and Mining, Kingdom of Saudi Arabia, was signed in 1978. The agreement provides for continuing assistance to the DGMR in establishing facilities and training Saudi Arabian scientists in earth science and mineral investigations. Work carried out under the agreement to date has been described in more than 250 reports.

Results of several projects sponsored by AID were highlighted by maps and reports published during the year. A series of 10 quadrangle maps of Liberia was published (see fig. 24). When these became available in late 1977, a set was formally presented to the Liberian Embassy (see fig. 25) in Washington, D.C. Liberia is now the only African country to be completely mapped geologically at 1:250,000-scale. A geographic map of Yemen (San'a') (fig. 26) on a Landsat image base and a companion multicolor geologic map, both prepared by the Survey at 1:500,000 scale, were published for the Government of Yemen. The proceedings of two conferences on remote sensing were prepared for publication by CENTO. These reports contain the results of training and information exchange projects involving applications of Landsat data to a wide range of Earth resources problems in the participating countries (Pakistan, Iran, and Turkey).

As part of a cooperative effort to help Nigeria select a site for a new Federal capital, geographic and land use maps of Nigeria were prepared and published. Based upon computer-enhanced Landsat imagery, these products are intended to provide reference, geologic, hydrologic, and land use information as a basis for site selection and engineering studies. The completion of the shooting of a deep seismic refraction line from the coastal waters of the Red Sea to the eastern side of the Arabian Shield was a major achievement during 1978. Twenty-four Survey scientists and technicians participated in the work, and high-quality data were collected. A series of interpretive papers is in preparation.

As part of the Geological Survey's continuing support for AID, a new program to assist other countries

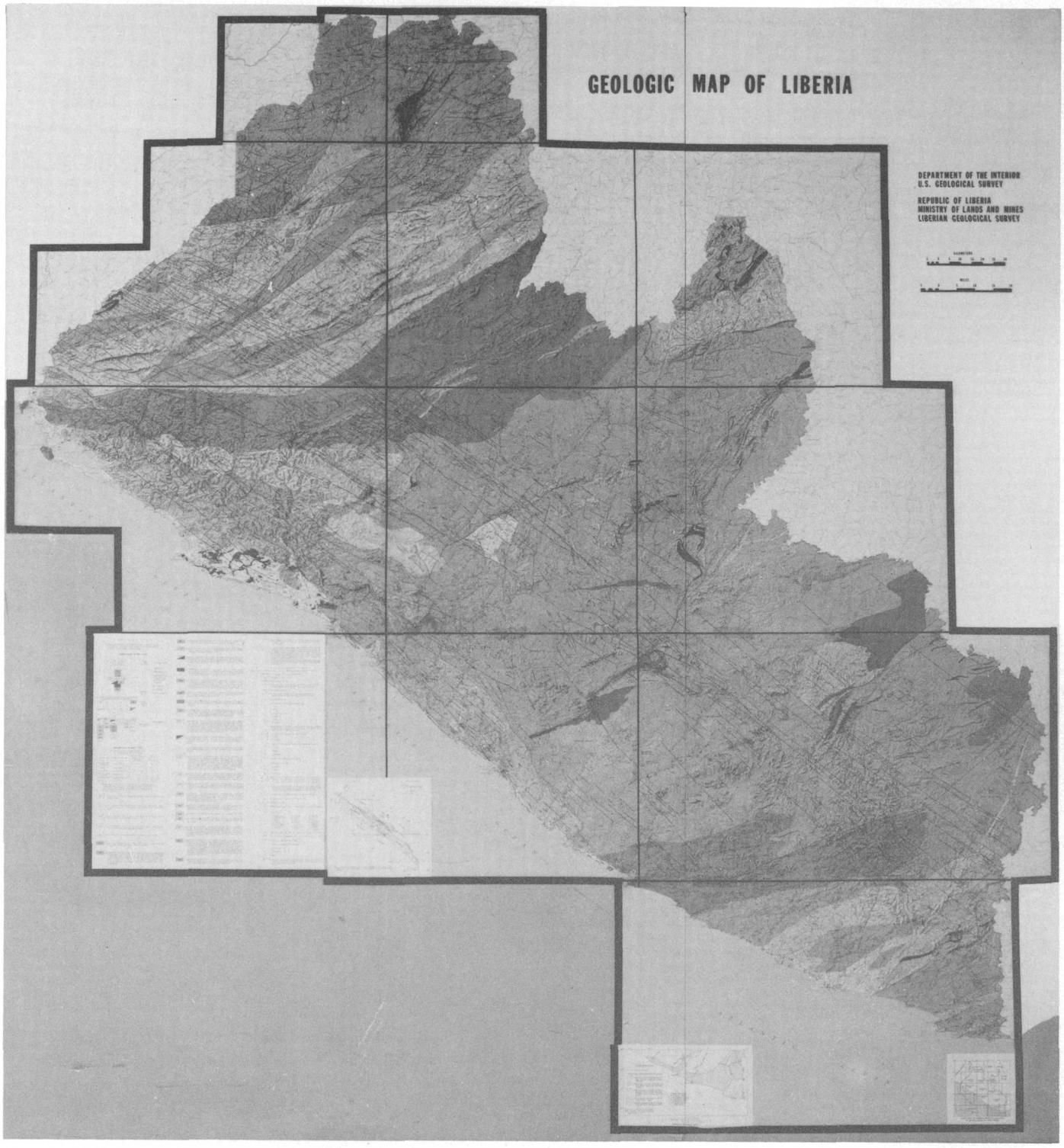


FIGURE 24.—Photograph of the composite geologic map of Liberia.

in the employment of new techniques for assessing and mitigating volcanic, earthquake, landslide, and flood hazards has been formulated. Objectives will be to identify and to analyze hazardous conditions, to devise programs and to introduce techniques that will minimize the effects of natural disasters, and to develop staff, institutions, and mechanisms for hazard studies.

Cooperative Research

Cooperative research is undertaken for the benefit of both Survey programs and those of the counterpart agencies. Objectives are to improve the knowledge of resources and geologic phenomena and the techniques and equipment for acquiring, processing, and reporting information. Programs are conducted

in the following categories: (1) bilateral agreements between the Survey and counterpart organizations, (2) multilateral cooperative projects involved with international organizations, and (3) joint survey projects such as the work in Antarctica.

Bilateral agreements have been made with Bolivia, Mexico, Morocco, West Germany, Poland, and Yugoslavia. In Bolivia, the Survey and the San Calixto Observatory will cooperate to establish a net to gather data on seismic events to enable analysis of earthquake hazards of the Cochabamba area and to expand knowledge of worldwide seismic conditions. In Mexico, cooperative research on techniques of geochemical exploration for copper with the Consejo de Recursos Minerales, now in its third year, has led to the discovery of areas having anomalous amounts of lead- and uranium-bearing minerals. Continuing research will be aimed at discovery of the sources and evaluation of their metal content. Mineral and energy resources, marine geology, geologic data acquisition and management systems, and applications of geology to agriculture and to management of environments are categories of research interests identified in the U.S.–West German bilateral agreement for cooperation.

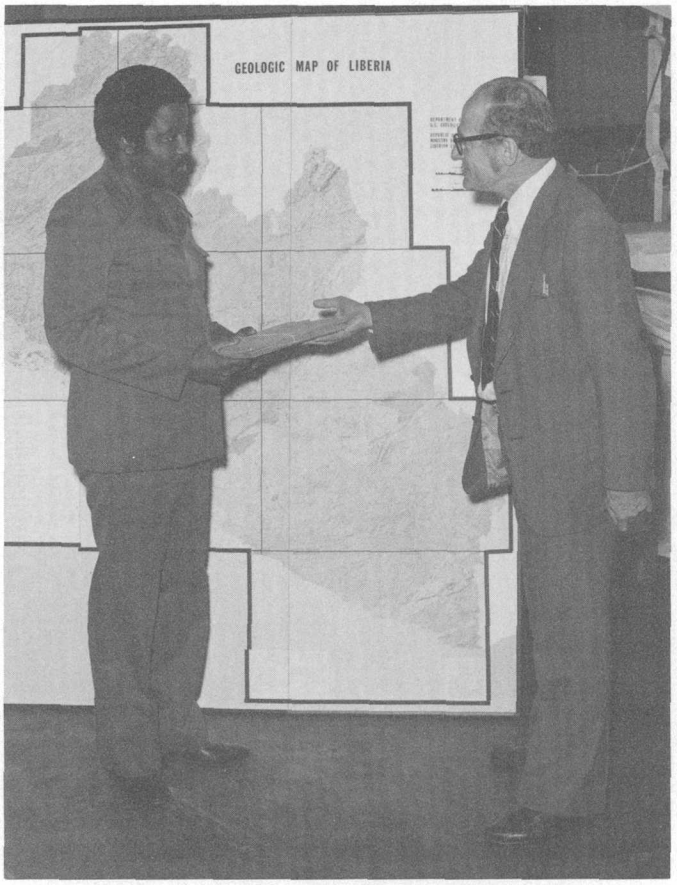


FIGURE 25.—Dr. James R. Balsley (right), Assistant Director, Land Resources, U.S. Geological Survey, presents the Geologic Map of Liberia to Mr. William V. S. Bull, Counselor to the Liberian Embassy, Washington, D.C., at the Survey's National Center in Reston.

Projects have been undertaken with Poland for research on the characteristics of coal basins and base-metal deposits and with Yugoslavia for the investigation of light metal and rare-earth minerals of granitoid massifs and for the design and development of data management systems and maps of geologic, seismic, and mineral distribution conditions specifically for land use planning.

The Survey cooperated in multilateral programs under the auspices of several international agencies. The International Geological Correlation Program involves geological agencies of 56 other countries under the joint sponsorship of the International Union of Geological Sciences (IUGS) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). Participation in the International Hydrological Program is under the general guidance of the U.S. National Committee on Scientific Hydrology in cooperation with UNESCO and the World Meteorological Organization. Through the Circum-Pacific Council on Energy and Resources (CPC), a nonprofit organization devoted to appraising the scientific and resource status of the Pacific region, Survey members are collaborating with scientists of civil and private agencies in dozens of CPC countries to prepare a series of maps depicting the geology, tectonics, geodynamics, energy, and mineral resources of the Pacific region. During the year, the geographic and base map series were published (1:10,000,000 scale). Survey personnel presented papers on energy and mineral source materials, tectonics, and geologic hazards and also contributed to workshops on sedimentary basin analysis, landslides, and remote sensing at the second Circum-Pacific Conference on Energy and Minerals Resources, Honolulu, Hawaii.

The Survey also cooperated in a UNESCO–Canadian Agency for International Development–AID joint project to present a training course on Landsat applications to land use and land cover mapping for five West African countries. The workshop was conducted at Ibadan, Nigeria, specifically for university staff members through whom the knowledge of new data types and methods might reach the students who will become the next generation of analysts and managers.

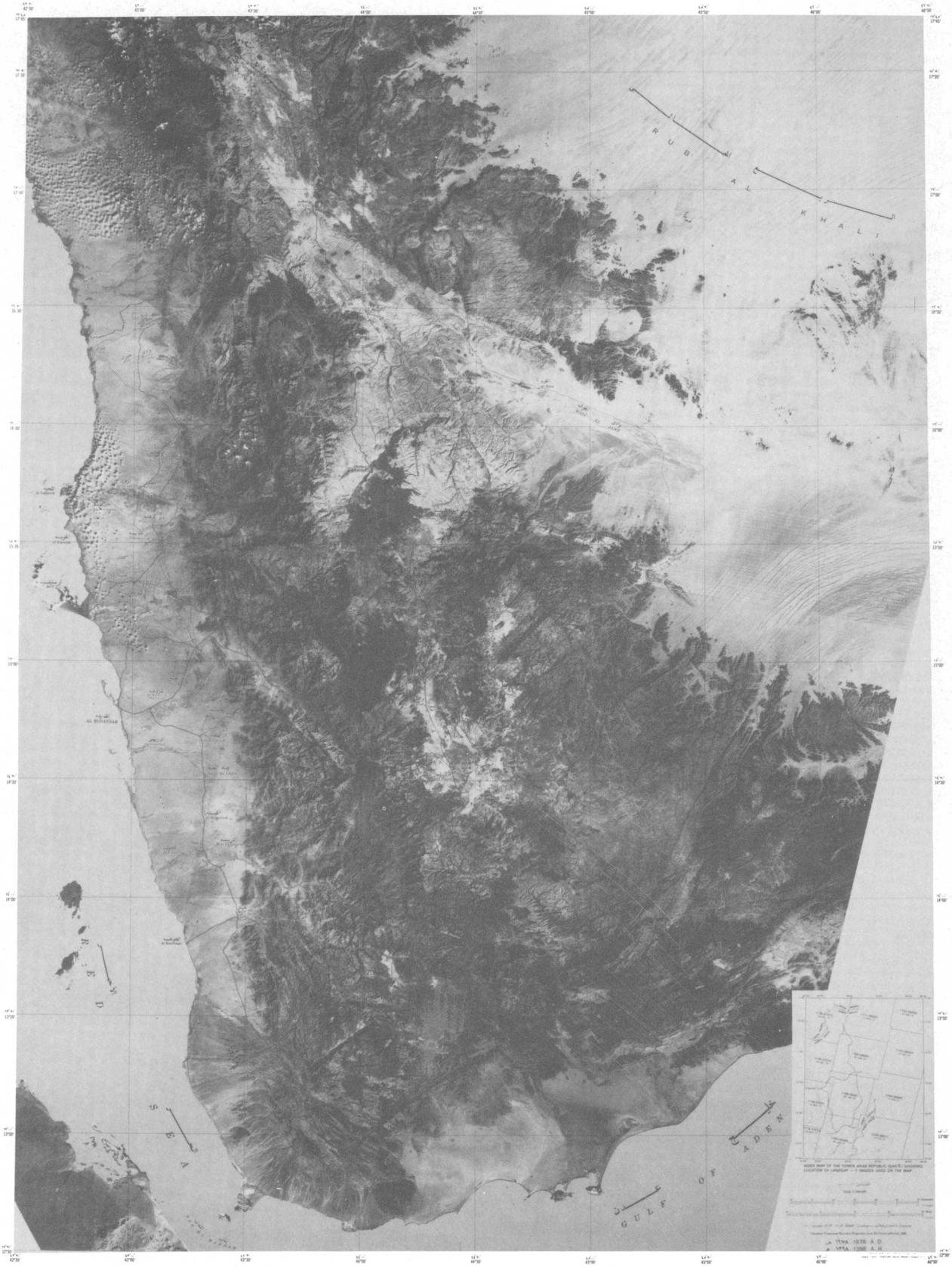
Representation and Participation in International Commissions, Working Groups, and Meetings

Activities in international representation included participation in multination commissions, working

وزارة الداخلية
مصلحة المساحة الجيولوجية الامريكية
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

الجمهورية العربية اليمنية
YEMEN ARAB REPUBLIC

مجموعات أبحاث مختلفة
خريطة رقم ١-١١٤٣-أ
MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1143-A



خريطة جغرافية للجمهورية العربية اليمنية (صنعاء)
GEOGRAPHIC MAP OF THE YEMEN ARAB REPUBLIC (SAN'Ā')

groups, and meetings. Sponsors included the Inter-American Development Bank, the CPC, McGill University, the Organization of American States, agencies of the United Nations, and the World Bank, in support of programs on water resources, marine mining and oil and gas production, tectonics and seismicity, geologic mapping, and land use mapping.

In addition, Survey personnel also participated in meetings and conferences of the Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas, the United Nations Economic and Social Commission for Asia and the Pacific, the Commission for the Geologic Map of the World, and various commissions and subcommissions of the IUGS.

As part of its effort to provide representation and exchange of information with agencies and programs in other countries and to keep informed on foreign resources and programs, the Geological Survey is cooperating with the Bureau of Mines and the Department of State in supporting a resources attaché program in selected U.S. embassies abroad. The resources attaché program provides a mechanism for exchange with other countries of information on minerals and fuels programs, resources, industries, and related activities. Resources attachés are now stationed in U.S. embassies in Australia, Belgium, Bolivia, Brazil, India, Indonesia, Japan, Mexico, South Africa, Thailand, and Venezuela.

Training and Information Exchange

Training and information exchange activities involve formal training programs including the regularly scheduled International Remote Sensing Workshop that is presented twice yearly at the EROS Data Center, formal training programs in other countries, and programs that associate individual participants with ongoing Survey projects in geology, water resources, topographic mapping, publications, and computer applications and also in college and industrial programs. By mid-1978, about 200 participants from 55 countries had begun or completed associated programs, 25 scientists from 14 countries had attended the spring International Remote Sensing Workshop, 18 scientists from 5 Central American countries had attended the workshop on applications of remote sensing in land use surveys that was sponsored by the Inter-American Development Bank, and a course on Landsat applications in land use and land cover mapping had been presented for the Government of Mexico in Mexico City. In July and August, a basic course on applications and methods in remote sensing was conducted at the Iranian Remote Sensing Center in Tehran. New courses in computer-assisted processing of Landsat data for geologic, land use, and environmental study are planned to begin in late 1978 in cooperation with the Northern Arizona State University.

In addition to contributions in formal programs, Survey personnel responded to requests by visitors including U.S. citizens, teachers, explorationists, and other industry representatives as well as foreign visitors. At midyear, visitors representing U.S. interests numbered 83, and 200 foreign visitors had come from 56 countries. The second edition of the "Worldwide Directory of National Earth Science Organizations" was published as Circular 771.

Students in the Minority Participation in Earth Science Program at the Global Seismicity Facilities, Golden, Colo., and at the Geologic Landmark, near Denver, Colo.

◀ FIGURE 26.—Photograph of multicolor geologic map of the Yemen Arab Republic (San'a').

GEOLOGICAL SURVEY LIBRARY

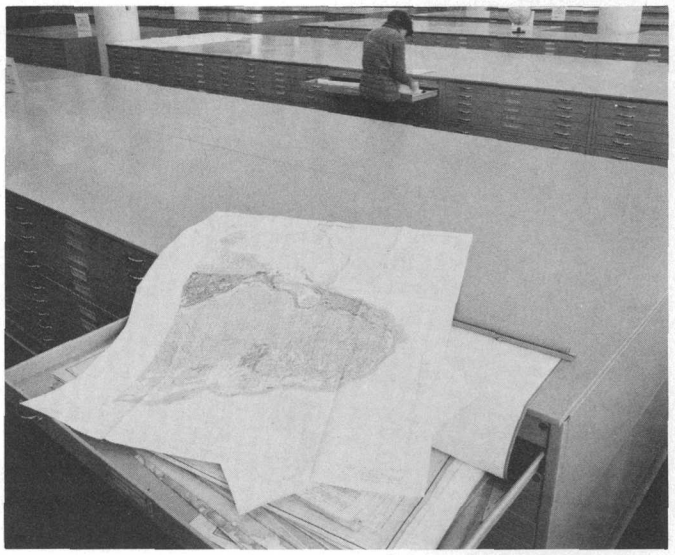
The Geological Survey Library is one of the largest earth science libraries in the world. The main library is located at the Survey's National Center in Reston, Va., with branches located at major research centers in Denver, Colo., Menlo Park, Calif., and Flagstaff, Ariz. These libraries collectively contain more than 2 million items. Although these holdings are intended primarily to support the research activities of the Geological Survey, the library also serves other Government agencies, State geological surveys, academic institutions, and research organizations throughout the country.

The open-house celebrating the opening of the new library in Denver, took place in November 1977. The new facility was brought about in the aftermath of a fire that heavily damaged the former library facility. The new accommodations boast of approximately 27,000 square feet of space for the clientele as well as the library staff. Hard work and dedication by the staff contributed greatly to the reestablishment of services in the new library. Correspondingly, the library facilities have been expanded at the field center in Flagstaff, reflecting the more diversified interests of the Survey there.

Machine-readable data produced as a result of cataloging through OCLC Inc. has been used to create a library accessions list. This monthly list alerts the user to new publications added to the library and is particularly beneficial to field offices with few or no library facilities. By alerting a broad spectrum of Survey users to the new acquisitions, a greater number of users is being made aware of library materials and services.

A users' guide has been drafted to provide information that will assist the researcher in the use of the library collections and services. The guide details methods of access to the collections of books, maps, and microfilms and explains how to make use of the reproduction facilities, lending and reference services, and online data-base searches.

Research facilities, National Center library.



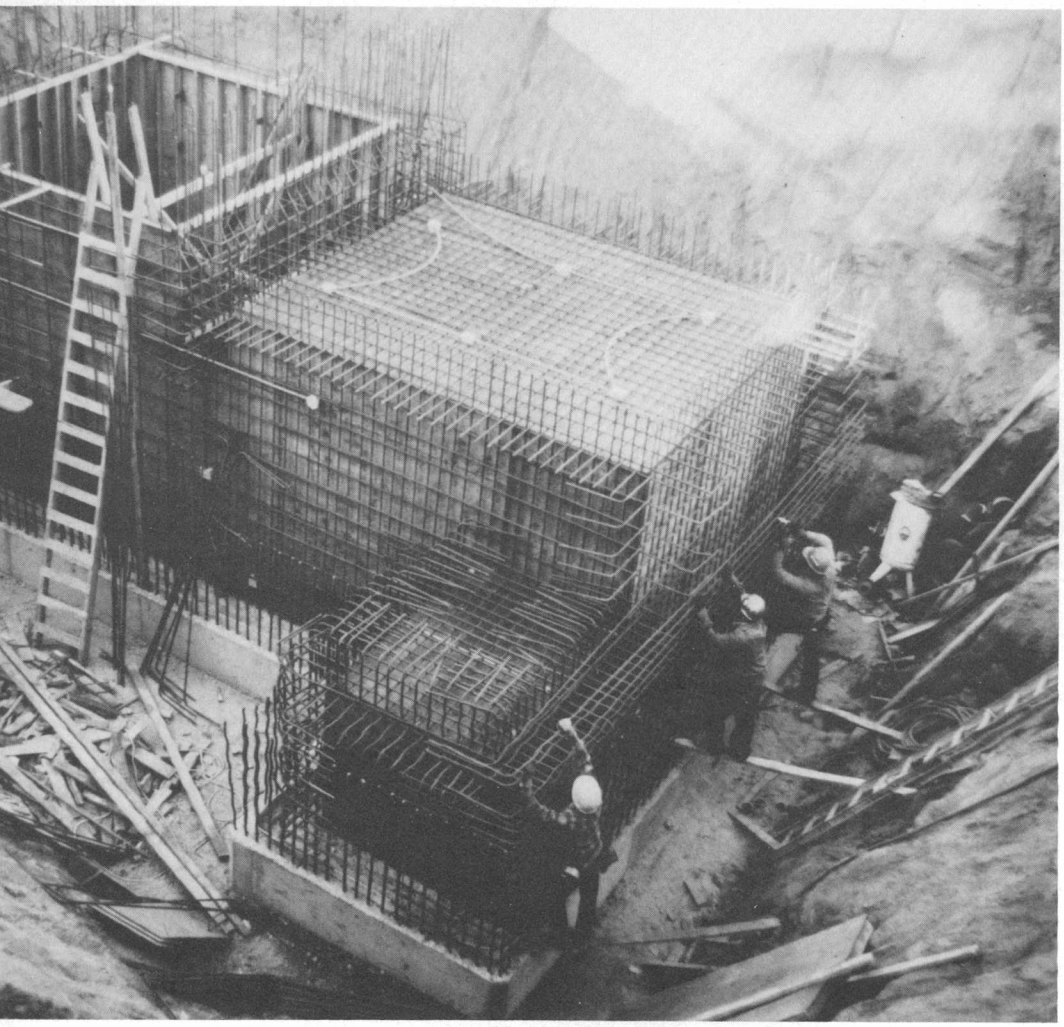
Portion of the map collection, National Center library.

Interlibrary loan and photoduplication activities continued to increase in volume and number of clientele serviced (table 44). More demands for these services are being produced by a wider range of libraries using the library's cataloged materials that appear on the OCLC data base. Likewise, the number of visitors from across the Nation and foreign countries who come to work with the collections has increased.

The number of Beehive Model 105 terminals being used to access the OCLC data base was increased by two, giving a total of five such terminals now being operated for library services. The Survey library continues to rank among the top six Federal libraries in the number of titles entered into this data base. Increased use of these same terminals is being made in the areas of acquisitions, reference, and interlibrary loan services.

Access to such data bases as GeoRef, GeoArchive, Chemcon, and NTIS Index is now available at the Reston, Denver, and Menlo Park libraries. The citations listed as the result of the literature searches of the online services have increased the demand for the serials, books, and reports listed. The increase in loan activities (table 44) is a reflection of the effect these activities have on other library services.

With the cooperation of the National Cartographic Information Center, the library, for the first time, was able to assemble a complete collection of all editions of the topographic quadrangle maps issued by the Survey. This collection represents an important historical collection in hard copy form. Statistics for fiscal year 1978 on library acquisitions, circulation, and lending-borrowing activities will be found in table 44.



OTHER ASPECTS OF GEOLOGIC DIVISION PROGRAMS

(clockwise from upper left): sandflow vents and interior damage in a house lying across a fissure associated with liquefaction (Caucete, Argentina); collecting up-to-date data on land and mineral resources still requires covering the ground the hard way (Bitch Creek, northwest flank of the Teton Range, Wyo.); thick packets of turbidite sandstone in the Makah Formation (southwesternmost coast of the Strait of Juan de Fuca, Wash.); construction of the underground radiocarbon dating laboratory (Menlo Park, Calif.).

Water Resources Investigations

INTRODUCTION

In the 1970's the United States experienced both the wettest and the driest weather in almost 50 years. Nevertheless, on the average, the overall supply of water remains remarkably constant—and ample. But this seeming abundance can be misleading; some parts of the country are consuming or eliminating from reuse more water than is locally available; and, in many areas where there is no shortage, water-quality problems are seriously limiting the usable supply. Even in our water-rich country, therefore, persistent efforts are needed to manage the water resources efficiently and to solve the myriad problems related to water quality. No area in the Nation can afford to be complacent about its water supply.

Wise management of resources requires that up-to-date scientific hydrologic information be readily available for planners. The Water Resources Division has the principal responsibility within the Federal Government for providing data and appraising water resources to facilitate evaluation of water problems. The Division's program is structured to present impartial accurate data and scientific analyses. It provides reports and maps to the public in Federal, State, and local publications; in technical journals; and through selected libraries.

The Water Resources Division provides extensive support to the missions of other Federal agencies and, under the Federal-State Cooperative Program, to State and local agencies. Therefore, the Division is aware of water-information needs at all levels of government and develops programs responsive to those needs. Through a network of offices in all 50 States, as well as in Puerto Rico and Guam (fig. 27), the Division works closely with State and local agencies. Addresses of District Offices are listed in the chapter on organizational and statistical data.

A major responsibility was assigned to the Survey in 1964 when it was designated the lead agency for coordinating water-data-acquistion activities of all Federal agencies, including information on streams, lakes, reservoirs, estuaries, and ground water. This coordination effort minimizes duplication of data collection among Federal agencies and strengthens the overall data base and its accessibility.

HIGHLIGHTS

In the past, not enough data have been available that describe where, how, and in what quantities water is used. Yet water-use data are critical for effective planning and management. To fill this information gap, a national system for water-use data was begun in 1978. Projects were implemented in 16 States as part of the Federal-State Cooperative Program. By 1982, similar projects should be underway in all States.

The National Water Data Exchange (NAWDEX) expanded its Master Water Data Index to identify more than 200,000 sites for which water data are available. Membership in NAWDEX increased from 84 members in September 1977 to 116 members in July 1978, and more than 400 organizations have been registered in the Water Data Sources Directory.

Intensive river-quality assessments of the Upper Chattahoochee River, Ga., and the Yampa River, Colo.-Wyo., were completed, and reports are in preparation. A study of the Potomac estuary, Washington, D.C., is in progress, and assessments of three basins (the Schuylkill River, Pa., Apalachicola River, Fla., and Carson-Truckee Rivers, Nev.-Calif.) will begin in fiscal year 1979.

A finding from prototype urban hydrology studies in Denver, Colo., Miami, Fla., Philadelphia, Pa., and Portland, Ore., during the past 5 years showed that storm-water runoff in urban areas is a significant source of pollutants entering rivers and streams. The Survey published several technical reports on these investigations, and recent improvements in automatic sampling equipment and analysis techniques will greatly expand the effectiveness of such urban studies in the future.

Water-surface profiles are needed to design structurally sound and environmentally harmonious stream crossings. Hydrologists obtained flood-flow data at 22 sites in Alabama, Louisiana, and Mississippi where densely wooded flood plains are crossed by highway embankments and single-opening bridges. New techniques are under investigation to use the data as a base for developing and evaluating two-dimensional digital models for predicting water-surface profiles.

Numerical simulation models of the simultaneous transport of water and heat in porous media offer a useful technical tool for the evaluation of aquifers for the storage of heat energy. Data collected in a field experiment of heat storage in an aquifer near Mobile, Ala., were analyzed, and a simulation model of the aquifer system was constructed. Simulation runs of the model indicated that it can satisfactorily reproduce the observed behavior of the system.

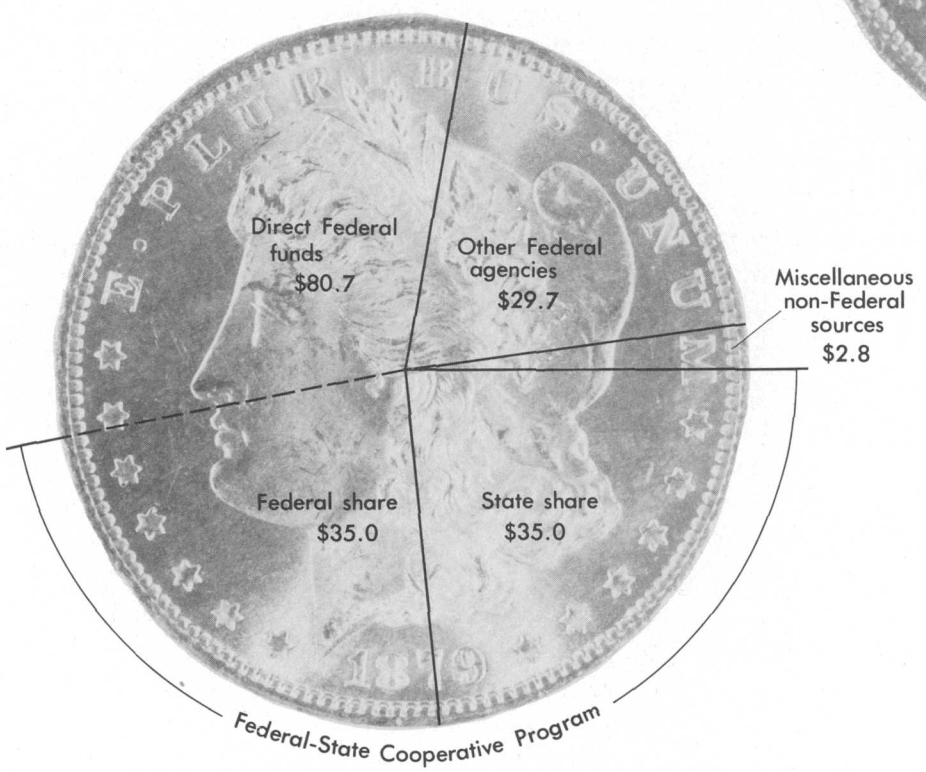
Water continues to be a key factor in energy development. Studies by the Water Resources Division in 1978 focused on the relationship of subsurface water to the disposal of high-level nuclear wastes, water problems related to in-situ development of oil shale, and water supplies and impacts related to the development of coal reserves.

In-depth studies of major regional aquifer systems began in fiscal year 1978. Investigations were underway in the California Central Valley, the northern Great Plains, and the High Plains regions. Available hydrologic information was analyzed, and observation networks and data-collection programs were implemented. In the northern Great Plains area, contracts for deep test drilling were awarded, and development of computer models of the aquifer systems of the three regions was begun.

Work has continued on a series of 21 Regional Ground-Water Appraisals. In 1978, appraisals were published for the following regions: Mid-Atlantic, Great Lakes, Souris-Red-Rainy, Tennessee, and Hawaii. The appraisals address matters of broad public concern—problems associated with urban-area management, land and water use planning, and the quantity and quality of regional ground-water supplies.

◀ Lower Falls, Grand Canyon of the Yellowstone. Yellowstone National Park, Wyo. (National Park Service.)

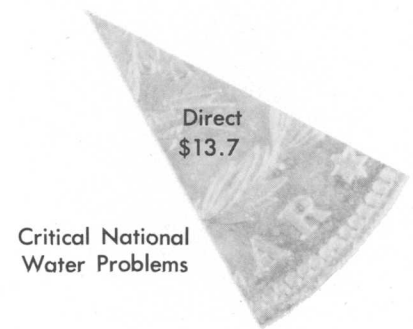
WATER RESOURCES INVESTIGATIONS



TOTAL $148.2 MILLION

SOURCE OF FUNDS

National Water Data System $134.5



USE OF FUNDS

BUDGET AND PERSONNEL

In 1978, the Water Resources Division employed 2,872 full-time personnel. They included scientists and engineers representing all fields of hydrology and related sciences, technical specialists, and administrative, secretarial, and clerical employees. An additional 1,250 permanent part-time and intermittent employees assisted in the work of the Division.

The $148.2 million available in 1978 for the Water Resources Investigations activities came from the following sources (table 6):

1. Direct Congressional appropriations.
2. Congressional, State, and local appropriations for the Federal-State Cooperative Program on a 50–50 basis.
3. Funds transferred from other Federal agencies.
4. Funds transferred from State and local agencies.

TABLE 6 —Water Resources Investigations activity obligations for fiscal year 1978, by program

[Dollars in millions]

Program	Source of funds					Percent change relative to fiscal year 1977
	Federal Program [1]	Federal-State Cooperative Program [2]	Other Federal agency programs [3]	Non-Federal programs [4]	Total	
Total	**45.7**	**70.0**	**29.7**	**2.8**	**148.2**	**+13**
National Water Data System	**32.0**	**70.0**	**29.7**	**2.8**	**134.5**	**+13**
Collection, analysis, and dissemination of streamflow, water quality, ground-water, and sediment data [5]	14.9	34.0	14.2	1.8	64.9	
Regional and areal resource appraisals, and regional aquifer system analyses	5.8	23.2	7.6	0.4	37.0	
Studies related to critical water problems	----	6.4	5.6	0.3	12.3	
Core program of hydrologic research	7.8	----	----	----	7.8	
Other data collection and applied research	----	6.4	2.3	0.3	9.0	
Hydrologic investigations on public lands (soil and moisture conservation)	.2	----	----	----	.2	
Publications and other supporting services	3.3	----	----	----	3.3	
Critical National Water Problems	**13.7**	**----**	**----**	**----**	**13.7**	**+ 8**
Accelerated energy research and development programs	10.6	----	----	----	10.6	
Coal hydrology	6.0	----	----	----	6.0	
Oil-shale hydrology	2.4	----	----	----	2.4	
Underground heat storage	.1	----	----	----	.1	
Low-level nuclear waste investigations	2.1	----	----	----	2.1	
Ground-water recharge	1.2	----	----	----	1.2	
Subsurface waste storage	1.3	----	----	----	1.3	
Flood-hazard mapping	.4	----	----	----	.4	
Estuarine and coastal studies	.2	----	----	----	.2	
Percent change relative to fiscal year 1977	**+32**	**+3**	**+12**		**+13**	

[1] Federal funds excluding those used to match funds from State and local agencies.

[2] Includes Federal funds used to match State and local agency funds on a 50-50 basis.

[3] Funds from 23 other Federal agencies transferred to the Geological Survey, Water Resources Division.

[4] Includes unmatched funds from State and local agencies, funds from permittees and licensees of the Federal Power Commission, and funds from minor miscellaneous sources.

[5] Federal funds include support of coordination of national water data and the National Water Data Exchange.

Federal Program

The water-data collection, resource investigation, and research activities of this program are carried out in areas where the Federal interest is paramount. These include bodies of water in the public domain, river basins and aquifers that transcend State boundaries, and other areas of international or inter-State concern. Activities include operation of surface-water and ground-water measurement stations throughout the country and sites established to provide data on water quality, the Survey's Central Laboratories System, hydrologic research and analytical studies, and a variety of supporting services. In 1978, the Federal Program totaled $45.7 million.

Federal-State Cooperative Program

Geological Survey programs have multiple objectives and serve the earth science and related information needs of a large number of government agencies and private groups. As major users of this information, State, regional, and local agencies have an important role in helping to define the scope of Survey programs. Accordingly, selected projects judged

to be of mutual benefit to the Federal, State, and local governments are funded on a 50–50 basis in the Federal-State Cooperative Program.

In fiscal year 1978, the Water Resources Division joined in cooperative programs with 610 State and local agencies; most of the work was done by the Survey, but State and local agencies provided half the funds. The overall programs totaled $70 million.

Through contact with the "real" world of water conservation, development, management, and use, the Water Resources Division anticipates and responds to changing priorities. Planning the annual program in each State is a mutual decision process, with the Survey representing national interests and the cooperating agencies representing State and local interests. As the need arises for additional and new kinds of water information, programs are jointly adjusted within the framework of priorities and resources. As a result, the work is problem oriented and interdisciplinary. The diverse program activities include collection of long-term multipurpose data (surface water, ground water, water quality, and water use); special interpretive studies of the physical, chemical, and biological characteristics of water; and appraisals for environmental impact evaluation, energy development, coastal zone management, subsurface waste storage, waste utilization, land use planning, flood-plain management, and flood-warning systems.

The strength of the Federal-State Cooperative Program lies in (1) coordinated programming for water information that responds to identified and developing needs of people at all levels and relates to the environmental aspects of water use, (2) the quality and acceptability of the water data accumulated through a uniform program in 50 States and several of the territories, and (3) the impartial nonadvocacy position of the Geological Survey in carrying out and reporting on its work.

Considerable information has been developed to characterize in detail the quantity, quality, and distribution of the Nation's water resources, but until now relatively little has been done to describe where, how, and in what quantities water is used. In recognition of this deficiency, the Division began the National Water Use Data Program by implementing investigations in 16 States during fiscal year 1978. The program provides for the comprehensive and systematic collection, analysis, and dissemination of water use data throughout the United States. Water use statistics are essential to planning and management decisions involving water quality, environmental impacts, energy development, and resource allocations. The program is being developed in stages through consultation with State and Federal agencies. Arrangements are being made for State or local agencies to collect field data in each State. Full implementation is anticipated by fiscal year 1982.

Another major area of emphasis within the Federal-State Cooperative Program is that of hydrologic studies related to coal development. Use of coal to lessen demand for imported oil has resulted in coal-related hydrologic studies in 31 States. Additional cooperative investigations related to alternative sources of energy include nuclear hydrology, oil shale hydrology, and geothermal research.

Examples of reports published during the past year are as follows:

- A ground-water-quality monitoring program for Nevada.
- Connector-well experiment in East Orange County, Fla.
- Limnology of Laguna Tortuguero, Puerto Rico.
- Stress and recovery of aquatic organisms as related to highway construction along Turtle Creek, Boone County, W. Va.
- Reaeration capacity of the Rock River between Lake Koshkonong, Wis., and Rockton, Ill.
- Well-response model of the confined area, Bunker Hill ground-water basin, San Bernadino County, Calif.
- Techniques for estimating flood discharge for Oklahoma streams.
- Ground-water resources of Cavalier and Pembina Counties, N. Dak.

Funds Transferred From Other Federal Agencies

Work carried out by the Geological Survey to provide support of the missions of other Federal agencies amounted to $29.7 million in fiscal year 1978. Examples of work done in cooperation with other Federal agencies are as follows:

Department of Agriculture	Hydrologic studies on small watersheds; sediment studies; stream discharge and quality.
Department of Defense—Corps of Engineers	Tidal flows in estuaries; subsidence studies; streamflow data; ground-water studies; sedimentation and water-quality studies.
Department of Energy	Hydologic and water-supply exploration studies at nuclear-explosion sites and at both operating and potential nuclear-waste sites; research in field of radiohydrology related to interaction between radioactive materials and various geohydrologic environments, both above and below ground; hydrologic modeling.
Department of Housing and Urban Development	Flood-plain delineation; flood profiles; flood-frequency stud-

	ies related to flood-insurance programs.
Department of the Interior:	
Bureau of Indian Affairs	Basic data collection; water resources appraisal studies; water-supply investigations on reservations.
Bureau of Land Management	Collection of basic hydrologic data; water-supply studies on public lands; effects of coal mining on hydrology.
Bureau of Mines	Collection of basic hydrologic data; hydrologic studies of abandoned coal mines.
Bureau of Reclamation	Collection of basic hydrologic data; ground-water resources, reservoir, and land-subsidence studies.
Fish and Wildlife Service	Collection of basic hydrologic data; ground-water recharge; water supply for fish hatcheries; instream flow evaluations; relation of ground water to lakes.
National Park Service	Collection of basic hydrologic data; water-resources appraisals of National Parks and Monuments; flood hazard, forest geomorphology, and ground-water studies.
Environmental Protection Agency	Studies related to energy research and development; municipal waste-disposal-site studies; relationship of ground water to lakes; collection of water-quality information.

The example that follows illustrates a project undertaken by the Water Resources Division to assist a Federal agency in resolving a specific water problem.

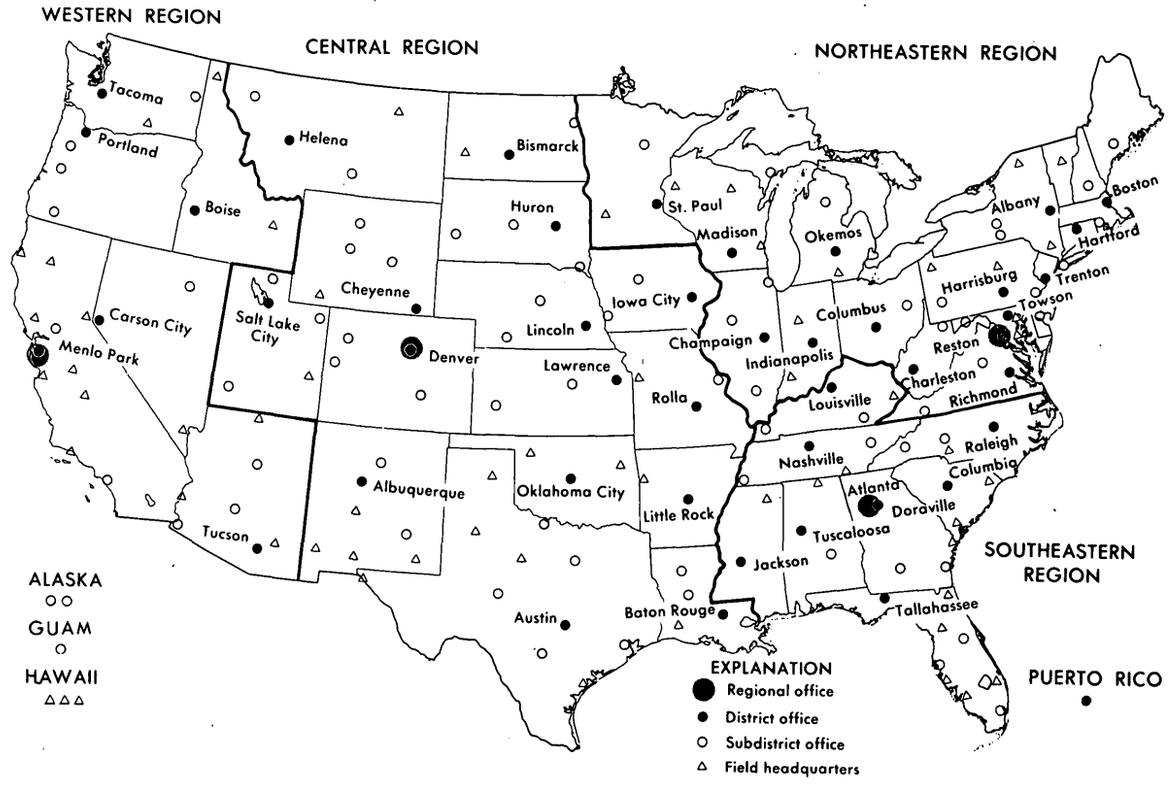
Cape Cod, Mass., is a hook-shaped peninsula that extends 40 miles into the ocean. Ground water in unconsolidated deposits that form the peninsula is the only local source of fresh water for residents and visitors to this nationally famous seashore resort. The water supply is under increasing stress from withdrawal uses and contamination, and the effects of this stress must be evaluated so that wise decisions on future land and water use can be made.

The National Park Service, custodians of the Cape Cod National Seashore on the outer tip of the Cape, is participating with the Water Resources Division and others in a study to determine aquifer characteristics, boundaries, recharge and discharge rates, and water quality. The information gathered is being used to construct a digital ground-water model to assess impacts of proposed land and water development. Such an assessment will allow optimum choice among alternative proposals for development.

Funds Transferred From State and Local Agencies

In this program, the Geological Survey is reimbursed by State and local agencies when there is both Federal interest and State or local interest in an investigation of water resources but where matching Federal funds are inadequate for cost sharing.

FIGURE 27.—Location of principal offices of the U.S. Geological Survey's Water Resources Division in the conterminous United States. Cities named are those where regional and district offices are located. Puerto Rico is included in the Southwestern Region, and Alaska, Guam, and Hawaii are included in the Western Region.



ACTIVITIES

National Water-Data System

COORDINATION OF WATER-DATA ACTIVITIES

In fiscal year 1978, the Survey's Office of Water Data Coordination (OWDC) continued its coordinating activities with Federal and other organizations and individuals. OWDC is counseled on these activities by two committees established by the Secretary of the Interior. The Interagency Advisory Committee on Water Data (Federal) is composed of representatives from more than 30 Federal agencies (table 7). The Advisory Committee on Water Data for Public Use (non-Federal) includes representatives from professional and technical societies, State and regional water agencies, universities, and consultants. Some of the many non-Federal organizations represented are the American Society of Civil Engineers, the American Water Works Association, the Association of American State Geologists, the Association of Western State Engineers, the Association of State and Interstate Water Pollution Control Administrators, the Conference of State Sanitary Engineers, the Chamber of Commerce of the United States, the Council of State Governments, the Manufacturing Chemists Association, the National Association of Conservation Districts, the National Governors' Conference, the National Water Resources Association, the National Water Well Association, the Universities Council on Water Resources, and the Water Pollution Control Federation. The major coordination efforts include planning, designing, and documenting water-data programs; developing standards for data acquisition and handling; and coordinating data activities of all Federal agencies.

"Working groups" are an integral part of OWDC's coordination effort. In the past year, they made important contributions to water-data acquisition activities. The Federal Working Group on Precipitation Quality recommended establishing a national program for precipitation-chemistry research in their July 1978 report. The Federal Working Group on Water-Quality Data Needs for Small Watersheds prepared a preliminary report which summarized water-quality data needs for watersheds of less than 50 square miles. The non-Federal Working Group on River Quality Assessment reviewed the finding of the river basin studies done on the Chattahoochee and Yampa Rivers and the progress of the Potomac estuary study and discussed plans for future demonstration assessments.

Another significant activity during 1978 was the restructuring of OWDC's computer file for the "Catalog of Information on Water Data" to serve as the base for NAWDEX's Master Water Data Index. The resultant computerized file will provide an expanded nationwide index of information on station-type water-data collection, including historic and current sites as well as those that are needed in the future.

Developing standards for collecting and handling water data is an important continuing interagency activity sponsored by OWDC. In the past year, two new chapters were added to the "National Handbook of Recommended Methods for Water-Data Acquisition."

TABLE 7 .—*Interagency Advisory Committee on Water Data, by department and agency*

AGRICULTURE:
Science and Education Administration–Federal Research
Economics, Statistics, and Cooperatives Service
Forest Service
Soil Conservation Service
COMMERCE:
Bureau of Census
Bureau of Domestic Commerce
National Oceanic and Atmospheric Administration
National Bureau of Standards
DEFENSE:
Army:
Corps of Engineers
Navy:
Naval Facilities Engineering Command
ENERGY:
Bonneville Power Administration
Division of Operational and Environmental Safety
Division of Regional Assessments
Federal Energy Regulatory Commission
HOUSING AND URBAN DEVELOPMENT
INTERIOR:
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Mines
Bureau of Reclamation
Fish and Wildlife Service
Geological Survey
Heritage Conservation and Recreation Service
National Park Service
Office of Surface Mining
Office of Water Research and Technology
TRANSPORTATION
INDEPENDENT AGENCIES:
Council on Environmental Quality
Environmental Protection Agency
International Boundary and Water Commission
International Joint Commission
Nuclear Regulatory Commission
Tennessee Valley Authority
Water Resources Council

COLLECTION, ANALYSIS, AND DISSEMINATION OF WATER DATA

The collection and analysis of hydrologic data, such as stream discharge, lake stage, water levels in wells, the chemical and biological characteristics and sedi-

TABLE 8.—*Number and type of measurement sites (stations) of the Geological Survey*

Type of station	Federal Program	Federal-State Cooperative Program	Other Federal agency programs	Non-Federal programs[1]	Total
SURFACE-WATER FLOW OR CONTENTS					
Continuous discharge	750	4,950	1,810	390	7,900
Partial discharge (high flow and (or) low flow)	100	7,500	450	50	8,100
Lake reservoir and contents	50	450	150	150	800
Total	900	12,900	2,410	590	16,800
SURFACE-WATER QUALITY					
Surface-water stations (excluding temperature only)	550	3,600	1,000	50	5,200
Sediment stations	250	750	279	1	1,280
Total	800	4,350	1,279	51	6,480
GROUND WATER					
Sites at which water levels and (or) pumpage are collected annually or more frequently				21,000	

[1] Includes permittees and licensees of the Federal Power Commission.

ment loads of streams, and water use statistics are fundamental aspects of water resources investigations. These kinds of measurements (table 8) are necessary to determine how much and what kind of water is available where and when. Comparisons can then be made between water used and water needed. Hydrologic data are essential not only for determining the adequacy of water supplies but also for engineering projects and public works, for preventing or lessening the impact of floods and droughts, for determining the feasibility of waterpower and irrigation projects, and for developing water pollution control and recreational facilities.

The Survey maintains continuous discharge records at 7,900 stream sites, analyzes water quality at more than 5,000 stream sites, and measures water levels or other hydrologic characteristics periodically in more than 21,000 wells.

National Stream Quality Accounting Network

The Geological Survey's National Stream Quality Accounting Network (NASQAN) provides a nationally uniform basis for continuously assessing the quality of U.S. rivers. Beginning with 50 stations in 1973, the network has been gradually enlarged to the present 445 stations, 100 of which were added in 1978. Present plans will expand the network to approximately 525 stations in 1979. Stations are generally located at the downstream ends of 349 accounting units (subregional drainage basins), which collectively encompass the surface of the Nation. At all NASQAN stations, about 60 water-quality characteristics are measured by identical methods of sampling and analysis at the same frequency at each station.

Beginning with the 1974 data, NASQAN summary reports and maps have been published annually. The maps cover a wide range of selected constituents. Each map shades the accounting unit to represent the data from the station(s) on rivers draining the unit. An example is shown in figure 28. The data show geographic patterns of water quality that reflect climate, geology, soil types, agricultural practices, human and animal populations, water pollution, and pollution-control practices. For example, most rivers of the Midwest and the Southwest are characterized by moderate to high levels of dissolved constituents as well as nutrients, sediment, and biota (floating and attached aquatic plants and indicator bacteria).

The NASQAN program provides information to planners and to the public on river quality in a particular area or region or nationwide. As the program continues, it will help answer such questions as, "Is water quality improving, or is it deteriorating?" Earlier studies attempting to answer that question revealed a lack of data on water-quality characteristics. At the present time, NASQAN is the only nationwide network designed to provide this needed long-term water-quality data on a continuing basis.

Central Laboratories System

In 1978, the Survey expanded the analytical services available through its Central Laboratories System, adding nearly 150 new measurements to its catalog. The demand for new and more complex water analyses has resulted from recent Federal legislation such as the Clean Water Act of 1977 and the Safe Drinking Water Act of 1977. The greatest increase in demand has been for the determination of trace elements and organic compounds identified under the Clean Water Act as toxic pollutants.

New analytical services available to meet these demands include multilevel analyses to provide data at

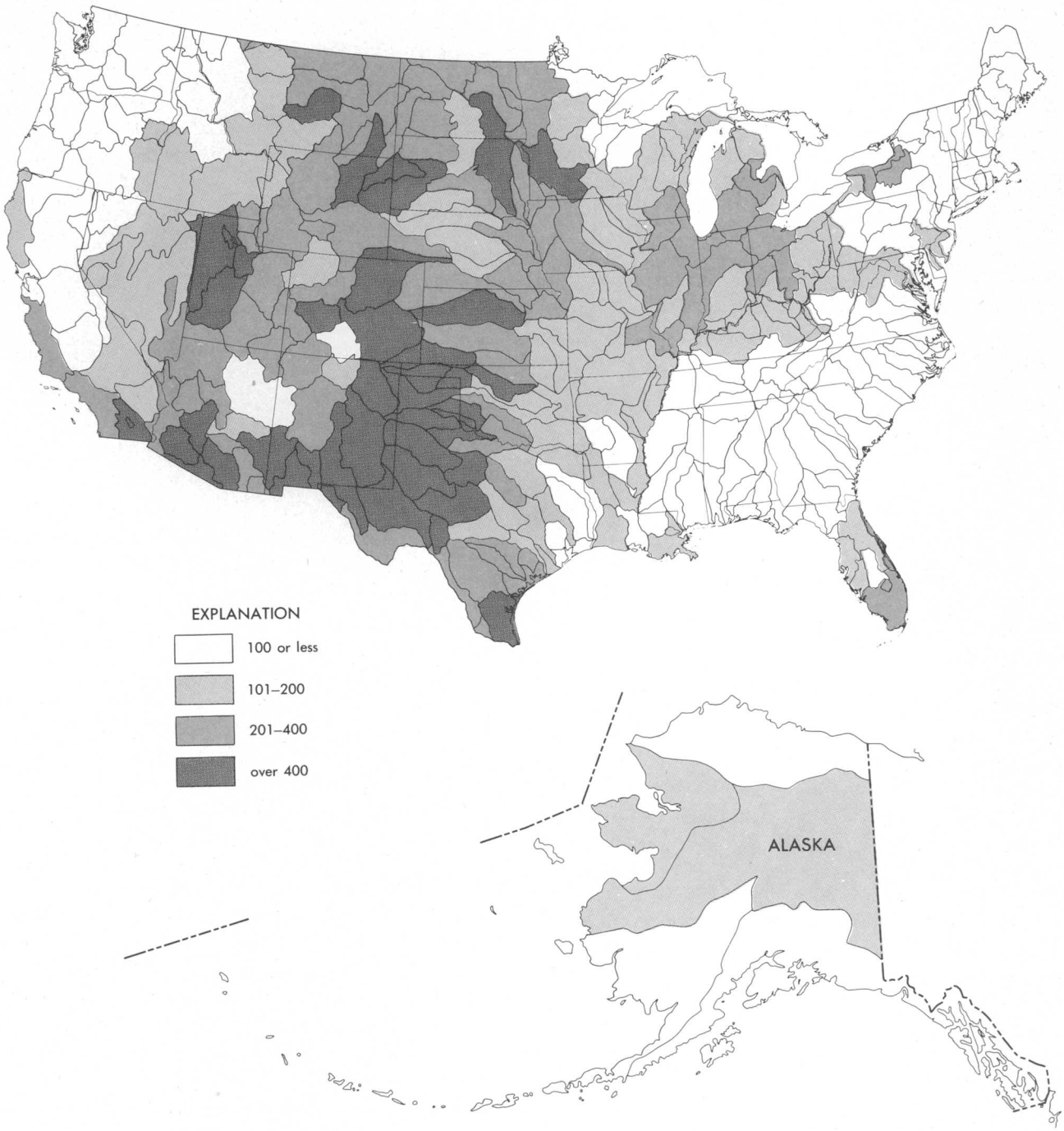


FIGURE 28.—Mean hardness as calcium carbonate in milligrams per liter (standard measurement) at the National Stream Quality Accounting Network (NASQAN) stations during the 1977 water year. Each accounting unit is shaded to show mean hardness for the NASQAN station(s) representing that unit.

the detection levels required for specific applications. For example, trace metals are analyzed by graphite-furnace atomic-absorption spectroscopy when data are needed at the submicrogram level, whereas techniques such as flame-emission spectroscopy are used, at lower cost, when less sensitivity is required. The addition of a new instrument, the inductively coupled-argon-plasma-emission spectrophotometer (ICP), has made simultaneous multielement analysis for inorganic constituents possible. In less than 1 minute, this computer-controlled technique gives results of a simultaneous analysis of 26 elements using only 0.169 fluid ounce of sample.

A major effort is now underway to develop and implement analytical methods for a wide variety of volatile and semivolatile organic compounds. The techniques used will rely heavily on gas chromatography–mass spectrometry for isolating and identifying specific organic compounds.

Regional Aquifer-System Analysis Program

With the ever-growing demands being placed on surface-water supplies, it is apparent that ground water will be increasingly used in the coming decades. The Regional Aquifer-System Analysis Program (RASA) has been set up to predict impacts of such increased use by studying several extensive aquifer systems throughout the country. To date, 25 systems have been identified for study, though the list is not final.

Projects now scheduled were selected on the basis of (1) the significance of the aquifer system as a present or potential water supply—particularly its significance to the national economy or at least to the economies of more than one State, (2) the severity of the water problems facing the project area, and (3) anticipated water needs, particularly for energy production, increasing irrigation, and increasing urban development.

The studies begun in 1978 include the California Central Valley, the northern Great Plains, and the High Plains. Future plans call for three or four new studies to begin each year through 1985.

National Water-Data Storage and Retrieval System

Most of the streamflow and stream-quality data that the Survey collects and analyzes are not only published in various Federal and State reports but are also filed in computer storage. The National Water-Data Storage and Retrieval System (WATSTORE) of the National Water-Data System, now contains approximately 70 percent of the streamflow and water-stage data and 35 percent of the ground-water and surface-water quality data collected by the Federal sector.

Four major files of WATSTORE, the Daily Values File, the Station Header File, the Peak Flow File, and the Ground-Water Site-Inventory File, are available to non-Survey users. An enormous volume of surface-water and ground-water inventory data collected by the Water Resources Division and other agencies may be accessed directly by users nationwide through their own computer terminals. These four files, plus others in the WATSTORE system, are available through more than 60 terminals in Survey field offices and through more than 40 terminals in other Federal or State offices.

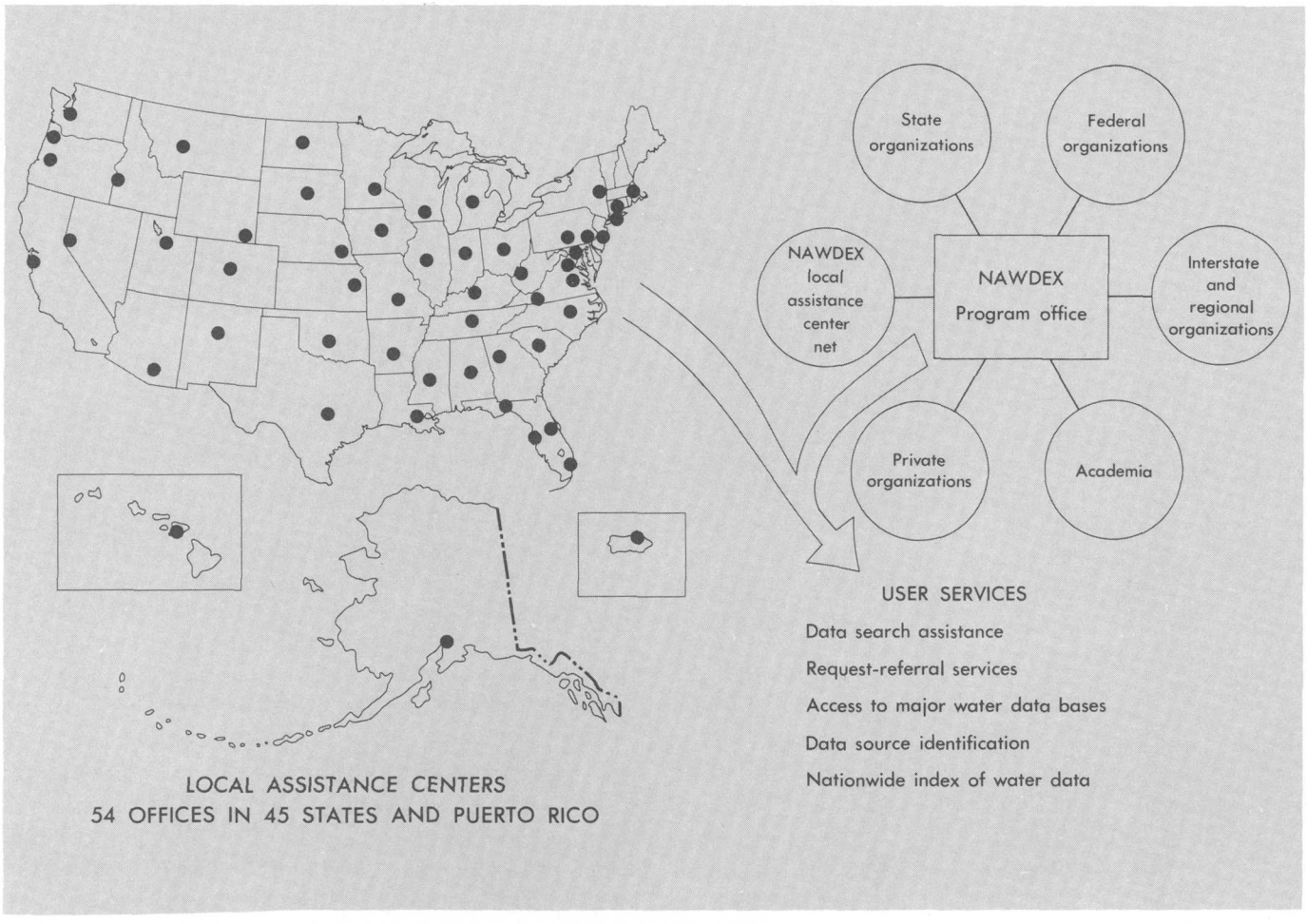
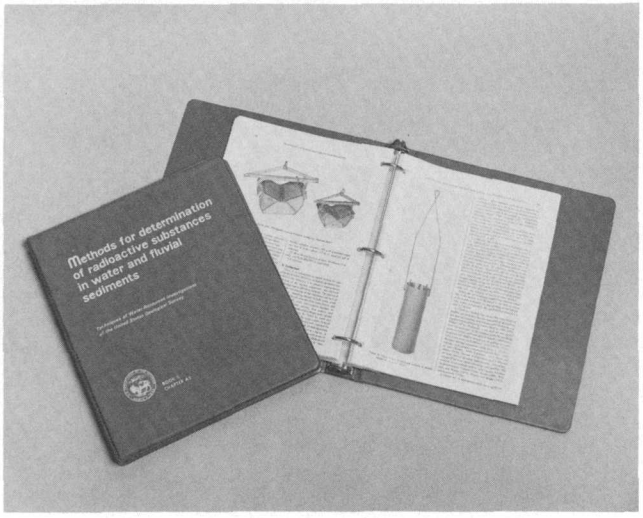


FIGURE 29.—User services and Local Assistance Center network of the National Water Data Exchange.

Survey Publishes "How-To" Manuals on Water-Quality Investigations



This year, the U.S. Geological Survey Central Water-Quality Laboratories will make over 500,000 analyses of the physical, chemical, and biological properties of approximately 100,000 water samples. That represents a fourfold increase in the demand for water-quality work over the past 5 years. The variety of constituents to be measured has widened markedly. For example, analyses of water samples for radioactive substances would have been considered "exotic" if they were requested 10 years ago—now they are routine. "Standard methods" for measuring dozens of additional substances were developed in 1978 which focused primarily on those classed as primary pollutants under recent legal actions, such as chloroform and dicholoromethane.

In line with this serious growing concern over manmade pollutants in water and their effects on

National Water Data Exchange

The National Water Data Exchange (NAWDEX), established in 1976, is a confederation of water-oriented organizations working together on a national basis to improve access to water information by assisting users in the identification, location, and acquisition of needed data (fig. 29). Member organizations are linked so that their water-data holdings may be readily exchanged for maximum use. A central program office within the Water Resources Division coordinates this linkage and provides overall management of the program.

For users' convenience, NAWDEX services are available through a nationwide network of Local Assistance Centers. An initial network of 54 centers in 45 States and Puerto Rico provides direct access to NAWDEX and makes local-area expertise available to aid in locating needed data. Included in this network are the facilities of 50 Geological Survey District and Subdistrict offices, the Texas Natural Resources Information System (TNRIS) in Austin, the Water Resources Research Institute of the Virginia Polytechnic Institute and State University in Blacksburg, the Iowa Water Resources Data System in Iowa City, and the Nebraska Natural Resources Information System in Lincoln.

NAWDEX provides a computerized Water Data Sources Directory, which is maintained in the Geological Survey's computer system in Reston, Va., and is accessible by most Local Assistance Centers through computer terminals. At present, this directory contains information compiled for more than 600 organizations. Information on other organizations will be added on a continuing basis. NAWDEX also maintains a nationwide indexing service through its Master Water Data Index. This computerized index identifies over 300,000 sites for which water data are available nationwide. Additional sites are being added on a continuing basis. The Master Water Data Index is also maintained in Reston and is accessible by most Local Assistance Centers through computer terminals.

As a part of its services, NAWDEX has direct access to and disseminates water data stored in the Environmental Protection Agency's (EPA) Storage and Retrieval System (STORET) and in WATSTORE. STORET services are available through the NAWDEX Program Office in Reston and the Local Assistance Center facilities provided by TNRIS. Data from the WATSTORE system are available through nearly all of the Local Assistance Centers. NAWDEX also has service-exchange arrangements with the Environmental Data and Information Service (EDIS) of the National Oceanic and Atmospheric Administration (NOAA), the Water Resources Scientific Information Center (WRSIC) of the U.S. Department of the Interior, and the Water Document Reference Centre (WATDOC) of the Canadian Department of Fisheries and the Environment. Various water data are available from data systems of other member organizations.

Through its Local Assistance Centers and by using the Water Data Source Directory and the Master Water Data Index, NAWDEX can readily assist users to locate data available for a specific geographic area. Listing and summary counts can be provided, or the user can be referred quickly to water-data systems, to bibliographic services, or to data-collecting or-

man as well as on aquatic life, the Water Resources Division has just published two new instruction manuals. One describes methods for collecting and analyzing aquatic biological and microbiological samples, and the other documents techniques for the determination of radioactive substances in water and fluvial sediments.

"Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples" includes methods used by the Survey to collect, to preserve, and to analyze water samples for their biological and microbiological properties. It discusses biological sampling and sampling statistics and describes in detail more than 45 individual methods of analysis including those for all major groups of aquatic organisms. The 332-page manual also contains a 184-term glossary and a list of over 1,300 taxonomic references.

"Methods of Determination of Radioactive Substances in Water and Fluvial Sediments" is a 95-page manual covering 17 methods for the determination of radioactivity, of natural and manmade radioactive isotopes, and of radiocarbon ages.

The new volumes are part of a series of more than 30 manuals covering the methods used by the Survey in its hydrologic investigations. The series is a standard reference source within the Survey, but more than 100,000 copies of the various manuals have been sold and distributed to scientists, engineers, and planners around the world.

Because new methods are constantly being developed and tested, the two water-quality manuals will be kept up to date by frequent revision. They are available from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202, an authorized agent of the Superintendent of Documents.

ganizations that are able to provide the information or other services required.

Membership in NAWDEX is voluntary and open to any water-oriented organization. Members are required, however, to enter into a formal agreement with the NAWDEX program office that defines a member's general commitment to take an active role in NAWDEX activities. As of September 30, 1978, there were 22 Federal and 98 non-Federal members of NAWDEX.

RESEARCH PROGRAM

Approximately 240 articles and reports from the research program were published in 1978. A sampling of research accomplishments follows.

Locating and developing geothermal resources is of national importance; however, problems associated with geothermal energy include disposing of spent thermal fluids and the fate of trace contaminants such as boron. To predict the mobility of boron in the environment, a model was developed that describes the boron-sorption process.

Multiple linear regressions were developed that relate water-quality characteristics to basin characteristics. Usable regression models were defined for 10 of 11 water-quality properties and explain from 58 to 89 percent of the variation of the properties.

In cooperation with the Fish and Wildlife Service, a new system for classifying wetlands of the United States was devised.

Chemical extraction procedures were developed for estimating the bioavailability of particulate trace metals in estuarine sediments. Sediment extractions involving complexation and (or) mild dissolution were found to best estimate bioavailability. Zinc concentrations in detritus-feeding estuarine macroinvertebrates are apparently controlled by the concentration and the physiochemical form of zinc in sediments that the animal ingests and by species-specific physiological factors.

Numerical simulation of the three-dimensional ground-water flow near lakes provided an increased understanding of seepage to and from lakes and allowed for improved estimates of the ground-water component of lake-water budgets. The simulation suggests new methods for managing lakes for water-level control and relating ground-water quality to lake quality.

A numerical model was developed that solves equations for heat and mass transfer in porous media. The model is used to analyze natural (cellular) convection in geothermal reservoirs with rock and fluid properties that vary spatially and with temperature. Transfer processes associated with hot-spring systems are also simulated to determine lateral conductive heat losses from the spring conduit as a function of spring discharge.

A computer program for simulating one-dimensional subcritical, gradually varied unsteady flow in a stream has been developed and documented. Given upstream and downstream boundary conditions and channel geometry data and roughness coefficients, stage and discharge can be calculated anywhere within a reach as a function of time. This program will simulate such common problems as flood waves, release from dams, and channels where storage may

be a consideration. It may also supply the needed flow information for mass-transport simulation.

In response to the need for fulfilling time-dependent data requirements (model supporting systems) of estuary and coastal embayment models, a comprehensive highly modular automated data-collection and processing system has been developed to effect the acquisition and reduction of bathymetric data used to delineate the bottom configuration of estuaries and coastal embayments. Another complementary system has been devised to translate, to edit, to collate, to file, and to retrieve various types of time-dependent data (water-surface elevations, temperatures, flow and wind vectors, dissolved-constituent concentrations). All time-dependent data are filed in a common location by a common format and are, thereby, easily accessible to activate a model for verification data with which to evaluate the performance of a model or, most importantly, as output results to illustrate the effect of some real or hypothetically imposed stress upon the water body. Consequently, water-management officials are provided with a rapid, economical, and systematic mechanism for effectively using flow-simulation models to evaluate various plans for coastal zone management.

A comprehensive microwave-sensing program was performed on the sea ice of the Beaufort Sea. Surface and aircraft measurements were obtained during all seasons using a wide variety of microwave sensors. In three test regions, each with an area of approximately 4.9 x 32.8 feet, detailed ice crystallography, dielectric properties, and brightness temperatures of first-year, multiyear, and first-year–multiyear mixtures were measured. Aircraft obtained passive microwave measurements that were able to distinguish first-year and multiyear ice types and concentration and gave new information on ways to observe ice mixtures and thin-ice types.

INTERNATIONAL ACTIVITIES

Technical assistance activities continued a trend from long-term programs to short assignments. Programs of several years' duration in Kenya and Yemen, both sponsored by the Agency for International Development, were completed. Only in Saudi Arabia, where four hydrologists were posted under a program of the U.S.–Saudi Arabia Joint Commission on Economic Cooperation, do Division personnel reside abroad.

Short-term advisory services were provided for Brazil, Saudi Arabia, Djibouti, the Philippines, and Turkey. The Water Resources Division cooperated with international training seminars and workshops in Argentina, India, Iran, Israel, Pakistan, Turkey, and Venezuela by providing lecturers and instructors. Hydrologic reports were issued on Cambodia, Egypt, Kenya, Indonesia, and the Dead Sea.

During the year, approximately 60 foreign scientists visited Reston headquarters to study or to discuss research and technological advances, particularly in computerized data processing. Of these visits, 27 lasted from days to months.

The Water Resources Division maintains liaison with international hydrological programs, such as those conducted by the United Nations Education, Science and Culture Organization (UNESCO), the World Meteorological Organization, and the International Atomic Energy Agency. The Division also cooperates with the Department of State in programs such as the International Decade for Drinking Water and Sanitation, which originated with the 1977 United Nations Water Conference, and in developing proposals for joint studies of desertification. Experts from within and outside the Survey participated in regional studies in Latin America and in the Far East.

The Division provides the Chairman and the Secretariat of the U.S. National Committee on Scientific Hydrology, which represents the country in the International Hydrological Program (IHP) of UNESCO. During 1978, work continued on the development of the program for the second phase (1981 to 1986) of the IHP and on the preparation of reports which are part of the current (1975 to 1980) phase of activities.

SUPPORTING SERVICES

These services provide for publication and operational support, personnel training, career development, and specific services for water resources activities. Publication standards and guidelines are developed, and the publication and release of a wide variety of reports are supervised and monitored. Training in the field and in the classroom provides the special knowledge and expertise not obtainable in academic institutions which are required to understand and execute the hydrologic investigations of the Survey.

Critical National Water Problems

COAL HYDROLOGY

Water is a critical component in developing the Nation's vast coal reserves. It is required for the miners, can be depleted or contaminated by the mining, is necessary for reclaiming mined lands, can be used to transport coal by slurry pipeline, and is necessary for cooling and other industrial uses when the coal is converted to other forms of energy.

In 1978, Survey-funded activities ranged from collecting hydrologic data from contractors to a complex regional analysis of the Madison aquifer. Studies

were underway in the 20 States that account for more than 96 percent of the Nation's annual coal production. Program emphasis continued to center on the Western States because a large percentage of the Nation's total coal reserve is under Federal ownership in those States and because the region is generally deficient in water supply.

Western water-energy studies are attempting not only to define the basic supply but also to assess the effect on development in-State and on the water resources of the adjacent States. At some point, as water demands approach the limit of available supply, tradeoffs among conflicting interests will have to be made so as to meet the most urgent needs; market-place pressures are expected to be the deciding factors. The Survey's program is attempting to obtain answers through a coordinated effort of State, local, and national agencies. As figure 30 illustrates, Geological Survey funding represents only slightly more than half the financial outlay for coal and other energy-related studies. Water Resources Division activities in coal hydrology are funded by EPA, the Bureau of Land Management, and 31 States (under the Federal-State Cooperative Program), in addition to direct appropriations.

OIL SHALE HYDROLOGY

Studies of the hydrologic problems related to developing oil shale deposits continue to focus more and more on Colorado. The only two active Federal prototype oil shale leases are in northwest Colorado. Both sites are under evaluation through modified in-situ techniques. Simply stated, these techniques involve driving a shaft through the zone to be developed, mining approximately 15 to 25 percent of the shale, fracturing the surrounding shale to refill the area mined, and then, through combustion controlled from the surface, retorting the shale in place. Currently, the mined shale will be stockpiled on the surface and will be surface-retorted when a sufficient volume of material is available to make it economically feasible. Hydrologic problems associated with these techniques include locating adequate water supplies for personnel, dewatering during development and production, disposing of what may be highly saline water pumped for dewatering, and the long-term effects of the retorted shale on the region's water supply after development. One major unknown under study is the potential for collapse into the retorted deposits some time after development. This is possible, even though the retort is backfilled with rubble. The part the ground-water system may play in potential collapse must be evaluated.

NUCLEAR HYDROLOGY

Nuclear power for energy generation is closely linked with disposal of radioactive waste. This waste, in addition to that from laboratories and hospitals, contains a variety of nuclides in a large range of concentrations. Concentrations of radioactivity of less

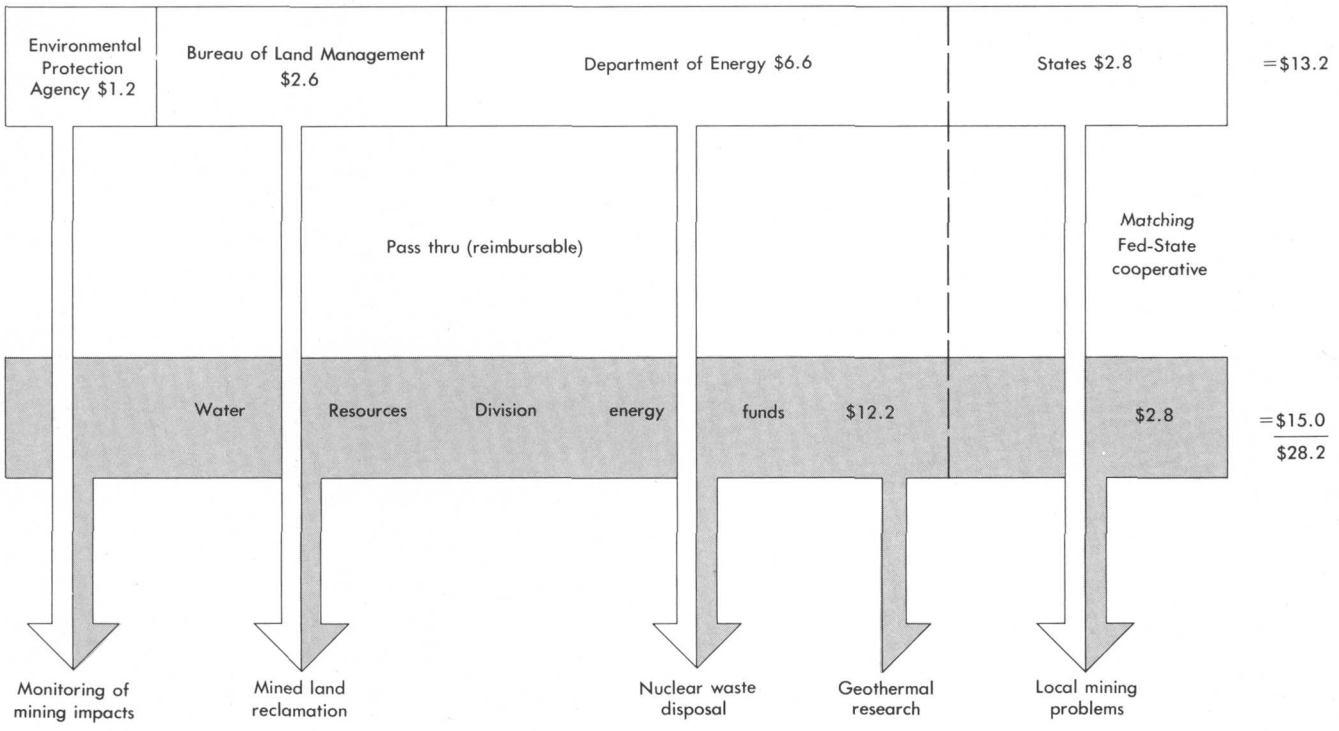


FIGURE 30.—Energy research and development program of the Water Resources Division for fiscal year 1978 (dollars in millions).

Reducing Losses from Rampaging Rivers

> Nature will always extract some price for use of her flood plains. However, this Nation's annual flood damage bill . . . is excessive, even in a growing economy. Beyond the dollar loss the accompanying toll in personal hardship cannot be calculated. In addition, opportunities are being lost to use flood plain lands effectively for recreation and wildlife purposes. (President Lyndon B. Johnson, August 10, 1966.)

In the decade since President Johnson made this observation, hydrologists and cartographers of the U.S. Geological Survey have intensified their efforts to research and to map flood-prone areas and to investigate the extent of major floods in the United States. One useful result is a practical guide to the use of such earth science information to reduce damage from floods—Professional Paper 942, published in 1977 by the Survey in cooperation with the Department of Housing and Urban Development. Entitled "Flood-Prone Areas and Land-Use Planning," the report emphasizes flood-plain planning in the San Francisco Bay

than 10 nanocuries per gram are considered low level. High-level wastes were originally defined as those resulting from the first cycle of reprocessing reactor fuel; however, the definition is now generally extended to include the spent fuel rods themselves. A third category of waste, referred to as transuranic (TRU), is also defined and consists of elements above uranium in the periodic table that generally have a very long half-life. There has been no disposal of high-level wastes to date. The Geological Survey, in cooperation with the Department of Energy, is characterizing several rock types that may be suitable as repositories for high-level wastes. Studies are in progress on the hydrology and geology of salt domes in Texas and Louisiana and on bedded salt in New Mexico, New York, Ohio, and Utah. Shale and granite are being studied in Nevada. Igneous crystalline rocks, in general, are being evaluated regionally.

Low-level waste has been buried in shallow landfills since the beginning of the atomic age. The Geological Survey has a program to investigate five of the six commercial low-level burial sites in New York, South Carolina, Kentucky, Illinois, and Nevada, as well as two Department of Energy disposal sites in Tennessee and Idaho. This program is designed to quantify the factors controlling the movement of dissolved radionuclides by ground water, which is generally regarded as one of the more likely mechanisms by which buried radionuclides can reach the biosphere. The program aims to develop hydrologic criteria for locating future low-level disposal sites and techniques for evaluating these criteria.

In connection with field studies of both low- and high-level waste, the following theoretical and laboratory studies are underway to:

- Use digital-modeling techniques to predict characteristics of ground-water flow and water-quality variations.
- Detect and identify radionuclides by borehole geophysical techniques.
- Evaluate geochemical kinetics of radionuclides.
- Predict movement of radionuclides in the saturated and unsaturated zones.
- Use techniques for interpreting paleohydrologic conditions to aid in extending the ground-water record.
- Determine the amount of ground-water recharge in arid areas.
- Improve techniques for carbon-14 dating of ground water.
- Determine the geochemical characteristics of trace elements in natural environments.

GROUND-WATER RECHARGE

Studies on ground-water recharge include the use of both spreading basins, in which highly treated sewage effluent is spread over a wide area of permeable soil, and injection wells. In the semiarid plains of Texas and New Mexico, methods are being

region, but the principles are applicable to other flood-prone areas throughout the country. Adherence to the principles could save many lives and millions of dollars. It has been estimated that there are 16,500 square miles of urban flood plains in the United States, an area equal to Massachusetts and New Jersey combined.

Professional Paper 942 points out that people tend to occupy flood plains because of the advanages of level ground, fertile soil, ease of access, and available water supplies—but often without full consideration of the attendant risks. The damage from flooding so often sustained is a direct consequence of inappropriate use of lands exposed to such risks.

Better management of flood-plain lands based on knowledge now available could reduce vulnerable uses within the floodway, could regulate building, and could prohibit dumping and filling or the building of structures that would obstruct the flow of floodwater. In undeveloped flood-prone areas, agricultural and other nonintensive uses could be permitted, but even agricultural use should be specifically suited to the flood-plain.

Measures for reducing flood losses are of two general types—structural, which involves the building of dams, levees, floodways, and similar structures for containment and direction of floodwaters, and nonstructural, which involves land use zoning of the flood plain. In the past, structural flood control was the most common, but it is more expensive and often not as effective as nonstructural control. Nonstructural control is becoming more and more feasible as identification and scientific study of flood-prone areas has expanded. Dams, dikes, and levees have played a role in reducing some flood losses, but sometimes they actually contributed to greater losses. Now the emphasis is shifting to a more balanced approach, combining structural controls with better land use planning and management. The San Francisco study described in the report is a convincing argument for land use management and is a practical working guide to reducing needless loss of life and property.

developed to predict the amount of water that can be returned to aquifers by studying the fundamental principles that control movement of water into aquifers, the rock-water interactions during storage, and the diffusion-dispersion phenomenon accompanying water movement after emplacement. Recent tests involving injection of surface water into wells indicate that such recharge can be successful, even with turbid water, if the aquifer permeability is due to secondary porosity. However, wells tapping aquifers in which permeability is governed by intergranular porosity are quickly plugged even by small quantities of suspended sediment. Temperature logs obtained during injection of water of a different temperature than that of the native ground water have been successfully used to determine zones containing solution openings in poorly consolidated rock. Moreover, work has been completed to show that such temperature changes may be related, by use of a theoretically based retardation factor, to chemical changes arising from injection of a conservative tracer. Other experiments involving recharge by spreading indicate that sulfate ions are significantly sorbed on aquifer materials and hence do not constitute a conservative tracer.

Recharge of aquifers using highly treated sewage by spreading basins has been shown to be successful on Long Island. Maximum recharge rates of more than 98 feet per day have been obtained, but more complete denitrification and virus removal was observed to occur after clogging of surface materials lowered the recharge rate to a minimum value of about 7 to 10 feet per day.

MAPPING IN FLOOD-PRONE AREAS

The mapping program of flood-prone areas aims to identify areas subject to inundation and to provide simple techniques for estimating the magnitude and frequency of future flood peaks at ungaged sites. ("Response to Recommendation 1 of the Task Force on Federal Flood Control Policy": House Document 465, 89th Congress, 47 p.).

In 1978, the Water Resources Division published approximately 100 maps of flood-prone areas. Most of the urgently needed mapping in areas having urban flood problems has been completed (nearly 13,000 maps and 1,000 descriptive pamphlets). Definition of flood-prone areas, primarily those downstream from dams and reservoirs, where structural failure could result in extensive loss of life and catastrophic flood damage, continued on a limited and selective basis.

In addition to reconnaissance flood mapping, the Geological Survey is one of several agencies making flood-insurance studies in cooperation with the Department of Housing and Urban Development. These studies include flood-profile information and delineation of 100-year floods (floods with a 1-percent

chance of occurring in any given year) on city or community maps with scales such as 1:4,800 (1 inch on the map equals 400 feet). Since 1970, more than 400 flood-insurance studies have been completed by the Water Resources Division, and studies in an additional 250 communities are in progress.

Documentation of major floods every year in the United States provides information required for the judicious management of flood plains. Field investigations of the Maine coastal floods of January and February 1978 and the Wyoming-Montana floods of May 1978 are in progress. Formal reports on the tragic flood caused by the failure of the Kelly Barnes Dam, Toccoa, Ga., in November 1977 and the severe Johnstown, Pa., flood of July 1977 are in preparation. In 1978, the Geological Survey and the National Weather Service completed joint reports on investigations of three disastrous floods in Maine in February 1976, in Colorado in July 1976, and in the Appalachian areas of Kentucky, Tennessee, Virginia, and West Virginia in April 1977.

Planners and designers need simple reliable methods for estimating the magnitude and frequency of future floods. The techniques published by the Water Resources Division from 1963 to 1965 have been used extensively by government agencies and the private sector. Updating of the Streamflow and Basin Characteristics File, a key feature in large-scale nationwide flood-frequency analysis, was completed.

SUBSURFACE WASTE STORAGE

Waste-disposal sites such as dumps, landfills, pits, ponds, lagoons, injection wells, and feedlots can adversely affect ground-water quality. Such sites exist in and near every city in the country. Nonpoint sources of water pollution include fertilizers, pesticides, irrigation water for food and fiber production, and chemicals for highway deicing. Accidental spills, storage-tank leaks, and pipeline breaks also affect ground water.

Ground water is replenished naturally, except in a few over-stressed aquifers. However, polluted water is effectively removed from fresh-water reserves for a long time. To maintain a current appraisal of the Nation's water resources, the Geological Survey is endeavoring to substantiate the amount "lost" through contamination, a statistic that may have a greater cumulative impact than the amount "lost" by declining water levels.

State and local agencies have the responsibility to provide safe drinking water and water for industrial and agricultural uses. They need information and technology to assess the impact of various waste-disposal activities on ground water and to predict how waste will move in ground water to determine the long-term impact. Waste-storage information is also necessary for designing and implementing monitoring programs for meeting the regulations of EPA and other Federal regulatory agencies.

The Subsurface Waste Storage Program is concerned with the fundamental principles of waste movement into and through the subsurface and with developing criteria and methodology for mapping and describing potential disposal aquifers and associated confining beds. Investigations include the chemical and physical reactions of waste with aquifer materials and ground water and the dilution and dispersion of pollutants, not only in the deep subsurface but also in the shallow and near-surface environment where most waste disposal takes place.

The program also seeks to develop and to test predictive models of waste movement in aquifers and unsaturated material and to evaluate the impacts and benefits of disposal of treated sewage on and beneath the land surface. In addition, the program develops new techniques, applications, and tools that will improve geophysical methods and interpretations of waste injection into aquifers and tracing of the movement of polluted water from surface or shallow disposal sites.

Predictive models of solute transport in ground water are limited at present to conservative compounds or a few chemicals having known reactions. One of the most difficult problems remaining is the development of methods to predict how nonconservative chemicals react with aquifer materials and how the reactions affect their movement. Most organic chemicals will be sorbed, at least temporarily, on particles in the aquifer. However, the sorption capacity may be exceeded, or changes in the pH or other characteristics of the water may release the contaminants, allowing their further movement by flowing ground water. Another problem is the determination of naturally occurring trace substances in ground water. For instance, small amounts of naturally occurring organic materials in ground water may form dangerous compounds in drinking water after the water is treated with chlorine.

Part of the Subsurface Waste Storage Program has been devoted to developing and demonstrating methodology and technology to describe aquifers that contain saline water and that are isolated from fresh-water aquifers by confining beds of clay or shale. These investigations describe large areas of the subsurface so that high-risk zones can be ruled out and targets for detailed exploration can be identified. They also describe methods of analysis that can be used in other areas where similar data are available. The results of these investigations save much time and money for the waste managers, plan-

ners, and regulators who are evaluating possible deep waste injection.

Since its beginning in 1970, the Subsurface Waste Storage Program has released more than 100 reports and articles.

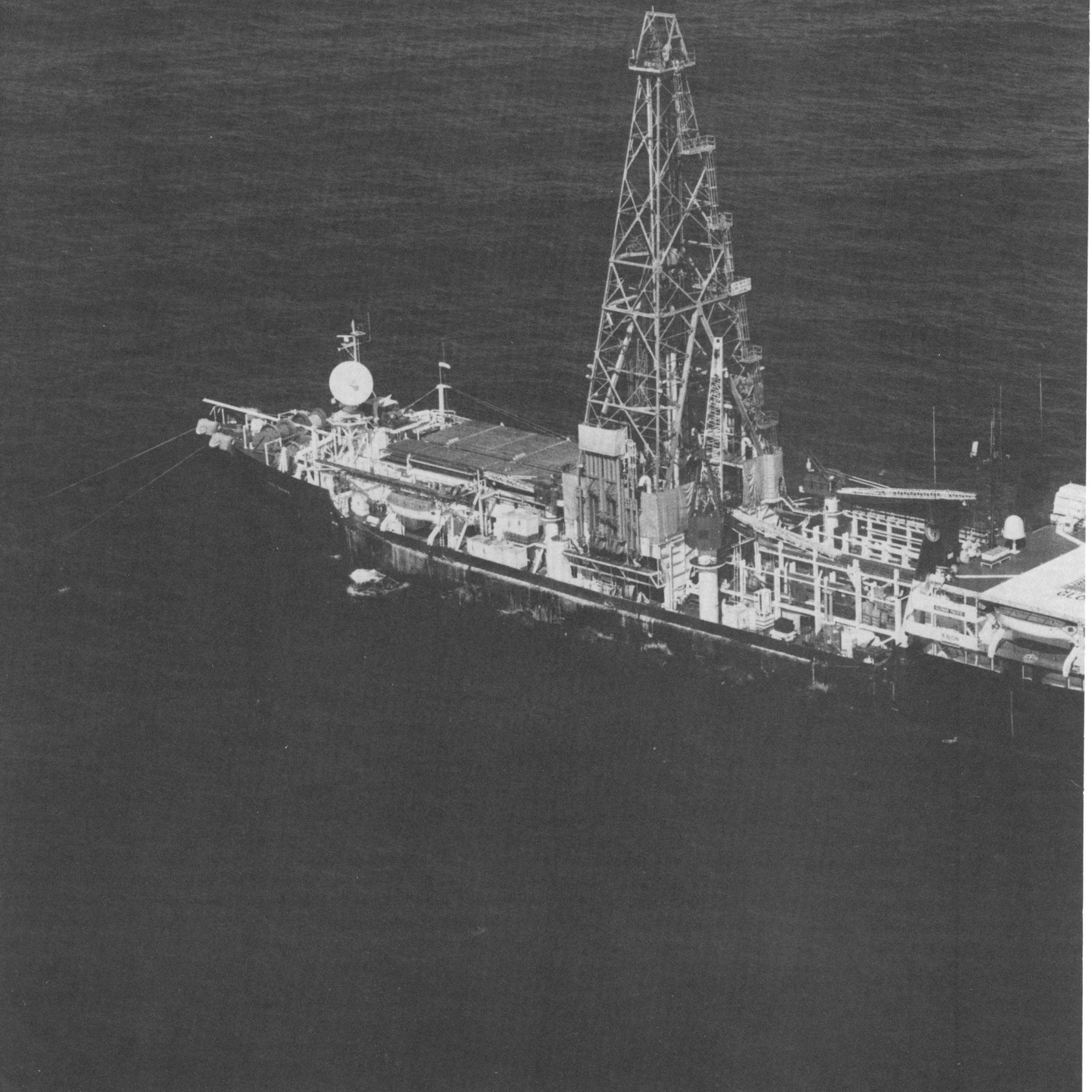
ESTUARINE AND COASTAL STUDIES

Studies continued on the biogeochemistry and circulation patterns in San Francisco Bay. In addition, an Interdisciplinary Potomac Estuary Study is being done cooperatively by members of eight separate but interlocking projects. Objectives of the study are to understand an urbanized estuary better, to determine urban influence on it, and to predict the results of changes brought about by these influences.

Major efforts are directed at calibrating and verifying a horizontal two-dimensional flow and transport model. Sediment-related studies are intended to enable computation of modern-day suspended loan transport and to determine historic and prehistoric sediment sources and deposition rates. Geochemical investigations are concerned primarily with phosphorus-cycle dynamics and heavy-metal distribution. Surveys of benthic macrofaunae and the submersed aquatic vegetation of main-stem and tributary shoreline areas are the major biological contributions.

Development of sinkholes caused or accelerated by ground-water withdrawal. This collapse is at a construction site in Jefferson County, Ala.

Conservation of Lands and Minerals



INTRODUCTION

The Conservation Division performs several evaluation and regulatory functions concerning the leasing, mining, and use of mineral and water resources on Federal and Indian lands. These functions were delegated to the Geological Survey by the Secretary of the Interior and are accomplished through two major missions:

- Resource evaluation which includes the classification of public lands to identify areas containing potentially valuable leasable minerals and areas valuable for waterpower and water-storage purposes and the evaluation of mineral resources on tracts of public land that are made available for private development through a competitive leasing process, are exchanged, or are sold.
- Supervision of operations associated with the exploration, development, and production of minerals from leased Federal, Indian, and Outer Continental Shelf (OCS) lands, including the collection of royalties for minerals produced and certain rentals.

Data acquired by the Geological Survey for the sound development of resources and protection of the environmental characteristics found on public lands also support the missions of other Federal agencies. These agencies include the Bureau of Land Management (BLM), the Bureau of Indian Affairs, the National Park Service, and the Bureau of Reclamation within the Department of the Interior. Agencies outside the Department include the Department of Defense, the Forest Service, the General Services Administration, the Environmental Protection Agency, and the Department of Energy.

In fiscal year 1978, Federal and Indian lands supplied a significant portion of the Nation's mineral production. More than 16 percent of the oil, 27 percent of all natural gas, and 13 percent of the Nation's coal were produced from leases on Indian and Federal lands onshore and offshore. This production clearly demonstrates the importance of the contribution from these lands to the Nation's supply of petroleum and minerals. The production of these minerals has had a significant impact on the Nation's economy. For example, in fiscal year 1978, the value of all commodities produced from leased Federal and Indian lands exceeded $10.5 billion. Lease rentals, royalties from the production of minerals, and various bonus payments provided more than $2.9 billion in revenue for the Federal Government.

◀ *Glomar Pacific,* a new drillship on its initial operation, was the first rig to begin drilling on the Atlantic Outer Continental Shelf.

Highlights

Activities during fiscal year 1978 included the following:

- Completion of tract evaluations for four lease sales totaling almost 3.5 million acres. Two of the sales were scheduled for the Atlantic and one each for the Gulf of Mexico and Lower Cook Inlet.
- Revision, drafting, and updating of Outer Continental Shelf Orders and Standards for the Atlantic, Gulf of Mexico, and Pacific areas (table 9).
- Supervision of operations included more than 6,100 inspections of offshore drilling rigs and platforms.
- Approval of 3,425 new onshore oil and gas exploration and development wells, preparation of 3,525 environmental analyses of proposed operations, and inspection of 27,630 onsite drilling and production operations.
- Supervision of mining operations on 2,143 mineral leases comprising 8.5 million acres including 565 coal leases and 397 uranium leases. Combined production value of 24 mineral commodities was over $1.3 billion.
- Supervision of exploration operations under 522 prospecting permits comprising 6.5 million acres for discovery or development of 24 different solid mineral commodities.
- Collection of $59.4 million in rents and royalties from the leasing of minerals on Federal and Indian lands.
- Evaluation of 380 tracts for proposed onshore oil and gas lease sales. In all, 367 tracts were sold in 21 sales.
- Evaluation of 132 tracts for 7 geothermal lease sales. Subsequently, more than 59,000 acres were leased in 34 tracts, with a total bonus paid to the Government of almost $1.1 million.
- Evaluation of 15 tracts for proposed coal lease sales under the National Research Defense Council vs. Hughes settlement. Five lease sales were held by BLM.
- Mineral resource evaluation of one oil shale tract for exchange.

Authority

The Geological Survey presently has the authority to classify public lands and to regulate mineral development on Federal and Indian lands, to protect the environment, and to collect a fair return from extracted resources. The authority comes from a complex body of mineral and land laws. Some laws carrying the Secretary's authority date back to the 1860's.

Congress created the U.S. Geological Survey in the act of March 3, 1879. The act stipulated that the Director of the Survey should classify the public lands to identify features pertaining to land values for many purposes.

The Mineral Leasing Act of 1920 provided for the leasing of coal and certain other mineral commodities. The leasable minerals on public lands now include oil, gas, coal, potash, sodium, phosphate, oil shale, asphaltic minerals, sulfur (only in New Mexico and Louisiana), and geothermal resources. All minerals, except common varieties such as sand and gravel on acquired lands and Indian lands, are leasable. A lessee is required to pay the Federal Government or the Indians a royalty based on the value

TABLE 9.—*Effective dates of Outer Continental Shelf Orders and Standards*

Order number and title	Gulf of Mexico area	Pacific area	Gulf of Alaska area	Mid-Atlantic area	North Atlantic area	South Atlantic area
1. Marking of Wells, Platforms, and Fixed Structures	8-28-69	6- 1-71	3- 1-76	7- 1-76	1- 1-78	2- 1-78
2. Drilling Procedures	1- 1-75	5- 1-76	3- 1-76	7- 1-76	1- 1-78	2- 1-78
3. Plugging and Abandonment of Wells	8-28-69	6- 1-71	3- 1-76	7- 1-76	1- 1-78	2- 1-78
4. Suspensions and Determination of Well Producibility	8-28-69	6- 1-71	3- 1-76	7- 1-76	1- 1-78	2- 1-78
5. Subsurface Safety Devices	6- 5-72	6- 1-71	3- 1-76	7- 1-76	1- 1-78	2- 1-78
6. Completion of Oil and Gas Wells	8-28-69	6- 1-71	-------	-------	-------	-------
7. Pollution and Waste Disposal	10- 1-76	6- 1-71	3- 1-76	7- 1-76	1- 1-78	2- 1-78
8. Platforms, Structures, and Associated Equipment	10- 1-76	6- 1-71	-------	-------	-------	-------
9. Oil and Gas Pipelines	10-30-70	6- 1-71	-------	-------	-------	-------
10. Sulphur Drilling Procedures (Gulf of Mexico) and Drilling of Twin Core Holes (Pacific)	8-28-69	6- 1-71	-------	-------	-------	-------
11. Oil and Gas Production Rates, Prevention of Waste, and Protection of Correlative Rights	5- 1-74	5- 1-75	-------	-------	-------	-------
12. Public Inspection of Records	2- 1-75	12- 1-74	3- 1-76	7- 1-76	1- 1-78	2- 1-78
13. Production Measurement and Commingling	10- 1-75	-------	-------	-------	-------	-------
14. Approval of Suspensions of Production	1- 1-77	-------	-------	-------	-------	-------
U.S. Geological Survey Standard GSS–OCS #1	2- 1-76	2- 1-76	2- 1-76	2- 1-76	-------	-------
U.S. Geological Survey Standard GSS–OCS–T1	12- 1-77	12- 1-77	12- 1-77	12- 1-77	-------	-------

or quantity of the mineral produced. Other laws authorize the leasing and management of metallic and nonmetallic minerals on Indian lands, railroad and other right-of-ways across public lands, acquired lands, and OCS lands.

By various statutory authorities, the Secretary of the Interior has promulgated in the Code of Federal Regulations (CFR), rules pertaining to the development of minerals on Federal and Indian lands. The principal Department of the Interior sections of the CFR concerning operations on Federal mineral leases are as follows:

- Onshore Federal Lands Regulations pertaining to operations—Parts 211, 221, 223, 225, 226, 231, 270, and 271 of Title 30.
- Outer Continental Shelf Regulations pertaining to royalty oil, operations, and so forth—Parts 225a, 250, 251, and 252 of Title 30.
- Onshore Federal Lands Leasing Regulations—Groups 3100, 3200, and 3500 of Title 43.
- Outer Continental Shelf Leasing Regulations—Group 3300 of Title 43.
- Indian Lands Leasing Regulations—Parts 171, 172, 173, 174, 176, and 177 of Title 25 and the pertinent onshore Federal operating regulations contained in Title 30.

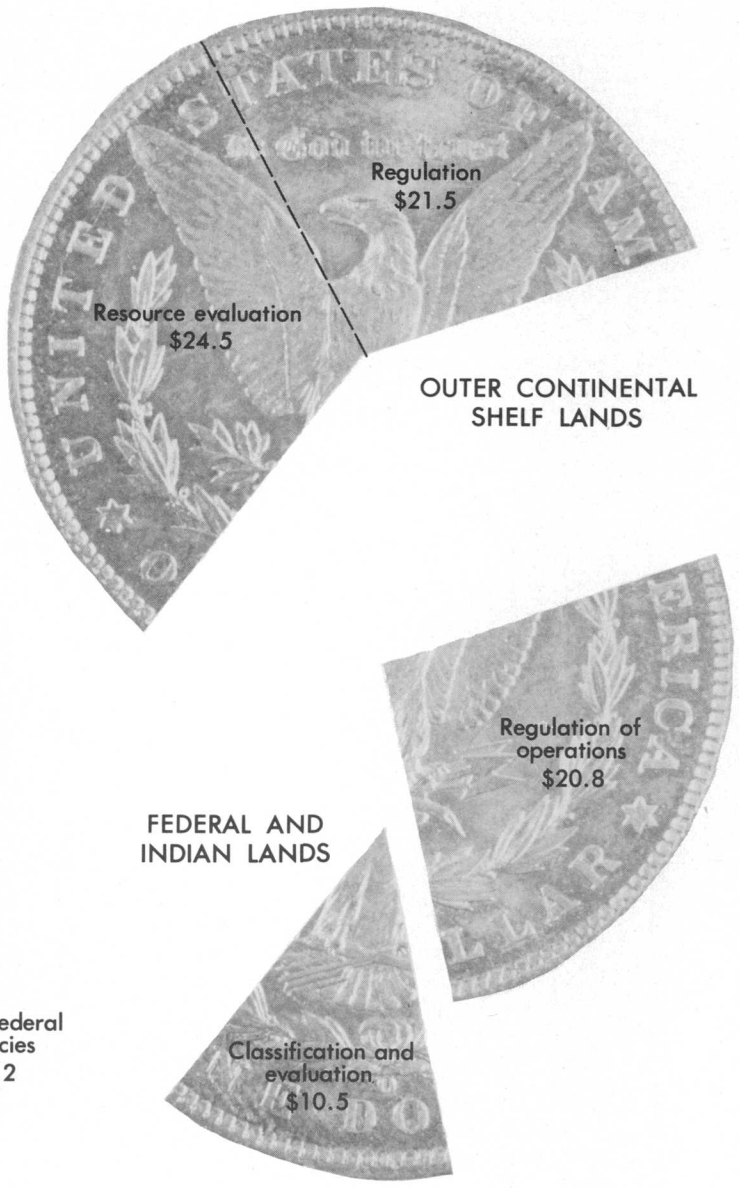
Although the Geological Survey administers or enforces some provisions of leasing regulations and all provisions of operating regulations, BLM and the Bureau of Indian Affairs administer most provisions of the leasing regulations.

Anchorage Conservation Division geologists assembling an auger, which is used to search for coal beds beneath the tundra. The auger will be mounted on the Rolligon used along the Kokolik River, National Petroleum Reserve in Alaska.

CONSERVATION OF LANDS AND MINERALS

TOTAL $77.5 MILLION

SOURCE OF FUNDS



USE OF FUNDS

BUDGET AND PERSONNEL

The source of funds for these programs is described under the Conservation of Lands and Minerals Budget Activity in the Geological Survey Budget. Funds for these activities have increased by 13.5 percent from $68.1 million in fiscal year 1977 to $77.3 million in fiscal year 1978. Program expenditures for fiscal years 1977 and 1978 are shown in table 10. The OCS lands subactivity was appropriated $45.9 million, an increase of 19.9 percent over the appropriation for fiscal year 1977. In fiscal year 1978, funding for the Federal and Indian lands subactivity increased to a total of $31.3 million. This represents a 5.2-percent increase for this subactivity.

In response to recently broadened responsibilities, the Division has filled many of the new professional positions with economists, computer specialists, and environmental scientists, in addition to the traditional disciplines of geophysics, geology, petroleum engineering, and mining engineering. Additional management personnel were hired during the same period to improve the over-all direction of programs.

TABLE 10.—*Conservation of Lands and Minerals activity obligations for fiscal years 1977 and 1978, by program*

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Program	Fiscal year 1977	Fiscal year 1978
Total	**$67.2**	[1] $77.5
Outer Continental Shelf (OCS) lands	**38.0**	**46.0**
Regulation of OCS oil and gas	16.8	21.4
OCS oil and gas tract selection and evaluation	21.2	24.6
Federal and Indian lands [2]	**29.2**	**31.5**
Regulation of operations	18.4	18.3
Oil and gas	9.8	11.6
Energy minerals (coal and uranium)	5.6	3.5
Oil shale	.8	.6
Geothermal resources	.8	1.2
Nonenergy minerals	1.4	1.4
Resource classification and evaluation	10.8	13.2
Oil and gas	.3	.9
Coal	8.6	9.9
Oil shale	.4	.2
Geothermal resources	.7	.8
Nonenergy minerals	.3	.9
Water resource development	.5	.5

[1] Included in this total is $200,000 for the total reimbursement program.

[2] Shifts in program funding for Federal and Indian Lands subactivities approved by the Appropriations Committee.

PROGRAMS AND ACTIVITIES

The programs of the Geological Survey support the minerals programs of the Department of the Interior. They are carried out in close cooperation with other agencies of the Department. The principal minerals activities focus on the following major programs: the classification and evaluation of mineral resources on Federal lands and the supervision of mineral development and extraction operations occurring on those lands under lease. For budget purposes and ease of administration, the offshore activities are separated from the onshore activities. Both offshore and onshore activities include prelease evaluation of resources; the postlease supervision of exploration, development, and production operations; and the computation and collection of royalty and certain rental payments. The onshore program also includes the classification of Federal lands for mineral development and waterpower and water-storage site potential.

Outer Continental Shelf Lands

Oil and gas leases on the OCS are issued by BLM, but the Geological Survey implements and enforces the operating regulations. The Geological Survey and BLM consult closely on the significant actions that precede each lease sale. The Survey provides BLM with the following:

- Assessments of petroleum resources and other technical information used to identify areas to lease and to schedule lease sales.
- Resource evaluations used to select tracts for each lease sale.
- Identification of geologic hazards.
- Mineral resource values for each tract to be used in determining the fair market value.

MONITORING DEVELOPMENT

Diligent development of OCS leased lands was a prime thrust during fiscal year 1978. This work centers on ascertaining the actual efforts being expended by lessees to determine the oil and gas resources contained on their leases and whether their efforts to extract these resources are adequate. The Survey monitors development through the use of detailed geologic, geophysical, and engineering studies. The total OCS budget for the Division in fiscal year 1978 was $45.9 million, an increase over 1977 of $7.6 million.

RESOURCE EVALUATION

Resource evaluation activities on the OCS focus on identifying areas for future lease sales, advising BLM on the selection of tracts to be offered for sale, estimating the value of oil and gas on each tract that is offered, and determining geologic hazards that affect specific tracts.

Between 1954 and 1966, tracts on the OCS were selected for sales without the Geological Survey evaluating their hydrocarbon potential. In 1967, the Geological Survey established an OCS mineral resource evaluation program to improve methods of tract selection and to develop methods of evaluating tracts proposed for OCS leasing.

To select tracts for leasing, BLM publishes a Call for Nominations and Comments in the "Federal Register," the official notice to the public. Responses assist in identifying individual offshore tracts that

subsequently may be sold. The Calls describe large areas that usually embrace several million acres. Interested parties are asked to nominate tracts within each area that they wish to have offered for lease because of the oil and gas resource potential.

Geophysical service companies operating under permits issued by the Survey conduct geophysical surveys in areas of interest. Data obtained from these surveys are furnished to the Survey and are used in evaluating the region. Once tracts have been selected, detailed geophysical maps are made; usually two reflecting horizons are mapped. Paleontological investigations are conducted using samples from drill cuttings when available. Also, available well, geochemical, and subsurface geologic data, including rock units and thicknesses, are studied to arrive at a range of net pay thicknesses and areal extents of potential reservoirs. Reservoir engineering and engineering evaluation then commences, and a dollar value is calculated for each tract.

The Department of the Interior uses the tract nominations and the resources and environmental information received from all interested parties, as well as resource, environmental, technological, and economic information from the Survey and other agencies, to select tracts (which may be offered for sale) for further analysis in the environmental impact statement.

Resource evaluation activities of significance included the following:

- Tract evaluations began during fiscal year 1978 for one sale in the Atlantic (OCS Sale No. 49), two sales in the Gulf of Mexico (OCS Sale Nos. 58 and 58a), and one State-Federal sale in the Beaufort Sea.
- An OCS lease sale for 135 tracts was held October 27, 1977, in Anchorage, Alaska (OCS Sale No. CI); 89 of the tracts were offered for bonus bids, and 46 were offered on a royalty-bid basis with a fixed cash bonus. Bids totaling almost $400 million on 87 tracts (57 bonus, 30 high royalty) were accepted.
- On March 28, 1978, the first OCS lease sale (No. 43) for tracts in the South Atlantic was held in Savannah, Ga. This sale introduced the sliding-scale royalty bidding system for OCS lands with 80 of the 224 tracts being offered on this basis. Only 57 tracts received bids, but 40 of these were sliding-scale royalty tracts; 43 tracts, consisting of 12 bonus and 31 sliding-scale royalty tracts, were sold for a total of almost $101 million.
- On April 25, 1978, an OCS lease sale (No. 45) in the Gulf of Mexico offered 145 tracts; 129 tracts were offered on the bonus system, and 16 tracts were offered on the sliding-scale royalty system. The lease sale was held in New Orleans, La., on April 25, 1978. Bids totaling more than $733 million were accepted on 80 bonus and 10 sliding-scale royalty tracts. A total of over $1.5 billion was offered for the 101 tracts receiving bids.
- The sliding-scale royalty leasing system utilizes bonus bidding. However, instead of a fixed royalty rate, a formula is specified that makes the royalty rate dependent on the total value of production during each quarter of the year. The royalty rate increases as the value of quarterly production increases. Approximately one-third of the tracts in OCS Sales Nos. 43 and 45 were offered under this sliding-scale system.
- Deep stratigraphic test wells are drilled on the OCS by industry. The operator, who represents the industrial group that desires to drill the test well, is issued a geologic exploration permit by the Geological Survey. During fiscal year 1978, one Continental Offshore Stratigraphic Test (COST) well was completed by industry. This well, Gulf of Alaska (Kodiak) COST No. 3, was completed in October 1977. The results of this test will be released to the public 5 years after completion of the test or 60 calendar days after the issuance of the first Federal lease within 50 miles of the test site, whichever is earlier. The operator submitted data and information to the Geological Survey as required by 30 CFR 251, the regulations which authorize deep stratigraphic testing on the OCS.
- To support tract evaluation, the Survey acquired more than 55,000 miles of common-depth-point seismic data from industry. These data are used to determine locations of potential hydrocarbon prospects. The Survey also acquired 5,830 miles of high-resolution geophysical data. High-resolution geophysical data, including side-scan sonar, are used to identify and map geologic features that may be hazardous to exploration or production activities on the OCS.
- Features such as unstable sediments, mudslides, slumping, shallow gas-bearing sediments, diapiric salt or shale near the surface, shallow faulting, and abnormally pressured sediments are referred to as geologic hazards. Where these geologic hazards exist, a tract may be withdrawn from a lease sale or offered with specific mitigating stipulations.
- To support the resource evaluation program, an additional 29,493 miles of magnetic data, 11,432 miles of gravity data, and 3,041 gravity stations were also purchased.

Estimates of reserves on the OCS were completed on a reservoir-by-reservoir basis for 70 oil and gas

fields during the fiscal year; analyses of reservoirs and estimates of reserves have been completed for 200 of about 335 fields identified in the Gulf of Mexico (fig. 31). In addition, 6 contracts were awarded to private consultants in September to estimate the reserves of 64 additional fields during the next fiscal year. Of the 12 fields on the OCS recognized off southern California, only 2 are producing, and not one is completely developed. It is anticipated that the limits of many of the fields here will be further defined by additional exploratory drilling. Under a continuing program of estimating reserves and updating inventory, each reservoir mapped is monitored for current production and for remaining reserves of recoverable oil and gas.

Since establishing the resource evaluation program, the Geological Survey has expanded its geophysical, geologic, and engineering capabilities to map, to select, and to evaluate the resource potential of the OCS. New Federal legislation resulted in the introduction of new bidding systems in an effort to stimulate competitive bidding.

SUPERVISION OF OPERATIONS

The Geological Survey supervises the activities of lessees who explore, develop, and produce oil and gas on the OCS. The Survey ensures that operations are conducted in compliance with Federal laws and Department of the Interior regulations for the conservation of the mineral resources and the protection of the ocean environment and that the royalties collected for the Government are correct and current. Royalties may be collected either in the form of monies or by taking a portion of the hydrocarbons produced (termed "taken-in-kind"). The Government sells "taken-in-kind" hydrocarbons to operators of small refineries. Supervision of operations on offshore leases includes the following:

- Review and approval of proposed company operating plans.
- Periodic onsite inspections and reviews of oil and gas exploration, development, and production operations from Federal leases.
- Computation, collection, and accounting of rents and royalties from produced oil and gas from Federal leases.

During fiscal year 1978, the Geological Survey supervised oil and gas operation on 2,250 leases and test well operations covering more than 11.5 million acres on the OCS areas of the Alaska, Pacific, Gulf of Mexico, and Atlantic coasts. Figure 32 shows the increase in offshore oil and gas lease activity since 1965.

The Geological Survey reviewed and approved more than 475 exploration and development plans in the Gulf of Mexico in fiscal year 1978. Survey personnel made more than 6,100 inspections of drilling rigs and production platforms. Most of these inspections occurred in the Gulf of Mexico, which has the largest concentration of marine oil and gas operations in the world.

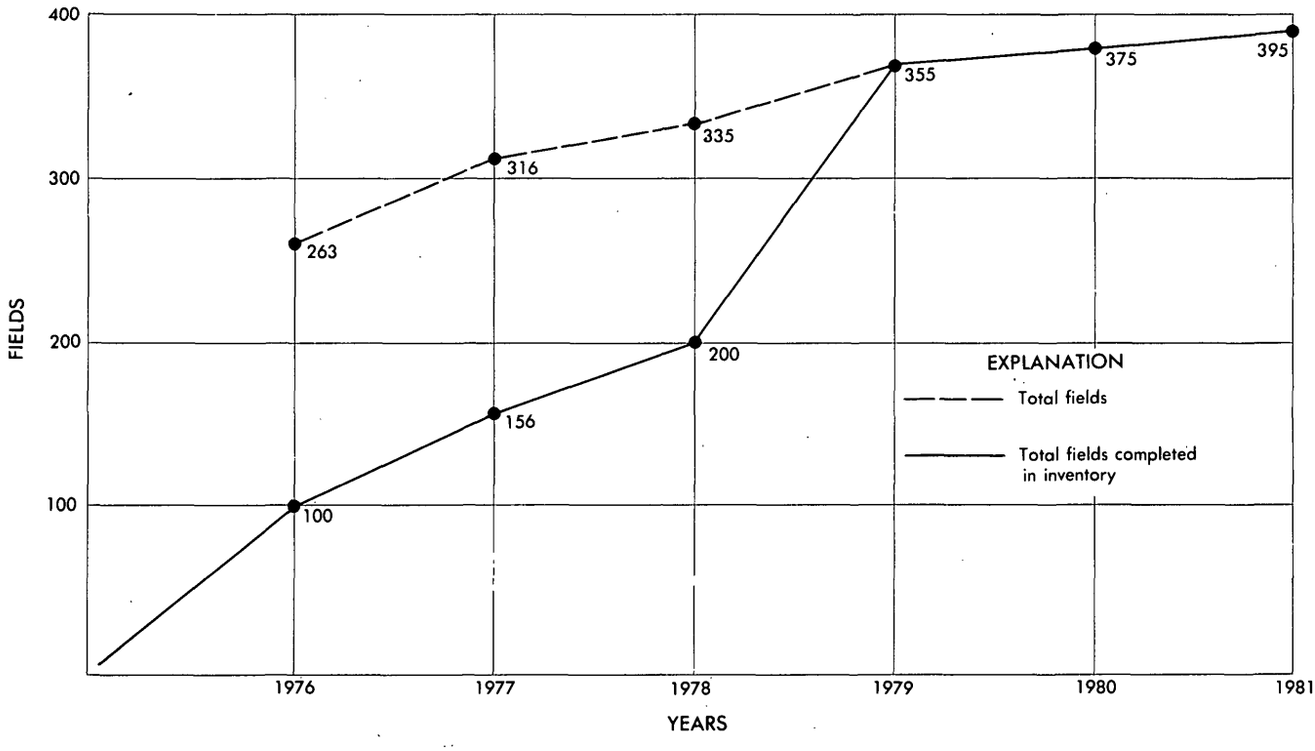


FIGURE 31.—Oil and gas reserve inventory for the Outer Continental Shelf.

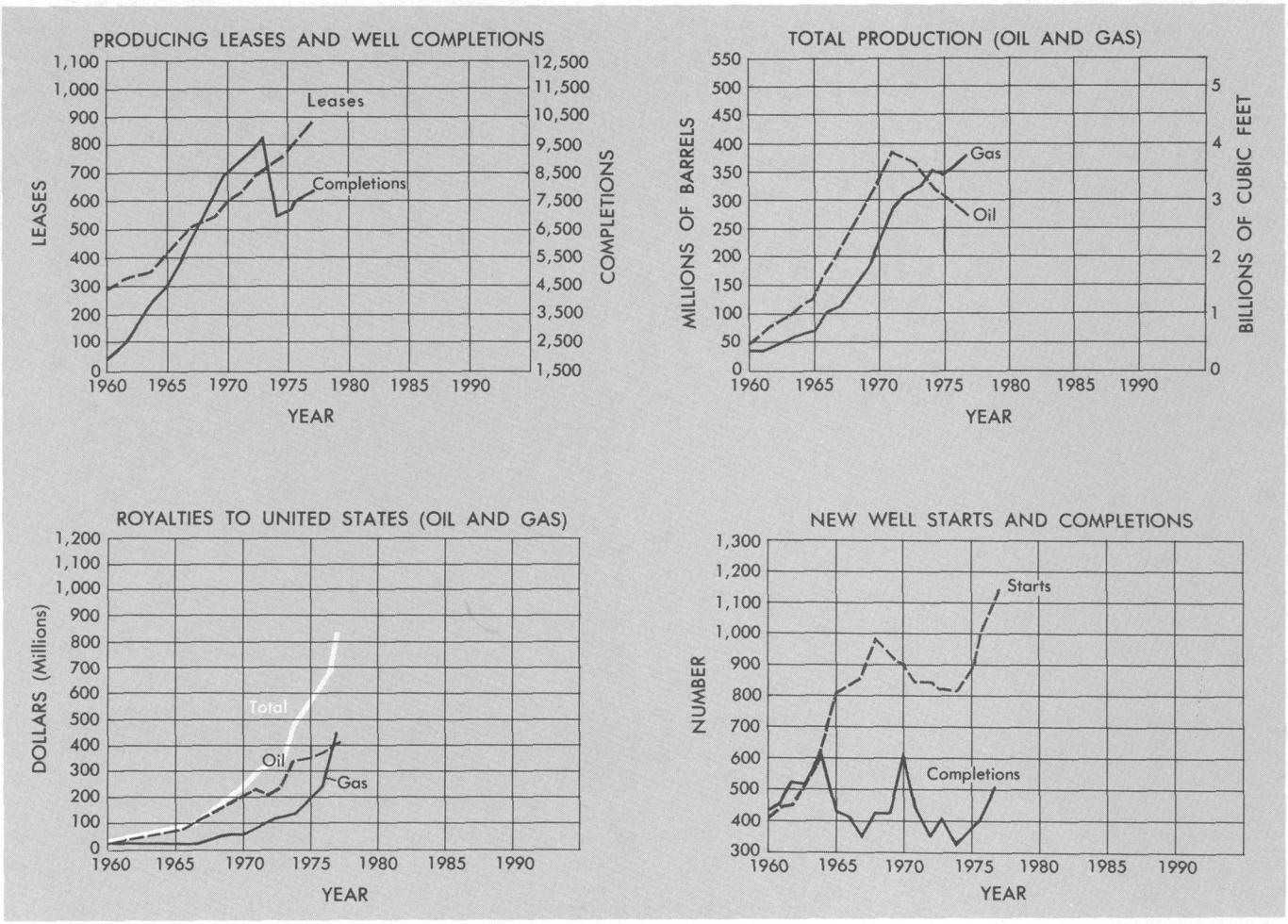


FIGURE 32.—Offshore oil and gas lease activity.

Exploratory drilling operations were initiated on Atlantic OCS leases in March 1978. Natural gas was encountered on one lease (fig. 33) in August 1978. At the end of the fiscal year, drilling operations were conducted on eight leases.

Production of petroleum products from the OCS totaled more than 291 million barrels of oil and 4,180 billion cubic feet of natural gas during the fiscal year. By the end of fiscal year 1978, more than 15,800 wells had been drilled offshore in Federal waters. Rents and royalties from this production provided more than $1 billion to the Government.

Since 1971, annual production of oil from existing OCS leases has decreased while production of natural gas has increased. A primary response of Government to the increased energy needs has been to stimulate exploration and development on existing offshore leases through an accelerated resource development program. This program is particularly important because from 3 to 10 years are needed, on the average, to produce hydrocarbons from new lease discoveries. Requests for approval of exploration plans and applications for a permit to drill have increased significantly. The companies carry out the exploration and drilling activities to locate undiscovered resources in the Continental Shelf areas.

Research and development projects supported by the Department of Energy for enhanced reservoir recovery techniques and potential new energy sources like the geopressured aquifers in the Gulf of Mexico may result in adding significant new domestic supplies of gas and geothermal energy for the Nation during the coming years.

Federal and Indian Lands

The Geological Survey classifies and evaluates the mineral resources and waterpower and water-storage sites on Federal lands (onshore). It also supervises operations related to exploration, development, and production of minerals on both Federal and Indian leases.

Federal laws provide for the leasing of specific minerals on lands that have always been under Federal ownership. These leasable minerals include oil and gas, coal, oil shale, asphaltic minerals, sodium,

potash, phosphate, geothermal resources, and sulfur (in New Mexico and Louisiana only).

Other Federal laws authorize the leasing of Indian and acquired lands for production of all metalliferous and nonmetalliferous minerals except common varieties of minerals such as sand and gravel.

RESOURCE CLASSIFICATION AND EVALUATION

The classification and evaluation of leasable mineral resources on Federal lands are major responsibilities of the Geological Survey. The classification actions (table 11) of the Geological Survey provide the means for the Federal Government to retain the title to leasable minerals and water resource development sites that otherwise might be lost with disposal of the surface rights and provide information for land use planning purposes to Federal and administering agencies. The Geological Survey scientists compile geologic, geophysical, and engineering data from many sources including their own field investigations to make the following classification actions:

- Classifying lands for their potential for valuable leasable minerals.
- Classifying lands for their potential for waterpower.
- Outlining the boundaries of areas that potentially are valuable for leasing for mineral development.
- Identifying waterpower and water-storage sites.

Information from these activities, along with comments and recommendations regarding development of the mineral resources are supplied to BLM, the agency that issues leases on Federal lands.

Once lands are classified as to their mineral character, resources of the lands must be evaluated before they are offered at lease sales. Onshore leases may be awarded competitively or noncompetitively (except for coal), depending upon whether or not the parcel lies within a "known leasing area." The Geological Survey performs a presale evaluation of each parcel offered competitively for leasing to determine the extent and value of leasable minerals on Federal land. Principal responsibilities in this regard are as follows:

FIGURE 33.—Semisubmersible drilling rig, *Ocean Victory*, encountered promising shows of natural gas in the Mid-Atlantic Outer Continental Shelf.

TABLE 11.—*Status of Federal land classifications, fiscal year 1978*

[Acres in thousands]

Commodity	Mineral lands withdrawn	Classified lands		Prospectively valuable lands [1]	Known leasing areas	
		Nonmineral	Mineral		Undefined	Defined
Oil and gas	------	------	4	1,476,886	6,402	11,873
Oil shale	14,177	101	------	15,116	------	------
Asphaltic minerals	------	------	------	17,946	------	------
Coal	20,076	35,699	42,722	345,286	------	16,800
Geothermal resources	------	------	------	103,091	------	3,354
Phosphate	1,547	4,661	462	30,654	2	79
Potassium	9,411	------	------	75,818	53	378
Sodium	------	------	629	266,248	567	288
Sulfur	------	------	------	5,593	------	------
Total	45,211	40,461	43,817	2,336,638	7,024	32,772

[1] These figures represent the total acreage for each leasable mineral commodity and, because some acreage contains more than one mineral commodity, do not reflect total acreage prospectively valuable.

- To make recommendations to the leasing agency about the size of each parcel offered and any special stipulations required.
- To evaluate each parcel on the basis of current geologic, geophysical, economic, and engineering data and, prior to the sale, to furnish the leasing agency with an economic evaluation of the minerals for each parcel and the technical basis by which the valuation was derived to assist the leasing agency to establish the minimum acceptable bid for each parcel.
- To make recommendations concerning the acceptance or rejection of the highest bid offered for each parcel.

The procedures used for both onshore and offshore mineral evaluation assure that the public receives a fair value for its mineral resources.

At the end of fiscal year 1978, 43.8 million acres of withdrawn land had been classified as mineral land, and 10,000 acres were classified valuable for waterpower development.

In complying with requests by other Federal agencies concerning leasable minerals on Federal lands, the Geological Survey prepared 854 mineral reports during fiscal year 1978.

Most Indian lands have been leased by competitive bidding methods. The Bureau of Indian Affairs has usually relied on the Survey to parcel tracts for sale, to recommend stipulations to be included in the leases regarding other surface use and drilling requirements, and to recommend acceptance or rejection of offered bids. Complete presale evaluations for Indian lease sales are done only when requested by the Bureau of Indian Affairs.

COAL

In fiscal year 1978, nearly 13 percent of the Nation's coal was produced from Federal and Indian land leases—primarily in Arizona, Utah, Wyoming, New Mexico, Colorado, North Dakota, and Montana.

The coal resource evaluation program has been providing basic geologic and engineering data and analyses for use in BLM's coal leasing program. The evaluation of coal is based on compilations of existing information and on basic data collected by field mapping and core drilling. During fiscal year 1978, principal coal projects were in progress in seven Western States. Large deposits of coal that lie close enough to the surface to be mined economically using surface mining techniques occur principally in the High Plains. Generally, this coal has a low sulfur content. Surface mining involves the use of large power-excavation and earthmoving equipment to remove overburden, to expose the underlying coal seams, to strip away the coal, and to replace the surface material. Underground mining methods must be used where the depth of overburden is too great for surface mining methods to be economical.

The Geological Survey conducts a coal resource evaluation program that requires compiling and, when necessary, acquiring basic engineering and geologic information. This effort includes the systematic collection of core samples of coal and overlying rocks and preparation of geologic maps to delineate the quantity, quality, and extent of coal resources. These activities are carried out to define Known Recoverable Coal Resource Areas (KRCRA's) as public lands containing coal. During fiscal year 1978, 878 test holes were drilled in Colorado, Montana, North Dakota, New Mexico, Utah, and Wyoming. Geologic data received from these test holes are released as open-file reports. Drilling information of this type is used to define KRCRA's and to select and to evaluate tracts for coal lease sales. In fiscal year 1978, 18 new KRCRA's covering about 4.2 million acres were defined, and about 748,161 acres were added to existing KRCRA's.

Other evaluation activities included evaluations of coal resources for Federal lands offered for lease by competitive bids and review of data submitted by applicants for preference right leases to determine if they met the requirements for this type of lease.

To assess the potential commercial value of federally owned coal resources in lease tracts, the Geological Survey compiles and analyzes technical, environmental, and economic information pertinent to the tracts; and, it considers current industry recovery techniques, costs, and present market conditions and estimates of future market demands and price changes.

The potential for coal of commercial value is shown on Coal Resource Occurrence and Coal Development Potential maps that are used by BLM and the Department for land use planning (fig. 34). Preparation of the 7.5-minute quadrangle maps began in fiscal year 1977, when contracts for completion of 511 maps were awarded. Contracts for another 234 maps were issued in fiscal year 1978.

Economic evaluation of coal resources performed prior to competitive lease sales were completed for BLM under the Department's short-term leasing policies. Use of such a procedure was related to an agreement that followed the court action in the National Resource Defense Council vs. Hughes case. Under this agreement, the Department may issue short-term leases when the proposed lease is required to maintain an existing operation or when the proposed lease is necessary to prevent the bypassing and loss of Federal coal during the course of adjacent mining operations. In addition, the agreement permits the Department to process 20 preference right lease applications providing these 20 applications are those which would cause the least environmental impact of all preference right lease applications pending before the Secretary on the date of the agreement.

OIL AND GAS

Oil and gas lands are leased competitively if they are located on Known Geologic Structures of producing oil and gas fields. A Known Geologic Structure of a known producing oil and gas field is a trap for hydrocarbons, whether structural or stratigraphic, in which oil or gas has accumulated. Known Geologic Structures are defined on the basis of geologic mapping, analysis of well logs, core sample data, and production records. Lessees and operators are required to submit these data to the Geological Survey. Lands not located on a Known Geologic Structure of a producing oil or gas field are leased noncompetitively by BLM.

A discovery well on or close to Federal lands increases the value of the oil and gas rights under these lands; therefore, boundaries of Known Geologic Structures are established as soon as possible after a discovery to authorize leasing of the lands by competitive bidding. The main basis for accepting or rejecting high bids at competitive sales is the fair market value which is determined by evaluation techniques. The basic data include lithologic, electric, and nuclear logs derived from wells and also include geologic structure maps and production records. By systematic analyses of all available geologic and engineering data pertaining to the evaluation of the resources, the Survey is able to provide BLM with an estimate of the value of the resource. BLM determines the fair market value of each tract and may reject any offer less than that value.

The Conservation Division has classified more than 16.5 million acres of land as being within Known Geological Structures. In fiscal year 1978, BLM held 21 lease sales in which tracts comprising 83,164 acres were offered for sale.

Oil and gas produced from Federal and Indian lands in 33 states account for about 6 percent of our total domestic production.

GEOTHERMAL RESOURCES

Congress provided for the development of geothermal resources on Federal lands through the Geothermal Steam Act of 1970. The act allows the Secretary of the Interior to lease Federal lands to private industry for exploration, development, and utilization of geothermal resources.

Geothermal resources comprise the heat stored in the Earth's crust that can be obtained by current recovery techniques. Most of the significant U.S. resources occur in the western part of the country, but commercially exploitable geothermal systems are relatively uncommon.

Geothermal energy can generate electricity or can be used directly for heating buildings or for industrial purposes. The principal use of geothermal energy in the United States at present is generation of electrical power. At The Geysers, Calif., powerplants (fig. 35) driven by geothermal steam generate almost as much electricity as is consumed in San Francisco. Shut-in producible wells (fig. 36) drilled on Federal lands in The Geysers area will be utilized after construction of adjacent powerplants. A new powerplant in the East Mesa area of California will utilize geothermal fluids from Federal leases.

Major projects involving direct use of lower temperature geothermal fluids include heating buildings in Boise, Idaho, and Klamath Falls, Oreg., and drying onions at a dehydrating plant in Nevada. The latter is one of the first industrial processing plants in the United States to utilize heat from geothermal fluids instead of natural gas on a commercial scale.

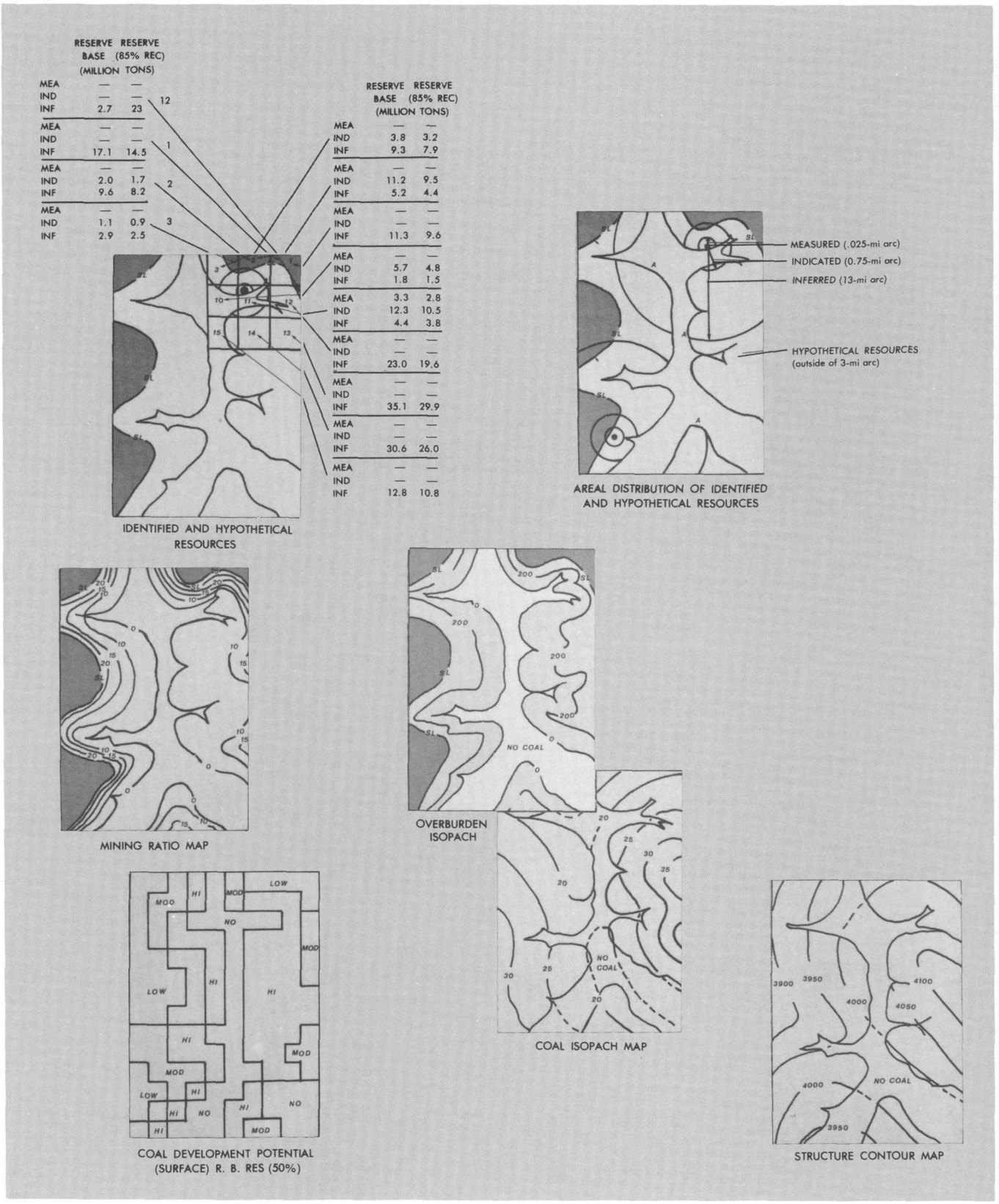


FIGURE 34.—Identification of areas suitable for coal development, using an idealized block diagram and maps, illustrate the concept of Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) mapping of coal beds A and B.

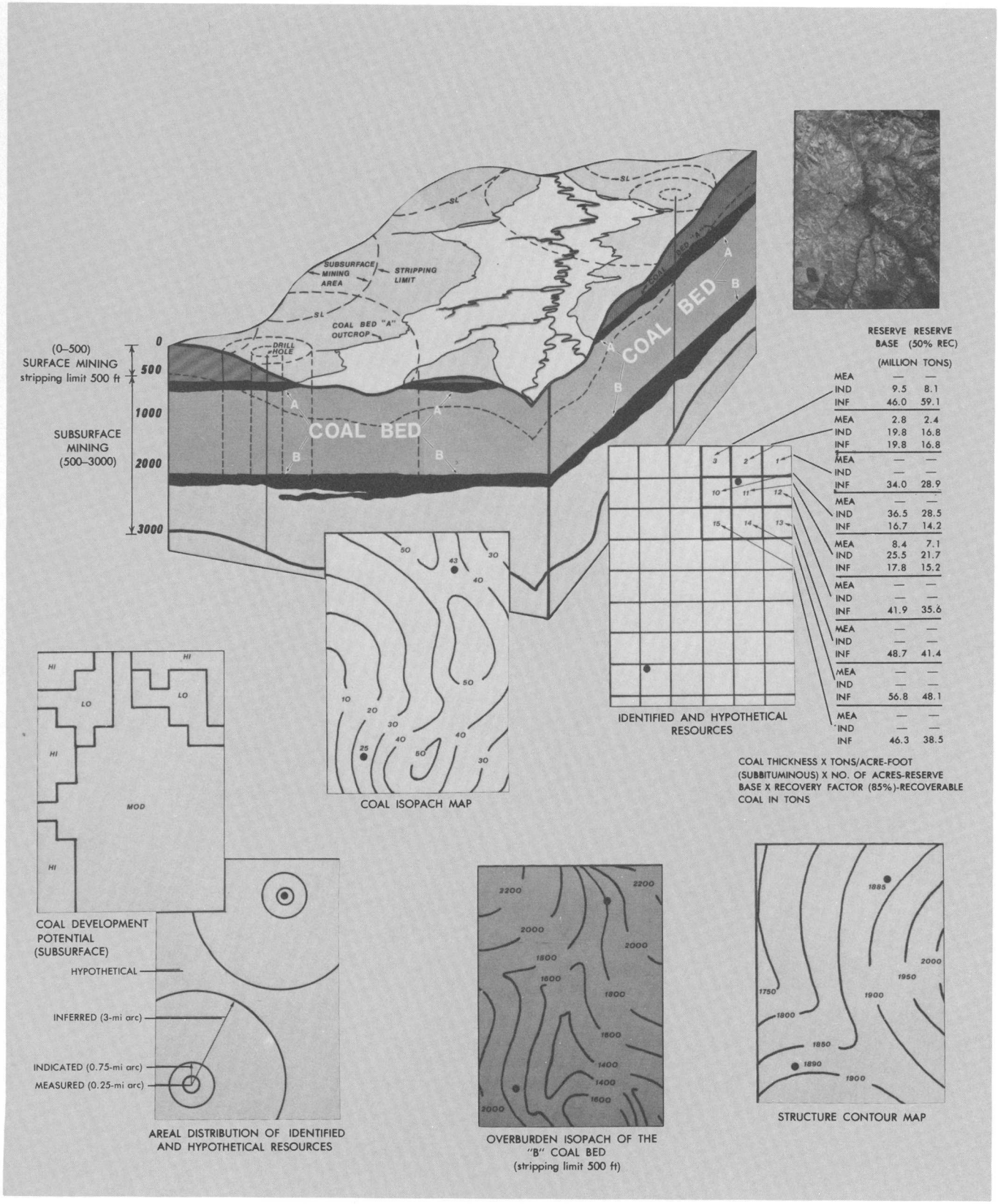


FIGURE 34.—Continued.

The Geological Survey supports the Department of the Interior program for developing geothermal resources by evaluating these resources, classifying the resource potential of the lands, recommending measures to protect the environment, and supervising operations on Federal leases. The leasing program, which began in 1974, is conducted under regulations on the leasing of geothermal resources which were published in 1973.

Lands classified as Known Geothermal Resource Areas (KGRA's) are leased competitively. All KGRA's are determined either by geologic, geochemical, and geophysical criteria or by overlap of land areas covered by applications for noncompetitive leases. Lands not included in KGRA's are available for noncompetitive leasing to the first qualified applicant. The Geological Survey prepares presale evaluations for lands to be leased competitively to establish the value of the resource.

Federal lands have been classified as KGRA's since fiscal year 1971. At the end of fiscal year 1978, 108 KGRA's had been designated. These KGRA's comprise 3.38 million acres in 11 Western States. Since these lands became available for leasing, 207 leases have been issued covering 363,000 acres. In addition, there are 921 noncompetitive Federal geothermal leases on 1.54 million acres outside of designated KGRA's.

FIGURE 35.—Geothermal powerplant and cooling tower at The Geysers, Calif.

OIL SHALE

The prototype oil shale leasing program, established in fiscal year 1971, encourages private industry to develop oil shale mining and processing technology on a commercial scale. In addition, the program provides for the maintenance of environmental integrity in the affected areas by requiring environmental safeguards and land restoration techniques.

Under this program, the Department of the Interior leased four tracts of land in Utah and Colorado through competitive bidding procedures. These tracts, totaling 20,400 acres received bonus bids of $449 million. The terms of each lease required the lessee to complete environmental baseline studies and to conduct investigations to determine the oil shale resources of each lease area.

WATERPOWER

Federal lands are classified by the Geological Survey for their waterpower or water-storage site potential. The classification helps to assure that the availability of sites in the future will be adequate and that site values will be properly considered in multiple use plans and land disposal actions. It also preserves the right of the Government to authorize and to license project development. About 14 million acres of Federal land are presently classified as potential waterpower or water-storage sites. During fiscal year 1978, the waterpower or the water-storage site potential of 10,000 acres of land was classified or reclassified. The Geological Survey also provided detailed site information for about 100 areas to Federal land management agencies for land use planning during the fiscal year. In addition, the Survey prepared more than 450 reports with recommendations requiring other interim uses or declassification of potential sites.

TAR SANDS

Legislation is being forwarded to Congress by the Department for introduction in the next session to provide for leasing tar sand deposits as "hydrocarbons." The proposed legislation would end more than a decade of uncertainty regarding the leasable status of this resource.

OTHER LEASABLE MINERALS

Phosphate and potash deposits were under increased development during the first half of the fiscal year. About 77 percent of the Nation's domes-

FIGURE 36.—A shut-in geothermal steam well at The Geysers, Calif.

tically produced potash now comes from Federal leases in New Mexico and California, and 11 percent of the phosphate comes from Federal (figs. 37 and 38) and Indian leases predominantly in Idaho.

Other valuable minerals mined on Federal and Indian lands comprise important portions of our Nation's mineral production (fig. 39). At present, 46 percent of the lead and 64 percent of the sodium compounds produced in the United States are extracted from leases on Federal lands.

Large reserves of uranium are being mined from lands under permits and leases on Indian land in New Mexico and Washington. Production of uranium oxide, or "yellow cake," from these lands accounts for 11 percent of domestic production. In the future, greater quantities of uranium ore will come from Indian land as new deep mines are opened. Additional sources are being identified that can be recovered by in situ mining techniques.

SUPERVISION OF OPERATIONS

The Geological Survey supervises oil, gas, and mining operations on Federal and Indian lands. In this regulatory program, oil, gas, geothermal resource, and mining operations are supervised by separate organizational units because of the difference in the technologies and engineering disciplines used to produce each type of mineral resource. However, the major program requirements for each type of mineral resource are basically the same: (1) review and approval of exploration and development plans, (2) supervision of exploration, development, and production operations, and (3) computation and collection of royalties and certain rentals. Other related activities, such as unitization, method of production measurement, transportation allowances, commingling of products, off-lease storage, and sales contracts, also require the prior approval or concurrence of the Survey.

COAL

For the first time since the Geological Survey assumed management responsibility for mineral leases in 1925, the value of coal produced on Federal and Indian lands exceeded the combined value of all other leasable minerals which are mined. A total of 565 coal leases comprising over 1 billion acres were supervised by the Conservation Division. A record 78.8 million tons of coal valued at $684 million were produced at 61 mines incorporating 118 Federal and Indian leases. Royalities derived from coal production were $18.8 million.

FIGURE 37.—Grading reclaimed area prior to planting at a phosphate mine in Idaho.

By the end of the fiscal year, 67 mining plans were approved for 29 underground, 36 surface, and 2 combined underground and surface coal mining operations.

The Geological Survey provided the Department of Energy with mining engineering assistance in evaluating and selecting a potential contractor for a coal mining research project. This project is directed toward developing the technology of mining thick coal seams by using a longwall mining system. The advantages of longwall mining compared to room and pillar mining are improved safety, high resource recovery, and minimizing undesirable surface disturbances. Resource recovery with the new technology is expected to be 60 or 70 percent compared to 15 to 30 percent by room and pillar mining methods.

OIL SHALE

Detailed development plans were approved for the Colorado tracts in August and September 1977.

On Federal Oil Shale Tract C–a, construction of surface facilities and the sinking of a 15-foot-diameter service and production shaft and a 7-foot-diameter ventilation shaft were started during fiscal year 1978. The Detailed Development Plan submitted by the lessees, Gulf Oil Corp. and Standard Oil of Indiana, proposes development of a 750-foot-thick zone of oil shale by in situ methods (fig. 40). The 700-foot underground retort will be "rubblized," hoisted to the surface, and retorted in surface retorts during commercial operations. An environmental monitoring program has been instituted to identify any potential problems that may endanger the integrity of the present ecosystem.

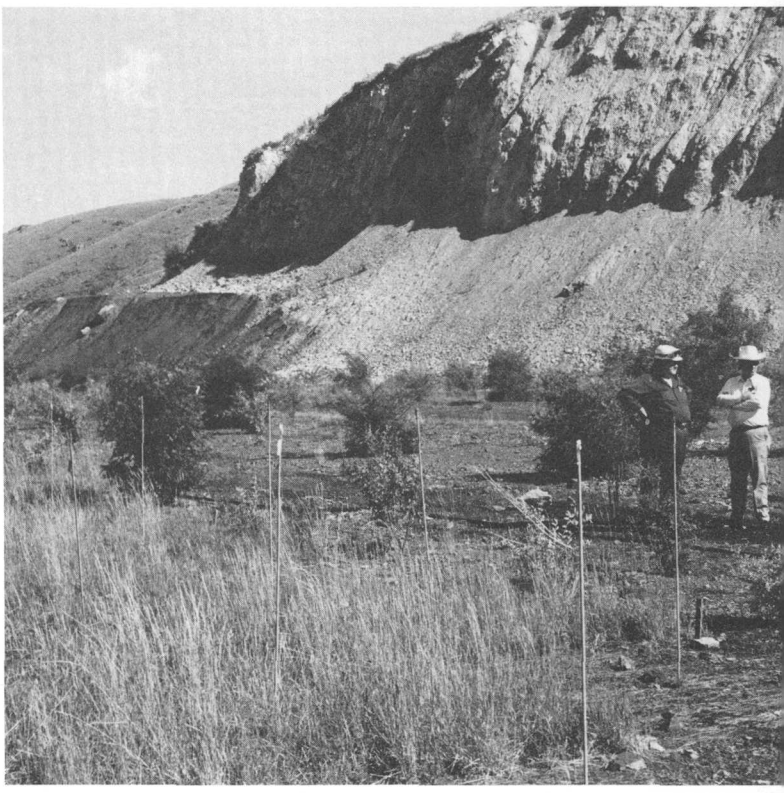
Federal Oil Shale Tract C–b in Colorado is being developed by a modified in situ extraction process (fig. 41). The lessee expects to recover about 1.2 billion barrels of oil during the projected 60-year life of the project. About 20 percent of the oil shale in a 300-foot layer will be mined by underground methods. The remaining oil shale will be broken by explosives to form columns of rubble several hundred feet on a side. The columns of rubblized rock will be used as large underground retorts. The rock at the top of each retort will be ignited. Oil distilled from the rubblized rock will trickle downward and collect in sumps at the base of the retort. Special shafts will convey gases developed during the retorting to the surface where they may be burned to generate power.

A 34-foot-diameter service shaft (fig. 42), a 29-foot production shaft, and a 12-foot ventilator-escape shaft were started during the fiscal year. A temporary 6-foot gas shaft will be drilled in fiscal year 1979.

OIL AND GAS

Regulatory procedures associated with onshore oil and gas development include review and approval of

FIGURE 38.—Revegetation and research plots at a phosphate mine in Idaho.



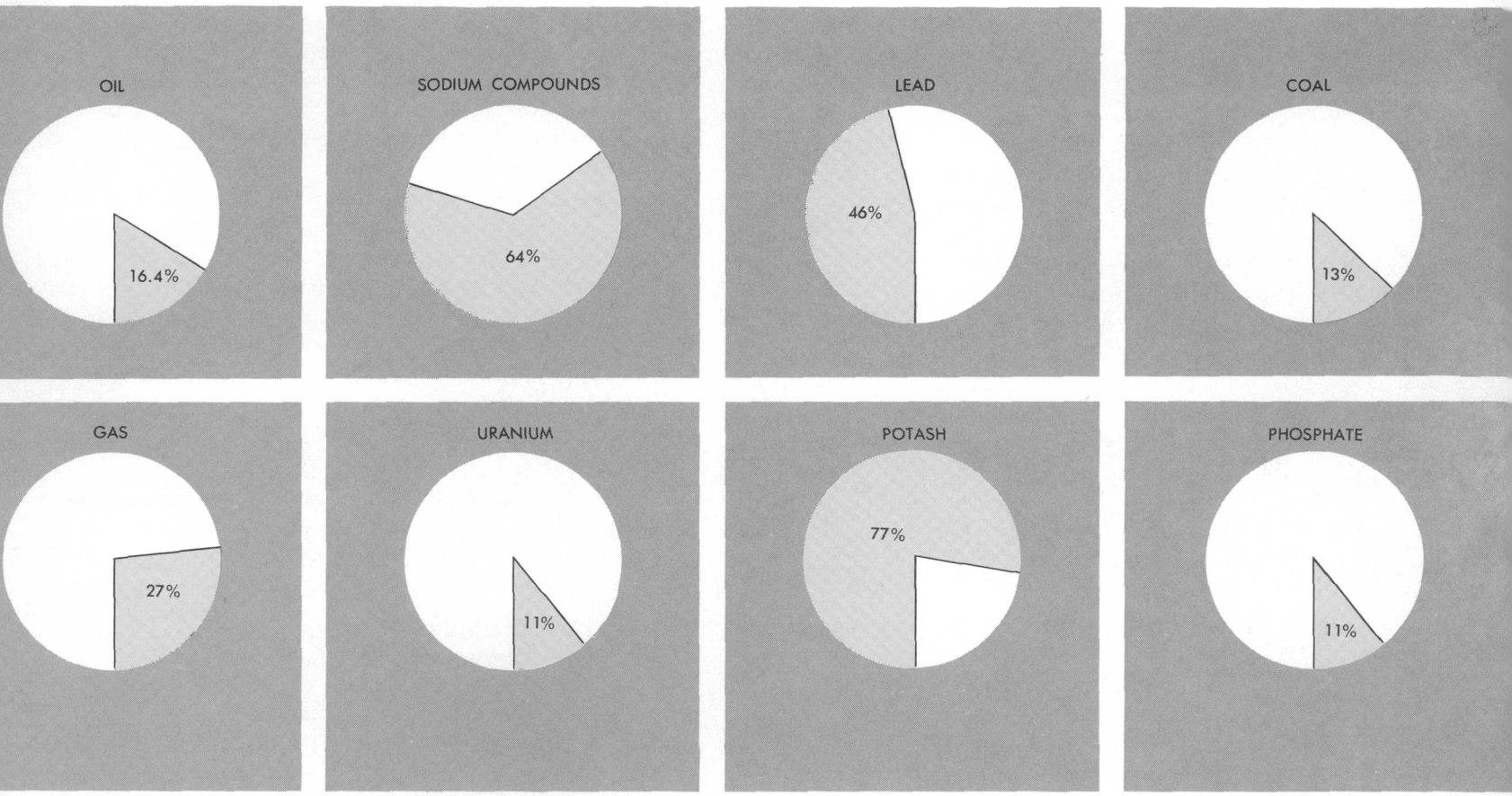


FIGURE 39.—Production from Federal and Indian lands as percentage of total U.S. production in fiscal year 1978.

development plans; regulation of exploration, development, and production activities; and the collection of appropriate royalties. For oil and gas production, the Survey must also approve off-lease storage facilities and unitization agreements that permit several owners to develop a single area cooperatively. The Geological Survey also approves methods of measuring production and the values established in the sales contracts. The Federal Government generally receives one-eighth of the resources produced as its royalty from onshore production.

At the close of fiscal year 1978, the Geological Survey was maintaining royalty accounts on 15,000 producing oil and gas lease accounts covering 8.7 million acres on Federal and Indian lands (fig. 43). This was a 5-percent increase over the 14,219 active leases under management the previous year.

The Geological Survey approved 3,425 new exploration and development wells, prepared 3,525 environmental analyses of proposed operations, and conducted 27,630 onsite inspections of drilling and producing operations.

During the year, all facilities handling water coproduced with hydrocarbons were formally reviewed. Approval was granted for disposal of the water produced when the methods or the facilities were found to be acceptable. Of over 14,000 such facilities, approximately 98 percent were found to be handling produced water acceptably, and enforcement actions were needed for only about 2 percent of the facilities. Where disposal facilities were unacceptable, enforcement actions ranged from assessment of liquidated damages to ordering cessation of operations.

Because most of the easily discovered oil and gas deposits have been developed, advanced techniques are now required to enhance recovery and to maintain production levels from these deposits. Substantial new supplies remain to be found, but most of these are believed to be located in remote areas and to be more costly to develop and to transport to the market than the deposits currently being produced. However, partly because of significant increases in the price of oil and gas, the search for new supplies onshore accelerated in fiscal year 1978 particularly in the "tight gas sands" basins in the Rocky Mountains.

The Overthrust Belt of Utah, Idaho, Wyoming, and Montana is a remote mountainous area with a limited road system. Large parts of the belt are in areas of the National Forest System and National Resource Lands being considered for inclusion in the Wilderness System. The recent numerous discoveries of oil and gas in the Overthrust Belt indicate that much of

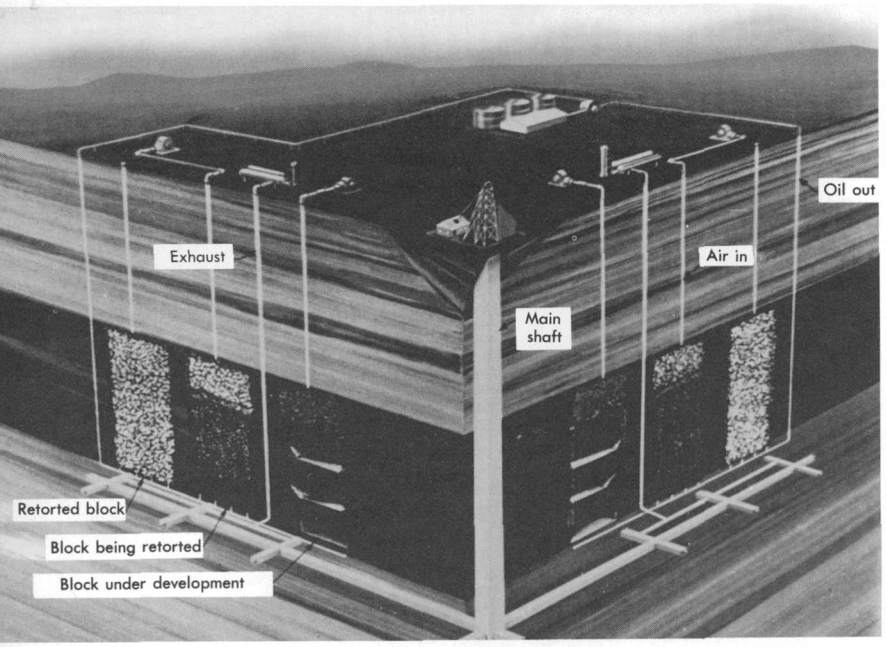


FIGURE 40.—Modified in situ development plan for Tract C–a.

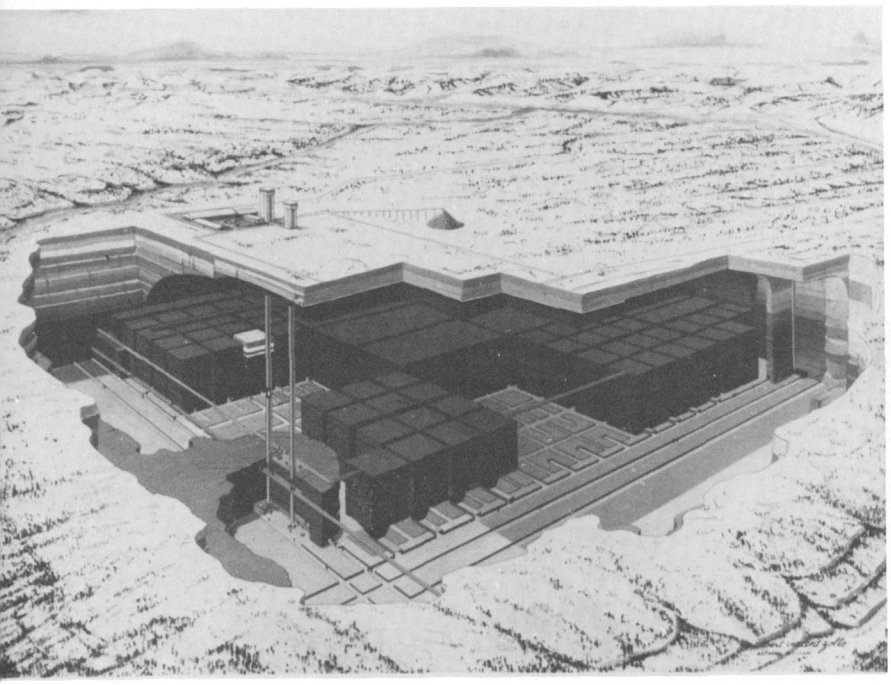


FIGURE 41.—Modified in situ development plan for Tract C–b.

this area is prospectively valuable for oil and gas development. The value conflicts between development of the oil and gas resource versus conservation of wilderness have created a need for major efforts by the Geological Survey to resolve the associated problems.

GEOTHERMAL RESOURCES

The Geological Survey's supervision of operations on Federal geothermal leases includes review and approval of exploration and development plans; inspection of exploration, development, and production activities of operators; and also the computation and collection of royalties and certain rents.

At the end of fiscal year 1978, there were 50 completed wells on Federal leases. Although 36 of these are capable of production, they remain shut-in because the powerplants that they will supply have not been completed.

At the close of fiscal year 1978, the Geological Survey was administering 1,170 geothermal leases covering almost 2.1 million acres on Federal and Indian lands. The Survey approved 28 new exploration and development wells, prepared 28 environmental analyses of proposed operations, and conducted 778 onsite inspections of drilling and producing operations.

FIGURE 42.—Construction of a 34-foot-diameter service shaft on a Federal oil shale lease in Colorado.

OTHER LEASABLE MINERALS

Production of 23 leasable mineral commodities in addition to oil, gas, and coal contributed $648.5 million to the Nation's gross national product and brought $40.6 million in royalty revenue to the Federal Government. Approximately 64 percent of sodium compounds produced in the country came from 21 sodium leases in Wyoming, Nevada, California, and Colorado; this production had a value of $222 million. About 77 percent of the Nation's potash was produced from 43 leases in New Mexico, Utah, California, and Nevada; production value was $150 million. About 46 percent of the country's lead was produced from 18 leases in Missouri and was valued at $125 million. Uranium is becoming increasingly important as a source of fuel for generating electricity at nuclear power generators; uranium mined from eight leases on Indian lands in New Mexico and Washington was valued at $66 million. Phosphate production from 18 leases in Idaho, Florida, Montana, and California was valued at $47 million. Copper was produced from three leases in Arizona and recovered from lead-zinc concentrates produced in Missouri; the value was $18 million. Zinc recovered from lead mining and processing operations in Missouri and Illinois was valued at $12 million. Other mineral commodities produced from Federal and Indian lands are listed in descending order of value produced: sand and gravel, silica sand, fluorspar, chat, limestone, feldspar, bentonite, barite, cinders, gypsum, clay, quartz crystals, molybdenum, wavellite, garnet, and quartz.

In addition to the leasable minerals, approximately one-fourth of the Nation's lithium is recovered as a byproduct from brines on sodium leases in Nevada. A small quantity of lithium was also recovered from brines on leases in California. Recovery of lithium in California ceased in fiscal year 1978.

In fiscal year 1976, the General Accounting Office suggested that certain changes in royalty payments be considered. Options for royalty payments were developed and are presently being reviewed within the Department.

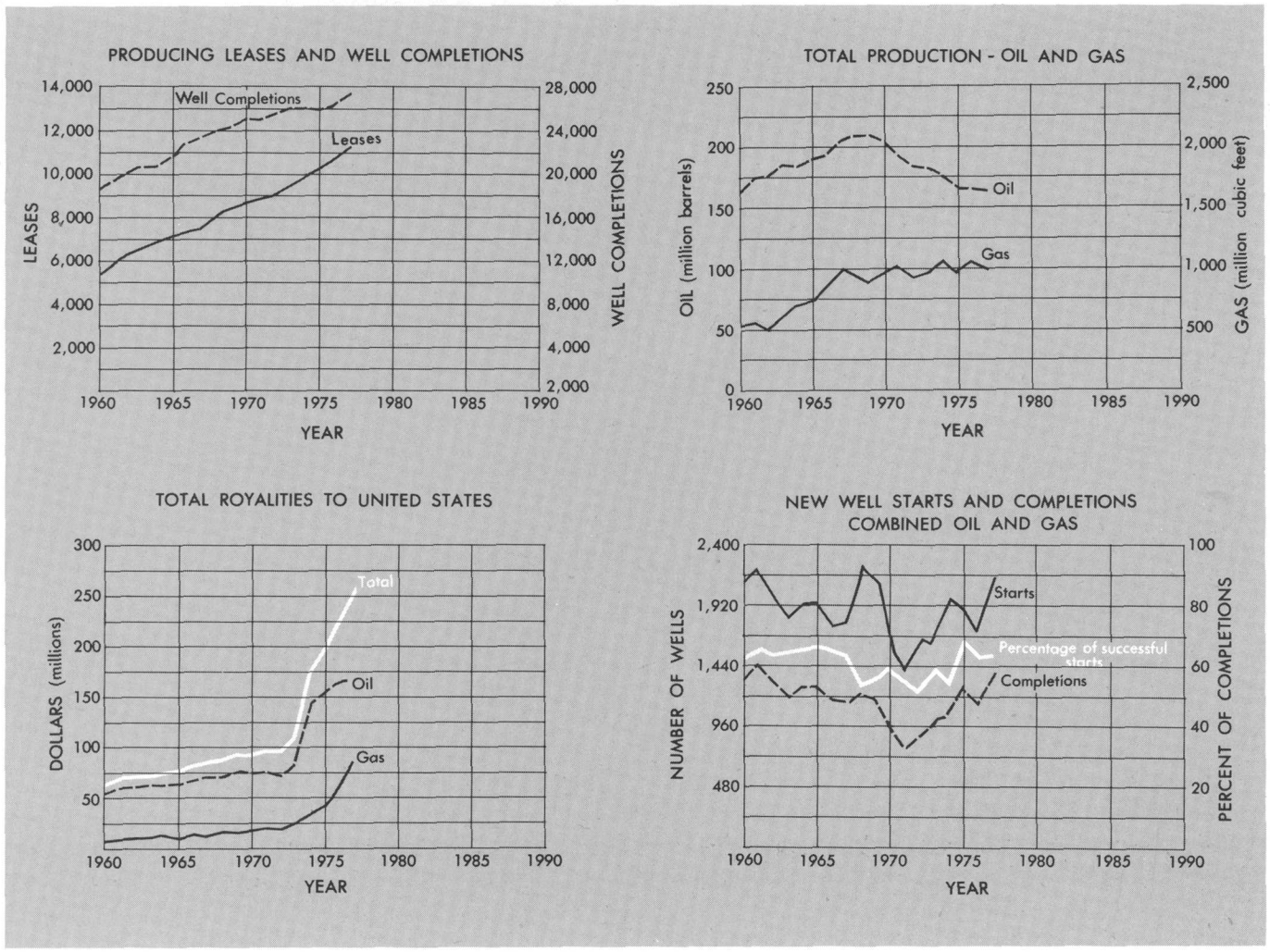


FIGURE 43.—Onshore oil and gas lease activity.

Land Information and Analysis

INTRODUCTION

As our population grows and nonreplenishable earth resources are consumed at an ever-increasing rate, the need to effectively communicate earth science data to planners, decisionmakers, and the general public has become of critical importance. Conservation and efficient use of our resources requires careful planning based on an ability to fully utilize earth resources information, in conjunction with the socioeconomic requirements and desires of the populace. Environmental concern led to enactment of the National Environmental Policy Act of 1969; recent Federal, State, and local land use legislation; and intensive study of the impact of shortages of energy and mineral resources. These actions have identified the unprecedented need that exists for earth science and resources information for planning and decisionmaking. Traditionally, however, most information products of the U.S. Geological Survey have been in the technical language and formats of the earth scientist and not readily usable by the planning community without interpretation.

The earth science information required to evaluate impacts of alternative uses of the land and to facilitate related planning and decisionmaking must be derived from more than one of the Geological Survey's core disciplines—geology, hydrology, cartography, and geography. In the past, the Geological Survey responded to the need for such information on a case-by-case basis, usually by one discipline, but, during recent years, it has become obvious that conducting land resource and environmental studies requires coordinating and documenting the expertise from more than one discipline. It has also become obvious that closer interaction between the data compilers and the data users (land resource planners and decisionmakers) is necessary to provide the needed data in an understandable and usable form.

Explicit in the Land Information and Analysis Office's mission is the presentation of scientific and engineering information about land and other natural resources in readily understandable language and formats to encourage its use by elected officials, planners, public interest groups, the legal profession, social scientists, and the general public.

The objectives of the Land Information and Analysis Office are as follows:

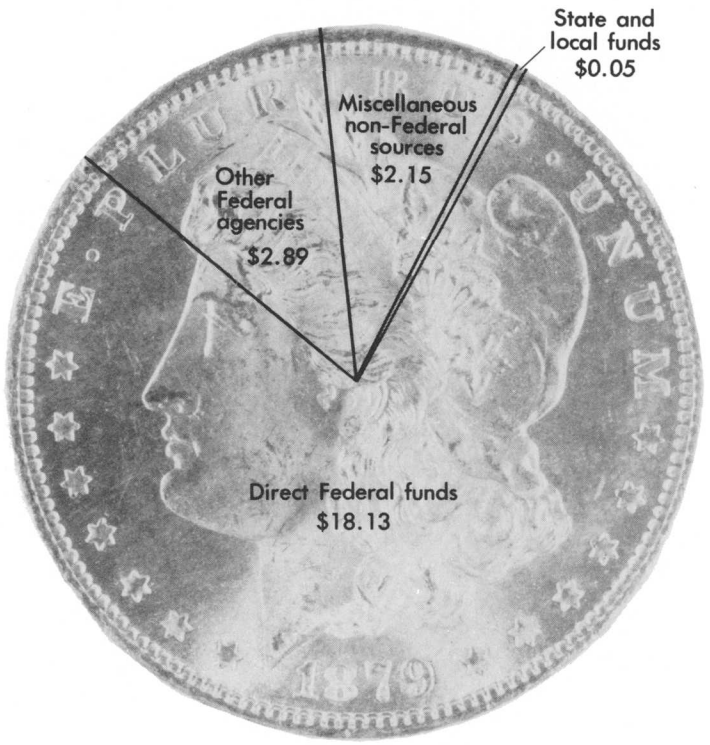
- Development and application of multidisciplinary earth sciences, other natural sciences, and geographic technology in support of land resources planning and decisionmaking.
- Mapping current land use and land cover.
- Accomplishment of Geological Survey activities directly related to the requirements of the National Environmental Policy Act (NEPA).
- Collecting, processing, and distributing remotely sensed data and applying other aspects of space technology in support of land resources planning and management and environmental impact analysis.

The task of achieving these objectives is carried on by the following multidisciplinary programs:

- Earth Sciences Applications (ESA).
- Resource and Land Investigations (RALI).
- Geography.
- Earth Resources Observation Systems (EROS).
- Environmental Impact Analysis (EIA).

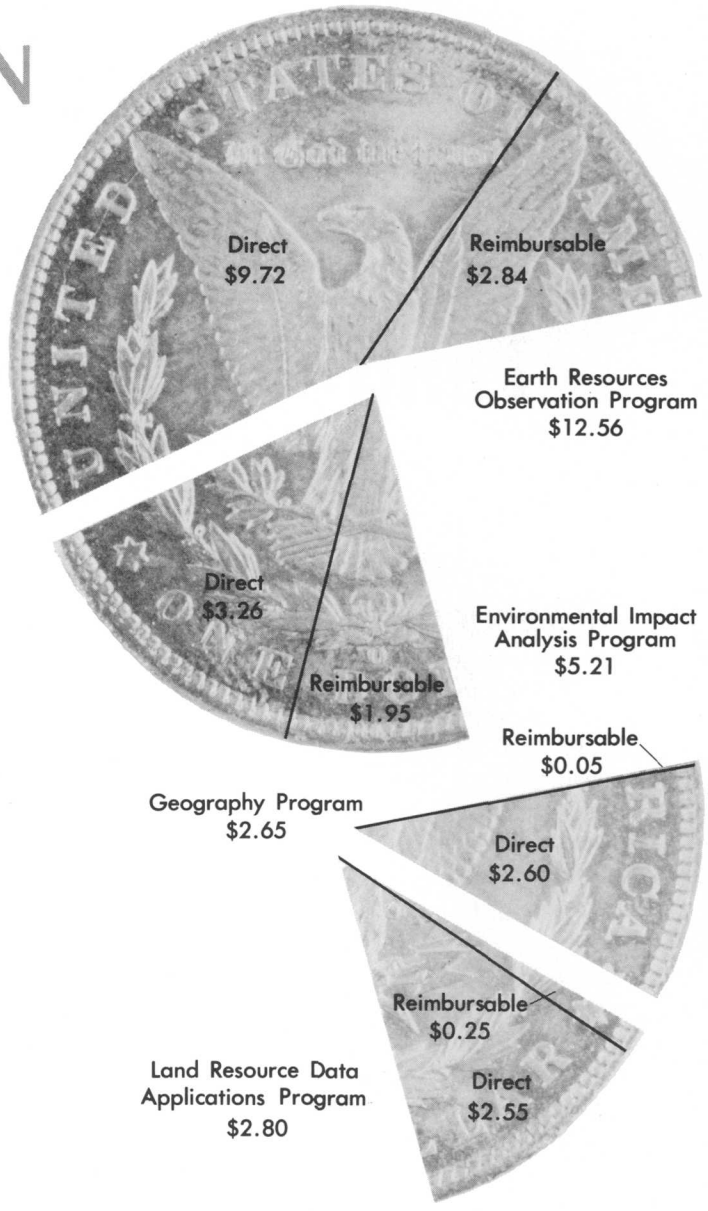
◀ Ocean City, Md., a typical example of intensive urbanization occuring on barrier islands. The multiple-use conflicts of such development are obvious on this aerial photograph which shows high-rise condominiums (foreground), a second-home development on reclaimed marshland (background), marshland, and commercialization along the highway, all on a rapidly eroding barrier island which is retreating landward.

LAND INFORMATION AND ANALYSIS



SOURCE OF FUNDS

TOTAL $23.22 MILLION



USE OF FUNDS

BUDGET AND PERSONNEL

Obligations for Land Information and Analysis Office activities in fiscal year 1978 amounted to $23.2 million, a decrease of 1 percent compared to fiscal year 1977 (table 12).

The work of the Land Information and Analysis Office is partly accomplished through contracts to private industry and through research grants. Of fiscal year 1978 funds, $7.475 million (32 percent) were expended on contracts. Contract services were the major source of operational support at the EROS Data Center (EDC). Cooperative programs with State agencies were carried on by the Geography Program for land use and land cover mapping. The programs of the Land Information and Analysis Office were carried out by 234 full-time career employees in 1978; at the end of the year, 162 were assigned to the Office's programs and 72 were assigned to other Survey offices in support of the work of the Land Information and Analysis Office. There were also 75 temporary or part-time employees. In addition, contract support services at EDC amounted to 290 man-years. Personnel of the Topographic, Computer, and Administrative Divisions assigned to EDC are included in the above numbers.

TABLE 12.—*Land Information and Analysis Office obligations for fiscal years 1977 and 1978*

[Dollars in millions. Data may differ from that in the statistical tables because of rounding]

Program	Fiscal year 1977	Fiscal year 1978
Total	**$23.48**	**$23.22**
Earth Resources Observation Systems Program	**11.94**	**12.56**
Direct program	9.55	9.72
Reimbursable program	2.39	2.84
Miscellaneous non-Federal sources	1.74	2.15
Other Federal agencies	.65	.64
Environmental Impact Analysis Program	**6.26**	**5.21**
Direct program	3.17	3.26
Rembursable program	3.09	1.95
Other Federal agencies	3.09	1.95
Geography Program	**2.72**	**2.65**
Direct program	2.53	2.60
Reimbursable program	.19	.05
States, counties, and municipalities	.19	.05
Other Federal agencies	----	----
Land Resource Data Applications Program (ESA and RALI)	**2.56**	**2.80**
Direct program	2.45	2.55
Reimbursable program	.11	.25
Other Federal agencies	.11	.25

HIGHLIGHTS

- Publication of "Nature to be Commanded . . ." (Professional Paper 950), an innovative book designed to communicate technical earth science information and methods to the layman.
- Publication, with the assistance of all other Survey divisions, of "A Guide to Obtaining Information from the USGS 1978" (Circular 777), to assist the public in obtaining Survey information products and in locating sources of unpublished information in the Survey.
- Establishment of an Outer Continental Shelf (OCS) Information Program, which aids State planners to evaluate the onshore impacts of OCS development and production. This is a cooperative effort within the Geological Survey between the Conservation Division and the Land Information and Analysis Office.
- Compilation of land use maps, land cover maps, and data for approximately 400,000 square miles of the United States, bringing the total area mapped to 1,000,000 square miles since the mapping program began in 1975.
- Acquisition of the services of a commercial communications satellite by the EROS Program, in conjunction with the National Aeronautics and Space Administration (NASA), to provide a data telemetry link between the Goddard Space Flight Center and EDC. This will reduce the time lag between acquisition and distribution of data from 4–6 weeks to 7–10 days.
- Participation with lead or nonlead responsibility in the preparation of 31 Environmental Impact Statements (EIS's). In addition, approximately 1,800 EIS's and related documents were reviewed.

EARTH SCIENCES APPLICATIONS PROGRAM

Program and Activities

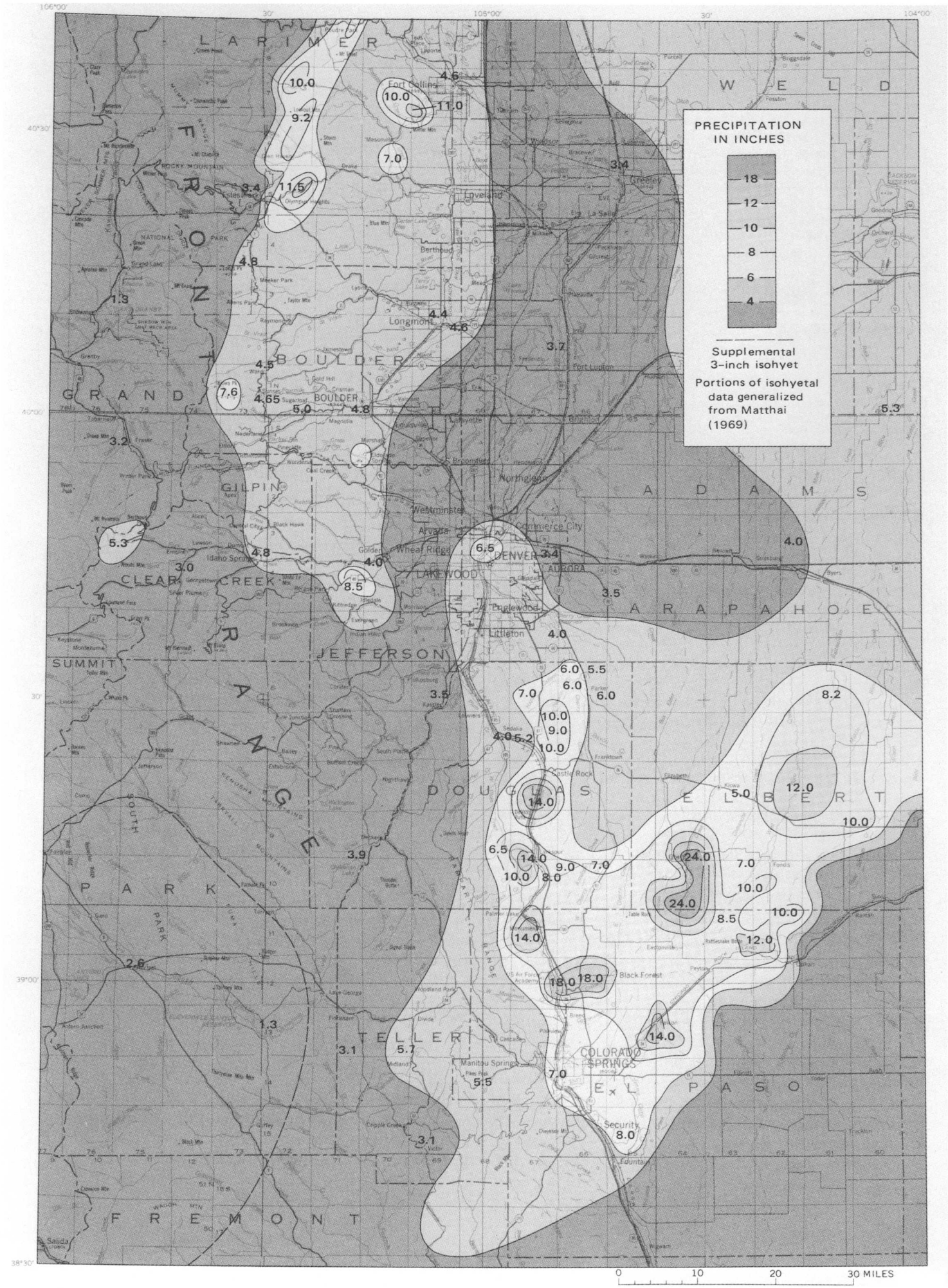
The Earth Sciences Application (ESA) Program directs and coordinates multidisciplinary Geological Survey activities designed to interpret, to demonstrate, and to encourage the use of earth science information for land resource decisionmaking. The program's principal means of achieving these goals are through specially designed projects and report products and through interaction with and technical assistance to users. In fiscal year 1978, the ESA Program continued to emphasize two main areas of interest, Urban Area Studies and Geologic Related Hazards Information.

Urban Area Studies

Since the Survey's multidisciplinary urban area studies were initiated in 1970, more than 600 basic data and interpretive reports and maps have been released, principally for 8 major urban areas, including about 40 new reports and maps in fiscal year 1978. Highlights and accomplishments of individual projects in the past year included the following:

COLORADO FRONT RANGE URBAN CORRIDOR

- Published a new geologic map of the Boulder–Ft. Collins–Greeley area (Miscellaneous Investigations Map I–855–G) showing both bedrock and surficial geology at a regional scale of 1:100,000 (1 inch equals about 1.6 miles). Similar maps for the Denver and the Castle Rock–Colorado Springs areas are in preparation.
- Published "Climatography of the Front Range Urban Corridor and Vicinity, Colorado" (Professional Paper 1019), a graphical summary of climatic conditions in this region of varied physiography and rapid urbanization (see fig. 44).


PRECIPITATION IN INCHES
18
12
10
8
6
4
Supplemental 3-inch isohyet
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EL PASO
FREMONT
ROCKY MOUNTAIN NATIONAL PARK
Fort Collins
Loveland
Longmont
Boulder
Golden
Wheat Ridge
Arvada
Westminster
Northglenn
Commerce City
DENVER
AURORA
LAKEWOOD
Englewood
Littleton
Idaho Springs
Castle Rock
Black Forest
Manitou Springs
COLORADO SPRINGS
Security
Salida
0 10 20 30 MILES

- Initiated a survey of the uses and users of earth sciences information in this project area.

FAIRFAX COUNTY IN VIRGINIA

- Released an innovative computer-composite map showing the susceptibility to contamination of aquifers in Coastal Plain deposits in Fairfax County (Open-File Report 78–265).
- Provided technical assistance to the Fairfax County Water Authority and its ground-water consultant regarding selection and evaluation of sites for a well-drilling and testing program. The initial interest in the possibility of developing a supplemental ground-water supply, as well as the preliminary selection of sites for testing, was based largely on the findings of the Fairfax County earth sciences applications project and was stimulated by a severe water shortage in Fairfax County during the summer of 1977.

PUGET SOUND AREA OF WASHINGTON

- Initiated a series of meetings with local government, industry, public interest, and citizens groups to brief these potential information users on the purposes of the Puget Sound earth sciences applications project and to solicit information on local problems and data needs.
- Released a new tectonic map of the Puget Sound region showing locations of faults, folds, and large-scale Quaternary deformation (Open-File Report 78–426). This map and the results of more recent studies by project personnel provide basic scientific information necessary for decisions on siting of nuclear powerplants in the area.

Geologic Related Hazards Information

- Met with designated representatives of about 30 States and 7 Federal agencies to develop mutually acceptable procedures for communicating information on geologic related hazards.
- Provided information on potential hazards to representatives of the States of Alaska, California, Montana, Wyoming, and Nevada. Potential hazards included active faults, landslides, rockfalls, and fissuring and faulting associated with subsidence resulting from ground-water withdrawals.
- Presented information on coastal zone geologic hazards at workshops in New Jersey, California, and Massachusetts. These workshops, the second series conducted under joint sponsorship of the Survey's RALI Program, the American Society of Planning Officials, and the Environmental Protection Agency (EPA), were focused on onshore impacts of offshore oil and gas development.

◀ FIGURE 44.—Maximum recorded precipitation in 24 hours (from Hanson, Chronic, and Matlock, 1978, map 18).

Other Activities

- Published "Postglacial Volcanic Deposits at Mount Baker, Washington, and Potential Hazards from Future Eruptions" (Professional Paper 1022–C).
- Published "Understanding Natural Systems—A Perspective for Land-Use Planning in Appalachian Kentucky" (Bulletin 1438). This report summarizes the results of the Kentucky River Area Development District Project, which was supported jointly by the Survey and the Appalachian Regional Commission and was coordinated by the ESA Program.

RESOURCE AND LAND INVESTIGATIONS PROGRAM

Program and Activities

The Resource and Land Investigations (RALI) Program was established in 1972 by the Secretary of the Interior to provide "the organizational framework to mobilize more effectively the Department's technological capacity and scientific competence for objective analysis of the alternatives in land use, to provide, with appropriate collaboration by other agencies of government, the knowledge base for efficient and safe land and resource development, and to evaluate the tradeoffs between resource development and environmental protection concerns." The Geological Survey was assigned the "lead agency" role to manage the RALI Program, which was chartered to improve technical communication between the collectors and analysts of resource and land information and the planners, managers, and decisionmakers in government, industry, and the public sector.

The RALI Program undertakes projects which address multidisciplinary natural resources management problems that affect the missions of many bureaus of the Department. The program's clientele are primarily Federal, State, and local land use planners. In addition, the program also supports other users who require a suite of earth sciences, biologic, and socioeconomic data, as well as planning methods, and technologies that are not available from any single Departmental bureau.

Program activities involved the following:

- Product evaluation, in which the utility and reliability of resource planning methods and technologies and the usefulness of information products are tested against the "real world"

problems of the planning community. An example of this activity is the ongoing study with the Council of State Governments to find more efficient and accurate ways for States to communicate their natural resource data needs to Federal data-producing agencies.

- Methodology development, in which the existing information base is used to generate, to analyze, and to evaluate alternatives in land and resource planning and decisionmaking. An example of this activity is the initiation of a cooperative program with the Council on Environmental Quality, including a contract with the American Arbitration Association to devise, to select, and to test methods for resolving disputes involving environmental actions subject to NEPA requirements and to develop and to test the NEPA litigation computer information system.
- Technology transfer, which includes the packaging of information in usable forms, conducting workshops and other educational events, and providing short-term technical assistance to State and local planning communities. An example of this activity is the Alaska Coastal Management Research and Demonstration Project (a joint effort between the Geological Survey and the Alaska Coastal Management Program), which provides information to local and State planners developing plans for managing the Alaskan Coastal Zone.
- Information dissemination, which includes the compilation of directories, catalogs, and bibliographies of land resource data and technologies. An example of this activity is "A Catalog to Sources and Services of Natural Science Data and Information in the U.S. Department of the Interior" (in press), which will provide a guide to Department of the Interior information sources for Federal, State, and local land use and resource planners.

Accomplishments

- Establishment of the Coastal Zone Management Act coordination office, which will review and comment on State Coastal Zone Management plans, provide a bureau focal point for dealing with the Department and the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration (NOAA) on coastal zone issues, and alert the Geological Survey to problems stemming from the Federal consistency provisions of the Coastal Zone Management Act.
- Completion of the first series of regional workshops on planning for onshore impacts of OCS oil and gas development. The second series of workshops, which will stress environmental and socioeconomic impacts and mitigating measures, has been initiated. Workshops are partly funded by EPA and are managed by the American Society of Planning Officials.
- Establishment of an OCS Information Program, pursuant to 30 CFR 252 and in anticipation of the passage of the Outer Continental Shelf Lands Act Amendments of 1978, to give States summary information to aid them in the planning for onshore and near shore socioeconomic, environmental, and fiscal impacts of OCS development and production.
- Draft report of a "Guideline to Identify, Manage, and Resolve Environmental Disputes," prepared jointly with the American Arbitration Association, which will aid public officials in anticipating environmental conflicts and managing their resolution within the existing regulatory framework.
- Initiation of the Western Coal Planning Assistance Project conducted jointly with the Missouri River Basin Commission to help State and local governments develop the technical methods and acquire the information needed to cope with the problems associated with coal and energy development.
- Completion of a joint project with the Department of Energy (Argonne National Laboratory) to develop methods for integrated mining, reclamation, and regional land use planning. A series of three regional workshops to transfer the project results to working planners, mining engineers, and concerned public officials was held under an interagency agreement with the Argonne National Laboratory.
- Completion of a project in cooperation with the Council of State Governments to assess the extent to which Wisconsin's various land record systems are amenable to automation and consolidation.
- Publication of "Environmental Resource Data: Intergovernmental Management Dimensions" by the Council of State Governments.

In little more than 5 years, the program and its cooperators, grantees, and contractors have either published, released, or have in preparation more than 80 reports, maps, inventories, and directories. The distribution of publications resulting from one supported activity, the Council of State Governments' Task Force on Natural Resource and Land-Use Information, had exceeded 30,000 copies by the end of fiscal year 1978. The program has also sponsored or

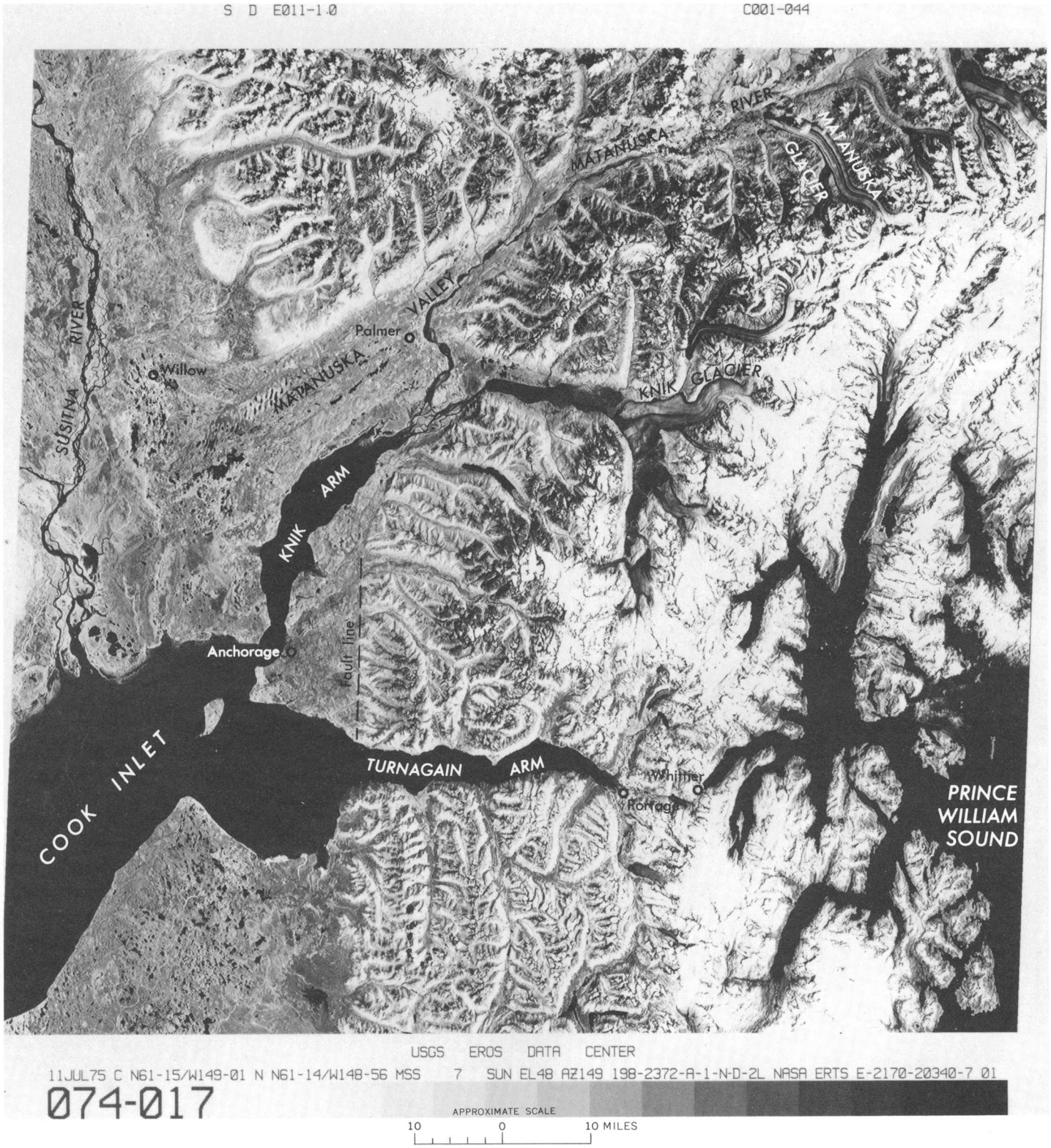
Landsat image showing the Anchorage, Alaska, area. This infrared (Band 7) Landsat 2 image demonstrates the use of satellite imagery as a tool of environmental scientists for regional land resource assessment. The image was obtained on July 11, 1975. ▶

cosponsored a national symposium and 24 regional and national workshops designed to transfer technical knowledge to State and local resource planners. Additional workshops are scheduled in fiscal year 1979 on topics including mined area reclamation, coastal zone planning, OCS information, and natural resource information systems.

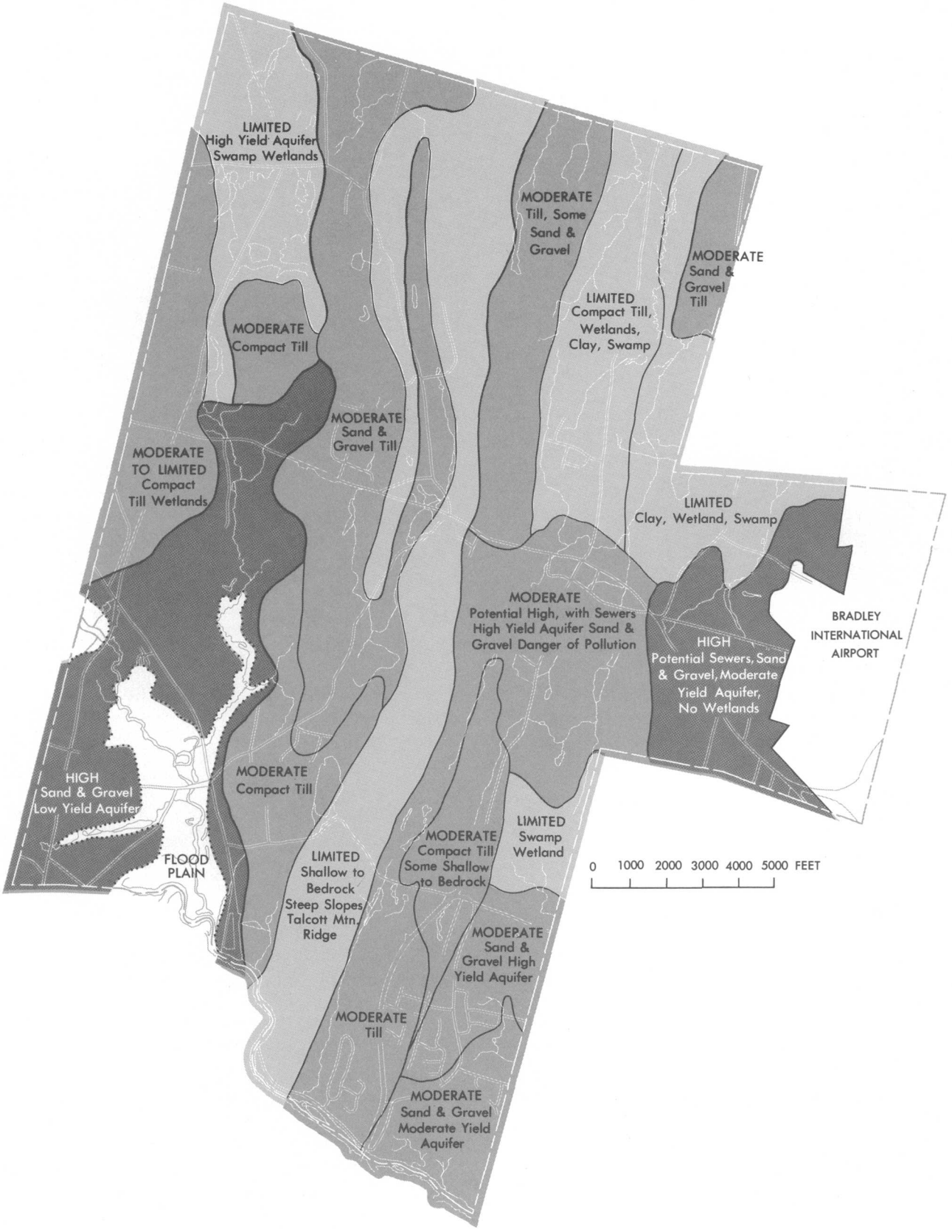
GEOGRAPHY PROGRAM

Program and Activities

Geography Program activities center on the delineation, analysis, and dissemination of spatially oriented land use and land cover maps and related data. To accomplish these tasks, program personnel keep



Resource Mapping Aids Town Planning



Nature's forces and processes continue virtually unimpeded by even the largest work of man. When man builds and lives in concert with nature, his works may persist for generations; when he does not, the products of his labors, and sometimes man himself, are soon obliterated. As Francis Bacon observed, "Nature to be commanded must be obeyed." To be obeyed, nature must be understood.

Earth scientists have developed many tools for observing nature's forces and processes and for documenting the changes in our environment that result from them. These tools help us to understand nature better: the opportunities presented by resources and the deterrents posed by natural hazards. Some of the most valuable tools—and the most readily understood—are earth science maps.

U.S. Geological Survey Professional Paper 950, *Nature to be Commanded . . .*, demonstrates several ways that earth science maps have been used in the urban planning process. The introduction discusses the uses of topographic, geologic, and hydrologic maps; it is followed by chapters describing the applications of earth science information in six varied environments across the country. The following discussion of natural resources mapping in East Granby, Conn., is condensed from a chapter in *Nature to be Commanded . . .*.

The town of East Granby is a rural residential New England community about 15 miles north of Hartford, Conn. As a small town, its problems are somewhat different from those of large urban areas. Sewer service extends to only a small part of the town, and municipal water service does not exist. Therefore, most of the houses rely upon onsite septic systems for waste disposal and onsite wells for water supply. A properly functioning waste disposal system and a safe reliable water supply, both on the same property, require careful planning. With urban population growth demanding land, rural areas are under pressure. Urban development strongly competes with farming and also spreads into sensitive areas where it may be harmful effects on the natural environment. Rural town planning must carefully consider these special problems as well as those that are common to both rural and urban areas.

Therefore, a somewhat different approach to planning may be taken in East Granby from that used in large urban areas. Here, large areas of land are available for growth; it is easier to plan around natural constraints than engineer through them. Development can be located in areas with few constraints or at a density that is low enough to minimize environmental impact. Of course, a sound development plan for a rural community, like that of a city, should be adjusted to the natural environment and should determine how the environment can be used most effectively by the community.

The natural resource data used for the plan of development for East Granby (prepared by the East Granby Planning and Zoning Commission with technical assistance from the Bureau of Local Government of the Connecticut Department of Community Affairs) were obtained from a detailed soil survey, surficial geologic maps, and hydrologic reports prepared over a period of many years by the U.S. Geological Survey and the Soil Conservation Service in cooperation with the Connecticut Geologic and Natural History Survey. From the data available, seven maps—showing unconsolidated materials, depth to bedrock, slope, areas having seasonal high-water table, ground water potential, flood plains, and inland wetlands and water courses—were prepared. Each of the maps is discussed separately in the plan of development, which describes the impact of development on the natural factors and the impact of the natural factors on development.

The natural resources maps describe single elements of the environment that interact in response to the stresses of development. For example, the rapid percolation rates of sands and gravels may be a positive factor in the location of septic systems; however, if an area also has high ground-water potential, the rapid movement of waste liquid may have a harmful effect on the water supply. This problem would be further complicated if the area were one of seasonal high-water table. For another example, areas underlain by glacial till generally have good foundation conditions. However, in areas of steep slope and especially where water levels are high, till often is less stable, which results in poor foundation conditions. The map shown here, natural land use intensities, is the result of the combination of all the natural factors maps. This map summarizes the land use potential of East Granby.

The inclusion of natural land use factors in the planning process familiarized commission members and citizens with the natural characteristics of their town and the influence of those factors of nature on development. The preparation and adoption of the plan, however, does not end the process of planning for the usefulness of the information obtained in that process, for the plan itself must now be implemented and will need to be revised from time to time. The natural factors maps will allow town agencies and officials, landowners, and potential developers to know the conditions they can expect to find in an area. These maps will not, however, replace detailed site review; rather, they will be the starting point for site reviews.

◀ Map showing land use intensities. This map indicates the relative suitability for development based on natural factors. Areas designated as high intensity have few site problems. Areas designated as moderate intensity are likely to have problems that require careful site planning. Areas designated as limited intensity probably have severe problems that require extensive and costly site preparation. (Map taken from *Nature to be Commanded. . . .*)

pace with current environmental concerns, technological innovations in the acquisition and handling of spatial data, and research endeavors which parallel their own basic geographic inquiries. The information gathered through these efforts is then transformed into products aimed at satisfying the needs of the Geography Program's user community.

The data and techniques made available by the Geography Program have their greatest utility in Federal, State, and regional agencies which apply them to land and water resources management. The private sector also has a growing need for environmental information to aid in land resource planning and management activities as well as for use in university-sponsored research activities.

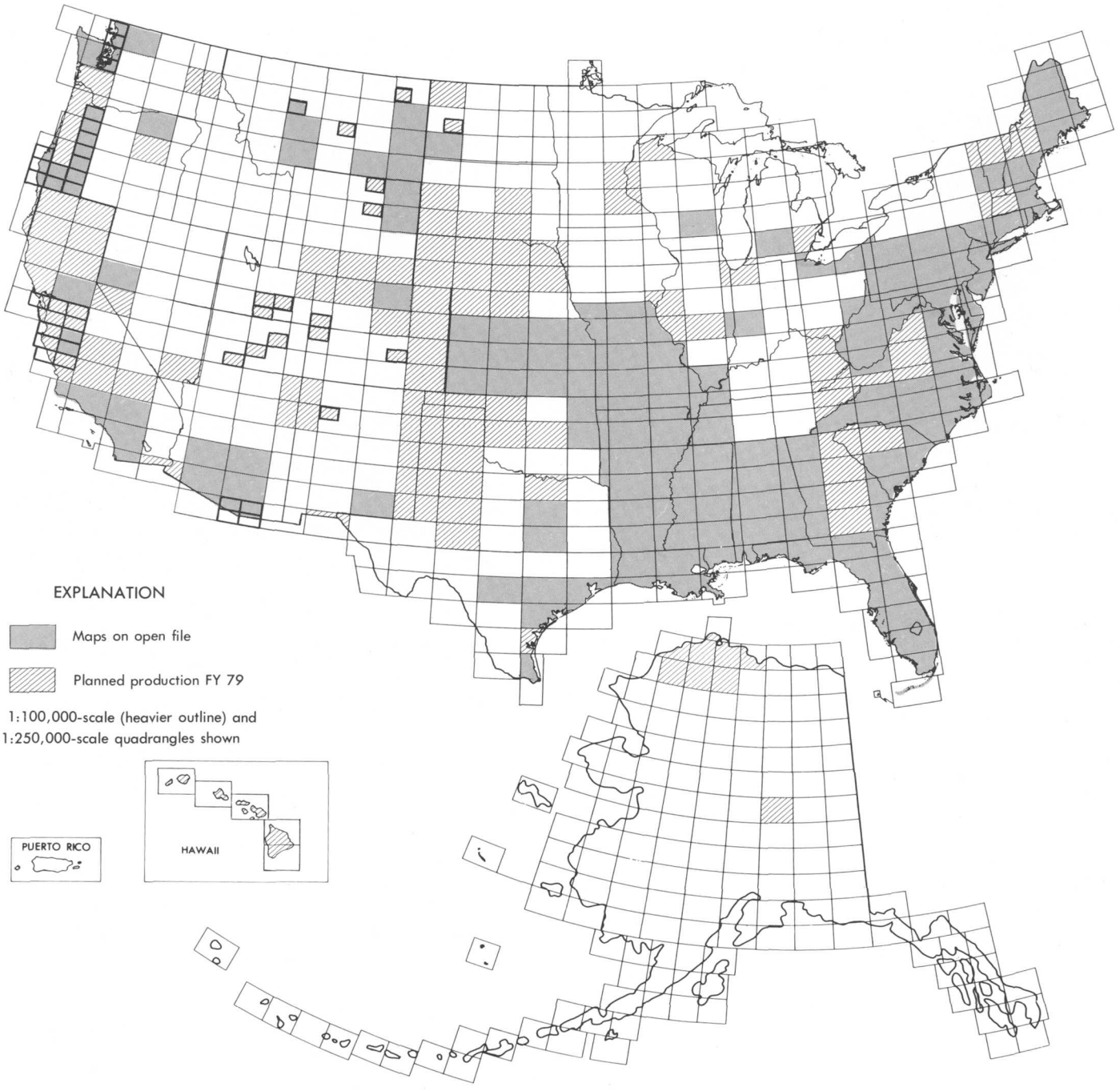
National Land Use and Land Cover Mapping and Data Compilation

Formally begun in 1975, the primary objective of this program is the production of current, reliable, and standardized land use and land cover maps as well as geographic data for the Nation. To broaden the usefulness of these maps and data, associated

maps of hydrologic units, political units, Census county subdivisions, and Federal land ownership are also compiled and released. Final products are in graphic, digital, and tabular statistical formats.

The chief source of land use and land cover data is recent high-altitude photographs. The classification system used in compiling the maps was developed to optimize the use of this kind of source material and to be as applicable as possible in a variety of land use mapping and analysis situations. Completed maps are open filed at scales of 1:250,000 or 1:100,000; this latter scale is used if map bases are available. Following the final reproduction of a compiled map, attention is turned to utilizing the map data in a geographic information system.

The Geographic Information Retrieval and Analysis System (GIRAS) functions to accommodate and to manipulate land use, land cover, and associated map information as digital data. Products include statistical summaries and variable-scale black-and-white or color-shaded computer plots. Also, a grid-compositing procedure exists that permits different maps, such as a land use and land cover map and its associated map of counties, to be "overlaid" in the computer.



Status of land use and land cover mapping.

In addition, statistics on land use and land cover may be obtained by county areas using this process.

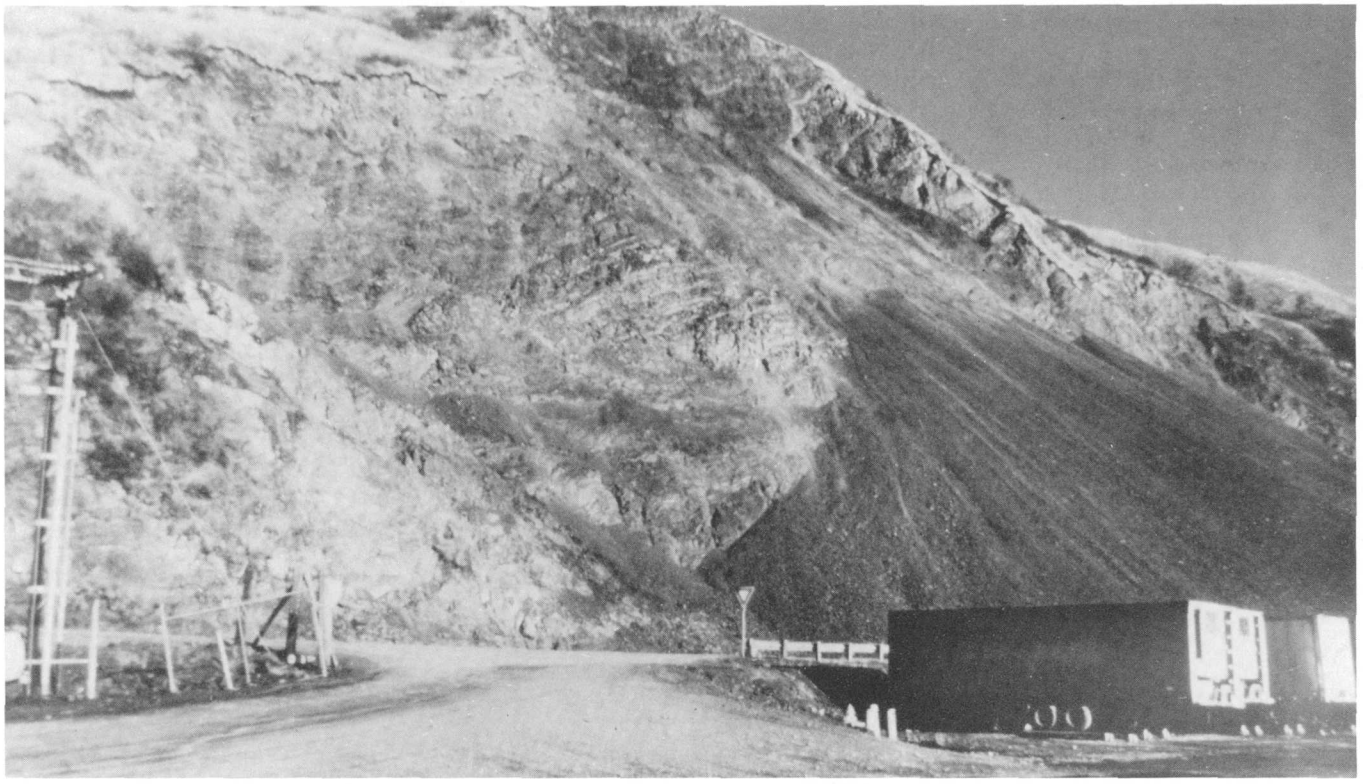
Geographers also undertake original investigations which explore such matters as the usefulness of Landsat data in land use and land cover mapping; computer, statistical, and empirical applications of land use data; and advanced mapping techniques. An excellent example of the results of these investigations is the use of GIRAS data in the production of map separation plates on an automatic plotter.

Technical Assistance

- Technical assistance is provided to users by the Geography Program at both Geological Survey and user installations by formal and informal training sessions, papers delivered at professional and technical meetings, and articles published in technical journals. Geography Program staff members participate in conferences and study groups as well as in ongoing projects, assess and propose solutions to "real world" problems, and meet regularly with individual user groups.

Accomplishments

- Compilation of 400,000 square miles of land use and land cover data for the year. Total area completed under this program and available to the public through fiscal year 1978 was 772,000 square miles. Mapping has focused on coastal and energy production areas as well as metropolitan areas. During fiscal year 1978, 85 sets of land use and land cover and associated maps were released, bringing the total number of quadrangle sets now on open file to 202.
- Completion of mapping for Alabama, Arkansas, Connecticut, Delaware, Florida, Kansas, Louisiana, Maryland, Mississippi, Missouri, New Jersey, North Carolina, Pennsylvania, Rhode Island, and West Virginia. Maps of California, Georgia, Maine, Massachusetts, New Hampshire, South Carolina, Vermont, and Virginia are planned for completion during fiscal year 1979.
- Digitizing and editing of land use and land cover data during fiscal year 1978 totaled 77,000 square miles. As of the end of the fiscal year, 400,000 square miles of data had been processed and included in GIRAS. Data for Arkansas, Florida, Kansas, Louisiana, and Pennsylvania are now completed.
- Completion of an investigation regarding the feasibility of employing computer-aided processing of Landsat digital data to update land use and land cover maps. Changes in the Phoenix, Ariz., suburban area were detected.
- Publication of a land use and land cover map illustrating the latest cost-effective computer techniques developed to inventory land use and land cover using Landsat digital data. Research on these techniques has shown that in certain cases

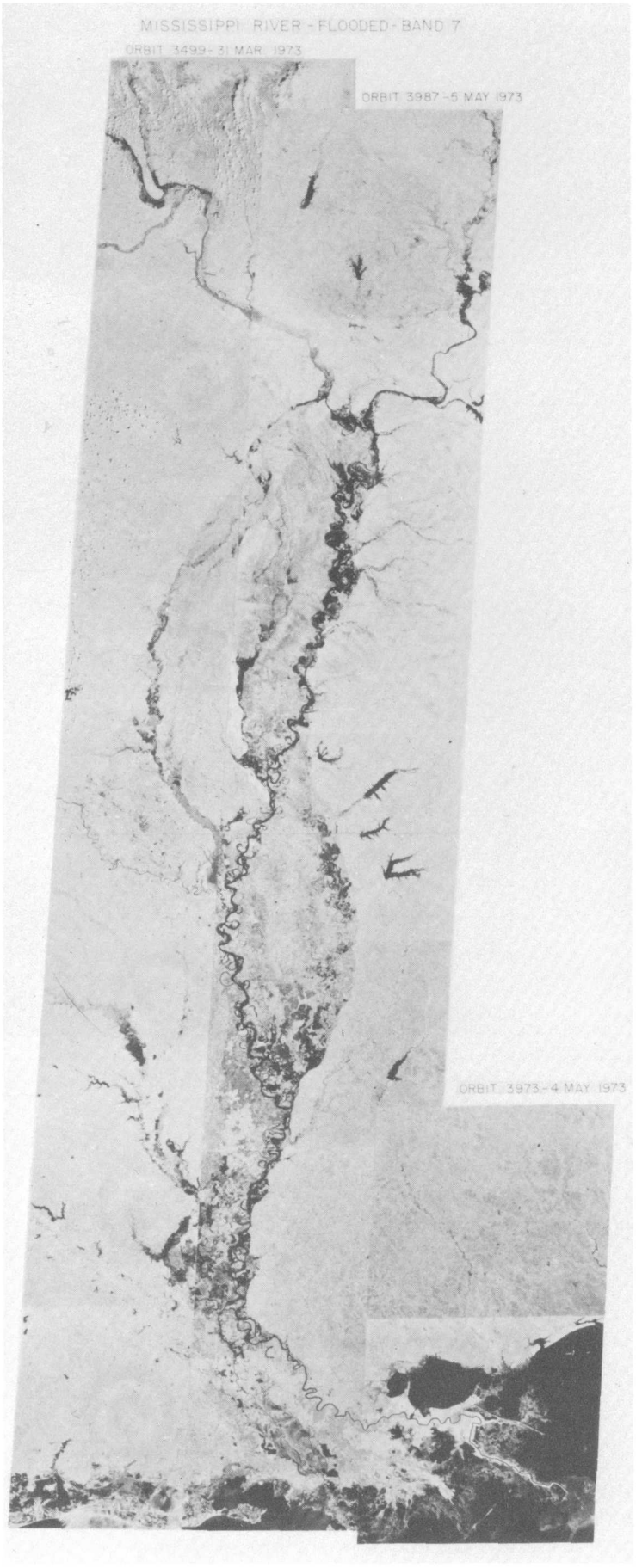


Landslide at Kodiak, Alaska. View from Sea—Land dock to landslide.

spectral signatures can be extended to apply to adjacent homogeneous geographic areas; in this case, land use and land cover was mapped for the Portland, Oreg., metropolitan area. This work was done as part of a cooperative effort with the Pacific Northwest Regional Commission and NASA.

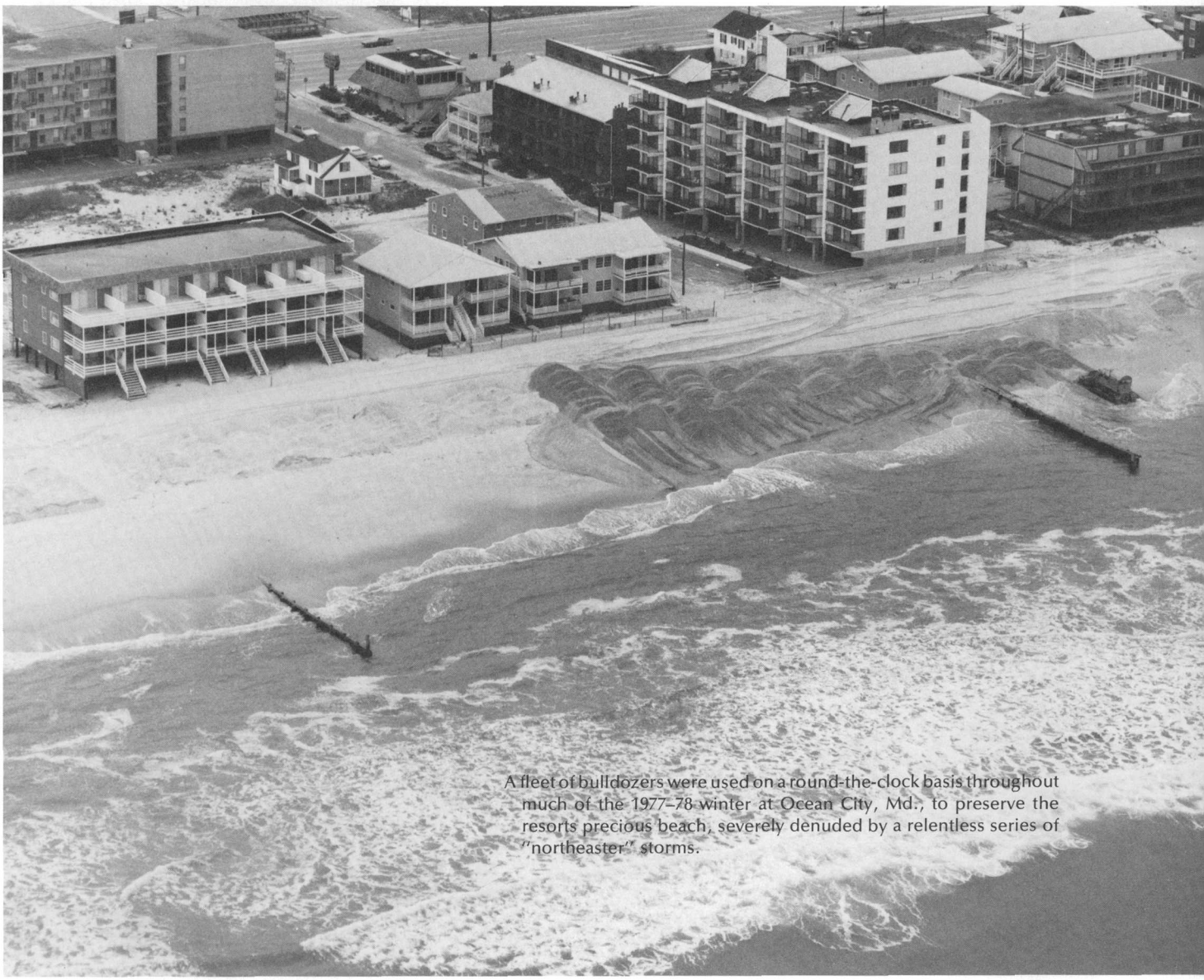
- Completion of research on the comparison of statistics obtained for 1:250,000-, 1:100,000-, and 1:24,000-scale maps in the Greater Atlanta Metropolitan Area.
- Statistical summaries of land use and land cover data tabulated by associated map sets were completed for Florida and Kansas.
- Publication of two additional maps in the Folio of Land Use Maps of the Washington Urban Area (I–858). Both new maps show land cover information derived from 1972 and 1973 Landsat digital data. One map (I–858–E) is overprinted with locational features and place names, and the other (I–585–F) is overprinted with 1970 census tracts and the 1972 urban area boundary. Land cover statistics are printed on the backs of the maps. Maps (I–858–A through D) previously published show land use in 1970 as interpreted manually from high-altitude aerial photography, an annotated orthophotograph, census tracts, and land use change from 1970 to 1972.
- Completion of a land cover map of the Puget Sound Region, Wash., derived from Landsat digital data. The map, compiled in cooperation with NASA and the Pacific Northwest Regional Commission, is the result of a demonstration project designed to show the utility of Landsat data for planning at the regional level. Technical assistance and support from the local planning community was significant and vital to the completion of the project.
- Delivery of land use and land cover maps, statistics, and digital data to Pennsylvania, Alabama, West Virginia, and Missouri and to the Delaware River Basin Commission for a comprehensive study of the basin.
- Completion of a study on the effects of oil and gas development on the northwest coast of the Kenai Peninsula in Alaska. This study identified and analyzed changes in land use and land cover during the past 30 years.
- Entering into a cooperative agreement to carry out a demonstration project with San Mateo County, Calif., to compile 18 land use and land cover map sheets at a scale of 1:24,000. The purpose of this experimental project is to implement new mapping techniques, to provide more detailed information, and to assess the possible benefit of land use and land cover mapping for land resource planning and management purposes at the county government level.
- Completion of mapping under a cooperative agreement for the State of North Carolina.
- Entering into a cooperative agreement with the State of Hawaii to compile land use and land cover maps covering that State at a scale of 1:100,000.
- Training seminars on map compilation conducted for personnel from the States of Alabama, West Virginia, and Hawaii.
- Major revision of the Geographic Information System (GIS) software was undertaken to utilize the Universal Transverse Mercator control for data rectification and to provide for greater ease of operation by persons not familiar with computer programming techniques. The revised computer programs encompass data editing and enable the conversion of polygonal data into grid cell format for ease of use with existing data bases.
- Training courses in the use of GIS Branch computer programs were held to assist State users in digitizing and utilizing their own data. These courses have involved personnel from the States of Arkansas, Louisiana, and South Carolina.
- Entering into a cooperative agreement for a Technical Assistance Program with the Ozarks Regional Commission.
- Completion of a preliminary vegetation and land cover map derived from Landsat digital data for the National Petroleum Reserve in Alaska (NPRA). The map is at a scale of approximately 1:500,000 and is a composite of 10 Landsat scenes covering an area of 38,000 square miles, roughly the size of Ohio. The map is being used in the environmental assessment for development in the NPRA area.
- Publication of Professional Paper 1099–B, "Land Use and Land Cover Information and Air-Quality Planning," an investigation of the applicability of land use and land cover data to air-quality monitoring for the Norfolk, Va., area. Findings from this investigation indicate that land use and land cover information can be used to estimate airborne emissions for use as inputs to diffusion models and to evaluate the implications of diffusion patterns in air-quality assessment and control.

Landsat 1 provided man's first opportunity to automatically delineate flooded areas over vast regions. Left: Distribution of water from data collected by satellite in a total time of 7 minutes. Right: Distribution of water over the same area during "normal conditions." ▶


MISSISSIPPI RIVER - FLOODED - BAND 7
ORBIT 3499 - 31 MAR. 1973
ORBIT 3987 - 5 MAY 1973
ORBIT 3973 - 4 MAY 1973


MISSISSIPPI RIVER - NORMAL STAGE - BAND 7
ORBIT 0989 - 2 OCT. 1972
ORBIT 0975 - 1 OCT. 1972
ORBIT 0208 - 7 AUG. 1972

Living With—And On—Barrier Islands



A fleet of bulldozers were used on a round-the-clock basis throughout much of the 1977–78 winter at Ocean City, Md., to preserve the resorts precious beach, severely denuded by a relentless series of "northeaster" storms.

- Coordination of digital cartographic activities with the Digital Applications Team, Topographic Division, to define common objectives and tasks in digital cartography and to select tasks where coordinated development is necessary.
- Compilation of land use and land cover data for Atlantic and Gulf Coast barrier islands in support of the Department of the Interior's Barrier Island Study Group, which was directed by the President to prepare recommendations for the preservation of remaining unspoiled barrier islands.

EARTH RESOURCES OBSERVATION SYSTEMS PROGRAM

Program and Activities

The Earth Resources Observation Systems (EROS) Program is administered by the Geological Survey for the Department of the Interior. The role of the EROS Program is to develop, to demonstrate, and to encourage applications of remotely sensed data acquired from aircraft and spacecraft that are relevant to functional responsibilities of the Department and agencies with related missions.

The program works closely with NASA and other Federal agencies to determine the results of present space technology use and the improvements needed in current and future systems in terms of the Department's information needs.

The EROS Program seeks new remote sensing applications to resource and environmental problems through research projects conducted in-house by program scientists and application studies conducted and funded jointly by other Federal agencies, universities, and State government organizations.

As part of his Environmental Message to Congress in May 1977, President Carter proposed a broad and ambitious set of actions designed to control pollution and protect health, assure environmentally sound energy development, improve the urban environment, protect natural resources, and preserve our national heritage. A portion of his plan for protecting natural resources specifically included coastal barrier islands, about which the President said,

> "Coastal barrier islands are a fragile buffer between the wetlands and the sea. The 189 barrier islands on the Atlantic and Gulf Coast are an integral part of an ecosystem which helps protect inland areas from flood waves and hurricanes. Many of them are unstable and not suited for development, yet in the past the federal government has subsidized and insured new construction on them. Eventually, we can expect heavy economic losses from this short-sighted policy."

The facts presented in the President's statement are profound, both environmentally and economically. Although the statement cites the eventuality of heavy economic losses, such losses are a current problem. The cost of preserving the shoreline along developed islands is already astronomical.

The problem is complicted by the disharmonious interaction of four competing processes: physical, biological, cultural, and economic. In the natural system, physical and biological processes proceed in an orderly manner. The biological system responds and adopts to variations in the physical system. When man enters into this delicately balanced regime, however, drastic alterations can, and usually do, occur. By attempting to satisfy his aesthetic and recreational needs (the cultural process), man introduces into the natural system a series of artificial features. Working in concert with this process is another human need to capitalize on a financially sound investment (the economic process). These two factors combine as man tries to maintain the "natural system" in the form most convenient for the satisfaction of his process requirements.

The battleground, therefore, is set for another classic encounter between man and nature. In this confrontation, man can never win. At best, he can only hope to delay an inevitable defeat—at a frustratingly high cost.

The rational use of barrier islands requires sound planning, based in part on reliable earth science information. To this end, the Department of the Interior's Barrier Island Work Group, which was formed by Presidential directive, has extensively used earth science information supplied by the Geological Survey (largely in the form of land use and land cover data) to prepare a series of recommendations to the President for the preservation of all remaining unspoiled barrier islands. Specifically, these data are useful for identifying dynamic versus stable areas; identifying those land cover types most frequently developed; assessing the magnitude of changes to barrier islands through natural processes; identifying where on barrier islands the most intensive development occurs; assessing land and resource opportunities foregone through development; identifying spoil areas, reclaimed marshlands, and the uses to which these areas are put; and assessing the magnitude of man-induced changes to barrier islands on a regional or national scale. Through applications such as these, earth science data are broadening their ability as hazard mitigation tools in the coastal zone as well as expanding their planning and policymaking usefulness.

Accomplishments during the past year include the following:

- Preparation of a satellite image atlas of glaciers of of the world in cooperation with the Geological Survey's Water Resources Division and NOAA. The U.S.S.R. Academy of Sciences and the British Antarctic Survey have also agreed to contribute to the atlas.
- Establishment of a cooperative program with the State of Maine. A short course in remote sensing was presented to personnel of the Maine Geological Survey. An EROS Program geologist analyzed the linear features on 10 Landsat images of Maine. A Maine Geological Survey hydrologist participated in a Ground Water Hydrology Workshop at the EROS Data Center.
- Development of a method for monitoring terrain and environmental changes in desert areas with Landsat images. The system will eventually be applicable to arid regions throughout the world.
- Development and use of both visual and automated computer analysis of Landsat images of the Palau Islands in the western Pacific. The technique permits correlation of the spectral response of submerged reefs and other sea bottom features with water depth.
- Publication of approximately 50 reports and articles concerning the applications of remotely sensed data to resources exploration, environmental problems, and image processing technology.

EROS Data Center

The EROS Data Center (EDC) in Sioux Falls, S. Dak., is the key facility of the EROS Program. The Center's

major functions are assistance and training in the use of remotely sensed data, development and demonstration of computer assisted image analysis techniques, and serving as the principal archive and distribution point for remotely sensed data collected by Geological Survey and NASA research aircraft and by Landsat, Skylab, Apollo, and Gemini spacecraft.

TRAINING AND ASSISTANCE

Of the training sessions conducted in fiscal year 1978 by EDC staff, 12 were designed specifically for Interior Department personnel, including the Geological Survey, the Bureau of Land Management (BLM), the Fish and Wildlife Service, and the National Park Service. In addition, 58 attendees representing 37 different countries participated in the 10th and 11th International Workshops; 48 trainees from Central America attended workshops conducted for the Inter-American Development Bank and the Mexican Government; and a 4-week course was held in Tehran for 35 participants at the request of the Iranian Government.

Two Coal Surface Mining Remote Sensing Workshops were offered, demonstrating practical techniques for gathering information mandated by the Surface Mining Control and Reclamation Act of 1977. Participants included personnel from State agencies, private industry, and several Department of the Interior bureaus.

DATA ANALYSIS LABORATORY

The Data Analysis Laboratory is equipped with interactive computer systems for the development, demonstration, and analysis of Landsat imagery and other digital data by computer-assisted image analysis techniques. The laboratory is used in demonstrations and training for more advanced students, but almost 70 percent of the operation of the three interactive computer systems during fiscal year 1978 was in support of applications projects. The Interactive Digital Image Manipulation System was in use nearly 16 hours per day.

The Bureau of Reclamation and BLM are installing similar systems in their Denver laboratories to continue applications projects, such as a land use inventory of the lower Colorado River area, which was begun in the EDC Data Analysis Laboratory.

APPLICATIONS ASSISTANCE FACILITIES

User assistance and training are conducted at Applications Assistance Facilities at Bay St. Louis, Miss., and Fairbanks, Alaska. A small EROS facility in the Canal Zone, Panama, serves as a distribution point for Landsat imagery and accession aids to several Central American countries. Six regional offices of the Survey's National Cartographic Information Center (NCIC) and State affiliate offices also maintain browse files and microfilm of Earth scenes of the United States obtained from aircraft and satellites. This year a faster and less expensive Landsat data reference system has been initiated. Microfiche catalogs indexed by a global network of paths and rows have replaced the old paper catalogs. The six NCIC regional centers are equipped with terminals to the main computer complex in Sioux Falls to facilitate processing of inquiries and purchases of imagery.

DATA PRODUCTION AND DISTRIBUTION

Since its establishment in 1972, EDC has distributed nearly 2 million reproductions of Earth images obtained from satellites and aircraft from the nearly 6 million presently in the data base. About one-half of the reproductions have been of Landsat images. More than 7,500 computer-compatible tapes of Landsat data have also been supplied to users.

The dollar value of all data produced in fiscal year 1978 is $3.2 million. Landsat products, while comprising only 19 percent of the data base, account for about 58 percent of the total sales. Of that total, sales of computer-compatible tapes amount to more than $400,000, which is about 20 percent of total Landsat sales; this reflects the increasing trend toward digital processing of Landsat data. Federal Government users were the principal purchasers of Landsat data during fiscal year 1978, accounting for approximately 35 percent of the total sales. Industrial and foreign users were the next largest categories, accounting for about 30 and 22 percent, respectively.

The principal application by industry is in mineral exploration and related geologic analysis activities by major petroleum and mining companies. From the 145 energy-related industries on a recent Forbes list of U.S. industries, 122 ordered data from EDC; 53 of these showed a highly repetitive ordering pattern, either in new orders for different areas or in standing orders for new data of the same area.

DIGITAL IMAGE PROCESSING SYSTEM

Landsat digital image processing systems have been installed by EDC and NASA, providing Landsat image products superior to those produced previously. The data processing and resulting products associated with the new systems are described in a revised Landsat Data Users Handbook prepared by NASA's Goddard Space Flight Center and EDC and planned for publication by the Geological Survey.

COMMUNICATIONS SATELLITE LINK

The Geological Survey and NASA have retained the services of a commercial communications satellite

carrier to provide a telemetry data link from Goddard Space Flight Center to EDC beginning in January 1979. This arrangement will reduce the time between acquisition of the data by Landsat and routine distribution to the user from 4–6 weeks to 7–10 days. Data will be available within 24 to 72 hours on an emergency basis. Landsat monitoring of time-dependent phenomena such as floods, extent of snow pack, and vigor of range grass are facilitated by the telemetry data link.

SEMINAR ON CHEMICAL AND EFFLUENT MANAGEMENT

The successful treatment of toxic chemical waste from EDC's photographic laboratory has received considerable attention in the photographic industry.

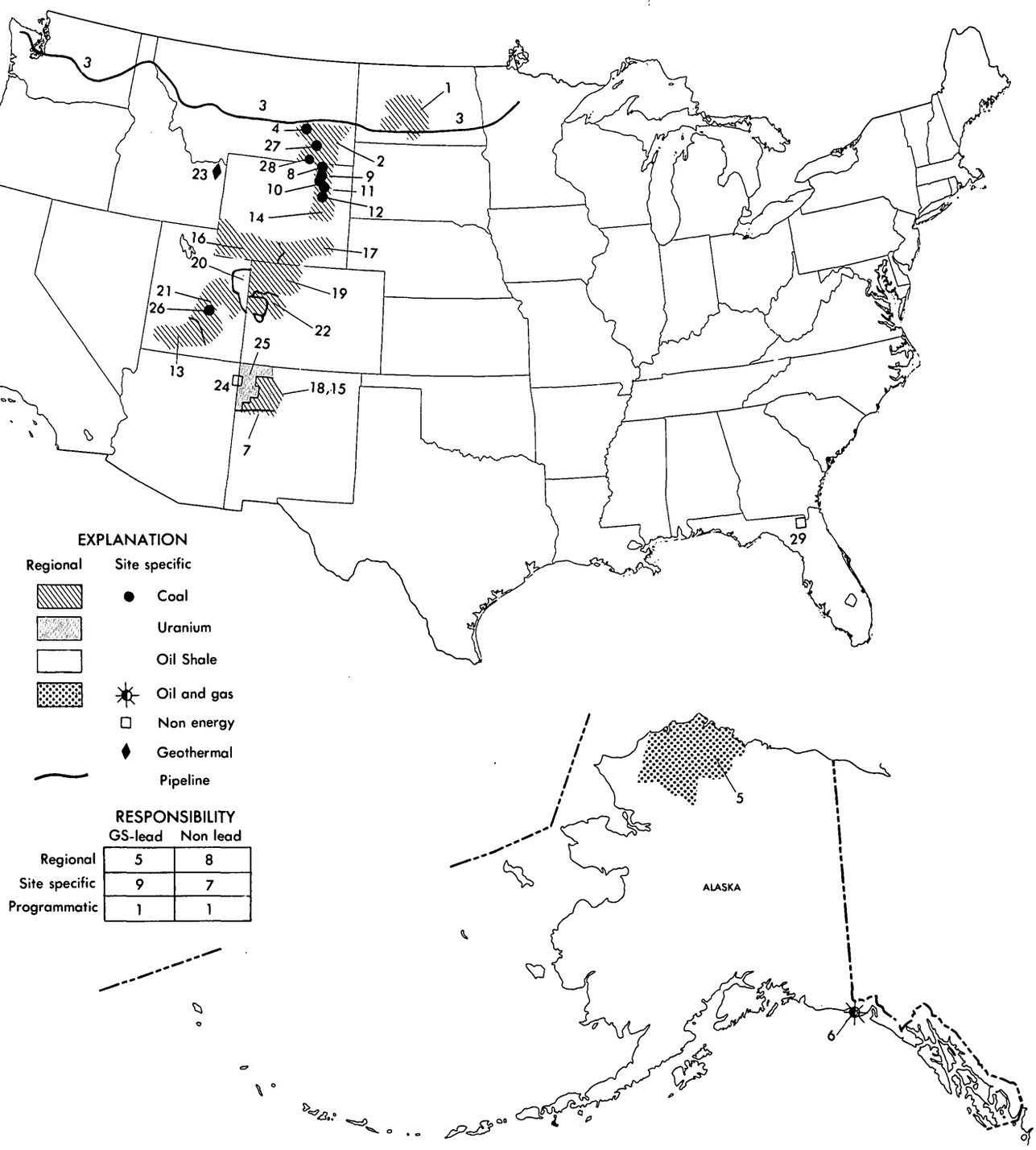


FIGURE 45.—Location for which environmental impact statements and studies were completed or in progress during fiscal year 1978. Locality numbers are keyed to table 13.

TABLE 13.—*Environmental impact statements and studies completed or in progress during fiscal year 1978*[1]

[Locality numbers keyed to fig. 45]

Title	State	Locality number	Project description
GEOLOGICAL SURVEY LEAD OR JOINT-LEAD RESPONSIBILITY			
Northern Powder River regional coal leasing and mining	Montana	2	Evaluate individual and cumulative regional impacts of leasing and mining in south-central Montana.
Mining law reform[1]	Nationwide	--	Determine impacts of proposed legislation to reform the mining law of 1872.
National Petroleum Reserve environmental analysis	Alaska	5	Evaluate impacts of alternative plans for development, production, transportation, and distribution of petroleum resources in the reserve.
Samovar Hills exploratory drilling	do	6	Determine impacts of Texaco Oil Co.'s proposed oil and gas exploratory drilling program.
East Gillette coal mine	Wyoming	8	Determine impacts of Kerr-McGee Co.'s proposed mine north of Gillette.
Caballo coal mine	do	9	Determine impacts of Carter Oil Co.'s proposed mine southeast of Gillette.
Peabody Big Sky coal mine	Montana	27	Determine impacts of coal mining in Peabody's expansion of the Big Sky mine.
Spring Creek coal mine	do	28	Evaluate impacts of coal mining at the Spring Creek coal mine, northern Powder River Basin, Mont.
Pronghorn coal mine	Wyoming	10	Evaluate impacts of Mobil Oil–Consolidated Coal Co.'s mining and reclamation plan southeast of Gillette.
Coal Creek coal mine	do	11	Determine impacts of Atlantic Richfield Co.'s proposed mining and reclamation plan south of Gillette.
Rochelle coal mine	do	12	Evaluate impacts of Peabody Coal Co.'s project in eastern Powder River Basin.
Southern Utah regional coal leasing and development	Utah	13	Evaluate individual and cumulative regional impacts of leasing and mining.
Oil shale tract leasing[2]	Utah-Colorado	20	Evaluate impacts of leasing two tracts for in-situ production of oil shale.
Central Utah regional coal leasing and development	Utah	21	Evaluate individual and cumulative regional impacts of leasing and mining.
Colstrip No. 3 and No. 4 power transmission line	Montana	4	Evaluate impacts of construction of two coal-fired electric generating units and associated coal mine and transmission systems at Colstrip, Mont.

Project	State	Locality number	Lead agency
GEOLOGICAL SURVEY PARTICIPATION			
West-central North Dakota regional coal leasing and development study[3]	North Dakota	1	Bureau of Land Management.
Osceola National Forest phosphate leasing	Florida	29	Do.
Northern Tier pipeline	Washington to Wisconsin	3	Do.
Eastern Powder River Basin regional coal leasing and development supplement	Wyoming	14	Do.
Southwestern Wyoming regional coal leasing and development[3]	do	16	Do.
South-central Wyoming regional coal leasing and development	do	17	Do.
Northwest Colorado regional coal leasing and development study supplement	Colorado	19	Do.

See footnotes at end of table.

TABLE 13.—*Environmental impact statements and studies completed or in progress during fiscal year 1978*[1]—Continued

Project	State	Locality number	Lead agency
GEOLOGICAL SURVEY PARTICIPATION—Continued			
San Juan Basin regional study	New Mexico	25	Bureau of Indian Affairs.
Navajo-Hopi land dispute	do	24	Do.
Star Lake–Bisti regional coal leasing and development	do	7	Bureau of Land Management.
West-central Colorado regional coal leasing and development	Colorado	22	Do.
United Nuclear Dalton Pass uranium mine[3]	New Mexico	18	Tennessee Valley Authority.
Targhee (Island Park) geothermal	Idaho	23	Forest Service.
Mobil Oil Crownpoint uranium mine	New Mexico	15	Tennessee Valley Authority.
Emery Generating Station Units 3 and 4	Utah	26	Bureau of Land Management.
Office of Surface Mining final coal mining regulations[1]	Nationwide	--	Office of Surface Mining.

[1] Not shown in figure 45. [2] Discontinued on December 30, 1977. [3] Completed.

To disseminate this technology to other government agencies and industry, EDC and the Society of Photographic Scientists and Engineers cosponsored a Seminar on Chemical and Effluent Management in Photographic Laboratories.

Status of Satellites

Shortly after the demise of Landsat 1 early in January, Landsat 3 was launched on March 5, 1978, as a new partner to Landsat 2. One of the tape recorders on Landsat 2 is inoperable, and the thermal infrared band on Landsat 3 is not working, but the satellites are sending data every 9 days from four bands of the multispectral scanners, as well as from high-resolution 131-foot return beam vidicon cameras on Landsat 3.

Water resource data from 101 ground measurement stations are being relayed through the Geostationary Operational Environmental Satellite (GOES), 30 stations relay water resource data through Landsat 3, and numerous other stations (seismic event counters, and so forth) also use GOES and Landsat 3.

Landsat D is expected to be launched in the Space Shuttle in 1981 and will include a four-band multispectral scanner to assure continuity of data to users. A seven-band thematic mapper will provide data resolution of 98 feet.

Three other experimental satellites launched in 1978 are transmitting data useful to Interior Department scientists. The Heat Capacity Mapping Mission is providing quantitative information useful in measuring thermal inertia of rocks; Seasat's synthetic aperture radar data is of special interest to oceanographers and geologists (communication with Seasat failed in October 1978); Nimbus 7 monitors polar areas not covered by Seasat, has a data collection system for relay of data from sensors deployed on the ground, and measures the chlorophyll absorption and surface temperature of vegetation in coastal areas.

William T. Pecora Memorial Symposium

The fourth William T. Pecora Memorial Symposium, on the applications of remote sensing data for wildlife management, was held in Sioux Falls, S. Dak., in October 1978. The symposium was sponsored by the National Wildlife Federation in cooperation with the Survey and NASA. The late Dr. Pecora, a former director of the Survey and Under Secretary of the Interior, was instrumental in developing the Landsat program.

Proceedings of the second Pecora Symposium on mapping with remotely sensed data were published by its sponsor, the American Society of Photogrammetry. Proceedings of the third Pecora Symposium on the applications of satellite data to petroleum and mineral exploration, sponsored by the American Association of Petroleum Geologists, are in press.

ENVIRONMENTAL IMPACT ANALYSIS PROGRAM

Program and Activities

The Environmental Impact Analysis (EIA) Program was established in 1975 to provide the Geological Survey's response to EIS preparation and review requirements of NEPA. The passage of NEPA in 1969 initiated the EIS preparation and review process. Federal agencies are required to prepare a detailed statement of any possible environmental impacts resulting from Federal activities having potentially significant effects on the quality of the environment. This law

requires Federal agencies with appropriate jurisdiction and expertise to review statements prepared by other Federal agencies.

The Geological Survey becomes involved as a lead agency in the preparation of statements as a result of the Conservation Division's supervision of mineral resource exploration, development, extraction, and reclamation operations on Federal lands. The Survey becomes involved as a nonlead agency as a result both of its supervisory function (as described above) and through its special expertise in the areas of geology, hydrology, and mining and petroleum engineering. Survey review of EIS's focuses on the adequacy with which pertinent aspects of the geologic and hydrologic environment are described, potential environmental impacts are discussed, and mitigating measures and alternatives are considered.

The EIA Program integrates Geological Survey EIS activities by providing the following:

- Direction, coordination, and expertise in the preparation of environmental impact statements for which the Survey has lead or joint-lead responsibility.
- Scientific and technical support in the preparation of impact statements for which the Survey has contributing responsibility.
- Technical analyses and reviews of impact statements and related documents prepared by other agencies.
- Manuals, guidelines, and training courses on the preparation and review of impact statements.
- Environmental research.

Preparation of a prototype EIS demonstrating an improved format was completed by the EIA Program and filed as a draft environmental statement during fiscal year 1978. This prototype is the outcome of a continuing effort begun in fiscal year 1976 to reduce the bulk and increase readability of the impact statement itself as a way to improve the EIS process. The EIS for the mining and reclamation plan proposed by Mobil Oil–Consolidation Coal Co. for the Pronghorn mine in Campbell County, Wyo., was selected for the demonstration (see essay, "The Pronghorn Environmental Impact Statement: An Improved Prototype").

During fiscal year 1978, the EIA Program assumed responsibility for the preparation of Oilspill Trajectory Analyses (OSTA's) for OCS Lease Sale EIS's and, beginning in fiscal year 1979, for OCS developmental EIS's. These analyses provide information for assessing probabilities of impacts of resource development, in draft and final EIS's, and provide a basis for comparison of the value of the resource considered for development with the cost of the impacts. Equipment and facilities for the OSTA's have been acquired and staffing is underway and expected to be completed during fiscal year 1979.

Work is underway for preparation of guidelines for preparing developmental OCS EIS's. Prior to the sale of an OCS lease tract, an EIS is prepared by BLM. Two environmental assessments are prepared by the Survey's Conservation Division prior to each activity following the sale of a lease tract: (1) exploration and (2) development and production. A developmental EIS, prepared prior to actual development of oil and gas on an OCS tract, draws on information contained in the previous documents as well as the information contained in the applicants' development plan. Because the time between preparation of the EIS prior to the sale of a tract and preparation of the developmental EIS is frequently long, the amount of information available for preparation of the developmental EIS may increase markedly, particularly in the areas of new development planning, changing technology, and improved understanding of geologic hazards. Therefore, methods for preparing these EIS's must be somewhat different from those used in other resource development EIS's for which guidelines have already been established. The new guidelines for preparation of developmental OCS EIS's are projected to be completed in fiscal year 1979.

Accomplishments

- Took lead or joint-lead responsibility for the preparation of 15 EIS's. Eleven EIS's concerned the development of coal, three concerned onshore oil and gas, and one concerned revision of the 1872 mining law (fig. 45 and table 13).
- Participated in a nonlead capacity in the preparation of 16 EIS's for which other Federal agencies had the lead responsibility. Fourteen of these EIS's were energy related, involving principally coal leasing and development, uranium, and geothermal energy (fig. 45 and table 13).
- Reviewed and commented on approximately 1,800 EIS's and related documents.
- Provided technical information, from other Survey programs, for the Forest Service for seven EIS's on geothermal energy resources and also for BLM for five EIS's on leasing of the OCS.
- Completed the draft environmental statement of a newly formatted EIS prototype on the Pronghorn coal mine in Campbell County, Wyo.
- Initiated establishment of guidelines for the preparation of developmental EIS's.
- Assumed responsibility for the preparation of OSTA's for OCS Lease Sale EIS's.

SELECTED REFERENCES

Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.

Clarke, P. F., Hodgson, H. E., and North, G. W., 1978, A guide to obtaining information from the U.S.G.S. 1978: U.S. Geological Survey Circular 777, 36 p.

Colton, R. B., 1978, Geologic map of the Boulder–Fort Collins–Greeley area, Colorado: U.S. Geological Survey Miscellaneous Investigations Map I–855–G, scale 1:100,000.

Council of State Governments, 1978, Environmental resource data—Intergovernmental management dimensions: 56 p.

Gower, H. D., 1978, Tectonic map of the Puget Sound region, Washington, showing faults, principal folds, and large-scale quaternary deformation: U.S. Geological Survey Open–File Report 78–426.

Hansen, W. R., Chronic, John, and Matlock, John, 1978, Climatography of the Front Range Urban Corridor and vicinity, Colorado: U.S. Geological Survey Professional Paper 1019, 59 p.

Johnston, R. H., and Van Driel, J. N., 1978, Susceptibility of Coastal Plain aquifers to contamination, computer composite map, Fairfax County, Virginia: U.S. Geological Survey Open–File Report 78–265.

Kachadoorian, Reuben, and Slater, W. H., 1978, Pillar Mountain landslide, Kodiak, Alaska: U.S. Geological Survey Open–File Report 78–217, 21 p.

Mitchell, W. B., Guptill, S. C., Anderson, K. E., Fegeas, R. G., and Hallam, C. A., 1977, GIRAS—A Geographic Information Retrieval and Analysis System for handling land use and land cover data: U.S. Geological Survey Professional Paper 1059, 16 p.

Newell, W. L., 1978, Understanding natural systems—A perspective for land-use planning in Appalachian Kentucky: U.S. Geological Survey Bulletin 1438, 50 p.

Reed, W. E., and Lewis, J. E., 1978, Land use and land cover information and air-quality planning: U.S. Geological Survey Professional Paper 1099–B, 43 p.

Robinson, G. D., and Spieker, A. M., eds., 1978, "Nature to be Commanded . . .": U.S. Geological Survey Professional Paper 950, 97 p.

U.S. Geological Survey, 1970, The national atlas of the United States of America: 417 p.

———1974, Land use map, 1970, Washington urban area, District of Columbia, Maryland, and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–A, scale 1:100,000.

———1974, Annotated orthophoto map, 1970, Washington urban area, District of Columbia, Maryland and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–B, scale 1:100,000.

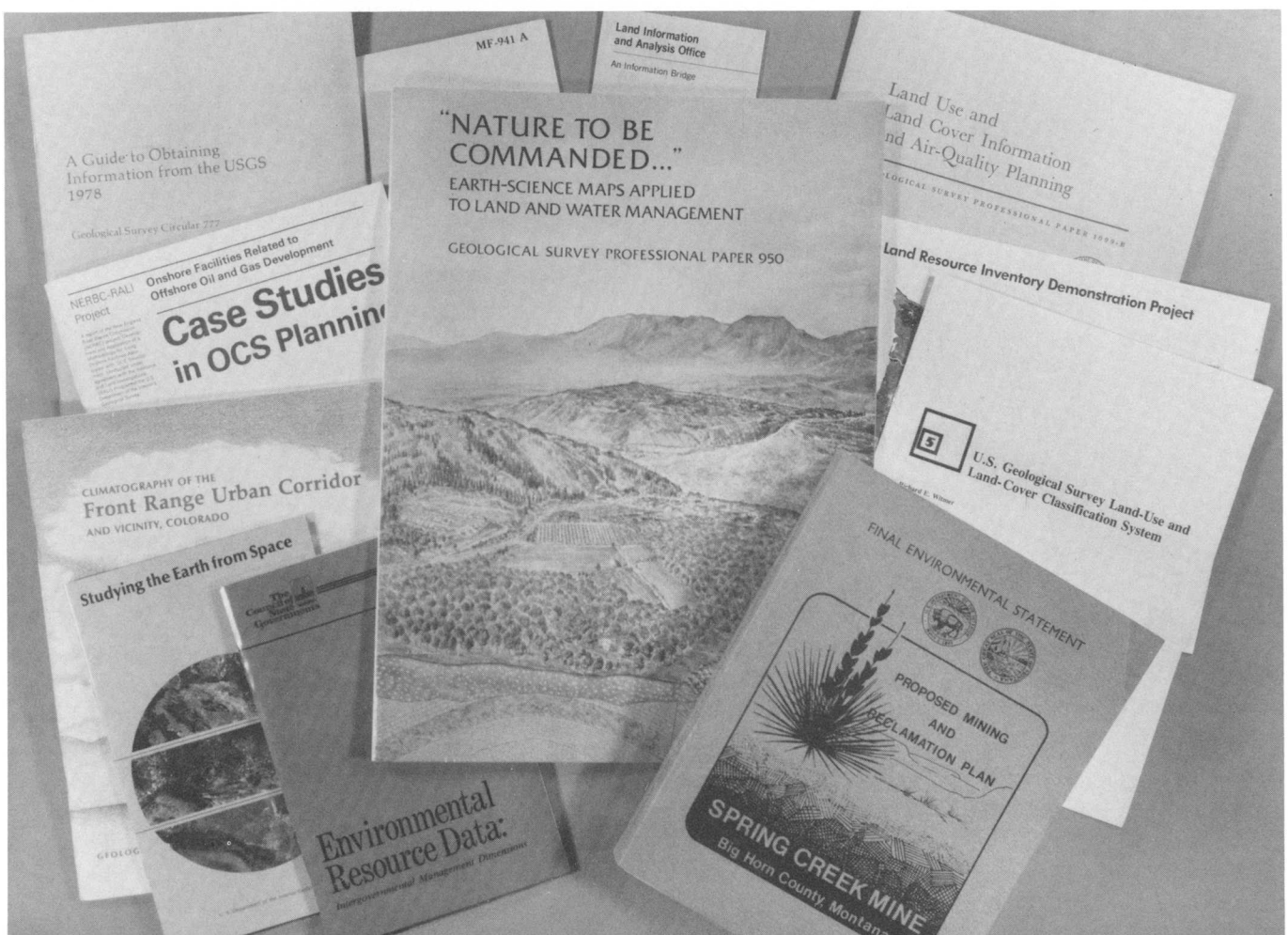
———1974, Census tracts, 1970, Washington urban area, District of Columbia, Maryland, and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–C, scale 1:100,000.

———1975, Land use change map, 1970–1972, Washington, urban area, District of Columbia, Maryland, and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–D, scale 1:100,000.

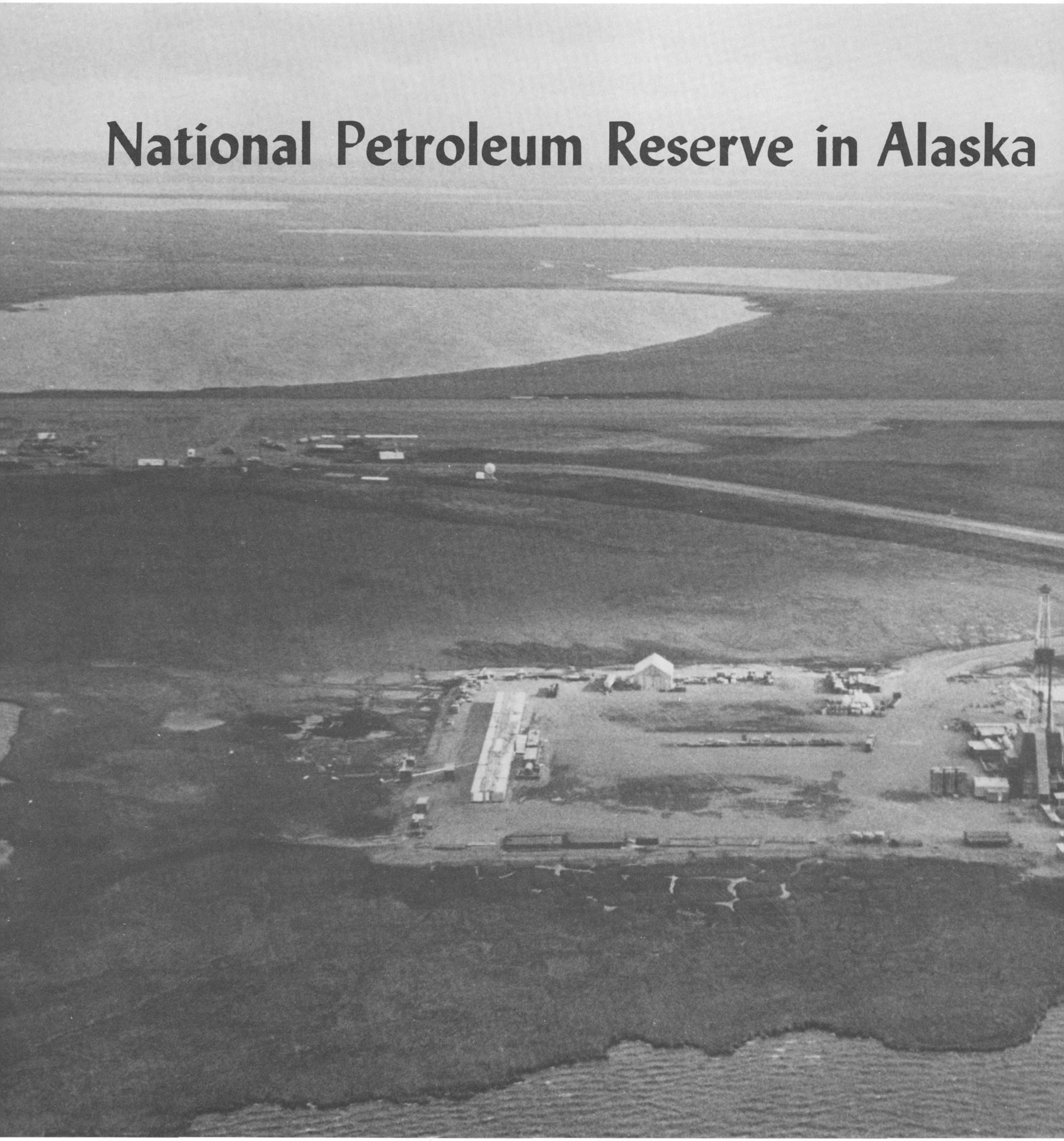
———1978, Land cover from Landsat, 1973, with place names, Washington urban area, District of Columbia, Maryland, and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–E, scale 1:100,000.

———1978, Land cover from Landsat, 1973, with census tracts, Washington urban area, District of Columbia, Maryland and Virginia: U.S. Geological Survey Miscellaneous Investigations Map I–858–F, scale 1:100,000.

The Land Information and Analysis Office produces a variety of diverse publications. This selection indicates the various facets of this effort to present earth science data to decision makers and to the public.



National Petroleum Reserve in Alaska



INTRODUCTION

During fiscal year 1978, the U.S. Geological Survey carried out its first full year of petroleum exploration activities on the National Petroleum Reserve in Alaska (NPRA) since the transfer of the Reserve (formerly the Naval Petroleum Reserve No. 4) from the Department of the Navy to the Department of the Interior on June 1, 1977, in accordance with the Naval Petroleum Reserves Production Act of 1976 (Public Law 94–258, 94th Congress, April 5, 1976). On transfer, the Geological Survey was charged with the responsibility of continuing the petroleum exploration program, which includes the following specific tasks:

1. Explore and evaluate the petroleum resources of NPRA by means of drilling and geologic and geophysical investigations and build an information base to assist Congress in determining the best use of the land within the Reserve.
2. Continue to develop and to produce natural gas from the South Barrow gas field or other fields as may be necessary and to supply gas at reasonable and equitable rates to the Native village of Barrow and other communities and installations of the Federal Government in the vicinity of Barrow.
3. Continue environmental rehabilitation of parts of the Reserve disturbed by previous exploration and construction activities.

At the time of transfer of the Reserve, the Department of the Navy, in its fourth year of a 26-well exploration program begun in 1974, had drilled 7 exploratory wells in the northern coastal part of the Reserve and had completed 7,680 miles of a 10,000-mile seismic reconnaissance survey. All the wells were dry or had only slight indications of oil except for the W. T. Foran well, which had good porosity and permeability and residual oil in the Sadlerochit Formation, the main producing zone at Prudhoe Bay (see table 14). During fiscal year 1978, the Geological Survey completed three additional exploratory wells, suspended drilling at one medium-depth well (a well that can be completed in one winter drilling season) during the summer months, started drilling one deep well, and constructed two pads for future drilling including one pad for year-round drilling in the western part of the Reserve. In addition, one exploratory and two development gas wells were drilled in the Barrow area, and four geophysical survey parties acquired 1,935 line miles of seismic data. Husky Oil NPR Operations, Inc., continued as the principal contractor for all phases of the exploration program.

◀ Inigok drill site with an all-weather airstrip in background, August 1978.

TABLE 14.—*Exploratory wells drilled by the Department of the Navy between 1975 and 1977 and wells drilled in fiscal year 1978 and planned for fiscal year 1979 by the U.S. Geological Survey*

Name	Location	Date spudded [1]	Date completed	Total depth (in feet)	Deepest horizon attained	Remarks
Cape Halkett No. 1.	18 miles ESE of Lonely.	3-24-75	5-23-75	9,900	"Argillite" basement (Devonian or older).	Dry; plugged and abandoned.
East Teshekpuk No. 1.	25 miles S of Lonely.	3-12-76	5-11-76	10,664	Granite Basement -----	Do.
South Harrison Bay No. 1.	50 miles SE of Barrow.	11-21-76	1-27-77	11,290	Lisburne Group (Mississippian).	Poor oil shows; plugged and abandoned.
Atigaru Point No. 1.	44 miles SE of Lonely.	1-12-77	3-10-77	11,535	"Argillite" basement (Devonian or older).	Do.
West Fish Creek No. 1.	51 miles SE of Lonely.	2-14-77	4-21-77	11,427	Kayak shale (Mississippian).	Do.
South Simpson No. 1.	41 miles WSW of Lonely.	3- 9-77	4-18-77	8,805	"Argillite" basement (Devonian or older).	Dry; plugged and abandoned.
W. T. Foran No. 1.	23 miles ESE of Lonely.	3- 7-77	4-16-77	8,864	----do ----------	Oil and gas shows; plugged and abandoned.
Drew Point Test Well No. 1.	14 miles W of Lonely.	1-13-78	3-13-78	7,946	----do ----------	Poor oil and gas shows; plugged and abandoned.
North Kalikpik Test Well No. 1.	37 miles SE of Lonely.	2-27-78	4-14-78	7,395	Kingak Shale (Jurassic) --	Do.
South Meade Test Well No. 1.	45 miles S of Barrow.	2- 8-78	-------	[2]9,825	----do ----------	Dry; drilling suspended until winter 1979.
Kugrua Test Well No. 1.	67 miles SW of Barrow.	2-13-78	5-30-78	12,588	Lisburne Group (Mississippian).	Dry; plugged and abandoned.
Inigok Test Well No. 1.	60 miles S of Lonely.	6- 7-78	-------	[2]19,755	"Argillite" basement [2] --	Drilling at 12,355 feet as of 9-28-78.
Tunalik Test Well No. 1.	22 miles SE of Icy Cape.	[2]11- 1-78	-------	[2]19,980	----do [2] ----------	Drilling to commence 11-1-78.
Peard Test Well No. 1.	25 miles NE of Wainwright.	Being planned	-------	[2]10,000	----do [2] ----------	----------
Ikpikpuk Test Well No. 1.	42 miles SW of Lonely.	----do -----	-------	[2]15,200	----do [2] ----------	----------
East Simpson Test Well No. 1.	55 miles SE of Barrow.	----do -----	-------	[2]7,300	----do [2] ----------	----------
J. W. Dalton Test Well No. 1.	3 miles E of Lonely.	----do -----	-------	[2]9,250	----do [2] ----------	----------
Lisburne Test Well No. 1.	110 miles SW of Umiat.	----do -----	-------	[2]15,000	Lisburne-Endicott Group.[2]	----------
Seabee Test Well No. 1.	1 mile NW of Umiat.	----do -----	-------	[2]15,000	Basal Cretaceous [2] -----	----------

[1] Drilling began. [2] Projected.

The petroleum exploration activities at NPRA are coordinated with two related studies mandated by Public Law 94–258. One study, due no later than January 1, 1980, relates to "the best overall procedure to be used in the development, production, transportation, and distribution of the petroleum resources in the reserve" and is referred to as the Presidential Study or the 105(b) Study. It consists of an economic analysis being conducted by the Office of Minerals Policy and Research Analysis in the Department of the Interior and an environmental analysis being conducted by the Geological Survey. The second study, due on April 5, 1979, is "to determine the values of, and best uses for, the lands contained in the reserve, taking into consideration (A) the natives who live or depend upon such lands, (B) the scenic, historical, recreational, fish and wildlife, and wilderness values, (C) mineral potential, and (D) other values of such lands" and is referred to as the 105(c) Study; the Bureau of Land Management is lead agency.

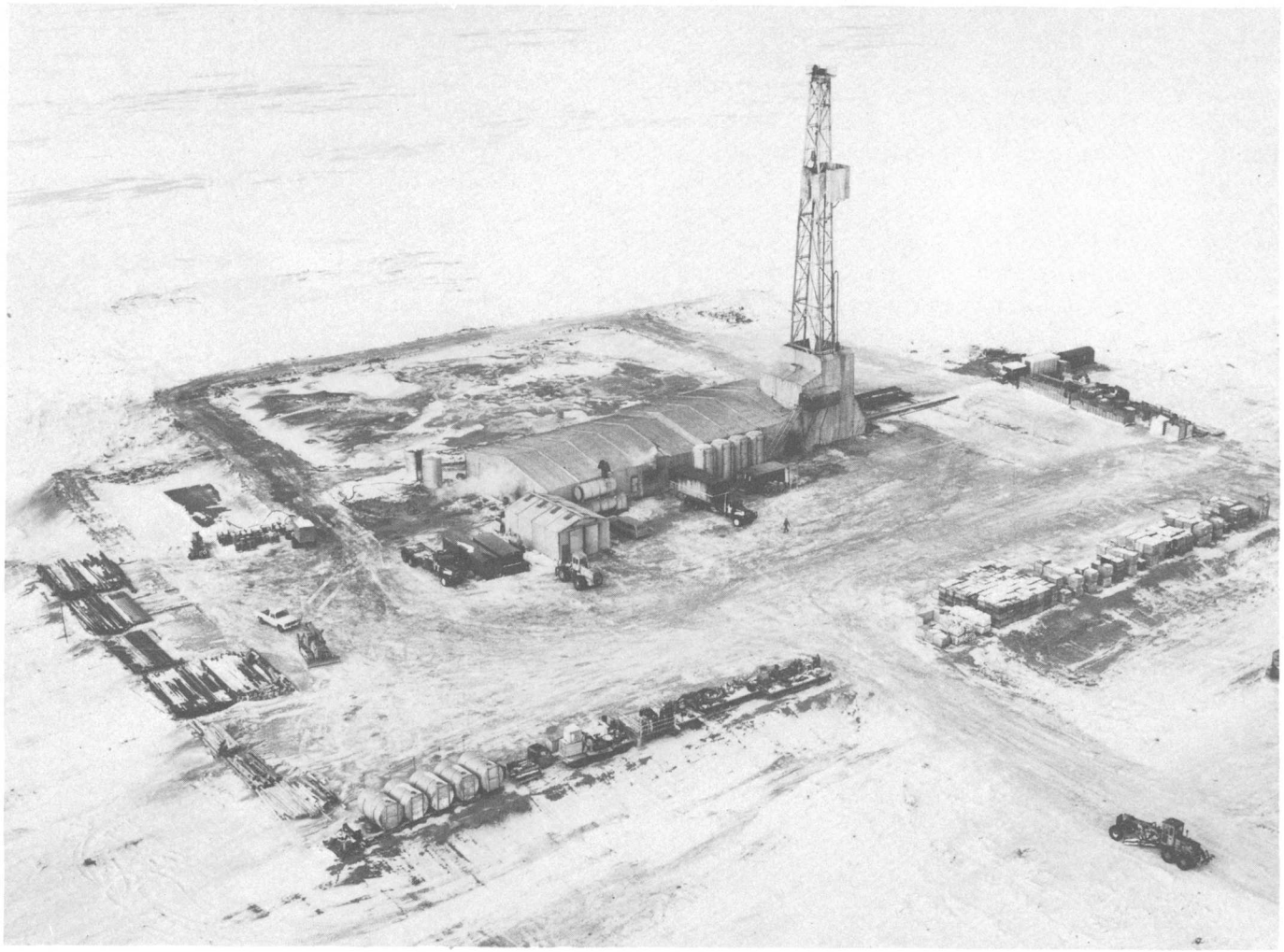
HIGHLIGHTS

- Drilling of four petroleum exploratory wells, three to completion and one for reentry in fiscal year 1979.
- Initiation of drilling of one deep well (year-round drilling) in the eastern part of the Reserve.
- Drilling of one exploratory and two development gas wells in the Barrow area; construction of a pad to perform down-hole rehabilitation work in fiscal year 1979 at an older gas well experiencing production problems.

- Construction of a drilling pad, roads, and an airstrip for year-round drilling during fiscal year 1979 at a deep-well site in the western part of the Reserve.
- Construction of a pad for fiscal year 1979 winter drilling in the north-central part of the Reserve.
- Acquisition, processing, and interpretation of 1,935 line miles of reconnaissance and detailed seismic data.
- Selection of six locations for exploratory drilling on the Reserve and three locations for development drilling in the Barrow area in fiscal year 1979.
- Location of 1,600 line miles of seimic survey to be acquired during fiscal year 1979 (1,000 line miles of reconnaissance and 600 miles of fill-in detail).
- Continuation of environmental rehabilitation activities on the Reserve including the collection and disposal of over 3,000 tons of debris and waste materials from 35 sites.
- Preparation of environmental assessments for each of six drilling sites, two pads, and miscellaneous support bases.
- Continuation of geologic studies to support petroleum exploration activities.
- Renewal of interagency agreements for continuing logistical, communications, and operational support for petroleum exploration activities.
- Negotiations of contract requirements with Husky Oil NPR Operations, Inc., for continuing the exploration program in fiscal year 1979.
- Coordination with other agencies and groups involved in related activities on the Reserve.

BUDGET AND PERSONNEL

The Survey received an appropriation of over $209 million during fiscal year 1978 for activities conducted within NPRA. The appropriation provided over $192 million to continue the ongoing evaluation and assessment of the Reserve, almost $15 million to operate the South Barrow gas field and to explore for and to develop additional gas reserves in the Barrow area, and $2 million for the environmental rehabilitation program which consists of the normal ongoing cleanup of current exploration activities and



Typical drilling site (East Teshekpuk No. 1)in winter. Living quarters are located nearby.

cleanup of areas of the Reserve disturbed during previous petroleum exploration and construction activities.

The Office of National Petroleum Reserve in Alaska was allocated 32 permanent full-time positions and 6 part-time positions for fiscal year 1978. Of the 32 permanent full-time positions, 3 have been staffed elsewhere in the Geological Survey to provide contract support to the program and to continually upgrade NPRA petroleum resource data as new information is acquired from the ongoing exploration program.

PROGRAM AND ACTIVITIES

The primary activity of the fiscal year 1978 exploration program was the drilling of exploratory wells on the Reserve (table 14). The goal of the drilling program is to sample a sufficient number of geologic structures identifiable from geophysical data to provide the information required to prepare a petroleum resource appraisal of the Reserve which will assist Congress in determining the best use of the land within NPRA. The first exploratory well drilled by the Geological Survey was the Drew Point Test Well No. 1 located on the Arctic Coast near Smith Bay about 14 miles west of the support camp at Lonely and about 37 miles west of the Navy's W. T. Foran Well No. 1 drilled in 1977 (see fig. 46). It appeared that oil may have migrated westward through the area of the W. T. Foran well toward a structural-stratigraphic feature near the Drew Point well. Although minor oil and gas shows were encountered, the potential reservoir zones were thin and (or) had low porosity and permeability. The shows of oil and gas and the marked stratigraphic changes between the Drew Point and W. T. Foran wells indicate the need for an additional well between the two locations. J. W. Dalton Test Well No. 1, located approximately 3 miles east of Lonely, represents such an intermediate location and will be drilled in fiscal year 1979. Drew Point spudded on January 13, 1978, and was completed in the pre-Devonian "Argillite" basement on March 13, 1978, at a depth of 7,946 feet.

North Kalikpik Test Well No. 1 was drilled near the eastern margin of the Reserve approximately 37 miles southeast of Lonely to test a postulated stratigraphic trap identified in seismic data. No attractive reservoirs were encountered, although the equivalent rocks of the target interval were highly organic and contained traces of bitumen and gas. These strata may be source beds for reservoirs that lie updip (northward) from the North Kalikpik well. Although the results at North Kalikpik are discouraging, they indicate that future exploration should include continued drilling for structural-stratigraphic traps between this well and the Arctic coastal area. The well spudded in February 1978 and was completed in the pre-Devonian "Argillite" basement in April 1978 at a depth of 7,395 feet.

The Kugrua Test Well No. 1 was drilled approximately 67 miles southwest of Barrow in a new area of the Reserve and reached a depth greater than any previous well in the western part of the Reserve. The well was drilled to test a seismic anomaly in Paleozoic strata in an onlap sequence along the Arctic Coast. Although the anomaly was penetrated, explanation of the relationship was not obvious, and additional wells may be required to resolve the relationships and identify reservoir developments. The seismic velocity interpretations may be related to an unanticipated sequence of Pennsylvanian-Mississippian age limestone exceeding 1,400 feet in thickness encountered by the well, the base of which was not penetrated and may lie an additional 1,800 feet below the well's total depth of 12,588 feet. The projected depth of the Kugrua well was 12,220 feet, but the caving shale and the unanticipated sequence of limestone at the bottom of the hole slowed drilling considerably. Drilling was continued into the spring breakup season by monitoring environmental aspects on a day-to-day basis, but this still did not provide enough time to drill to the "Argillite" basement. The Kugrua well spudded in February 1978 and was abandoned in May 1978.

Reserve pit at the South Meade drilling site in March 1978.

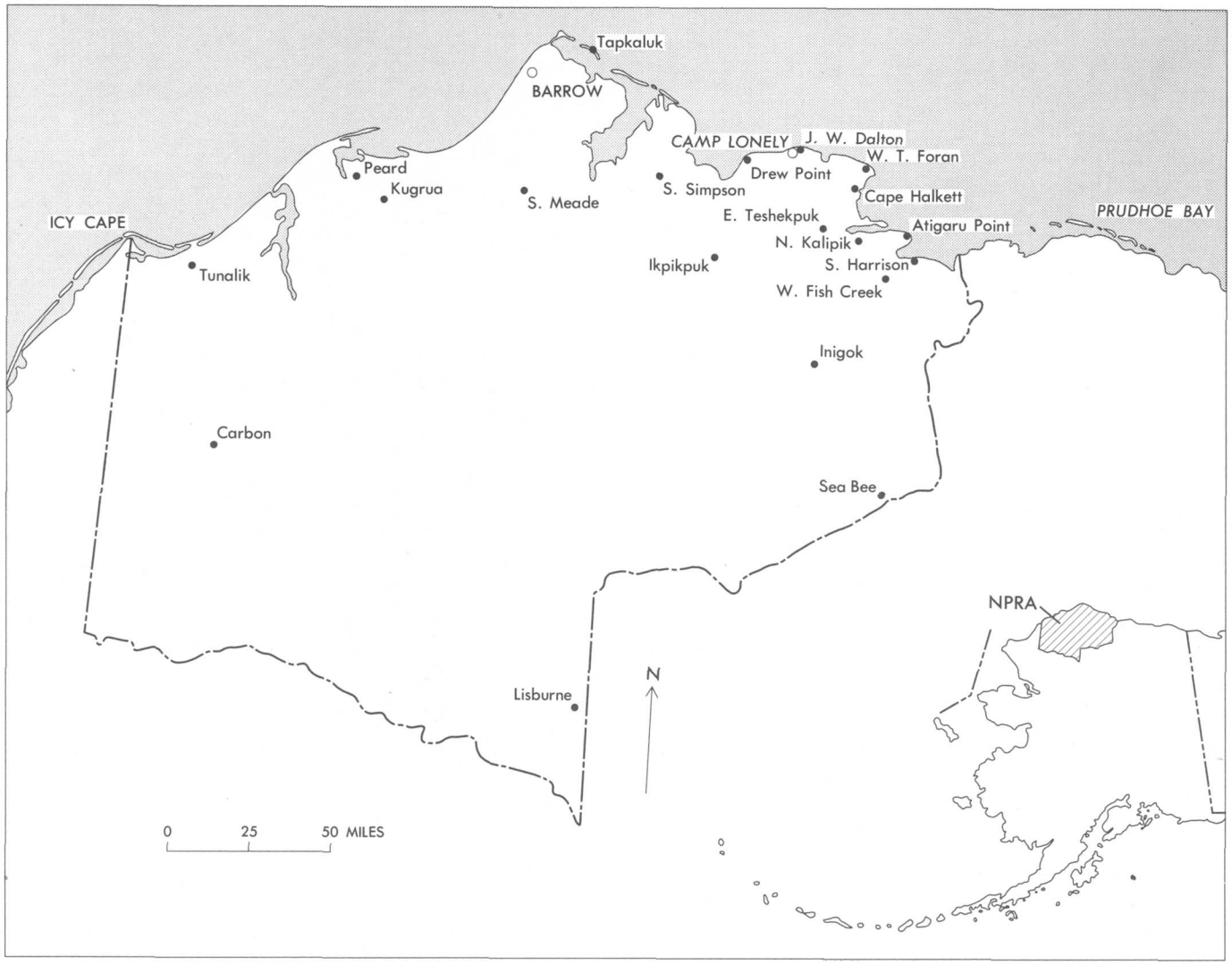


FIGURE 46.—Exploration wells on the National Petroleum Reserve in Alaska.

The South Meade Test Well No. 1 was drilled 45 miles south of Barrow to test for possible oil and gas accumulation in truncated onlap strata on the southern flank of the Barrow Arch. Like the Kugrua well, South Meade is a new play area. Caving shales at several intervals caused severe drilling problems and required several fishing operations for lost drilling tools. Because of an inability to complete fishing operations at 8,065 feet, the hole was plugged back, and a sidetrack hole was begun at 5,761 feet. The hole reached a depth of 8,516 feet in a thick shale unit when spring breakup conditions required suspension of drilling for the summer months. No attractive hydrocarbon reservoirs were encountered to its present depth. The hole was conditioned for future reentry and completion in fiscal year 1979. The South Meade well spudded in February 1978 and was suspended in May 1978.

Two deep exploratory wells (Tunalik and Inigok) were planned for fiscal year 1978, but drilling commenced at only one location because the drilling rig could not be moved from the Kugrua well site to the Tunalik site before the spring thaw began. Inigok Test Well No. 1, which is located 60 miles south of Lonely, spudded on June 7, 1978, and continued drilling throughout the summer months. As of September 30, 1978, the well was drilling ahead at 12,524 feet. Approximately 360 drilling days will be required to complete the well to the "Argillite" basement, which has been projected at 19,775 feet. The well is designed to test structures developed in the east-central part of NPRA as well as to provide valuable stratigraphic information on the deeper rocks in the interior of the Reserve. To facilitate year-round drilling, an all-season drilling pad, roads, and an airstrip were constructed.

A second deep test, Tunalik Test Well No. 1, approximately 22 miles southeast of Icy Cape in the western part of NPRA, was scheduled to be drilled to the "Argillite" basement at a projected depth of

19,980 feet beginning November 1, 1978. Because drilling will continue during the summer of 1979, an all-season drilling pad, roads, and an airstrip were constructed during fiscal year 1978.

A second drilling pad was constructed approximately 42 miles southwest of Lonely for drilling Ikpikpuk Test Well No. 1, which is projected to a depth of 15,200 feet. This well will be drilled during the winter of fiscal year 1979.

In the Barrow area, three wells were drilled (table 15). The first well, South Barrow Well No. 16, was drilled as an exploratory well approximately 2 miles northeast of the South Barrow gas field in an attempt to locate a new gas field to supplement the diminishing reserves of the South Barrow gas field. The well, drilled on a seismically identifiable structure, penetrated the entire section of sediments to the "Argillite" basement. Small shows of gas were noted, but the primary objective, the "Barrow gas sand," was not encountered perhaps because erosion had moved the sand at this location or a fault had interrupted its continuity. A secondary objective, the Sag River sandstone, a potential oil reservoir, was also missing. The well spudded in January 1978 and reached a total depth of 2,399 feet in February 1978; it was then plugged and abandoned.

Two development wells located about 10 miles east of the South Barrow gas field were drilled in a new gas field discovered by the Department of the Navy during the fiscal year 1977 drilling season. South Barrow Well No. 17, drilled about 1 mile east of the Navy discovery well, was designed to better define the productive limits of the gas sands in the new field and to determine if the Sag River sandstone was capable of oil production. Production tests indicated an absolute open flow potential of 7.2 million cubic feet of gas per day, but the well also produced appreciable quantities of water. Below the gas zone, the Sag River sandstone was tested for possible oil production, but the tests were negative. South Barrow Well No. 19 was drilled a little more than 0.5 mile northwest of the Navy discovery well. Production tests in the "Barrow gas sand" resulted in a calculated absolute open-flow potential of 7.2 million cubic feet of gas per day with no water. Tests for oil in the Sag River sandstone were negative. Drilling at both wells reached total depth, but completion was suspended until production facilities are constructed at the new field. Development Well No. 18 had been earlier deferred to the fiscal year 1979 drilling season. In addition to the drilling in the Barrow area, a pad was constructed at South Barrow No. 6, drilled by the Department of the Navy in 1964, to permit repair of production tubing in the well. This work will be undertaken early in fiscal year 1979.

The Geological Survey continued to operate and maintain the South Barrow gas field which supplies natural gas to the village of Barrow and Federal installations in the vicinity of Barrow.

Geophysical studies at NPRA continued during fiscal year 1978 with the acquisition, processing, and interpretation of 1,935 line miles of reconnaissance and detailed seismic surveys in various parts of the Reserve, including offshore areas in the vicinity of Barrow. Four geophysical field parties were employed to acquire the seismic data. Two crews operated in the Driftwood and southern Foothills area, one at Umiat, and one in the northern coastal area. In the

TABLE 15.—*Barrow gas wells recently drilled by the Department of the Navy and the U.S. Geological Survey*

Name	Location	Date spudded [1]	Date completed	Total depth (in feet)	Deepest horizon penetrated	Status
South Barrow No. 11.	Sec. 14, T. 22 N., R. 18 W.	2-10-74	3- 6-74	2,350	"Argillite" basement (Devonian or older).	Completed as gas producer.
South Barrow No. 12.	Sec. 23, T. 22 N., R. 17 W.	3-10-74	5- 4-74	2,285	----do ----------	Suspended as marginal gas well.
Iko Bay [2] --------	Sec. 16 ,T. 21 N., R. 16 W.	1- 2-75	3- 8-75	2,731	----do ----------	Marginal gas well.
South Barrow No. 13.	Sec. 14, T. 22 N., R. 18 W.	12-17-76	1-16-77	2,535	----do ----------	Shows of gas; suspended as marginal gas well.
South Barrow No. 14.	Sec. 25, T. 22 N., R. 17 W.	1-28-77	3- 3-77	2,257	Sag River sandstone (Triassic).	Suspended; to be completed as gas well.
South Barrow No. 16.	Sec. 1, T. 22 N., R. 18 W.	1-28-78	2-18-78	2,399	"Argillite" basement (Devonian or older).	Dry; plugged and abandoned.
South Barrow No. 17.	Sec. 30, T. 22 N., R. 16 W.	3- 2-78	4-13-78	2,382	----do ----------	Suspended; edge well; produces water with gas.
South Barrow No. 19.	Sec. 14, T. 22 N., R. 17 W.	4-17-78	5-17-78	2,300	----do ----------	Suspended; to be completed as gas well.

[1] Drilling began.
[2] The Iko Bay well was drilled approximately 20 miles southeast of Barrow to locate a new gas field to supplement the gas supply for Barrow.

southern Foothills, about 1,360 line miles of reconnaissance data were collected to complete a grid of about 6-mile spacing to determine the general geologic structure and to identify possible future drilling targets. Along the Arctic coastal plain, about 575 miles of high-resolution seismic data were acquired, including some high-resolution data on a detailed grid to delineate the Barrow gas sands and other potential reservoirs in the northern coastal area. In addition, approximately 200 miles of previously acquired seismic data were reprocessed for special stratigraphic evaluation.

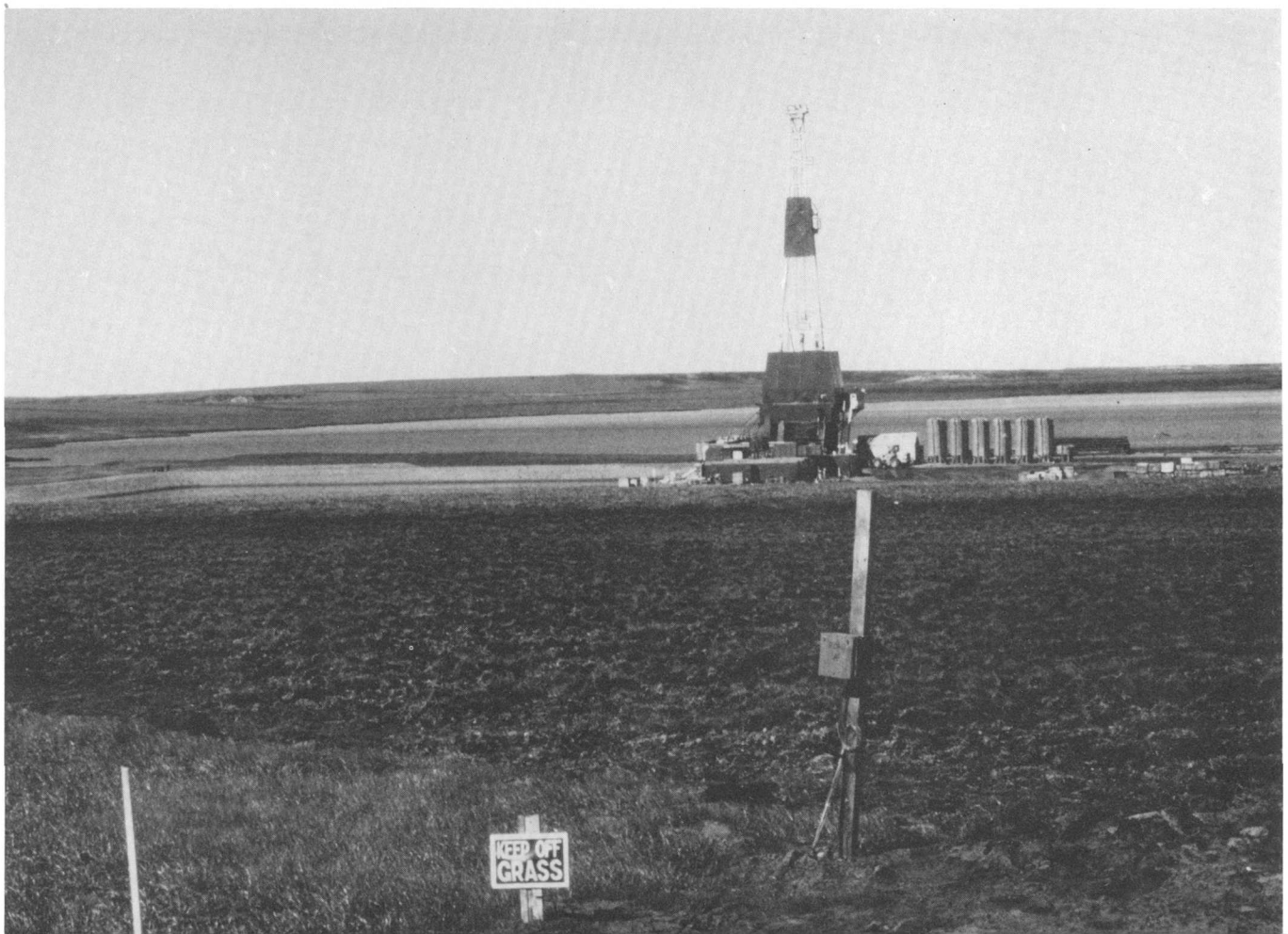
In addition to the drilling and geophysical investigations, a number of geologic studies are underway by the Geological Survey and by contractors to support oil exploration activities. Geochemical studies were conducted to identify the type and the amount of organic matter in rocks from wells and outcrop and to determine thermal history and source rock potential. Studies of selected rock units in NPRA and adjacent areas were carried out to determine their depositional environment, structure, petroleum potential, reservoir properties, and stratigraphic relationships. Structural and stratigraphic field studies were conducted to supplement well and seismic data and to resolve problems arising from interpretation of subsurface geologic and geophysical data. Geologic engineering studies performed related to the source of construction materials for roads, airfields, and drilling pads and to the development of designs for expedient surfacings for roads and airfields for summer operation.

The exploration program in fiscal year 1979 will include completion of the two deep wells begun in fiscal year 1978, the Inigok and Tunalik test wells, and reentry and completion of the South Meade test well. Four medium-depth test wells will be drilled in the northern coastal region (Peard, Ikpikpuk, East Simpson, and J. W. Dalton), and drilling will be initiated at two deep-well sites in the southern part of NPRA (Lisburne and Seabee) (see tables 14 and 15.) At the conclusion of the fiscal year 1979 program, a total of 19 exploration wells will have been drilled on the Reserve.

In the Barrow area, the Geological Survey will continue to operate and to maintain the South Barrow gas field as the primary source of natural gas for the community of Barrow and the Federal installations in the vicinity. The new gas field east of South Barrow will be further developed by construction of engineering facilities such as access roads, pipelines, and a pressure reducing station preparatory to the eventual production of gas from the new field.

To complete the petroleum assessment of NPRA and to aid in any further test drilling, approximately 1,600 line miles of seismic data will be acquired, processed, and interpreted from the southern Foothills and the Barrow area. Environmental rehabilitation activities will be continued in areas of the Reserve not previously completed.

Test plots for grass for revegetation at the Inigok Test Well No. 1 in July 1978.




IBM
System 370


3600 READER PRINTER

Program Support Activities

ADMINISTRATIVE DIVISION

General Administration

The cost of executive direction and coordination of U.S. Geological Survey programs by the Office of the Director and of the financial, procurement, personnel, and other administrative services provided by the Administrative Division is called General Administrative Expenses. During fiscal year 1978, these expenses (table 33) amounted to $16.5 million. They were funded from (1) the "General Administration" budget activity, $3.7 million, (2) assessments on the directly appropriated activities, $9.1 million, and (3) assessments on the reimbursable programs, $3.7 million. No assessments are made on cooperative funds from State and local governments. General Administrative Expenses represent only about 3.3 percent of the total Survey budget.

Administrative Management

The several administrative management activities of the Administrative Division are carried on at Survey Headquarters in Reston, Va., and at three major Regional Centers—Eastern Region, also headquartered at Reston; Central Region, headquartered in Denver, Colo.; and Western Region, headquartered in Menlo Park, Calif. In addition, there are satellite offices in Atlanta, Ga., Rolla, Mo., Metairie, La., Sioux Falls, S. Dak., Flagstaff, Ariz., and Anchorage, Alaska, which provide primarily personnel and facilities or supply management service functions to Survey installations in the immediate or nearby areas.

As with the program activities of the Survey, the support activities are continuously engaged in trying to improve their capability to provide their services in the most effective and efficient manner. In addition to a continuing review of how to improve its regular personnel, procurement, fiscal, and general service activities, the Administrative Division routinely undertakes numerous special projects aimed at implementing newly mandated administrative requirements, changes in the location or thrust of program activities, and revisions to one or more major portions of the Survey's administrative services delivery system. Some of these are described below.

Above: Computer operator running the nationwide IBM 370/158 system in support of the U.S. Geological Survey scientific community. Below: Reader-printer can be used to make paper copies of reports from microfiche.

PROCUREMENT AND CONTRACTING ACTIVITIES

As a means of more effectively and efficiently accomplishing its goals, the Survey has increased its reliance on procurement and contracting methods to obtain the products and services needed to carry out its programs. Over the last few years, there have been major changes in the size and composition of the procurement program.

The most striking change is the growth of the procurement program. Since 1970, procurement activity has not only increased in relative terms, from 14 to 53 percent of total program dollars, but in absolute terms, from $23 million to $350 million, or roughly 1,500 percent.

Another major change has taken place in the type of goods and services being procured. At the start of the decade, practically all Survey procurement was for commercially available equipment and very little for research. Procurement actions were relatively simple and generally of small dollar value. Recently, however, Survey procurement has changed drastically and now includes a large number of research and development contracts, research grants, complicated service contracts, and the purchase of many sophisticated and specialized pieces of equipment that are frequently not available on the commercial market in the necessary configuration, thus requiring very complex procurements.

Two policy areas of potentially great impact on the Survey's procurement activities have received close review and study over the last few months. One is the recently enacted Federal Grant and Cooperative Agreement Act of 1977. This act distinguishes Federal program activities in which the primary purpose is procurement from those in which the primary purpose is assistance. A contract is defined as the appropriate method for accomplishing procurement; a grant, where Federal involvement is small, and a cooperative agreement, where Federal involvement is substantial, are defined as the appropriate methods for accomplishing assistance. The other major policy area is the current effort to revise Office of Management and Budget Circular A–76, which provides government-wide guidance on the conditions and circumstances under which a Federal program activity will be performed in-house or contracted out. Both of these policy documents may have a major impact on the size and scope of the Survey's procurement activities in the future.

PERSONNEL MANAGEMENT

In the area of personnel management, several significant activities have been accomplished.

As a result of new governmentwide requirements imposed by the Civil Service Commission, the Geological Survey has developed and implemented a new personnel evaluation method for ranking and evaluating candidates for promotional opportunities. The method uses job-related placement factors known as KSAP's (Knowledge, Skills, Abilities, and Personal Characteristics). These factors, determined by personnel specialists and selecting officials, are used to determine basic eligibility for the position and to rank the best qualified candidates among those eligible. The major benefits of this new method are that the employee is much better informed about the specific requirements of the job and the selecting official is better able to evaluate the employee's specific experience in terms of those requirements.

As part of the Administrative Division's effort to provide greater local administrative support to field offices, a new personnel office has been established in Metairie. This office provides direct personnel management support to the Conservation Division's Outer Continental Shelf operations in the Gulf Coast area.

Because of its experience with Flexitime, the Survey has become a nationally recognized source of information on the subject of flexible working schedules. Interested organizations throughout the Federal Government, State and local governments, labor unions, universities, and private companies have been referred to the Survey by such organizations as the Civil Service Commission, the National Council on Alternative Working Patterns, the National Center for Productivity and Quality of Working Life, and the Prentice-Hall publication, "Public Personnel Administration." Since 1975, when it first implemented the Flexitime program, which now covers 10,000 employees nationwide, the Survey has responded to over 350 requests for information and has, on many occasions, given presentations to other organizations (both within and outside the Federal Government) interested in exploring the possible use of flexible working schedules. A complete evaluation of the Survey's experience with the use of Flexitime at Reston was published in booklet form by the Survey in February 1978. This booklet, "A Comprehensive Report of a One-Year Experiment with Flexitime at the U.S. Geological Survey," has become a widely requested source of information on this subject. As a followup, an evaluation of our experience since extending Flexitime to the entire organization is planned and will furnish valuable information to the Federal Government and other interested organizations.

SPACE AND FACILITIES MANAGEMENT

Continuing efforts are being made to make the most effective use of Survey buildings and facilities. Several major improvements have been initiated during the year.

At Sioux Falls, an area where water conservation is especially essential, a recirculating water system has been designed for installation at the Earth Resources Observation Systems Data Center. The system will recycle all the water used for photograph processing and air-conditioning. In addition, feasibility and design studies have been completed and construction is ready to begin on modifications that will permit the use of solar energy for heating the water used at the center.

At the Central Region headquarters, renovation has been completed on the Survey's space that was destroyed by fire in March 1976. The damaged section has been given a new roof, and the renovated interior is nearly ready to be occupied. Two other buildings occupied by the Survey have been extensively renovated and enlarged. One is now in use with a new and safer radioisotope laboratory, and the other will be ready for occupancy by the end of 1978.

In the Western Region, a project has been initiated to strengthen several Survey buildings in Menlo Park to withstand seismic disturbances. In Hawaii, the Survey, working jointly with the National Park Service, is developing a program to upgrade and to renovate the Hawaii Volcano Observatory and to establish a visitor information and interpretive center in the original observatory building.

IMPROVEMENTS IN INFORMATION MANAGEMENT

As part of the President's program to reduce the reporting burden placed upon the public by Government agencies, the Survey has been conducting a program to reduce the number of reports which it requires from the public and the manhours spent completing them. The number of manhours has been reduced by 11 percent, and several reports have been eliminated entirely.

The four-volume "Survey Manual," the major system of policy and procedures directives, has been revised and brought up-to-date through the use of contract assistance. Procedures have been developed to implement and monitor compliance with the provisions of the Freedom of Information and Privacy Acts.

In the area of administrative information systems, implementation of the first phase of the Procurement Management Information System and installation of the Administrative Division's data entry terminal network in Reston, Denver, and Menlo Park have been completed. In addition, modernizing pro-

cedures for entering data into the Bureau Accounting System by utilizing a video terminal system has nearly been completed. Tests are underway to evaluate the concept of extending the entry of certain kinds of financial data to field installations.

The use of word processing technology, which is very closely related to computer technology, offers potential benefits and savings to any organization with a large volume of correspondence. For an organization like the Survey, which has not only a large volume of correspondence but also a large publications workload involving repeated typing in the process of manuscript preparation, editing, and, eventually, typesetting for printing, the opportunities for savings are even greater. To assure that the maximum benefits, in the form of manpower savings, are realized from this rapidly growing and changing technology, the Division has become heavily involved in assisting Survey personnel select the proper word processing applications and the proper equipment for those applications.

COMPUTER CENTER DIVISION

Scientific research within the U.S. Geological Survey is supported by the Computer Center Division's nationwide system of computer facilities. The primary Survey batch processing installation, located in the National Center, Reston, Va., consists of two IBM 370/155 computers. Together, these computers provide high-speed magnetic core memory for 8 million characters of information and online magnetic disk storage for 8.9 billion characters of information. During fiscal year 1978, more than 1,100 users from over 100 remote locations, as well as the National Center, submitted approximately 376,000 jobs to these computers. Most of the terminals used to access these computers are run by the Operating Divisions. To supply required additional batch capacity during fiscal year 1978, a contract was signed with American Management Systems to provide computing services. The services are provided through access by users to one of the Survey's existing batch processor communications controllers, ensuring that the user can use identical procedures regardless which computer processes the data.

The time-sharing needs of the Geological Survey are being supported by the three Honeywell Multics computers located in Denver, Colo., Menlo Park, Calif., and Reston. Each system provides high-speed magnetic core memory for 2 million characters of information, bulk store memory (faster than disk) storage for 8 million characters of information, and 1.2 billion characters of disk storage. To allow Geological Survey scientists to access one or more of these computers, the Computer Center Division has acquired a nationwide communications network from TYMNET, Inc., which provides reliable connections from many varieties of terminals located in all major metropolitan areas for the cost of a local telephone call. In essence, users can access any of the three Multics locations from any location in the United States.

Approximately 1,400 users are registered on one or more of the three Honeywell Multics systems and are currently averaging more than 21,000 interactive sessions per month.

In addition, the Survey operates the following large computers:

- Burroughs Corporation Model B–6700 computer at the Earth Resources Observation Systems Data Center in Sioux Falls, S. Dak.
- Systems Engineering Laboratories, Inc., Model 86 computer at the Mid-Continent Mapping Center, Rolla, Mo.
- Digital Equipment Corporation Model 11/15, Model 11/20, Model 11/40, and Model 11/45 computers at Flagstaff, Ariz.

The Geological Survey has obtained many minicomputers and minicomputer-type devices to support local field and laboratory investigations. These computers are dedicated to specific local requirements and operate in real time.

Some examples of computer applications in operation or under development during 1978 are as follows:

- Conversion of the Cartographic Automatic Mapping package to the Multics computers.
- Implementation of a set of programs that allow the system management programs within the IBM systems to better handle peak user requirements.
- Operation of a real-time seismic monitoring and earthquake detection network.
- Maintenance of the National Water Data Storage and Retrieval System, including ground-water data.
- Simulation of surface-water and ground-water behavior in areas expected to be mined for coal and oil shale.
- Use of an Economic Simulation System for analysis of lease sale tracts.
- Tracking of Bureau of Land Management and Geological Survey activities as an aid to interbureau and interdivisional program coordination leading to Outer Continental Shelf lease sales.
- Tracking of oil spills from satellite-obtained data.
- Custom enhancement of Landsat pictures with areas of special geologic interests.

Highlights of computer support activities included the following:

- Acquisition of additional computing services to prevent the recent overload of IBM 370/155 computers from reaching unmanageable proportions.
- Implementation of a set of programs to allow the IBM system management programs to better handle the peak user demands. These programs are estimated to have saved as much as 20 percent in systems overhead.
- Major conversion effort to convert many software packages from the overload IBM systems to the Honeywell Multics.

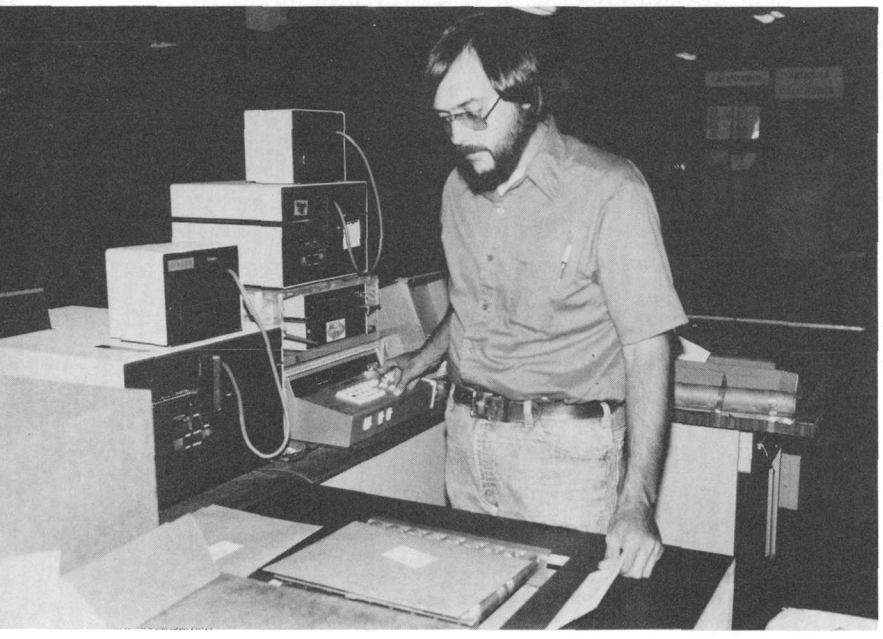
PUBLICATIONS DIVISION

Results of research and investigations conducted by the U.S. Geological Survey are made available to the public through increasingly diverse information services and publications.

The Publications Division edits the Survey's scientific and technical publications, including professional papers, bulletins, water-supply papers, and circulars. The Division also prepares nontechnical booklets designed to communicate many of the Survey programs to the public in a clear and understandable manner. In addition to preparing reproduction manuscripts for geologic, hydrologic, and other thematic maps, the Division prints topographic and thematic maps, and warehouses and distributes all Survey maps and books.

The number of reports approved for publication by the Geological Survey continues to increase. About 59 percent of the 3,713 reports prepared in fiscal year 1978 were designated for publication in professional journals and monographs outside the Survey; about 24 percent were placed in open file; and the remainder were scheduled for publication by the Survey (table 35). The Survey also produced over 10,263 topographic, hydrologic, and geologic maps in fiscal year 1978 (table 36). Most of these maps were scheduled for publication.

Electronic metering equipment is used to determine the exact postage needed to mail an open-file report to a customer.



Highlights

- Printing of 22.6 million copies of 5,855 different maps.
- Distribution of 8.7 million copies of maps of which 6.2 million copies were sold for $6.1 million.
- Transmittal of 144 technical manuscripts to the Government Printing Office for printing.
- Distribution of 215,918 copies of technical reports of which 53,931 copies were sold for $157,343.
- Release of 1,016 open-file reports of which 27,804 copies were sold for $183,047.

Guide to Information and Publications

Throughout this report, reference has been made to information services and publications of the Geological Survey. This section describes how and where the public may acquire information and obtain products.

To buy Survey book publications and maps of areas east of the Mississippi River and to request Survey circulars, catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Branch of Distribution
1200 S. Eads St.
Arlington, VA 22202

To buy maps of areas west of the Mississippi River and to request Survey catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Branch of Distribution
Box 25286, Bldg. 41, Federal Center
Denver, CO 80225

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

U.S. Geological Survey
Distribution Section
101 12th Ave., Box 12
Fairbanks, AK 99701

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

U.S. Geological Survey
Open-File Services Section
Box 25425, Federal Center
Denver, CO 80225

To get on the mailing list for the monthly list of "New Publications of the Geological Survey" (free), write:

U.S. Geological Survey
Branch of Data Systems
329 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To subscribe to the "Earthquake Information Bulletin" write:

Superintendent of Documents
Government Printing Office
Washington, DC 20402

To buy books and maps of local areas and general interest, visit the U.S. Geological Survey Public Inquiries Offices in the following states:

Alaska:
108 Skyline Bldg.
508 2d Ave.
Anchorage, AK 99501

California:
7638 Federal Bldg.
300 N. Los Angeles St.
Los Angeles, CA 90012

504 Customhouse
555 Battery St.
San Francisco, CA 94111

Colorado:
169 Federal Bldg.
1961 Stout St.
Denver, CO 80294

Texas:
1C45 Federal Bldg.
1100 Commerce St.
Dallas, TX 75242

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

Virginia:
302 National Center, Rm. 1C402
12201 Sunrise Valley Dr.
Reston, VA 22092

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

Washington, D.C.
1028 General Services Bldg.
19th and F Sts., NW
Washington, DC 20244

To obtain information on cartographic data, write or visit the U.S. Geological Survey, National Cartographic Information Centers (NCIC), in the following states:

California:
NCIC–West
345 Middlefield Rd.
Menlo Park, CA 94025

Colorado:
NCIC–Rocky Mountain
Box 25046, Stop 501
Bldg. 25, Federal Center
Denver, CO 80225

Missouri:
NCIC–Mid-Continent
1400 Independence Road
Rolla, MO 65401

Virginia:
NCIC–Headquarters
507 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

NCIC–East
536 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To obtain information on satellite and space photography, write or visit:

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

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

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

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

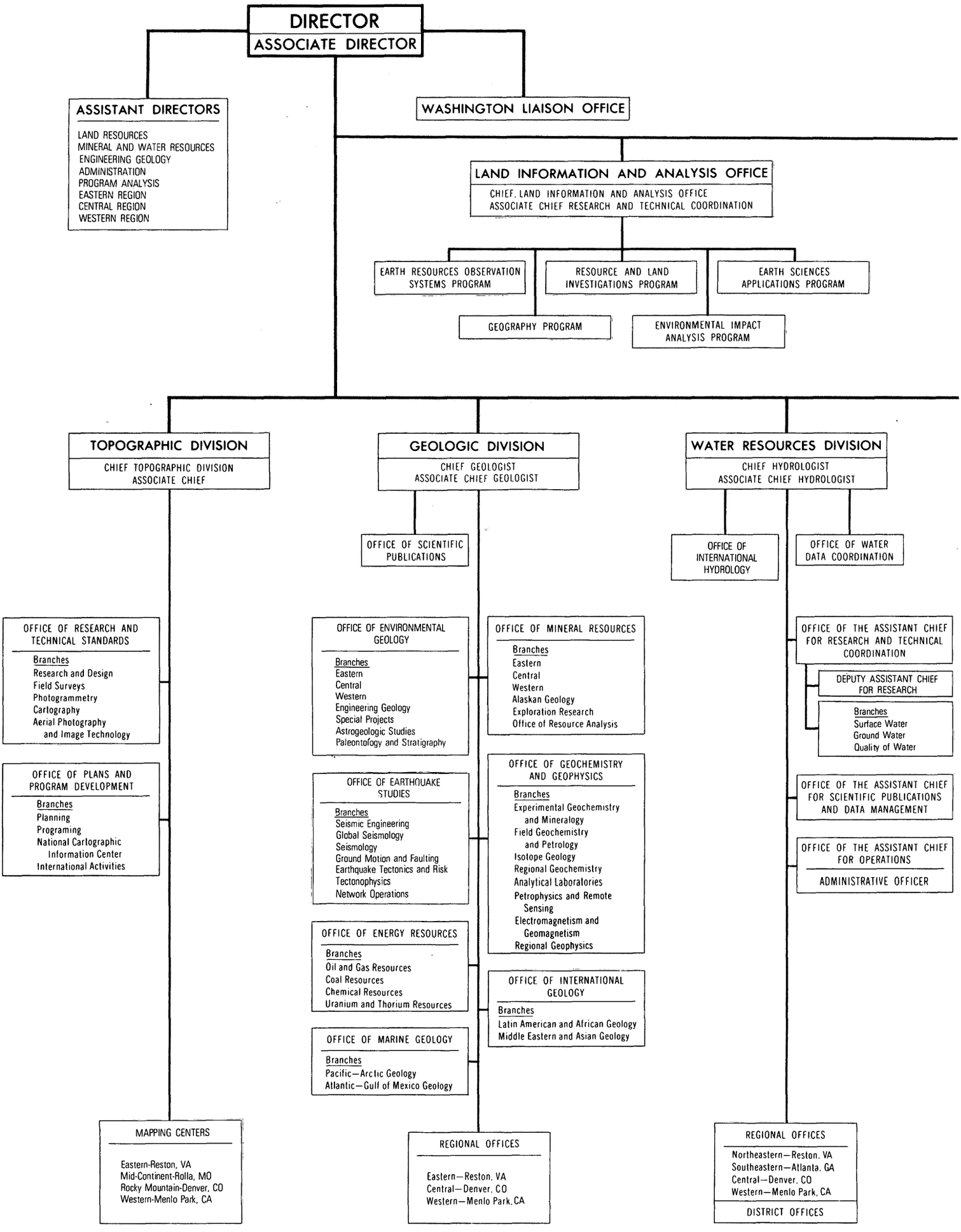
U.S. Geological Survey
Office of Water Data Coordination
417 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

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

U.S. Geological Survey
Water Information Group
420 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

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

U.S. Geological Survey
Geologic Inquiries Group
907 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092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ASSOCIATE CHIEF RESEARCH AND TECHNICAL COORDINATION
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RESOURCE AND LAND INVESTIGATIONS PROGRAM
EARTH SCIENCES APPLICATIONS PROGRAM
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ENVIRONMENTAL IMPACT ANALYSIS PROGRAM
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GEOLOGIC DIVISION
CHIEF GEOLOGIST
ASSOCIATE CHIEF GEOLOGIST
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Field Surveys
Photogrammetry
Cartography
Aerial Photography and Image Technology
OFFICE OF PLANS AND PROGRAM DEVELOPMENT
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Special Projects
Astrogeologic Studies
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OFFICE OF EARTHQUAKE STUDIES
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Global Seismology
Seismology
Ground Motion and Faulting
Earthquake Tectonics and Risk
Tectonophysics
Network Operations
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Chemical Resources
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Office of Resource Analysis
OFFICE OF GEOCHEMISTRY AND GEOPHYSICS
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Isotope Geology
Regional Geochemistry
Analytical Laboratories
Petrophysics and Remote Sensing
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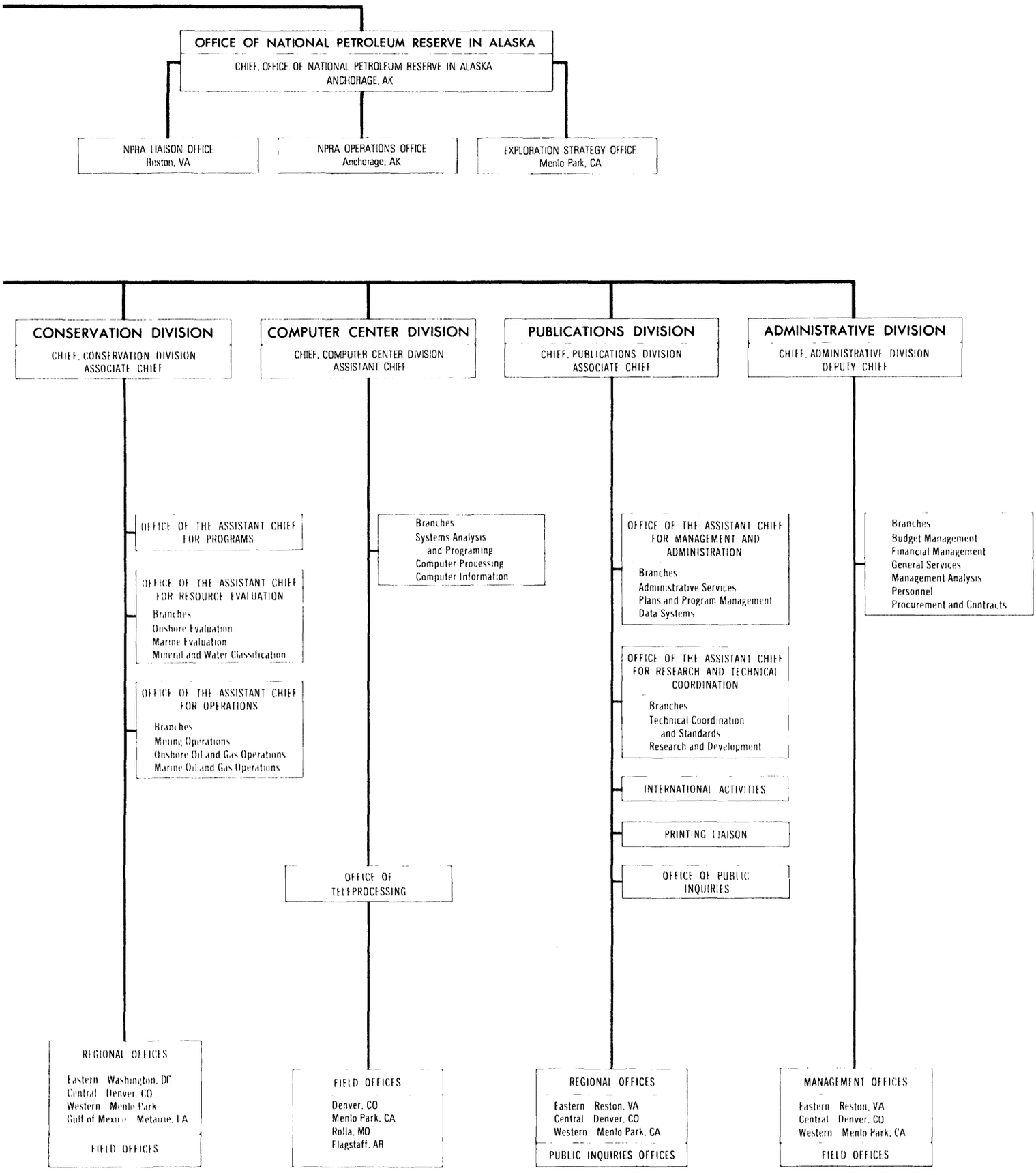
DEPUTY ASSISTANT CHIEF FOR RESEARCH
Branches
Surface Water
Ground Water
Quality of Water
OFFICE OF THE ASSISTANT CHIEF FOR SCIENTIFIC PUBLICATIONS AND DATA MANAGEMENT
OFFICE OF THE ASSISTANT CHIEF FOR OPERATIONS
ADMINISTRATIVE OFFICER
MAPPING CENTERS
Eastern-Reston, VA
Mid-Continent-Rolla, MO
Rocky Mountain-Denver, CO
Western-Menlo Park, CA
REGIONAL OFFICES
Eastern—Reston, VA
Central—Denver, CO
Western—Menlo Park, CA
REGIONAL OFFICES
Northeastern—Reston, VA
Southeastern—Atlanta, GA
Central—Denver, CO
Western—Menlo Park, CA
DISTRICT OFFICES

Organizational and Statistical Data

U.S. Geological Survey Chart of Organization



U.S. Geological Survey Offices

HEADQUARTERS OFFICES

12201 Sunrise Valley Drive
National Center, Reston, VA 22092

[As of September 30, 1978. Update of this list will be found on p. 208]

OFFICE OF THE DIRECTOR

Official	Name	Telephone Number	Address
Director	H. William Menard	(703) 860–7411	National Center, STOP 101
Associate Director	W. A. Radlinski	(703) 860–7412	National Center, STOP 102
Special Assistant (Washington Liaison)	Jane H. Wallace	(202) 343–3888	Rm. 7343, Interior Bldg., Washington, DC 20240
Assistant Director—Land Resources	James R. Balsley	(703) 860–7488	National Center, STOP 104
Assistant Director—Mineral and Water Resources	[Vacant]	(703) 860–7481	National Center, STOP 171
Assistant Director—Geologic Engineering	Henry W. Coulter	(703) 860–7491	National Center, STOP 106
Assistant Director—Administration	Edmund J. Grant	(703) 860–7201	National Center, STOP 201
Assistant Director—Program Analysis	Dale D. Bajema	(703) 860–7435	National Center, STOP 105
Assistant Director—Eastern Region	William B. Overstreet	(703) 860–7414	National Center, STOP 109
Assistant Director—Central Region	Robert E. Evans	(303) 234–4630	Box 25046, STOP 101, Denver Federal Center, Denver, CO 80225
Assistant Director—Western Region	George E. Robinson	(415) 323–8111	345 Middlefield Road, Menlo Park, CA 94025
Congressional Liaison Officer	Talmadge W. Reed	(703) 860–6438	National Center, STOP 112
Information Officer	Frank H. Forrester	(703) 860–7444	National Center, STOP 119

TOPOGRAPHIC DIVISION

Official	Name	Telephone Number	Address
Chief	Rupert B. Southard	(703) 860–6231	National Center, STOP 516
Associate Chief	[Vacant]	(703) 860–6232	National Center, STOP 516
Office of Research and Technical Standards, Chief	Roy R. Mullen	(703) 860–6291	National Center, STOP 519
Office of Plans and Program Development, Chief	Doyle G. Frederick	(703) 860–6281	National Center, STOP 514
National Cartographic Information Center, Chief	Gary W. North, Jr.	(703) 860–6187	National Center, STOP 507

GEOLOGIC DIVISION

Official	Name	Telephone Number	Address
Chief Geologist	Dallas L. Peck	(703) 860–6531	National Center, STOP 910
Associate Chief Geologist	[Vacant]	(703) 860–6531	National Center, STOP 910
Deputy Chief Geologist, Operations	Penelope Henshaw	(703) 860–6532	National Center, STOP 910
Deputy Chief Geologist, Program and Budget	Donald H. Dow	(703) 860–6544	National Center, STOP 910
Office of Scientific Publications, Chief	Robert E. Davis	(703) 860–6575	National Center, STOP 904
Office of Environmental Geology, Chief	John C. Reed, Jr.	(703) 860–6411	National Center, STOP 908
Office of Earthquake Studies, Chief	Robert L. Wesson	(703) 860–6471	National Center, STOP 905
Office of Energy Resources, Chief	Charles Masters	(703) 860–6431	National Center, STOP 915
Office of Marine Geology, Chief	Charles Masters, Acting	(703) 860–6431	National Center, STOP 915
Office of Mineral Resources, Chief	George E. Becraft	(703) 860–6562	National Center, STOP 913
Office of Geochemistry and Geophysics, Chief	Robert Tilling	(703) 860–6584	National Center STOP 906
Office of International Geology, Chief	John A. Reinemund	(703) 860–6418	National Center, STOP 917

WATER RESOURCES DIVISION

Official	Name	Telephone Number	Address
Chief Hydrologist	Joseph S. Cragwall, Jr.	(703) 860–6921	National Center, STOP 409
Associate Chief Hydrologist	O. Milton Hackett	(703) 860–6921	National Center, STOP 408
Assistant Chief Hydrologist, Scientific Publications and Data Management	Solomon M. Lang, Acting	(703) 860–6877	National Center, STOP 440
Assistant Chief Hydrologist, Operations	Thomas J. Buchanan	(703) 860–6801	National Center, STOP 441

WATER RESOURCES DIVISION—Continued

Official	Name	Telephone Number	Address
Assistant Chief Hydrologist, Research and Technical Coordination	Leslie B. Laird	(703) 860–6971	National Center, STOP 414
Office of Water Data Coordination, Chief	R. H. Langford	(703) 860–6931	National Center, STOP 417
Office of International Activities, Chief	James R. Jones	(703) 860–6548	National Center, STOP 470

CONSERVATION DIVISION

Official	Name	Telephone Number	Address
Chief	Don E. Kash	(703) 860–7524	National Center, STOP 600
Associate Chief	Hillary A. Oden	(703) 860–7524	National Center, STOP 600
Assistant Chief, Resources Evaluation	Robert L. Rioux	(703) 860–7571	National Center, STOP 640
Assistant Chief, Operations	John Duletsky	(703) 860–7515	National Center, STOP 620
Assistant Chief, Programs	Harold L. Pumphrey	(703) 860–7581	National Center, STOP 630

LAND INFORMATION AND ANALYSIS OFFICE

Official	Name	Telephone Number	Address
Chief	James R. Balsley	(703) 860–7488	National Center, STOP 104
Associate Chief, Research and Technical Coordination	Philip Cohen	(703) 860–7471	National Center, STOP 703
Earth Resources Observation Systems Program, Chief	John M. DeNoyer	(703) 860–7881	National Center, STOP 730
Geography Program, Chief	James R. Anderson	(703) 860–6344	National Center, STOP 710
Resource and Land Investigations Program, Chief	J. Ronald Jones	(703) 860–6717	National Center, STOP 750
Environmental Impact Analysis Program, Chief	Daniel B. Krinsley	(703) 860–7455	National Center, STOP 760
Earth Sciences Applications Program, Chief	Donald R. Nichols	(703) 860–6961	National Center, STOP 720

OFFICE OF NATIONAL PETROLEUM RESERVE IN ALASKA

Official	Name	Telephone Number	Address
Chief	George Gryc	(907) 276–7422	* 2525 "C" Street—Suite 400, Anchorage, AK 99503
Technical Officer	Valentine Zadnik	(703) 860–6208	National Center, STOP 151
Program Officer	Keith M. Beardsley	(703) 860–6208	National Center, STOP 151

COMPUTER CENTER DIVISION

Official	Name	Telephone Number	Address
Chief	Carl E. Diesen	(703) 860–7106	National Center, STOP 801
Assistant Chief	Charles H. Tyler	(703) 860–7109	National Center, STOP 801
Office of Teleprocessing	Ralph N. Eicher	(703) 860–7119	National Center, STOP 805

PUBLICATIONS DIVISION

Official	Name	Telephone Number	Address
Chief	Harry D. Wilson, Jr.	(703) 860–7181	National Center, STOP 341
Associate Chief	Melvin E. Hanes	(703) 860–7181	National Center, STOP 341
Assistant Chief, Management and Administration	Van M. Rayburn	(703) 860–7181	National Center, STOP 341
Assistant Chief, Research and Technical Coordination	Bernard J. Thien.	(703) 860–7183	National Center, STOP 341
Office of Public Inquiries	Robbie S. Ritchey	(703) 860–7185	National Center, STOP 341
Printing Liaison Office	Jesse R. Upperco	(703) 860–7622	National Center, STOP 330
International Activities	A. L. Dilonardo	(703) 860–7186	National Center, STOP 341

ADMINISTRATIVE DIVISION

Official	Name	Telephone Number	Address
Chief	Edmund J. Grant	(703) 860–7201	National Center, STOP 201
Deputy Chief	Lewis Menen	(703) 860–7203	National Center, STOP 202
Personnel Officer	Maxine C. Millard	(703) 860–6127	National Center, STOP 215
Contracts Officer	William Burk	(703) 860–7261	National Center, STOP 205

* Office of National Petroleum Reserve in Alaska is headquartered in Anchorage, Alaska.

SELECTED FIELD OFFICES

TOPOGRAPHIC DIVISION

REGIONAL MAPPING CENTER

Mapping Center	Chief	Telephone Number	Address
Eastern	Peter F. Bermel	(703) 860–6352	National Center, STOP 567
Midcontinent	Lawrence H. Borgerding	(314) 364–3680, ext. 111	1400 Independence Rd., Rolla, MO 65401
Rocky Mountain	Albert E. Letey	(303) 234–2351	Box 25046, STOP 510, Denver Federal Center, Denver, CO 80225
Western	John R. Swinnerton	(415) 323–8111, ext. 2411	345 Middlefield Rd., Menlo Park, CA 94025

GEOLOGIC DIVISION

REGIONAL OFFICES

Region	Regional Geologist	Telephone Number	Address
Eastern	Eugene G. Roseboom, Jr.	(703) 860–6631	National Center, STOP 953
Central	William R. Keefer	(303) 234–3625	Box 25046, STOP 911, Denver Federal Center Denver, CO 80225
Western	Joseph I. Ziony	(415) 323–8111,	345 Middlefield Rd., Menlo Park, CA 94025

WATER RESOURCES DIVISION

REGIONAL OFFICES

Region	Regional Hydrologist	Telephone Number	Address
Northeastern	James E. Biesecker	(703) 860–6985	National Center, STOP 433
Southeastern	Robert J. Dingman	(404) 881–4395	1459 Peachtree St., NE., Suite 200, Atlanta, GA 30392
Central	Alfred Clebsch, Jr.	(303) 234–3661	Box 25046, STOP 406, Denver Federal Center, Denver, CO 80225
Western	William H. Robinson	(415) 323-8111, ext. 2337	345 Middlefield Rd., Menlo Park, CA 94025

DISTRICT OFFICES

State	District Chief	Telephone Number	Address
Alabama	William J. Powell	(205) 752–8104	P.O. Box V, 202 Oil and Gas Board Bldg., University of Alabama University, AL 35486
Alaska	Harry Hulsing	(907) 277–5526	218 E St., Anchorage, AK 99501
Arizona	Robert D. Mac-Nish	(602) 792–6671	Federal Bldg., 301 W. Congress St., Tucson, AZ 85701
Arkansas	Richard T. Sniegocki	(501) 378–5246	2301 Federal Office Bldg., 700 W. Capital Ave., Little Rock, AR 72201
California	Richard M. Bloyd	(415) 323–8111, ext. 2326	855 Oak Grove Ave., Menlo Park, CA 94025
Colorado	James F. Blakey	(303) 234–5029	Box 25046, STOP 415, Denver Federal Center, Denver, CO 80225
Connecticut	David McCartney	(203) 244–2528	135 High St. Room 235 Hartford, CT 06103

WATER RESOURCES DIVISION/DISTRICT OFFICES—Continued

State	District Chief	Telephone Number	Address
Delaware	Walter F. White, Jr.	(301) 828–1535	See Maryland District Office
District of Columbia	Walter F. White, Jr.	(301) 828–1535	See Maryland District Office
Florida	Clyde S. Conover	(904) 386–1118	325 John Knox Rd., Suite F–240, Tallahassee, FL 32303
Georgia	John R. George	(404) 221–4858	6481 Peachtree Industrial Blvd., Suite B, Doraville, GA 30360
Hawaii	Benjamin L. Jones	(808) 546–8331	P.O. Box 50166, 300 Ala Moana Blvd., Honolulu, HI 96850
Idaho	Ernest F. Hubbard, Jr.	(208) 384–1750	Box 036 Federal Bldg., Room 365, 550 W. Fort St., Boise, ID 83724
Illinois	Larry G. Toler	(217) 359–3918	P.O. Box 1026, 605 N. Neil St., Champaign, IL 61820
Indiana	Dennis K. Stewart	(317) 269–7101	1819 N. Meridian St., Indianapolis, IN 46202
Iowa	Oscar Lara	(319) 338–0581, ext. 521	P.O. Box 1230, 400 S. Clinton St., Iowa City, IA 52240
Kansas	Joseph S. Rosenshein	(913) 864–4321	1950 Ave. A, Campus West, University of Kansas, Lawrence, KS 66045
Kentucky	Philip A. Emery	(502) 582–5241	572 Federal Bldg., 600 Federal Pl. Louisville, KY 40202
Louisiana	Albert N. Cameron	(504) 389–0281	P.O. Box 66492, 6554 Florida Blvd., Baton Rouge, LA 70896
Maine	John A. Baker	(617) 223–2822	See Massachusetts District Office
Maryland	Walter F. White, Jr.	(301) 828–1535	208 Carrol Bldg., 8600 La Salle Rd. Towson, MD 21204
Massachusetts	John A. Baker	(617) 223–2822	150 Causeway St., Suite 1001, Boston, MA 02114
Michigan	T. Ray Cummings	(517) 372–1910, ext. 561	6520 Mercantile Way, Suite 5, Lansing, MI 48910
Minnesota	Donald R. Albin	(612) 725–7841	1033 Post Office Bldg., St. Paul, MN 55101
Mississippi	Lamar E. Carroon	(601) 969–4600	430 Bounds St., Jackson, MS 39206
Missouri	Donald L. Coffin	(314) 364–3680, ext. 185	1400 Independence Rd., M.S. 200, Rolla, MO 65401
Montana	George M. Pike	(406) 449–5263	P.O. Box 1696, 421 Federal Bldg., Helena, MT 59601
Nebraska	[Vacant]	(402) 471–5082	406 Federal Bldg., and U.S. Courthouse, 100 Centennial Mall North, Lincoln, NE 68508
Nevada	Frank T. Hidaka	(702) 882–1388	227 Federal Bldg., 705 N. Plaza St., Carson City, NV 89701
New Hampshire	John A. Baker	(617) 223–2822	See Massachusetts District Office

WATER RESOURCES DIVISION/DISTRICT OFFICES—Continued

State	District Chief	Telephone Number	Address
New Jersey	Harold Meisler	(609) 989–2162	P.O. Box 1238, 436 Federal Bldg., 402 E. State St., Trenton, NJ 08607
New Mexico	William E. Hale	(505) 766–2246	P.O. Box 26659, Western Bank Bldg., Room 809, 505 Marquette N.W., Albuquerque, NM 87125
New York	Laurance A. Martens	(518) 472–3107	P.O. Box 1350, 343 U.S. Post Office and Courthouse Bldg., Albany, NY 12201
North Carolina	Ralph C. Heath	(919) 755–4510	P.O. Box 2857, Room 432, Century Postal Station, Raleigh, NC 27602
North Dakota	Grady Moore	(701) 255–4011, ext. 601	821 East Interstate Ave., Room 332, New Federal Bldg., 3d St. and Rosser Ave., Bismark, ND 58501
Ohio	David E. Click	(614) 469–5553	975 West Third Ave., Columbus, OH 43212
Oklahoma	James H. Irwin	(405) 231–4256	201 N.W. 3d St., Rm. 621, Oklahoma City, OK 73102
Oregon	Stanley F. Kapustka	(503) 234–3361, ext. 4776	P.O. Box 3202, 830 NE. Holladay St., Portland, OR 97232
Pennsylvania	Don C. Perkins, Acting	(717) 782–3468	P.O. Box 1107, 4th Floor, Federal Bldg., 228 Walnut St., Harrisburg, PA 17108
Puerto Rico	Craig B. Bentley	(809) 783–4660	P.O. Box 34168, Bldg. 652, Ft. Buchanan, PR 00934
Rhode Island	John A. Baker	(617) 223–2822	See Massachusetts District Office
South Carolina	Rodney N. Cherry	(803) 765–5966	2001 Assembly St., Suite 200, Columbia, SC 29201
South Dakota	Richard E. Fidler	(605) 352–8651, ext. 258	P.O. Box 1412, 200–4th St. SW., Room 308, Huron, SD 57350
Tennessee	Stanley P. Sauer	(615) 251–5424	A–413 Federal Bldg., U.S. Courthouse, Nashville, TN 37203
Texas	I. Dale Yost	(512) 397–5766	649 Federal Bldg., 300 E. 8th St., Austin, TX 78701
Utah	Theodore Arnow	(801) 524–5663	8002 Federal Bldg., 125 S. State St., Salt Lake City, UT 84138
Vermont	John A. Baker	(617) 223–2822	See Massachusetts District Office
Virginia	William E. Forrest	(804) 782–2427	200 W. Grace St., Rm. 304, Richmond, VA 23220
Washington	Charles R. Collier	(206) 593–6510	1201 Pacific Ave., Suite 600, Tacoma, WA 98402
West Virginia	David H. Appel	(304) 343–6181, ext. 310	3017 Federal Bldg. and U.S. Courthouse, 500 Quarrier St. E., Charleston, WV 25301

WATER RESOURCES DIVISION/DISTRICT OFFICES—Continued

State	District Chief	Telephone Number	Address
Wisconsin	William B. Mann	(608) 262–2488	1815 University Ave., Room 200, Madison, WI 53706
Wyoming	William Dudley	(307) 778–2220, ext. 2153	P.O. Box 1125, 2120 Capitol Ave., Room 5017, Cheyenne, WY 82001

CONSERVATION DIVISION

REGIONAL OFFICES

Region	Conservation Manager	Telephone Number	Address
Eastern	George Brown	(202) 254–3137	1725 K St., N.W., Suite 204, Washington, DC 20006
Central	George H. Horn	(303) 234–2855	Box 25046, STOP 609, Denver Federal Center, Denver, CO 80225
Gulf of Mexico Outer Continental Shelf Operations	A. Dewey Acuff	(504) 837–4720, ext. 9381	P.O. Box 7944, 434 Imperial Office Blvd., 3301 N. Causeway Blvd., Metairie, LA 70010
Western	[Vacant]	(415) 323–8111, ext. 2093	345 Middlefield Rd., Menlo Park, CA 94025

LAND INFORMATION AND ANALYSIS OFFICE

EARTH RESOURCES OBSERVATION SYSTEMS DATA CENTER

Location	Official in Charge	Telephone Number	Address
South Dakota	Allen H. Watkins	(605) 594–6123	EROS Data Center, Sioux Falls, SD 57198

NATIONAL PETROLEUM RESERVE IN ALASKA

DISTRICT OFFICES

Office	Chief	Telephone Number	Address
NPRA Operations Office	Max Brewer	(907) 276–7422	2525 "C" Street—Suite 400, Anchorage, AK 99503
Exploration Strategy Office	Arthur Bowsher	(415) 323–2917	345 Middlefield Rd., Menlo Park, CA 94025

PUBLICATIONS DIVISION

REGIONAL OFFICES

Region	Official in Charge	Telephone Number	Address
Eastern	Lewis D. Brown	(703) 860–6761	National Center, STOP 328
Central	John L. Heller	(303) 234–4974	Box 25046, STOP 303, Denver Federal Center, Denver, CO 80225
Western	Fred Kunkel	(415) 323–8111, ext. 2537	345 Middlefield Rd., Menlo Park, CA 94025

PUBLIC INQUIRIES OFFICES

Location	Official in Charge	Telephone Number	Address
Alaska	Margaret I. Erwin	(907) 277–0577	108 Skyline Bldg., 508 2d Ave., Anchorage, AK 99501

PUBLICATIONS DIVISION/PUBLIC INQUIRIES OFFICES—Continued

Location	Official in Charge	Telephone Number	Address
California:			
Los Angeles	Lucy E. Birdsall	(213) 688–2850	7638 Federal Bldg., 300 N. Los Angeles St., Los Angeles, CA 90012
San Francisco	Jean V. Molleskog	(415) 556–5627	504 Customhouse, 555 Battery St., San Francisco, CA 94411
Colorado	Alice M. Coleman	(303) 837–4169	169 Federal Bldg., 1961 Stout St., Denver, CO 80294
District of Columbia	Bruce A. Hubbard	(202) 343–8073	1028 GSA Bldg., 19th and F Sts. NW., Washington, DC 20244
Texas	Jimmie L. Wilkinson	(214) 749–3230	1C45 Federal Bldg., 1100 Commerce St., Dallas, TX 75242
Utah	Wendy R. Hassibe	(801) 524–5652	8105 Federal Bldg., 125 S. State St., Salt Lake City, UT 84138
Virginia	A. Ernestine Jones	(703) 860–6167	1C402 National Center, STOP 302, 12201 Sunrise Valley Dr., Reston, VA 22092
Washington	Eula M. Thune	(509) 456–2524	678 U.S. Courthouse, W. 920 Riverside Ave., Spokane, WA 99201

BRANCH OF DISTRIBUTION OFFICES

Location	Official in Charge	Telephone Number	Address
Alaska	Natalie Cornforth	(907) 452–1951	101 12th Ave., Box 12, Fairbanks, AK 99701
Colorado	Dwight F. Canfield	(303) 234–3832	Box 25286, STOP 306, Denver Federal Center, Denver, CO 80225
Virginia	George V. DeMeglio	(703) 557–2781	1200 S. Eads St., Arlington, VA 22202

ADMINISTRATIVE DIVISION

REGIONAL MANAGEMENT OFFICES

Region	Regional Management Officer	Telephone Number	Address
Eastern	Roy Heinbuch	(703) 860–7691	National Center, STOP 290
Central	Thomas J. Lyons	(303) 234–3736	Box 25046, STOP 202, Denver Federal Center, Denver, CO 80225
Western	Avery W. Rogers	(415) 323–2211	345 Middlefield Rd., Stop 11, Menlo Park, CA 94025

COOPERATORS AND OTHER FINANCIAL CONTRIBUTORS

[Cooperators listed are those with whom the U.S. Geological Survey had a written agreement cosigned by Survey officials and the cooperating agency, for financial cooperation in fiscal year 1978. 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 with whom the Geological Survey had research contracts and to whom it supplied research funds are not listed.]

FEDERAL COOPERATORS

Council on Environmental Quality

Department of Agriculture:
- Economics, Statistics, and Cooperatives Service
- Forest Service
- Science and Education Administration
- Soil Conservation Service

Department of the Air Force:
- AFWL/PRP Kirtland AFB
- Air Force Academy
- Headquarters (AFTAC/AC)
- Nellis Air Force Base
- Pease Air Force Base
- Vandenberg Air Force Base

Department of the Army:
- Corps of Engineers
- Fort Carson Military Reservation
- Rocky Mountain Arsenal
- White Sands Missile Range

Department of Commerce:
- Bureau of the Census
- Economic Development Administration
- National Bureau of Standards
- National Oceanic and Atmospheric Administration:
  - National Marine Fisheries Service
  - National Ocean Survey
  - National Weather Service

Department of Defense Agencies and Joint Service Schools:
- Defense Advanced Research Projects Agency
- Defense Civil Preparedness Agency
- Defense Intelligence Agency
- Defense Mapping Agency

Department of Energy:
- Alaska Power Administration
- Albuquerque Operations Office
- Bonneville Power Administration
- Chicago Operations Office
- Division of Geothermal Energy
- Division of Petroleum, Natural Gas, and In-situ Technology
- Division of Uranium Resources and Enrichment
- Federal Energy Regulatory Commission
- Grand Junction Office
- Idaho Operations Office
- Lawrence Livermore Laboratory
- Los Alamos Science Laboratory
- Naval Petroleum and Oil Shale Reserves
- Nevada Operations Office
- Oak Ridge Operations Office
- Office of Environmental Effects
- Richland Operations Office
- San Francisco Operations Office
- Savannah River Operations Office

Department of Health, Education and Welfare

Department of Housing and Urban Development

Department of the Interior:
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Reclamation
- National Park Service
- Office of Library and Information Services
- Office of the Secretary
- Office of Surface Mining Reclamation and Enforcement
- Outer Continental Shelf Program Coordination Office
- Trans-Alaska Pipeline
- U.S. Fish and Wildlife Service
- Water Resources Council

Department of the Navy:
- Civil Engineering Laboratory, Naval Construction Battalion Center
- Naval Facilities Engineering Command
- Naval Oceanographic Office
- Naval Weapons Center, China Lake
- Public Works Center
- U.S. Marine Corps, Camp Pendleton

Department of State:
- Agency for International Development
- International Boundary Commission, United States and Canada
- International Boundary and Water Commission, United States and Mexico

Department of Transportation:
- Federal Highway Administration
- St. Lawrence Seaway Development Corporation

Department of the Treasury:
- U.S. Customs Service

Environmental Protection Agency:
- Cincinnati Research Center
- Corvallis Environmental Research Laboratory
- Lake Shagawa
- Office of Energy, Minerals, and Industry
- Office of Monitoring and Technical Support
- Office of Radiation Programs
- Office of Research and Development
- Office of Water Programs
- Region I, Boston, Massachusetts
- Region II, Edison, New Jersey
- Region V, Chicago, Illinois
- Region VIII, Denver, Colorado
- Region X, Seattle, Washington
- Upper Mississippi River Basin Commission

General Services Administration

National Academy of Sciences

National Aeronautics and Space Administration

National Science Foundation

Navajo and Hopi Indian Relocation Commission

Nuclear Regulatory Commission

Tennessee Valley Authority

United States Arms Control and Disarmament Agency

United States Civil Service Commission

Upper Mississippi River Basin Commission

STATE, COUNTY, AND LOCAL COOPERATORS

Alabama:
- Alabama Highway Department
- Commission of Jefferson County
- Geological Survey of Alabama

Alaska:
- Alaska Department of Fish and Game
- Alaska Department of Natural Resources:
  - Division of Lands and Water Management
  - Division of Geological and Geophysical Surveys
- Alaska Department of Transportation and Public Facilities
- Alaska State Office of the Pipeline Coordinator
- Department of Environmental Conservation
- Fairbanks North Star Borough
- Kenai Peninsula Borough
- Municipality of Anchorage
- State Policy Development and Planning
- Thomas Bay Power Commission

Arizona:
- Arizona Department of Health Services
- Arizona Game and Fish Department
- Arizona State Land Department
- Arizona Water Commission
- City of Flagstaff
- City of Safford
- City of Tucson
- Flood Control District of Maricopa County
- Gila Valley Irrigation District
- Maricopa County Municipal Water Conservation District No. 1
- Metropolitan Water District of Southern California
- Pima County Board of Supervisors
- Salt River Valley Water Users' Association
- San Carlos Irrigation and Drainage District
- Show Low Irrigation Company
- University of Arizona

Arkansas:
- Arkansas Department of Pollution Control and Ecology
- Arkansas Division of Soil and Water Resources
- Arkansas Geologic Commission
- Arkansas State Highway and Transportation Department

California:
- Alameda County Flood Control and Water Conservation District, Zone 7
- Alameda County Water District

California—Continued
- Antelope Valley-East Kern Water Agency
- California Department of Conservation, Division of Mines and Geology
- California Department of Fish and Game
- California Department of Navigation and Ocean Development
- California Department of Transportation
- California Department of Water Resources
- California Water Resources Control Board
- Carpinteria County Water District
- Casitas Municipal Water District
- City and County of San Francisco, Hetch Hetchy Water and Power
- City of Lompoc
- City of Merced
- City of Modesto, Public Works Department
- City of San Diego
- City of Santa Barbara, Public Works Department
- City of Thousand Oaks
- Coachella Valley County Water District
- Contra Costa County Flood Control and Water Conservation District
- County of Modoc, Public Works Department
- County of San Diego, Department of Sanitation and Flood Control
- County of San Mateo, Department of Public Works
- Desert Water Agency
- East Bay Municipal Utility District
- Georgetown Divide Public Utility District
- Goleta County Water District
- Imperial County Department of Public Works
- Imperial Irrigation District
- Indian Wells Valley County Water District
- Kern County Water Agency
- Kings River Conservation District
- Lake County Flood Control and Water Conservation District
- Livermore Amador Valley Water Management Agency
- Los Angeles County Flood Control District
- Los Angeles Department of Water and Power
- Madera County Flood Control and Water Conservation Agency
- Madera Irrigation District
- Marin County Department of Public Works
- Marin Municipal Water District
- Merced Irrigation District
- Metropolitan Water District of Southern California
- Mojave Water Agency
- Montecito County Water District
- Monterey County Flood Control and Water Conservation District
- Napa County Flood Control and Water Conservation District
- North Marin County Water District

California—Continued

Orange County Environmental Management Agency
Orange County Water District
Oroville-Wyandotte Irrigation District
Pacheco Pass Water District
Paradise Irrigation District
Riverside County Flood Control and Water Conservation District
Sacramento County Department of Public Works
San Benito County Water Conservation and Flood Control District
San Bernardino Valley Municipal Water District
San Francisco Water Department
San Luis Obispo County: Engineering Department
San Mateo County Department of Environmental Management
Santa Barbara County Flood Control and Water Conservation District
Santa Barbara County Water Agency
Santa Clara Valley Water District
Santa Cruz City, Flood Control and Water Conservation District, Zone 4
Santa Cruz County, Flood Control and Water Conservation District
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Siskiyou County Flood Control and Water Conservation District
Soquel Creek County Water District
Terra Bella Irrigation District
Tulare County Flood Control District
Turlock Irrigation District
United Water Conservation District
University of California:
Division of Environmental Studies (Davis)
School of Forestry and Conservation (Berkeley)
Ventura County Flood Control District
Western Municipal Water District
Woodbridge Irrigation District
Yolo County Flood Control and Water Conservation District

Colorado:

Arkansas River Compact Administration
Central Yuma Ground Water Management District
City and County of Denver, Board of Water Commissioners
City of Aspen
City of Aurora
City of Colorado Springs:
Department of Public Utilities
Office of the City Manager
City of Fort Collins
City of Glenwood Springs
City of Northglenn
City of Pueblo
Colorado City Water and Sanitation District
Colorado Department of Health, Water Pollution Control Division
Colorado Department of Highways
Colorado Department of Local Affairs
Colorado Department of Water Resources:
Office of the State Engineer
Colorado River Water Conservation District
Colorado Water Conservation Board
Colorado West Area Council of Governments
County of Jackson
Denver Regional Council of Governments
Eagle County Commissioners
El Paso County:
Board of Commissioners
Water Association

Colorado—Continued

Frenchman Ground Water Management District
Jefferson County Health Department
Marks Butte Ground Water Management District
Metropolitan Denver Sewage Disposal District No. 1
Pikes Peak Area Council of Governments
Pitkin County Board of County Commissioners
Pueblo Area Council of Governments
Purgatoire River Water Conservancy District
Rio Grande Water Conservation District
Routt County Commissioners
St. Vrain and Left Hand Water Conservancy District
Sand Hills Ground Water Management District
Southeastern Colorado Water Conservancy District
Southern Ute Indian Tribe
Southwestern Water Conservation District
Urban Drainage and Flood Control District
White River Soil Conservation District

Connecticut:

City of Hartford, Department of Public Works
City of New Britain
City of Torrington
Department of Environmental Protection
Northwest Regional Planning Agency
Town of Fairfield
Town of Manchester
Town of Newtown
Town of South Windsor
Town of Wilton

Delaware:

Delaware Geological Survey, University of Delaware
Department of Natural Resources and Environmental Control
New Castle County, Public Works Department

District of Columbia:

Department of Environmental Services

Florida:

Brevard County
Broward County
Broward County Environmental Quality Control Board
City of Boca Raton
City of Bradenton
City of Clearwater
City of Cocoa
City of Deerfield Beach
City of Fort Lauderdale
City of Gainesville
City of Hallandale
City of Hollywood
City of Jacksonville
City of Pensacola
City of Perry
City of Pompano Beach
City of St. Petersburg
City of Sarasota
City of Tallahassee
City of Tampa
City of West Palm Beach
Collier County
Englewood Water District
Escambia County
Florida Bureau of Water Resources Management:
Florida Department of Environmental Regulation

Florida—Continued
- Florida Department of Natural Resources:
  - Bureau of Geology
  - Division of Parks and Recreation
- Florida Department of Transportation
- Florida Division of Recreation and Parks
- Florida Keys Aqueduct Authority
- Hendry County
- Hillsborough County
- Lake County
- Lake Worth Utilities Authority
- Lee County
- Loxahatchee River Environmental Control District
- Manasota Basin Board
- Manatee County
- Marion County
- Metropolitan Dade County
- Miami-Dade Water and Sewer Authority
- Monroe County
- Nassau County, Ocean Highway and Port Authority
- Northwest Florida Water Management District
- Old Plantation Water Management District
- Orange County
- Palm Beach County
- Pinellas County
- Polk County
- Reedy Creek Improvement District
- St. Johns County
- St. Johns River Water Management District
- Sarasota County
- Seminole County
- South Florida Water Management District
- Southwest Florida Water Management District
- Sumter County Recreation and Water Conservation and Control Authority
- Suwannee River Authority
- Suwannee River Water Management District
- Town of Highland Beach
- University of South Florida
- Village of Tequesta
- Volusia County
- Walton County
- Windermere Water and Navigational Control District
- Winter Haven Lake Region

Georgia:
- Chatham County
- City of Albany
- City of Brunswick
- City of Columbus
- City of Covington
- City of East Point
- City of Valdosta
- Dekalb County
- Department of Natural Resources:
  - Environmental Protection Division
  - Geologic and Water Resources Division
- Department of Transportation

Hawaii:
- City and County of Honolulu:
  - Board of Water Supply
  - Department of Public Works
- State Department of Health

Hawaii—Continued
- State Department of Land and Natural Resources:
  - Division of Water and Land Development
- State Department of Transportation

Idaho:
- Idaho Department of Health and Welfare
- Idaho Department of Transportation
- Idaho Department of Water Resources
- Panhandle Health District
- South Central District Health Department

Illinois:
- Bloomington and Normal Sanitary District
- City of Springfield
- Cook County, Forest Preserve District
- DuPage County Highway Department
- Environmental Protection Agency
- Fountain Head Drainage District
- Illinois Environmental Protection Agency
- Illinois Institute for Environmental Quality
- Kane County Highway Department
- McHenry County Regional Planning Commission
- Metropolitan Sanitary District of Greater Chicago
- Sanitary District of Bloom Township
- State Department of Registration and Education, Illinois State Geological Survey and State Water Survey
- State Department of Transportation:
  - Division of Highways
  - Division of Water Resources

Indiana:
- City of Indianapolis
- City of Logansport
- Indiana Board of Health
- Indiana Department of Natural Resources
- Indiana Highway Commission
- Ohio River Valley, Water Sanitation Commission
- Town of Carmel

Iowa:
- City of Cedar Rapids
- City of Des Moines
- City of Fort Dodge
- City of Harlan
- Iowa Department of Environmental Quality
- Iowa Department of Transportation, Highway Research Board
- Iowa Geological Survey
- Iowa Natural Resources Council
- Iowa State University:
  - Department of Agricultural Engineering
  - Engineering and Mineral Resources Research Institute
  - Iowa Agricultural Experiment Station
- University of Iowa:
  - Institute of Hydraulic Research
  - University Physical Plant

Kansas:
- City of Wichita
- Kansas Department of Transportation
- Kansas-Oklahoma Arkansas River Commission
- Kansas State Board of Agriculture:
  - Division of Water Resources
- Kansas State Department of Health and Environment

STATE, COUNTY, AND LOCAL COOPERATORS—Continued

Kansas—Continued
- Kansas State Water Resources Board
- Northwest Kansas Ground Water Management District No. 4
- Southwest Kansas Ground Water Management District No. 3
- State Geological Survey of Kansas
- Western Kansas Ground Water Management District No. 1

Kentucky:
- Kentucky Department of Commerce:
  - Division of Research and Planning
- Kentucky Department for Natural Resources and Environmental Protection:
  - Division of Conservation
  - Division of Water Quality
  - Division of Water Resources
- Kentucky Department of Transportation:
  - Division of Design
- Kentucky Geological Survey, University of Kentucky

Louisiana:
- Capital Area Ground Water Conservation Commission
- Louisiana Office of Highways:
  - Department of Transportation and Development
- Louisiana Office of Public Works:
  - Department of Transportation and Development
- Sabine River Compact Administration

Maine:
- Androscoggin Valley Regional Planning Commission
- Cobbossee Watershed District
- Department of Environmental Protection
- Greater Portland Council of Governments
- Maine Public Utilities Commission
- Southern Kennebec Regional Planning Commission
- Town of Wilton

Maryland:
- City of Baltimore, Bureau of Engineering, Water Supply Division
- Maryland Department of Health and Mental Hygiene
- Maryland Department of Transportation, The State Highway Administration
- Maryland Geological Survey
- Montgomery County, Office of Environmental Planning
- Washington Suburban Sanitary Commission

Massachusetts:
- Department of Public Works:
  - Division of Highways
  - Division of Research and Materials
- Metropolitan District Commission, Water Division
- State Water Resources Commission:
  - Division of Water Pollution Control
  - Division of Water Resources

Michigan:
- Branch County
- City of Ann Arbor
- City of Battle Creek
- City of Clare
- City of Coldwater
- City of Flint
- City of Jackson
- City of Lansing
- City of Mason

Michigan—Continued
- City of St. Johns
- City of St. Louis
- City of Ypsilanti
- Department of Agriculture
- Department of Natural Resources:
  - Geological Survey Division
- Department of State Highways and Transportation
- Dickinson County Board of Road Commissioners
- Genesee County Drain Commission
- Huron-Clinton Metropolitan Authority
- Imlay City
- Kalamazoo County Metropolitan Planning Commission
- Kent County Airport
- Macomb County Road Commission
- Oakland County-Drain Commission
- Otsego Road Commission
- Tri-County Regional Planning Commission
- Van Buren County Road Commission
- Washtenaw County Metropolitan Planning Commission
- Ypsilanti Township

Minnesota:
- City of Apple Valley
- City of Eagan
- City of Lakeville
- Douglas County, Wisconsin Soil and Water Conservation District
- Metropolitan Waste Control Commission
- Minnesota Department of Health:
  - Division of Environmental Health
- Minnesota Department of Highways
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- Minnesota Pollution Control Agency
- Minnesota State Planning Agency

Mississippi:
- City of Jackson
- Harrison County Board of Supervisors
- Harrison County Development Commission
- Jackson County Board of Supervisors
- Jackson County Port Authority
- Mississippi Air and Water Pollution Control Commission
- Mississippi Board of Water Commissioners
- Mississippi Geological Survey
- Mississippi Marine Resources Council
- Mississippi Research and Development Center
- Mississippi State Highway Department
- Pat Harrison Waterway District
- Pearl River Valley Water Supply District

Missouri:
- City of Springfield:
  - Sanitary Services Department
- Department of Conservation
- Department of Natural Resources:
  - Division of Environmental Quality, Laboratory Services Program
  - Division of Geology and Land Survey
- Little River Drainage District
- Missouri State Highway Commission
- St. Louis County, Department of Highways and Traffic

Montana:
- Department of Natural Resources and Conservation
- Lewis and Clark County, Board of County Commissioners

Montana—Continued
Missoula County Commissioners
Montana Bureau of Mines and Geology
Montana Department of Health and Environmental Sciences
Montana Department of Highways
Montana State Fish and Game Department
Montana State University
Wyoming State Engineer (*see also* Wyoming).

Nebraska:
Blue River Association of Ground Water Conservation Districts
Central Platte Natural Resources District
Kansas-Nebraska Big Blue River Compact Administration
Lower Loup Natural Resources District
Nebraska Department of Roads
Nebraska Department of Water Resources
Nebraska Natural Resources Commission
Nehama Natural Resources District
University of Nebraska:
  Conservation and Survey Division
  Water Resources Center

Nevada:
Carson City Department of Public Works
Nevada Bureau of Mines and Geology
Nevada Department of Conservation and Natural Resources:
  Division of Environmental Protection Services
  Division of Water Resources
Nevada Department of Highways
Nevada Environmental Protection Service

New Hampshire:
New Hampshire Water Resources Board
New Hampshire Water Supply and Pollution Control Commission

New Jersey:
Bergen County
Camden County, Board of Chosen Freeholders
Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Morris County Municipal Utilities Authority
New Jersey Department of Agriculture
New Jersey Department of Environmental Protection:
  Division of Fish, Game and Shell Fisheries
  Division of Water Resources
North Jersey District Water Supply Commission
Passaic Valley Water Commission
Somerset County, Board of Chosen Freeholders
Township of Cranford

New Mexico:
Albuquerque Metropolitan Arroyo Flood Control Authority
City of Albuquerque
City of Las Cruces
Costilla Creek Compact Commission
Elephant Butte Irrigation District
New Mexico Bureau of Mines and Mineral Resources
New Mexico Environmental Improvement Agency
New Mexico State Engineer and Interstate Stream Commission
New Mexico State Highway Department
Pecos River Commission
Rio Grande Compact Commission

New York:
Central New York State Parks and Recreation Commission

New York—Continued
City of Albany, Department of Water and Supply
City of Auburn
City of New York:
  Board of Water Supply
  Environmental Protection Administration
County of Chautauqua, Department of Planning and Development
County of Cortland, Planning Department
County of Duchess, Civil Defense
County of Monroe, Water Authority
County of Nassau, Department of Public Works
County of Onondaga:
  Department of Public Works
  Water Authority
County of Putnam
County of Rockland, Drainage Agency
County of Suffolk:
  Department of Environmental Control
  Water Authority
County of Ulster, Ulster County Legislature
County of Westchester, Department of Public Works
Department of Transportation
Hudson River-Black River Regulating District
Irondequoit Bay Pure Waters District
New York State Department of Environmental Conservation (*see also* Pennsylvania)
New York State Department of Environmental Conservation
New York State Department of Health, Division of Sanitary Engineering
New York State Department of Transportation, Bridge Planning and Railroads Bureau
New York State Education Department, Museum and Science Service
New York State Museum and Science Service
New York State University Agricultural and Technical College
New York State University, Regents Research, Inc.
Oswegatchie River-Cranberry Reservoir Commission
Power Authority of the State of New York
Rochester Water Bureau
Town of Brighton
Town of Clarkstown
Town of Fishkill
Town of Warwick
Town of Waterford
Village of Nyack

North Carolina:
Agricultural Experiment Station
City of Burlington
City of Charlotte
City of Durham, Department of Water Resources
City of Greensboro
City of Rocky Mount
City of Winston-Salem
State Board of Transportation
State Department of Natural and Economic Resources:
  Division of Resource Planning and Evaluation
State Department of Natural Resources and Community Development

North Dakota:
North Dakota Geological Survey
Oliver County Board of County Commissioners
State Department of Health
State Water Commission

Ohio:
City of Canton, Water Department
City of Columbus, Department of Public Service
City of Toledo
Geauga County
Miami Conservancy District
Ohio Department of Natural Resources
Ohio Department of Transportation, Division of Highways
Ohio Environmental Protection Agency
Three Rivers Watershed District

Oklahoma:
City of Oklahoma City
Oklahoma State Department of Highways
Oklahoma State Geological Survey
Oklahoma State Health Department
Oklahoma State Water Resources Board
State Pollution Control Coordinating Board

Oregon:
Burnt River Irrigation District
City of Corvallis
City of Eugene, Water and Electric Board
City of Lakeside, Lakeside Water District
City of McMinnville, Water and Light Department
City of Medford, Public Works Department
City of Portland:
  Department of Public Utilities
  Department of Water Works
City of Rogue River
Columbia Region Association of Governments
Confederated Tribes of Umatilla Indian Reservation
Confederated Tribes of Warm Springs Reservation
Coos Bay-North Bend Water Board
Coos County, Board of Commissioners
Department of Environmental Quality
Department of Fish and Wildlife
Douglas County, Department of Public Works
Lane County
Multnomah County, Board of Commissioners
Oregon State Highway Commission
Oregon State Water Resources Department
Rogue Valley Council of Governments

Pennsylvania:
Chester County Commissioners
Chester County Health Department
Chester County Water Resources Authority
City of Bethlehem
City of Easton
City of Harrisburg, Department of Public Works
City of Philadelphia, Water Department
Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Letort Regional Authority
New York State Department of Environmental Conservation (*see also* New York)
Pennsylvania Department of Environmental Resources:
  Bureau of State Parks
  Bureau of Surface Mine Reclamation
  Bureau of Topographic and Geologic Survey
  Bureau of Water Quality Management
  Office of Resource Management
  State Soil and Water Conservation Commission

Pennsylvania—Continued
Slippery Rock State College
State Department of Transportation
Susquehanna River Basin Commission

Rhode Island:
City of Providence
State Department of Environmental Management:
  Division of Land Resources
State Department of Natural Resources
State Water Resources Board

South Carolina:
City of Lancaster
Commissioners of Public Works, Spartanburg Water Works
State Department of Highways and Public Transportation
State Health and Environmental Control
State Public Service Authority
State Water Resources Commission

South Dakota:
Black Hills Conservancy Subdistrict
City of Sioux Falls
City of Watertown
South Dakota Department of Natural Resource Development:
  Division of Geological Survey
  Division of Water Rights
South Dakota Department of Transportation

Tennessee:
City of Franklin
City of Lawrenceburg
City of Manchester
City of Memphis:
  Light, Gas and Water Division
  Public Works Division
  Water Division
Lincoln County Utilities Board
Metropolitan Government of Nashville and Davidson County, Department of Public Works
Murfreesboro Water and Sewer Department
Shelby County
Tennessee Department of Conservation:
  Division of Geology
  Division of Water Resources
Tennessee Department of Public Health, Division of Water Quality Control
Tennessee Department of Transportation
Tennessee Wildlife Resources Agency
University of Tennessee

Texas:
City of Austin
City of Dallas
City of Fort Worth
City of Garland
City of Houston
City of Mesquite
Pecos River Commission
Sabine River Compact Administration
State Department of Highways and Public Transportation
Texas Department of Water Resources

STATE, COUNTY, AND LOCAL COOPERATORS—Continued

Utah:
- Bear River Commission
- Salt Lake County
- State Department of Natural Resources:
  - Division of Oil, Gas, and Mining
  - Division of Water Resources
  - Division of Water Rights
  - Division of Wildlife Resources
- Utah Geological and Mineral Survey

Vermont:
- Agency of Environmental Conservation
- State Department of Water Resources
- Town of Springfield

Virginia:
- City of Alexandria, Department of Transportation and Environmental Services
- City of Newport News, Department of Public Utilities
- City of Roanoke, Utilities and Operations
- City of Staunton
- James City County
- Southeastern Public Service Authority of Virginia
- Virginia Department of Conservation and Economic Development, Division of Mineral Resources
- Virginia Department of Highways and Transportation
- Virginia State Water Control Board

Washington:
- Chelan County Public Utility District No. 1
- City of Bellevue Public Works Department
- City of Everett
- City of Seattle:
  - Department of Lighting
  - Water Department
- City of Tacoma:
  - Department of Public Utilities
  - Department of Public Works
- Clallam County Board of County Commissioners
- Hoh Indian Tribe
- Lewis County Board of Commissioners
- Makah Tribal Council
- Municipality of Metropolitan Seattle
- Pierce County Board of Commissioners
- Pacific County Board of County Commissioners
- Quileute Tribal Council

Washington—Continued
- Quinault Indian Business Council
- Shoalwater Bay Tribal Council
- South Columbia Basin Irrigation District
- Spokane County
- Spokane Tribe of Indians
- Tulalip Board of Directors
- Washington State Department of Ecology
- Washington State Department of Fisheries
- Washington State Department of Game
- Washington State Department of Highways
- Washington State Department of Natural Resources
- Yakima Tribal Council

West Virginia:
- Clarksburg Water Board
- Morgantown Water Commission
- West Virginia Department of Highways
- West Virginia Department of Natural Resources, Division of Water Resources
- West Virginia Geological and Economic Survey

Wisconsin:
- Dane County Regional Planning Commission
- Douglas County Soil and Water Conservation District
- Madison Metropolitan Sewage District
- Sokaogon Chippewa (Mole Lake), Community of Wisconsin
- Southeastern Wisconsin Regional Planning Commission
- State Board of Soil and Water Conservation Districts
- State Department of Natural Resources
- State Department of Transportation:
  - Bridge Section
  - Division of Highways
- Town of Schleswig
- University of Wisconsin Extension, Geological and Natural History Survey

Wyoming:
- Cheyenne Board of Public Utilities
- Geological Survey of Wyoming
- Water Resources Research Institute, University of Wyoming
- Wyoming Conservation Commission
- Wyoming Department of Agriculture
- Wyoming Department of Economic Planning and Development
- Wyoming Department of Environmental Quality
- Wyoming Highway Department
- Wyoming State Engineer (*see also* Montana)

OTHER COOPERATORS AND CONTRIBUTORS

Appalachian Regional Commission

Coastal Plains Regional Action Planning Commission

Government of Algeria

Government of American Samoa

Government of Guam

Government of Iran

Government of Malaysia

Government of Nigeria

Government of the Northern Mariana Islands

Government of Saudi Arabia

Government of Tobago

Government of Trinidad

Missouri River Basin Commission

New England River Basins Commission

Organization of American States

Ozarks Regional Action Planning Commission

Puerto Rico:
Puerto Rico Aqueduct and Sewer Authority
Puerto Rico Department of Natural Resources
Puerto Rico Environmental Quality Board
Puerto Rico Highway Authority
Puerto Rico Water Resources Authority

Trust Territory of the Pacific Islands

United Nations

Virgin Islands:
College of the Virgin Islands

Budgetary and Statistical Data

[Data in these tables may differ slightly from data in the individual division chapters because of rounding; and totals may sometimes not add because of rounding.]

TABLE16 —*Geological Survey budget for fiscal years 1973 to 1978, by activity and sources of funds*

[In thousands of dollars]

Budget activity	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$211,944**	**$249,437**	**$338,764**	**$353,970**	**$102,858**	**$433,403**	**$698,272**
Direct program	149,971	171,983	253,605	264,434	77,570	319,460	576,393
Reimbursable program	61,973	77,454	85,159	89,536	25,288	113,943	121,879
States, counties, and municipalities	28,011	32,443	35,124	35,006	8,956	39,621	40,784
Miscellaneous non-Federal sources	3,620	4,695	6,399	7,923	1,991	10,229	12,825
Other Federal agencies	30,342	40,316	43,636	46,607	14,341	64,093	68,270
Alaska Pipeline Related Investigations	**1,239**	**890**	**344**	**287**	**85**	**317**	**272**
Direct program	1,239	890	344	287	85	317	272
Reimbursable program	------	------	------	------	------	------	------
Other Federal agencies	------	------	------	------	------	------	------
Topographic Surveys and Mapping	**40,271**	**43,664**	**52,597**	**52,220**	**13,289**	**57,073**	**69,520**
Direct program	35,172	37,161	45,350	43,354	11,548	50,311	61,356
Reimbursable program	5,099	6,503	7,247	6,866	1,741	6,762	8,164
States, counties, and municipalities	3,719	4,942	4,995	3,675	882	3,268	3,320
Miscellaneous non-Federal sources	600	643	594	501	133	601	499
Other Federal agencies	780	918	1,658	2,690	726	2,893	4,345
Geologic and Mineral Resource Surveys and Mapping [1]	**57,979**	**73,563**	**114,477**	**115,554**	**32,194**	**130,269**	**163,193**
Direct program	42,895	49,877	89,018	92,322	24,829	100,007	123,830
Reimbursable program	15,084	23,686	25,459	23,232	7,365	30,262	39,363
States, counties, and municipalities	1,556	1,681	1,550	1,467	383	1,403	956
Miscellaneous non-Federal sources	2,306	2,684	3,751	4,936	1,120	6,439	8,510
Other Federal agencies	11,222	19,321	20,158	16,829	5,862	22,420	29,897
Water Resources Investigations [2]	**78,103**	**88,352**	**101,437**	**112,480**	**30,716**	**131,509**	**146,014**
Direct program	40,185	45,433	53,420	57,176	15,916	68,555	[3]78,487
Reimbursable program	37,918	42,919	48,017	55,304	14,800	62,954	67,527
States, counties, and municipalities	22,736	25,820	28,546	29,735	7,672	34,761	36,457
Miscellaneous non-Federal sources	664	721	901	940	260	1,331	1,429
Other Federal agencies	14,518	16,378	18,570	24,629	6,868	26,862	29,641
Conservation of Lands and Minerals [4]	**14,748**	**18,213**	**36,082**	**41,677**	**13,386**	**67,427**	**77,409**
Direct program	14,700	18,172	36,032	41,489	13,375	67,239	77,299
Reimbursable program	48	41	50	188	6	188	110
Miscellaneous non-Federal sources	3	------	4	1	------	16	9
Other Federal agencies	45	41	46	187	6	172	101
Land Information and Analysis [5]	**13,125**	**13,003**	**16,994**	**17,278**	**8,919**	**23,476**	**23,226**
Direct program	11,876	11,458	15,461	14,908	7,795	17,698	18,132
Reimbursable program	1,249	1,545	1,533	2,370	6,124	5,778	5,094
States, counties, and municipalties	------	------	33	130	19	189	51
Miscellaneous non-Federal sources	------	593	1,093	1,496	469	1,741	2,153
Other Federal agencies	1,249	952	407	744	636	3,848	2,890
National Petroleum Reserve in Alaska	------	------	------	------	------	**9,154**	**202,704**
Direct program	------	------	------	------	------	2,079	202,598
Allocation transfer	------	------	------	------	------	7,063	106
Reimbursable program (Federal)	------	------	------	------	------	12	------
General Administration [6]	**3,217**	**3,517**	**3,671**	**3,398**	**1,491**	**3,760**	**3,650**
Direct program	3,217	3,517	3,671	3,398	1,491	3,760	3,650
Facilities	687	5,475	10,309	9,500	2,530	9,494	10,769
Direct program	687	4,475	10,309	9,500	2,530	9,494	10,769

See footnotes at end of table.

TABLE 16.—*Geological Survey budget for fiscal years 1973 to 1978, by activity and sources of funds*—Continued

Budget activity	1973	1974	1975	1976	Transition quarter	1977	1978
Miscellaneous services to other accounts	**$2,575**	**$2,760**	**$2,853**	**$1,576**	**$253**	**$924**	**$1,515**
Reimbursable program	2,575	2,760	2,853	1,576	253	924	1,515
Miscellaneous non-Federal sources	47	54	56	49	10	102	225
Other Federal agencies	2,528	2,706	2,797	1,527	243	822	1,290

[1] Funds include: Mineral Discovery Loan Program activity for fiscal years 1973 to 1975; and parts of Geothermal Investigations, Minerals Policy, and Arctic Environmental Studies components of the Special Resource and Environmental Projects activity for fiscal years 1973 to 1975. Funds exclude the Land Resource Analysis program for fiscal years 1973 to 1976.

[2] Funds exclude Employee Compensation Payments subactivity for fiscal years 1973 to 1976.

[3] Funds for the Airborne Positioning System, appropriated to Water Resources Investigations are included as obligations of Topographic Surveys and Mapping ($2,172 thousand).

[4] Funds include parts of Geothermal Investigations component of the Special Resource and Environmental Projects activity for fiscal years 1973 to 1975.

[5] Budget activity funds are reconstructed for fiscal years 1973 to 1975 and include: Earth Resources Observation System activity for fiscal years 1973 to 1975; Urban Area Studies and Energy Impact Evaluation components of the Special Resource and Environmental Projects activity for fiscal years 1973 to 1975; Land Resources Analysis program of the Geologic and Mineral Resource Surveys and Mapping activity for fiscal years 1974 and 1975; and the Land Use Data and Analysis activity for fiscal year 1975.

[6] Funds include Employee Compensation Payments subactivity of the Water Resources Investigations activity for 1973 to 1976.

TABLE 17.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*

[In thousands of dollars]

State	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	**$55,633**	**$65,256**	**$70,151**	**$69,252**	**$17,482**	**$79,163**	**$80,598**
Total State Share [2]	28,011	32,443	35,124	35,019	8,986	40,617	40,784
Alabama	**928**	**1,094**	**1,212**	**1,124**	**171**	**1,234**	**1,074**
State share	514	554	623	550	87	607	532
Alaska	**838**	**897**	**1,162**	**782**	**202**	**1,141**	**1,275**
State share	399	410	410	407	101	561	654
Arizona	**1,001**	**1,144**	**1,248**	**1,255**	**335**	**1,393**	**1,552**
State share	510	576	646	639	177	700	783
Arkansas	**596**	**857**	**887**	**811**	**190**	**1,033**	**1,118**
State share	288	455	410	371	94	481	543
California	**4,115**	**4,789**	**4,690**	**4,825**	**1,271**	**5,336**	**6,079**
State share	2,053	2,280	2,337	2,473	675	2,714	3,091
Colorado	**1,128**	**1,484**	**2,445**	**2,199**	**662**	**3,052**	**3,036**
State share	575	837	1,324	1,196	349	1,564	1,561
Connecticut	**687**	**814**	**1,069**	**858**	**241**	**871**	**864**
State share	292	374	523	415	108	421	411
Delaware	**121**	**130**	**194**	**213**	**54**	**225**	**192**
State share	81	74	106	116	30	121	109
District of Columbia	**3**	**3**	**3**	**3**	**1**	**4**	**4**
State share	1	1	1	2	------	2	2
Florida	**3,643**	**5,083**	**5,575**	**5,763**	**1,481**	**6,428**	**7,219**
State share	1,858	2,552	2,781	2,851	735	3,202	3,667
Georgia	**2,008**	**3,239**	**3,083**	**2,510**	**552**	**2,452**	**1,706**
State share	1,041	1,611	1,531	1,243	275	1,209	866
Hawaii	**653**	**691**	**697**	**896**	**191**	**897**	**1,000**
State share	337	339	341	501	101	460	518
Idaho	**675**	**718**	**749**	**852**	**223**	**952**	**1,131**
State share	344	353	366	417	111	465	611
Illinois	**646**	**544**	**645**	**848**	**208**	**1,109**	**1,092**
State share	333	277	323	459	120	592	575
Indiana	**1,107**	**1,363**	**1,288**	**1,519**	**366**	**1,987**	**2,006**
State share	590	678	632	779	182	981	1,078
Iowa	**525**	**608**	**617**	**822**	**241**	**1,004**	**1,031**
State share	259	299	302	405	121	494	521
Kansas	**1,358**	**1,402**	**1,424**	**1,525**	**442**	**1,721**	**2,237**
State share	676	686	716	752	220	849	1,113
Kentucky	**2,212**	**2,451**	**2,728**	**2,828**	**717**	**3,015**	**2,407**
State share	1,039	1,122	1,229	1,300	327	1,433	1,018
Louisiana	**1,240**	**1,900**	**1,740**	**1,694**	**440**	**2,628**	**1,856**
State share	674	980	902	862	227	1,319	929

See footnotes at end of table.

TABLE 17.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
Maine	**$ 168**	**$ 175**	**$ 248**	**$ 313**	**$ 89**	**$ 333**	**$ 382**
State share	91	96	127	181	50	179	191
Maryland	**695**	**851**	**1,011**	**1,016**	**243**	**1,176**	**1,174**
State share	356	435	530	517	125	602	605
Massachusetts	**1,379**	**1,346**	**1,618**	**1,627**	**368**	**1,402**	**1,593**
State share	625	656	810	779	191	684	801
Michigan	**947**	**930**	**1,054**	**1,078**	**252**	**1,101**	**1,203**
State share	425	436	505	521	123	541	596
Minnesota	**1,420**	**1,903**	**1,639**	**1,191**	**320**	**1,082**	**1,759**
State share	727	966	817	625	198	566	949
Mississippi	**593**	**645**	**743**	**646**	**170**	**713**	**754**
State share	340	325	415	316	85	349	407
Missouri	**732**	**657**	**678**	**642**	**207**	**827**	**635**
State share	375	322	337	316	105	420	316
Montana	**402**	**505**	**587**	**596**	**146**	**1,330**	**676**
State share	223	255	287	301	76	673	338
Nebraska	**588**	**705**	**731**	**785**	**187**	**957**	**1,048**
State share	298	344	358	396	95	469	522
Nevada	**640**	**689**	**846**	**922**	**244**	**1,063**	**1,440**
State share	288	304	332	367	103	415	456
New Hampshire	**139**	**177**	**172**	**230**	**63**	**248**	**187**
State share	67	97	73	99	28	103	92
New Jersey	**856**	**1,051**	**977**	**1,090**	**276**	**1,269**	**1,437**
State share	433	530	501	565	143	642	851
New Mexico	**1,107**	**1,332**	**1,439**	**1,510**	**338**	**1,537**	**1,621**
State share	601	662	714	768	175	778	838
New York	**2,395**	**2,796**	**2,977**	**2,822**	**727**	**3,008**	**3,363**
State share	1,229	1,415	1,585	1,615	407	2,568	1,893
North Carolina	**1,038**	**1,586**	**1,885**	**1,462**	**379**	**1,805**	**1,713**
State share	492	771	942	724	197	894	858
North Dakota	**899**	**763**	**998**	**990**	**246**	**834**	**1,023**
State share	461	369	489	489	125	408	505
Ohio	**1,028**	**978**	**1,093**	**1,255**	**336**	**1,598**	**1,799**
State share	520	481	563	671	175	838	973
Oklahoma	**634**	**702**	**748**	**786**	**196**	**846**	**936**
State share	340	344	368	386	98	414	462
Oregon	**828**	**896**	**902**	**899**	**287**	**1,230**	**1,214**
State share	432	439	443	449	163	639	610
Pennsylvania	**2,047**	**2,357**	**2,415**	**2,510**	**554**	**2,718**	**2,688**
State share	1,042	1,195	1,209	1,269	284	1,365	1,366
Rhode Island	**90**	**97**	**110**	**124**	**31**	**145**	**160**
State share	50	52	54	60	16	72	80
South Carolina	**574**	**546**	**574**	**557**	**142**	**603**	**625**
State share	301	279	284	272	71	296	329
South Dakota	**423**	**471**	**515**	**528**	**146**	**562**	**662**
State share	230	227	251	259	73	275	331
Tennessee	**589**	**851**	**952**	**1,035**	**280**	**1,255**	**1,383**
State share	321	422	470	508	139	615	686
Texas	**3,794**	**4,046**	**4,261**	**4,351**	**1,102**	**4,621**	**4,525**
State share	1,949	2,027	2,100	2,148	550	2,354	2,244
Utah	**1,069**	**1,068**	**1,361**	**1,314**	**334**	**1,631**	**1,451**
State share	530	534	838	745	186	810	726
Vermont	**129**	**144**	**130**	**138**	**28**	**134**	**142**
State share	66	73	64	68	14	70	70
Virginia	**793**	**905**	**858**	**737**	**142**	**768**	**778**
State share	421	466	442	378	78	393	397
Washington	**1,988**	**2,121**	**2,208**	**2,115**	**509**	**3,271**	**2,537**
State share	962	1,037	1,104	1,066	265	1,653	1,243
West Virginia	**620**	**946**	**775**	**716**	**175**	**830**	**688**
State share	332	521	448	418	105	472	388
Wisconsin	**1,354**	**1,563**	**1,706**	**1,874**	**552**	**1,703**	**1,883**
State share	638	775	883	999	297	935	1,026
Wyoming	**612**	**698**	**853**	**754**	**167**	**903**	**901**
State share	310	328	514	397	86	391	381
American Samoa	**64**	**63**	**70**	**40**	**9**	**60**	**64**
State share	32	31	32	20	4	30	32

See footnotes at end of table.

TABLE 17.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
Guam	**$ 43**	**$ 62**	**$ 65**	**$ 68**	**$ 18**	**$ 70**	**$ 85**
State share	21	31	32	33	9	33	47
Northern Marianas	------	------	------	------	------	------	**18**
State share	------	------	------	------	------	------	9
Puerto Rico	**1,347**	**1,303**	**1,293**	**1,016**	**185**	**843**	**922**
State share	557	682	585	463	84	396	459
Trust Territories	**125**	**117**	**170**	**170**	**44**	**173**	**180**
State share	62	58	84	84	22	84	90
Virgin Islands	(3)	(3)	**33**	**18**	**2**	**32**	**70**
State share	(3)	(3)	31	9	1	16	35

[1] Includes Federal funds from direct program.
[2] Includes reimbursable program funds from States, counties, and municipalities.
[3] Included with Puerto Rico funds.

TABLE 18.—*Geological Survey reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978, by agency*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$30,342**	**$40,316**	**$43,636**	**$46,607**	**$14,347**	**$56,195**	**$66,874**
Appalachian Regional Commission	------	189	179	------	------	------	------
Department of Agriculture	273	356	891	2,008	605	2,130	2,727
Department of Commerce	73	(1)	154	2,205	36	334	183
National Oceanic and Atmospheric Administration	------	2,001	434	1,513	772	1,947	1,708
Ozarks Regional Commission	------	60	49	------	------	------	------
Department of Defense	8,443	13,351	11,247	11,965	3,195	12,308	15,655
Department of Energy [2]	(3,011)	(4,029)	(3,854)	(4,704)	(1,926)	(8,573)	(14,980)
Bonneville Power Administration	118	136	105	130	32	141	138
Department of Housing and Urban Development	2,095	3,581	3,069	4,624	1,873	6,003	3,789
Department of the Interior	(2,208)	(2,312)	(9,361)	(6,290)	(2,362)	(12,186)	(16,528)
Bureau of Indian Affairs	149	340	697	759	277	915	2,385
Bureau of Land Management	207	251	5,114	3,682	1,467	9,011	10,791
Bureau of Mines	------	------	1,735	148	------	200	108
Bureau of Reclamation	855	676	721	790	267	1,199	1,871
National Park Service	459	529	617	576	230	542	791
Office of Saline Water [3]	156	------	------	------	------	------	------
Office of the Secretary	------	------	------	------	44	------	------
Office of Surface Mining	------	------	------	------	------	------	135
Office of Territorial Affairs	8	------	------	------	------	------	------
U.S. Fish and Wildlife Service	256	380	372	205	45	178	447
Department of State	2,756	2,177	1,698	949	221	1,075	1,010
Department of Transportation	------	------	4	470	240	313	193
Environmental Protection Agency	916	1,127	1,389	1,921	777	2,137	3,074
National Aeronautics and Space Administration	6,507	5,672	3,449	3,584	1,051	2,648	2,763
National Science Foundation	333	1,375	1,928	1,650	40	2,712	848
Nuclear Regulatory Commission	------	------	1,195	1,439	427	1,758	1,318
Tennessee Valley Authority	255	212	252	216	70	297	216
Miscellaneous Federal agencies	944	1,168	1,686	1,542	499	1,774	1,882
Miscellaneous services to other accounts	2,528	2,706	2,797	1,527	253	822	1,290

[1] Included in miscellaneous Federal agencies.
[2] Shown as Energy Research and Development and Federal Energy Administration prior to October 1, 1977; includes Atomic Energy Commission funds for fiscal years 1973 and 1974. See also funds from Nuclear Regulatory Commission in fiscal 1975.
[3] Merged in 1974 with the Office of Water Resources to form the Office of Water Research and Technology.

TABLE 19.—*Topographic Surveys and Mapping direct program funds for fiscal years 1973 to 1978, by subactivity*

[In thousands of dollars]

Subactivity	1973	1974	1975	1976	Transition quarter	1977	1978
Total direct program	**$35,172**	**$37,161**	**$45,350**	**$45,354**	**$11,548**	**$50,311**	**$61,356**
Quadrangle mapping and revision	33,433	35,046	41,148	38,266	9,396	42,390	50,657
Small-scale and special mapping	1,739	2,115	2,661	5,358	1,730	5,278	7,865
National Cartographic Information Center [1]	(675)	(1,043)	1,541	1,730	422	2,643	2,835

[1] NCIC funds included in the Quadrangle Mapping and Revision subactivity prior to fiscal 1975.

TABLE 20.—*Topographic Surveys and Mapping Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*

[In thousands of dollars]

State	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	**$7,438**	**$9,884**	**$9,990**	**$7,350**	**$1,764**	**$6,536**	**$6,640**
Total State share [2]	3,719	4,942	4,995	3,675	882	3,268	3,320
Alabama	**50**	**38**	**62**	**48**	------	**32**	**30**
State share	25	19	31	24	------	16	15
Arkansas	**54**	**58**	**72**	**74**	**28**	**38**	**68**
State share	27	29	36	37	14	19	34
California	**186**	**198**	**252**	**206**	**66**	**252**	**212**
State share	93	99	126	103	33	126	106
Colorado	------	**4**	**830**	**420**	**158**	**678**	**486**
State share	------	2	415	210	79	339	243
Connecticut	**40**	**120**	**124**	**110**	**56**	**84**	**66**
State share	20	60	62	55	28	42	33
Florida	**572**	**578**	**454**	**450**	**76**	**378**	**650**
State share	286	289	227	225	38	189	325
Georgia	**1,218**	**2,294**	**1,992**	**1,340**	**244**	**580**	**360**
State share	609	1,147	996	670	122	290	180
Hawaii	------	------	------	------	------	**86**	**112**
State share	------	------	------	------	------	43	56
Illinois	**120**	**30**	**70**	**70**	**8**	**70**	**66**
State share	60	15	35	35	4	35	33
Indiana	**136**	**136**	**136**	**108**	**2**	**94**	**134**
State share	68	68	68	54	1	47	67
Iowa	------	------	------	**176**	**64**	**226**	**202**
State share	------	------	------	88	32	113	101
Kansas	**248**	**286**	**268**	**266**	**104**	**202**	**296**
State share	124	143	134	133	52	101	148
Kentucky	**180**	**278**	**254**	**204**	**60**	**330**	**410**
State share	90	139	127	102	30	165	205
Louisiana	**50**	**152**	**120**	**90**	**22**	**98**	**90**
State share	25	76	60	45	11	49	45
Maine	**40**	**40**	**40**	**40**	**20**	**38**	**34**
State share	20	20	20	20	10	19	17
Maryland	**22**	**20**	**20**	**30**	**2**	**32**	**20**
State share	11	10	10	15	1	16	10
Massachusetts	**196**	**190**	**250**	**250**	**6**	**108**	**278**
State share	98	95	125	125	3	54	139
Michigan	**100**	**100**	**100**	**100**	------	**100**	**100**
State share	50	50	50	50	------	50	50
Minnesota	**708**	**1,092**	**840**	**246**	------	**4**	**478**
State share	354	546	420	123	------	2	239
Missouri	**130**	**134**	**134**	**110**	**44**	**124**	**74**
State share	65	67	67	55	22	62	37
Nevada	**40**	**58**	**54**	**58**	**32**	**84**	**46**
State share	20	29	27	29	16	42	23
New Mexico	------	------	**16**	**16**	------	------	------
State share	------	------	8	8	------	------	------

See footnotes at end of table.

TABLE 20.—*Topographic Surveys and Mapping Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
New York	**$234**	**$366**	**$226**	------	**$12**	------	**$80**
State share	117	183	113	------	6	------	40
North Carolina	**172**	**672**	**890**	**502**	**124**	**632**	**578**
State share	86	336	445	251	62	316	289
North Dakota	**242**	**88**	**222**	**198**	**10**	**32**	**120**
State share	121	44	111	99	5	16	60
Ohio	**150**	**150**	**150**	**150**	**38**	**178**	**134**
State share	75	75	75	75	19	89	67
Oklahoma	**112**	**110**	**110**	**110**	**36**	**96**	**88**
State share	56	55	55	55	18	48	44
Oregon	**78**	**44**	**92**	**32**	**24**	**100**	**26**
State share	39	22	46	16	12	50	13
Pennsylvania	**326**	**392**	**312**	**224**	**32**	**252**	**110**
State share	163	196	156	112	16	126	55
Rhode Island	------	------	------	------	------	**18**	**6**
State share	------	------	------	------	------	9	3
South Carolina	**120**	------	**36**	------	------	------	------
State share	60	------	18	------	------	------	------
South Dakota	**50**	**50**	**50**	**50**	**28**	**44**	**44**
State share	25	25	25	25	14	22	22
Tennessee	**38**	**50**	**44**	**16**	------	**6**	------
State share	19	25	22	8	------	3	------
Texas	**742**	**726**	**686**	**682**	**170**	**666**	**380**
State share	371	363	343	341	85	333	190
Utah	**114**	**120**	**100**	**100**	**40**	**100**	**126**
State share	57	60	50	50	20	50	63
Vermont	**20**	**40**	**34**	**20**	------	------	**4**
State share	10	20	17	10	------	------	2
Virginia	**132**	**232**	**218**	**188**	**14**	**286**	**218**
State share	66	116	109	94	7	143	109
Washington	**32**	**34**	**6**	**28**	**6**	**10**	**22**
State share	16	17	3	14	3	5	11
West Virginia	**298**	**506**	**228**	**142**	**26**	**182**	**46**
State share	149	253	114	71	13	91	23
Wisconsin	**402**	**412**	**414**	**410**	**208**	**290**	**422**
State share	201	206	207	205	104	145	211
Wyoming	**10**	**10**	**10**	**10**	**4**	**6**	**12**
State share	5	5	5	5	2	3	6
Puerto Rico	**76**	**76**	**74**	**76**	------	------	**12**
State share	38	38	37	38	------	------	6

[1] Includes Federal funds from direct program.

[2] Includes reimbursable program funds from States, counties, and municipalities.

TABLE 21.—*Topographic Surveys and Mapping reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978, by agency*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$780**	**$918**	**$1,658**	**$2,690**	**$726**	**$2,893**	**$4,345**
Department of Agriculture	------	95	326	1,256	433	1,468	1,939
Department of Commerce	------	------	------	187	------	121	169
Department of Defense	35	92	183	151	42	271	789
Department of the Interior	68	238	441	284	78	544	760
Bureau of Indian Affairs	60	165	198	209	20	179	95
Bureau of Land Management	------	73	243	74	58	325	444
Bureau of Reclamation	------	------	------	1	------	10	10
National Park Service	------	------	------	------	------	13	------
Office of Territorial Affairs	8	------	------	------	------	------	------
U.S. Fish and Wildlife Service	------	------	------	------	------	17	211
Department of Transportation	------	------	4	257	30	65	------
National Aeronautics and Space Administration	207	235	97	132	------	33	2
National Science Foundation	198	46	257	111	5	94	203
Miscellaneous Federal agencies	272	212	350	312	138	297	483

TABLE 22.—*Geologic and Mineral Resource Surveys and Mapping direct program funds for fiscal years 1973 to 1978, by subactivity*

[In thousands of dollars]

Subactivity	1973	1974	1975	1976	Transition quarter	1977	1978
Total direct program	**$42,895**	**$49,877**	**$89,018**	**$92,322**	**$24,829**	**$100,007**	**$123,830**
Land Resource Surveys [1]	19,246	23,077	33,385	34,077	9,681	35,202	54,315
Mineral Resource Surveys [2]	14,026	14,971	18,017	19,775	5,316	23,757	26,393
Energy Resource Surveys	5,197	6,696	22,376	23,080	5,863	26,250	27,828
Offshore Geologic Surveys	4,426	5,133	15,240	15,470	3,969	14,798	15,294

[1] Funds adjusted for fiscal year 1973 to include geologic mapping in support of Mineral Resource Surveys.
[2] Funds adjusted for fiscal year 1973 to exclude geologic mapping and to include the Mineral Discovery Loan Program activity for fiscal 1973.

TABLE 23.—*Geologic and Mineral Resource Surveys and Mapping Federal-State Cooperative funds for fiscal years 1973 to 1978, by State*

[In thousands of dollars]

State	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	**$4,270**	**$4,254**	**$4,541**	**$3,910**	**$917**	**$3,487**	**$3,061**
State share [2]	1,556	1,681	1,550	1,479	413	1,403	956
Alabama	**10**	**10**	**15**	------	------	------	------
State share	10	5	5	------	------	------	------
Alaska	**332**	**238**	**476**	------	------	------	------
State share	135	93	75	------	------	------	------
Arkansas	**85**	**125**	**165**	**110**	------	**107**	**75**
State share	36	27	27	27	------	27	27
California	**79**	**362**	**57**	**99**	**35**	**47**	**33**
State share	22	80	21	66	35	47	33
Colorado	**50**	------	------	------	------	------	------
State share	30	------	------	------	------	------	------
Connecticut	**235**	**208**	**258**	**200**	**62**	**144**	**148**
State share	69	75	75	75	16	60	56
Florida	------	------	------	------	------	------	**3**
State share	------	------	------	------	------	------	3
Georgia	------	**6**	**10**	------	------	------	**12**
State share	------	3	5	------	------	------	11
Iowa	------	**16**	------	------	------	------	------
State share	------	8	------	------	------	------	------
Kentucky	**1,332**	**1,454**	**1,599**	**1,643**	**413**	**1,682**	**911**
State share	600	630	675	718	176	778	277
Maryland	**27**	**14**	**19**	------	------	------	------
State share	10	7	9	------	------	------	------
Massachusetts	**633**	**563**	**581**	**630**	**180**	**509**	**454**
State share	205	228	205	205	97	184	183
Michigan	**216**	**178**	**158**	**148**	**45**	**128**	**132**
State share	65	65	65	65	20	65	65
Nevada	**249**	**254**	**384**	**396**	**87**	**413**	**751**
State share	90	90	105	110	25	97	115
New Hampshire	**31**	**59**	**50**	**53**	**13**	**45**	------
State share	13	39	13	13	3	7	------
New Mexico	**20**	**40**	**11**	**18**	**2**	**6**	**12**
State share	10	20	------	18	2	6	12

See footnotes at end of table.

TABLE 23.—*Geologic and Mineral Resource Surveys and Mapping Federal-State Cooperative funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
New York	------	**$20**	**$21**	------	------	**$18**	**$10**
State share	------	10	10	------	------	18	10
North Carolina	**99**	**40**	**18**	------	------	**6**	------
State share	12	6	18	------	------	6	------
Pennsylvania	**30**	**10**	------	------	------	------	------
State share	15	5	------	------	------	------	------
South Carolina	------	------	**5**	------	------	------	------
State share	------	------	5	------	------	------	------
Texas	**3**	------	------	------	------	------	------
State share	3	------	------	------	------	------	------
Utah	**18**	**7**	**6**	**37**	**8**	**6**	**8**
State share	7	7	4	4	5	3	4
Washington	**122**	**67**	**134**	**81**	**7**	**42**	**105**
State share	30	20	30	35	3	16	20
West Virginia	**20**	**20**	**21**	**3**	**17**	**1**	------
State share	10	10	10	3	17	1	------
Wisconsin	**82**	**76**	**68**	**121**	**8**	**18**	**16**
State share	8	8	8	8	2	6	8
Wyoming	**27**	**26**	**11**	**35**	------	**107**	**135**
State share	2	2	2	2	------	1	1
Puerto Rico	**570**	**461**	**474**	**336**	**40**	**208**	**256**
State share	174	243	183	130	12	81	131

[1] Includes Federal funds from direct program.

[2] Includes reimbursable program funds from States, counties, and municipalities.

TABLE 24.—*Geologic and Mineral Resource Surveys and Mapping reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978, by agency*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$11,222**	**$19,321**	**$20,158**	**$16,828**	**$5,862**	**$22,420**	**$29,897**
Appalachian Regional Commission	------	189	179	------	------	------	------
Department of Commerce	------	------	------	342	------	176	14
National Oceanic and Atmospheric Administration	------	2,001	434	1,513	772	1,947	1,708
Department of Defense	1,431	5,670	2,648	2,443	739	1,902	3,107
Department of Energy [1]	2,134	3,125	2,895	3,401	1,480	6,396	12,062
Department of Housing and Urban Development	294	224	817	------	------	------	------
Department of the Interior	156	------	5,719	2,330	1,209	3,957	7,210
Office of the Secretary	------	------	------	------	44	------	------
Bureau of Indian Affairs	------	------	243	370	144	467	1,796
Bureau of Land Management	------	------	3,741	1,851	915	3,192	4,927
Bureau of Mines	------	------	1,735	109	------	138	60
Bureau of Reclamation	------	------	------	------	71	149	427
National Park Service	------	------	------	------	35	11	------
Office of Saline Water [2]	156	------	------	------	------	------	------
Department of State	1,975	1,510	1,056	359	73	477	503
Environmental Protection Agency	------	------	------	------	------	190	364
National Aeronautics and Space Administration	4,708	4,745	2,938	2,800	977	2,433	2,667
National Science Foundation	135	1,329	1,604	1,538	35	2,618	645
Nuclear Regulatory Commission	------	------	1,195	1,439	427	1,758	1,318
Miscellaneous Federal agencies	389	528	673	663	150	566	299

[1] Shown as Energy Research and Development and Federal Energy Administration, prior to October 1, 1977; includes Atomic Energy Commission funds for fiscal years 1973 and 1974. See also funds from Nuclear Regulatory Commission in fiscal year 1975.

[2] Merged in 1974 with the Office of Water Resources to form the Office of Water Research and Technology.

TABLE 25.—*Water Resources Investigations direct program funds for fiscal years 1973 to 1978, by subactivity*

[In thousands of dollars]

Subactivity	1973	1974	1975	1976	Transition quarter	1977	1978
Total direct program [1]	**$40,185**	**$45,433**	**$53,420**	**$57,176**	**$15,916**	**$68,555**	**$78,487**
National Water Data System	37,523	42,993	48,191	48,494	12,816	55,826	70,393
Federal program	16,334	17,695	21,183	20,487	5,724	21,809	35,424
Federal-State program [2]	21,189	25,298	27,008	28,007	7,092	34,017	34,969
Energy hydrology [3]	2,662	2,440	5,229	8,682	3,100	12,729	8,094

[1] Direct program funds exclude the Employee Compensation Payments subactivity for fiscal years 1973 to 1978.
[2] Federal share of Federal-State Cooperative Program.
[3] Prior to 1978, shown as Critical National Water Problems.

TABLE 26.—*Water Resources Investigations, Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*

[In thousands of dollars]

State	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	**$43,925**	**$51,118**	**$55,554**	**$57,742**	**$14,763**	**$68,778**	**$70,805**
State share [2]	22,736	25,820	28,546	29,735	7,672	35,756	36,457
Alabama	**868**	**1,044**	**1,135**	**1,042**	**165**	**1,112**	**1,044**
State share	479	529	587	509	84	546	517
Alaska	**506**	**659**	**686**	**782**	**202**	**1,141**	**1,275**
State share	264	317	335	407	101	561	654
Arizona	**1,001**	**1,144**	**1,248**	**1,255**	**335**	**1,393**	**1,552**
State share	510	576	646	639	177	700	783
Arkansas	**457**	**674**	**650**	**627**	**162**	**888**	**975**
State share	225	399	347	307	80	435	482
California	**3,850**	**4,229**	**4,381**	**4,520**	**1,170**	**5,037**	**5,784**
State share	1,938	2,101	2,190	2,304	607	2,541	2,927
Colorado	**1,078**	**1,480**	**1,615**	**1,779**	**504**	**2,374**	**2,550**
State share	545	835	909	986	270	1,225	1,318
Connecticut	**412**	**486**	**687**	**548**	**123**	**643**	**650**
State share	203	239	386	285	64	319	322
Delaware	**121**	**130**	**194**	**213**	**54**	**225**	**192**
State share	81	74	106	116	30	121	109
District of Columbia	**3**	**3**	**3**	**3**	**1**	**4**	**4**
State share	1	1	1	2	0	2	2
Florida	**3,071**	**4,505**	**5,055**	**5,257**	**1,405**	**6,050**	**6,566**
State share	1,572	2,263	2,521	2,593	697	3,013	3,339
Georgia	**790**	**939**	**1,081**	**1,170**	**308**	**1,872**	**1,334**
State share	432	461	530	573	153	919	675
Hawaii	**653**	**691**	**697**	**896**	**191**	**811**	**880**
State share	337	339	341	501	101	417	458
Idaho	**675**	**718**	**749**	**852**	**223**	**952**	**1,131**
State share	344	353	366	417	111	465	611
Illinois	**526**	**514**	**575**	**778**	**200**	**1,039**	**1,026**
State share	273	262	288	424	116	557	542
Indiana	**973**	**1,227**	**1,152**	**1,411**	**364**	**1,893**	**1,872**
State share	523	610	564	725	181	934	1,011
Iowa	**525**	**592**	**617**	**646**	**177**	**778**	**829**
State share	259	291	302	317	89	381	420
Kansas	**1,110**	**1,116**	**1,156**	**1,259**	**338**	**1,519**	**1,941**
State share	552	543	582	619	168	748	965
Kentucky	**698**	**719**	**875**	**981**	**244**	**1,003**	**1,086**
State share	348	353	427	480	121	490	536
Louisiana	**1,190**	**1,748**	**1,620**	**1,604**	**418**	**2,530**	**1,766**
State share	649	904	842	817	216	1,270	884
Maine	**128**	**135**	**208**	**273**	**69**	**295**	**348**
State share	71	76	107	161	40	160	174
Maryland	**646**	**817**	**972**	**986**	**241**	**1,144**	**1,154**
State share	335	418	511	502	124	586	595

See footnotes at end of table.

TABLE 26.—*Water Resources Investigations, Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
Massachusetts	**$ 550**	**$ 593**	**$ 787**	**$ 747**	**$ 182**	**$ 785**	**$ 861**
State share	322	333	480	449	91	446	479
Michigan	**631**	**652**	**796**	**830**	**207**	**873**	**971**
State share	310	321	390	406	103	426	481
Minnesota	**712**	**811**	**799**	**945**	**320**	**1,078**	**1,281**
State share	373	420	397	502	198	564	710
Mississippi	**593**	**645**	**743**	**646**	**170**	**713**	**754**
State share	340	325	415	316	85	349	407
Missouri	**602**	**523**	**544**	**532**	**131**	**503**	**561**
State share	310	255	270	261	67	249	279
Montana	**402**	**505**	**587**	**596**	**146**	**1,330**	**676**
State share	223	255	287	301	76	673	338
Nebraska	**588**	**705**	**731**	**785**	**187**	**957**	**1,048**
State share	298	344	358	396	95	469	522
Nevada	**351**	**377**	**408**	**468**	**125**	**566**	**643**
State share	178	185	200	228	62	276	318
New Hampshire	**108**	**118**	**122**	**177**	**50**	**203**	**187**
State share	54	58	60	86	25	96	92
New Jersey	**856**	**1,051**	**977**	**1,090**	**276**	**1,269**	**1,427**
State share	433	530	501	565	143	642	841
New Mexico	**1,087**	**1,292**	**1,412**	**1,476**	**336**	**1,531**	**1,609**
State share	591	642	706	742	173	772	826
New York	**2,161**	**2,410**	**2,730**	**2,822**	**715**	**2,990**	**3,273**
State share	1,112	1,222	1,462	1,615	401	2,550	1,843
North Carolina	**767**	**876**	**977**	**960**	**255**	**1,095**	**1,111**
State share	394	430	479	473	135	536	557
North Dakota	**657**	**675**	**776**	**792**	**236**	**802**	**903**
State share	340	325	378	390	120	392	445
Ohio	**878**	**828**	**943**	**1,105**	**298**	**1,420**	**1,665**
State share	445	406	488	596	156	749	906
Oklahoma	**522**	**592**	**638**	**676**	**160**	**750**	**848**
State share	284	289	313	331	80	366	418
Oregon	**750**	**852**	**810**	**867**	**263**	**1,130**	**1,188**
State share	393	417	397	433	151	589	597
Pennsylvania	**1,691**	**1,955**	**2,103**	**2,186**	**522**	**2,466**	**2,578**
State share	864	994	1,053	1,107	268	1,239	1,311
Rhode Island	**90**	**97**	**110**	**124**	**31**	**127**	**154**
State share	50	52	54	60	16	63	77
South Carolina	**454**	**546**	**533**	**557**	**142**	**603**	**625**
State share	241	279	261	272	71	296	329
South Dakota	**373**	**421**	**465**	**478**	**118**	**518**	**618**
State share	205	202	226	234	59	253	309
Tennessee	**551**	**801**	**908**	**1,019**	**280**	**1,249**	**1,383**
State share	302	397	448	500	139	612	686
Texas	**3,049**	**3,320**	**3,575**	**3,669**	**932**	**3,955**	**4,145**
State share	1,575	1,664	1,757	1,807	465	2,021	2,054
Utah	**937**	**941**	**1,255**	**1,177**	**286**	**1,525**	**1,317**
State share	466	467	784	691	161	757	659
Vermont	**109**	**104**	**96**	**118**	**28**	**134**	**138**
State share	56	53	47	58	14	70	68
Virginia	**661**	**673**	**640**	**549**	**128**	**482**	**560**
State share	355	350	333	284	71	250	288
Washington	**1,834**	**2,020**	**2,068**	**2,006**	**496**	**3,219**	**2,410**
State share	916	1,000	1,074	1,017	259	1,632	1,212
West Virginia	**302**	**420**	**526**	**511**	**132**	**647**	**642**
State share	173	258	324	314	75	380	365
Wisconsin	**870**	**1,075**	**1,224**	**1,343**	**336**	**1,395**	**1,445**
State share	429	561	668	786	191	784	807
Wyoming	**575**	**662**	**832**	**709**	**163**	**790**	**754**
State share	303	321	507	390	84	387	374
American Samoa	**64**	**63**	**70**	**40**	**9**	**60**	**64**
State share	32	31	32	20	4	30	32
Guam	**43**	**62**	**65**	**68**	**18**	**70**	**85**
State share	21	31	32	33	9	33	47
Northern Marianas	------	------	------	------	------	------	**18**
State share	------	------	------	------	------	------	9

See footnotes at end of table.

TABLE 26.—*Water Resources Investigations, Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*—Continued

State	1973	1974	1975	1976	Transition quarter	1977	1978
Puerto Rico	**$701**	**$766**	**$745**	**$604**	**$145**	**$635**	**$654**
State share	345	401	365	295	72	315	322
Trust Territories	**125**	**117**	**170**	**170**	**44**	**173**	**180**
State share	62	58	84	84	22	84	90
Virgin Islands	(3)	(3)	**33**	**18**	**2**	**32**	**70**
State share	------	------	31	9	1	16	35

[1] Includes Federal funds from direct program.
[2] Includes reimbursable program funds from States, counties, and municipalities.
[3] Included with Puerto Rico funds.

TABLE 27.—*Water Resources Investigations reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978, by agency*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$14,518**	**$16,378**	**$18,570**	**$24,631**	**$6,868**	**$26,862**	**$29,641**
Department of Agriculture	273	261	565	753	172	662	788
Department of Commerce	73	(1)	154	1,733	36	37	------
Department of Defense	6,953	7,554	8,391	9,367	2,414	10,135	11,759
Department of Energy [2]	877	904	959	1,142	446	2,177	2,918
Bonneville Power Administration	118	101	105	130	32	141	138
Department of Housing and Urban Development	1,801	3,018	2,252	4,624	1,873	6,003	3,789
Department of the Interior	1,984	2,026	3,190	3,668	1,035	4,597	6,410
Bureau of Indian Affairs	89	175	256	179	113	269	494
Bureau of Land Management	207	178	1,130	1,749	494	2,406	3,407
Bureau of Mines	------	------	------	39	------	62	48
Bureau of Reclamation	855	676	721	790	196	1,040	1,434
National Park Service	459	529	617	576	155	518	791
U.S. Fish and Wildlife Service	256	367	361	205	45	161	236
Department of State	781	667	642	589	148	598	507
Department of Transportation	------	------	47	214	31	242	193
Environmental Protection Agency	916	1,127	1,389	1,921	571	1,847	2,610
National Aeronautics and Space Administration	343	284	235	213	14	60	59
National Science Foundation	------	------	67	------	------	------	------
Tennessee Valley Authority	255	212	252	216	70	297	216
Miscellaneous Federal agencies	262	325	494	191	58	207	392

[1] Included with miscellaneous Federal agencies funds.
[2] Prior to October 1, 1977, shown as Energy Research and Development. Includes Atomic Energy Commission funds for fiscal years 1973 and 1974.

TABLE 28.—*Conservation of Lands and Minerals direct program funds for fiscal years 1973 to 1978, by subactivity*

[In thousands of dollars]

Subactivity	1973	1974	1975	1976	Transition quarter	1977	1978
Total direct program	**$14,700**	**$18,172**	**$36,032**	**$41,489**	**$13,347**	**$67,239**	**$77,299**
Outer Continental Shelf lands	8,114	10,957	23,196	26,194	9,119	37,970	45,995
Federal and Indian lands	6,586	7,215	12,836	15,295	4,255	29,269	31,304

TABLE 29.—*Conservation of Lands and Minerals reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$45**	**$41**	**$46**	**$186**	**$6**	**$172**	**$101**
Department of Defense	24	25	25	25	------	------	------
Miscellaneous Federal agencies	21	16	21	161	6	172	101

TABLE 30.—*Land Information and Analysis direct program funds for fiscal years 1973 to 1978, by subactivity*

[In thousands of dollars]

Subactivity	1973	1974	1975	1976	Transition quarter	1977	1978
Total direct program	**$11,876**	**$11,458**	**$15,461**	**$14,908**	**$7,795**	**$17,698**	**$18,132**
Earth Resources Observation Systems	10,357	8,962	8,284	8,158	4,840	9,545	9,719
Environmental Impact Analysis	------	------	2,605	2,040	1,310	3,172	3,260
Geography	------	------	2,013	2,341	747	2,527	2,600
Land Resource Data Applications [1]	1,519	2,496	2,559	2,369	898	2,454	2,553

[1] Prior to 1978, this subactivity was shown as "Earth Sciences Applications" and "Resource and Land Investigations."

TABLE 31.—*Land Information and Analysis reimbursable program funds from other Federal agencies for fiscal years 1973 to 1978, by agency*

[In thousands of dollars]

Agency	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**$1,249**	**$1,000**	**$407**	**$744**	**$636**	**$3,848**	**$2,890**
Department of Defense	------	10	------	------	------	------	------
Department of Housing and Urban Development	------	339	------	------	------	------	------
Department of the Interior	------	48	11	15	40	3,088	2,148
Bureau of Land Management	------	35	------	8	------	3,088	2,013
Bureau of Mines	------	------	------	3	------	------	------
National Park Service	------	------	------	------	40	------	------
Office of Surface Mining	------	------	------	------	------	------	135
U.S. Fish and Wildlife Service	------	13	11	4	------	------	------
Department of Transportation	------	------	------	------	179	6	------
Environmental Protection Agency	------	------	------	------	206	100	100
National Aeronautics and Space Administration	1,249	408	179	443	60	122	35
Ozarks Regional Commission	------	60	49	31	------	------	------
Miscellaneous Federal agencies	------	87	168	255	151	532	607

TABLE 32.—*Land Information and Analysis Federal-State Cooperative Program funds for fiscal years 1973 to 1978, by State*

[In thousands of dollars]

State	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	------	------	**$66**	**$250**	**$38**	**$362**	**$92**
Total State share [2]	------	------	33	130	19	190	51
Alabama	------	------	------	**34**	**6**	**90**	------
State share	------	------	------	17	3	45	------
California	------	------	------	------	------	------	**50**
State share	------	------	------	------	------	------	25
Florida	------	------	**66**	**56**	------	------	------
State share	------	------	33	33	------	------	------
Hawaii	------	------	------	------	------	------	**8**
State share	------	------	------	------	------	------	4
Missouri	------	------	------	------	**32**	**200**	------
State share	------	------	------	------	16	109	------
New Jersey	------	------	------	------	------	------	**10**
State share	------	------	------	------	------	------	10
North Carolina	------	------	------	------	------	**72**	**24**
State share	------	------	------	------	------	36	12
Pennsylvania	------	------	------	**100**	------	------	------
State share	------	------	------	50	------	------	------
West Virginia	------	------	------	**60**	------	------	------
State share	------	------	------	30	------	------	------

[1] Includes Federal funds from direct program.

[2] Includes reimbursable funds from States, counties, and municipalities.

TABLE 33.—*Program support funds for fiscal years 1973 to 1978, by activity*

[In thousands of dollars]

Program support activity	1973	1974	1975	1976	Transition quarter	1977	1978
Administrative Expenses [1]	**$7,173**	**$8,197**	**$10,806**	**$11,451**	**$3,675**	**$13,982**	**$16,486**
General Administration [2]	3,217	3,517	3,671	3,398	1,492	3,760	3,650
Direct program assessments [3]	2,352	2,770	5,126	5,766	1,466	7,015	9,092
Reimbursable program assessment [4]	1,604	1,910	2,009	2,287	717	3,207	3,744
Electronic data processing and related services [5]	**6,168**	**6,987**	**8,425**	**7,432**	**1,922**	**12,728**	**15,318**
Funded by Survey programs [6]	4,177	4,828	6,129	6,700	1,908	12,631	14,987
Funded by miscellaneous accounts [7]	1,991	2,159	2,296	732	14	97	331
Publication services	**11,656**	**11,932**	**13,004**	**15,468**	**3,705**	**15,412**	**16,445**
Funded by Survey programs [6]	11,147	11,432	12,488	14,662	3,469	14,719	15,421
Funded by miscellaneous accounts [7]	509	500	516	806	236	693	1,024

[1] Obligations of the Director's Office for executive direction and of the Administration Division for management services.

[2] Direct program funds of the General Administration budget activity. Obligations reconstructed for fiscal years 1973 to 1975 to include Employee Compensation Payments.

[3] Assessments made on direct program funds of other budget activities.

[4] Assessments made on reimbursable program funds of other budget activities. No assessments are made on cooperative funds from State and local governments.

[5] Obligations of the Computer Center Division.

[6] Obligations charged to Survey program activities.

[7] Obligations charged to the Miscellaneous Services to Other Accounts activity for reimbursable work done for other agencies.

TABLE 34.—*Geological Survey end-of-year employment for fiscal years 1973 to 1978, by organizational unit*

Organizational unit	1973	1974	1975	1976	1977	1978
Total	**9,387**	**9,921**	**10,435**	**[1]11,868**	**[2]11,930**	**[3]12,577**
Permanent employment	8,089	8,357	8,999	[1] 9,049	[2] 9,326	9,587
Other than permanent employment	1,298	1,564	1,436	2,819	2,604	2,990
Topographic Division	**2,020**	**1,956**	**1,877**	**1,859**	**1,870**	**1,909**
Permanent employment	1,758	1,762	1,719	1,664	1,644	1,642
Other than permanent employment	262	194	158	195	226	267
Geologic Division	**2,147**	**2,406**	**2,572**	**3,170**	**2,981**	**3,173**
Permanent employment	1,766	1,888	2,135	2,089	2,046	2,060
Other than permanent employment	381	518	437	1,081	935	1,113

See footnotes at end of table.

TABLE 34.—*Geological Survey end-of-year employment for fiscal years 1973 to 1978, by organizational unit*—Continued

Organizational unit	1973	1974	1975	1976	1977	1978
Water Resources Division	**3,419**	**3,611**	**3,610**	**4,131**	**3,946**	**4,170**
Permanent employment	2,900	2,910	2,957	2,895	2,840	2,950
Other than permanent employment	519	701	653	1,236	1,106	1,220
Conservation Division	**568**	**647**	**990**	**1,242**	**1,586**	**1,759**
Permanent employment	547	612	926	1,143	1,498	1,633
Other than permanent employment	21	35	64	99	88	126
Land Information and Analysis Office	**72**	**85**	**114**	**175**	**191**	**200**
Permanent employment	52	68	89	116	126	127
Other than permanent employment	20	17	25	59	65	73
National Petroleum Reserve in Alaska	------	------	------	------	**25**	**30**
Permanent employment	------	------	------	------	22	23
Other than permanent employment	------	------	------	------	3	7
Director's Office	**57**	**64**	**66**	**71**	**76**	**91**
Permanent employment	55	62	57	59	63	64
Other than permanent employment	2	2	9	12	13	27
Administrative Division	**382**	**408**	**441**	**468**	**508**	**526**
Permanent employment	341	366	398	403	424	448
Other than permanent employment	41	42	43	65	84	78
Facilities [4]	------	**15**	**30**	**51**	**58**	**58**
Permanent employment	------	15	30	37	37	37
Other than permanent employment	------	------	------	14	21	21
Computer Center Division	**174**	**182**	**198**	**154**	**174**	**172**
Permanent employment	153	159	178	125	145	144
Other than permanent employment	21	23	20	29	29	28
Publications Division	**548**	**547**	**537**	**527**	**501**	**472**
Permanent employment	517	515	510	498	467	442
Other than permanent employment	31	32	27	29	34	30

[1] Includes 20 Bureau clerical pool in fiscal year 1976.
[2] Includes 14 Bureau clerical pool in fiscal year 1977.
[3] Includes 17 Bureau clerical pool in fiscal year 1978.
[4] Administrative Division personnel assigned to the operation of the Survey's Headquarter facilities.

TABLE 35.—*Number of Geological Survey reports approved for publication for fiscal years 1973 to 1978, by organizational unit*

Organizational unit	1973	1974	1975	1976	Transition quarter	1977	1978
Total	**2,548**	**2,755**	**2,888**	**3,418**	**883**	**3,735**	**3,713**
Book reports [1]	147	155	144	146	29	179	225
Journal of Research articles [2]	107	90	85	101	19	93	95
Open-file reports	380	440	570	781	215	851	943
Basic data reports	255	230	256	207	44	102	76
Outside publications [3]	1,659	1,840	1,833	2,183	576	2,531	2,374
Topographic Division	**53**	**53**	**33**	**36**	**6**	**41**	**38**
Book reports	------	------	------	------	------	------	------
Journal of Research articles	2	1	------	------	------	3	------
Open-file reports	------	------	------	------	------	------	4
Outside publications	51	52	33	36	6	38	34
Geologic Division	**1,419**	**1,546**	**1,811**	**2,209**	**578**	**2,527**	**2,496**
Book reports	91	96	90	101	16	108	95
Journal of Research articles	79	69	70	62	14	62	75
Open-file reports	216	245	379	499	145	581	704
Outside publications	1,033	1,136	1,272	1,547	403	1,776	1,622
Water Resources Division	**953**	**1,002**	**926**	**1,061**	**245**	**943**	**949**
Book reports	54	56	50	42	11	42	122
Journal of Research articles	26	20	15	38	5	23	15
Open-file reports	149	181	152	264	55	215	173
Basic data reports	255	230	256	207	44	102	76
Outside publications	469	515	453	510	130	561	563

See footnotes at end of table.

TABLE 35.—*Number of Geological Survey reports approved for publication for fiscal years 1973 to 1978, by organizational unit*—Continued

Organizational unit	1973	1974	1975	1976	Transition quarter	1977	1978
Conservation Division	**17**	**18**	**44**	**28**	**15**	**78**	**80**
Book reports	------	2	1	------	1	1	------
Journal of Research articles	------	------	------	------	------	------	------
Open-file reports	13	11	32	13	10	48	55
Outside publications	4	5	11	15	4	28	25
Director's Office [4]	**106**	**136**	**74**	**84**	**39**	**146**	**150**
Book reports	2	1	3	3	1	5	8
Journal of Research articles	----	----	----	1	----	6	5
Open-file reports	2	3	7	5	5	7	7
Outside publications	102	132	64	75	33	128	130

[1] Book reports include Survey Professional Papers, Bulletins, Water-Supply Papers, Circulars, and other report series.
[2] Before January 1973, articles were published as part of the annual "Geological Survey Research" Professional Paper.
[3] Articles by Survey authors published in non-Survey technical and scientific journals and periodicals, in symposium proceedings, and the like.
[4] Includes reports of the Land Information and Analysis Office, Administrative Division, Computer Center Division, and Publications Division.

TABLE 36.—*Number of maps produced by the Geological Survey for fiscal years 1973 to 1978, by organizational unit*

Organizational unit	1973	1974	1975	1976	Transition quarter	1977	1978
Total [1]	**10,304**	**7,361**	**8,722**	**9,099**	**2,310**	**11,354**	**10,263**
Topographic Division	**5,313**	**4,938**	**7,288**	**7,339**	**2,080**	**10,508**	**9,604**
Quadrangle maps	5,117	4,780	7,087	6,757	1,970	10,012	8,948
New standard quadrangles	2,347	2,052	2,016	1,405	237	1,318	1,083
Orthophotoquads	49	15	2,869	3,197	730	4,127	4,467
Revisions	1,118	966	923	656	165	1,081	1,322
Reprints	1,603	1,747	1,279	1,499	838	3,486	2,076
Small-scale and special maps	148	121	171	582	114	496	656
1:250,000 series	57	50	52	37	5	31	50
Antarctica	5	------	4	6	------	------	------
State bases	2	------	2	34	1	14	7
Other	25	8	24	112	6	1	7
Reprints	59	63	80	73	54	117	84
Intermediate scale	------	------	9	259	32	304	452
Topographic maps indexes	48	37	30	61	16	29	56
Geologic Division [2]	**320**	**215**	**229**	**285**	**71**	**384**	**488**
Water Resources Division [3]	**4,650**	**2,192**	**1,198**	**1,358**	**109**	**361**	**164**
Hydrologic maps	84	52	58	653	70	60	79
Flood-prone area maps	4,566	2,140	1,140	705	39	301	85
Conservation Division [4]	**8**	**9**	**5**	**14**	----	**14**	**2**
Director's Office [4]	**13**	**7**	**2**	**103**	**46**	**87**	**5**

[1] Additional maps are produced for inclusion in book reports.
[2] Geologic and geophysical maps.
[3] Includes hydrologic unit maps.
[4] Miscellaneous maps and charts.

TABLE 37.—*Oil and gas operations on the Outer Continental Shelf lands for calendar years 1973 to 1978*

Activity	1973	1974	1975	1976	1977	[1]1978
Number of exploration permits issued	**350**	**400**	**486**	**422**	**472**	**640**
Lease sales:						
Number of sales	6	5	4	4	3	5
Number of tracts offered	276	1,006	1,374	536	358	500
Area (acres in thousands)	1,515	5,006	7,248	2,827	1,843	2,695
Number of tracts sold	187	356	321	246	211	168
Area (acres in thousands)	1,033	1,762	1,680	1,278	1,101	8,849
Percentage	67.8	35.4	23.4	45.9	58.9	62.6
Bonuses (dollars in thousands)	$3,082,463	$5,022,861	$1,088,133	$2,242,899	$1,568,565	$1,400,000

See footnotes at end of table.

TABLE 37.—*Oil and gas operations on the Outer Continental Shelf lands for calendar years 1973 to 1978*—Continued

Activity	1973	1974	1975	1976	1977	[1]1978
Status of leases:						
Total number of leases supervised	1,266	1,590	1,792	1,996	2,148	2,250
Total area (acres in thousands)	5,614	7,247	8,321	9,432	10,235	11,500
Number of producing leases	726	748	790	833	896	980
Area (acres in thousands)	3,039	3,147	3,253	3,477	3,893	4,250
Percentage	57.3	47.0	44.0	41.7	41.7	43.5
Number of nonproducing leases	540	842	1,002	1,163	1,252	1,270
Area (acres in thousands)	2,575	4,100	5,069	5,956	6,342	7,250
Percentage	42.7	53.0	56.0	58.3	58.3	56.5
Lease operations:						
Number of platforms	2,016	2,059	2,084	2,100	2,255	2,360
Number of new well starts	820	816	892	1,041	1,158	1,275
Number of new wells completed	420	310	392	432	528	630
Number of new zones completed	600	398	515	530	651	869
Oil zones	304	226	225	264	292	410
Gas zones	288	155	277	258	347	450
Service zones	8	17	13	8	12	9
Total number of completed wells	6,421	6,218	6,104	6,770	7,914	8,544
Total number of completed zones	10,187	8,750	9,074	13,407	10,700	11,400
Oil zones	6,868	4,418	4,519	6,760	4,877	5,200
Gas zones	2,987	2,403	2,765	3,648	3,098	3,180
Service zones	332	416	325	333	404	400
Other zones [2]	------	1,513	1,465	2,666	2,321	2,620
Pipeline (miles under supervision) [1]	6,450	6,700	7,150	7,400	9,650	[3]12,400
Production:						
Oil and condensate (barrels in millions)	395	361	330	317	304	291
Percentage of domestic production	11.8	11.2	10.8	10.8	10.2	10.0
Gas (cubic feet in billions)	3,212	3,515	3,459	3,596	3,738	4,180
Percentage of domestic production	14.0	16.0	17.2	18.1	18.8	21.1
Gasoline and LPG [4] (gallons in millions)	1,635	2,032	1,983	1,924	2,055	2,250
Percentage of domestic production	6.1	7.9	7.9	8.0	8.4	9.2

[1] Estimated.
[2] New classification since 1974.
[3] Includes DOI and DOT jurisdictional pipelines.
[4] Liquified petroleum gas.

TABLE 38.—*Revenues from leases on Outer Continental Shelf lands for calendar years 1973 to 1978*

[In thousands of dollars]

	1973	1974	1975	1976	1977	1978 [1]
Total revenue	**$3,494,981**	**$5,598,758**	**$1,723,758**	**$2,967,861**	**$2,509,742**	**$2,465,000**
Bonuses	3,082,462	5,022,861	1,088,133	2,242,899	1,568,565	1,400,000
Minimum royalties	2,391	2,048	2,086	2,128	1,679	2,000
Rentals	8,949	13,533	17,522	23,371	19,830	21,000
Number of accounts	(647)	(1,036)	(1,203)	(1,430)	(1,239)	(1,400)
Shut-in-gas payments	53	32	40	38	21	20
Totals:						
Royalties	**401,126**	**560,284**	**615,545**	**699,425**	**919,647**	**1,042,000**
Production value	**(2,486,865)**	**[2](3,570,054)**	**(3,924,915)**	**(4,395,905)**	**(5,774,056)**	**6,499,000**
Number of accounts	(1,158)	(2,260)	(2,468)	(2,850)	(3,378)	(3,400)
Oil and condensate:						
Royalties	271,491	384,367	399,527	412,303	441,147	452,000
Production value	(1,620,732)	(2,398,794)	(2,428,849)	(2,533,410)	(2,683,000)	2,769,000
Gas:						
Royalties	118,245	142,257	195,198	268,090	449,323	566,000
Production value	(736,878)	(881,634)	(1,205,678)	(1,652,843)	(2,766,397)	3,468,000
Gasoline and LPG [3]:						
Royalties	7,768	19,797	16,376	19,656	27,688	22,000
Production value	(105,437)	(254,744)	(216,043)	(246,449)	(314,642)	(250,000)
All Others [4]:						
Royalties	3,622	4,468	4,444	[5]624 (CR)	1,489	2,000
Production value	(23,818)	(38,832)	(74,345)	(30,262) (CR)	(9,436)	12,000

[1] Estimated in part.
[2] Includes $3,950,000 of lost oil and gas.
[3] Liquified petroleum gas.
[4] All others includes salt, sulfur, oil, and gas lost.
[5] Credit due to productive leases transferred to Louisiana Supreme Court decree of June 16, 1975.

TABLE 39.—*Oil, gas, and geothermal operations on Federal and Indian lands for calendar years 1973 to 1978*

Activity	1973	1974	1975	1976	1977	1978 [1]
Competitive oil and gas lease sales [2]:						
Tracts offered:						
Number of tracts:	339	421	420	480	509	500
Area (acres in thousands)	86,681	98,064	102,367	96,900	95,194	89,500
Tracts sold:						
Number of tracts	311	295	356	356	334	465
Area (acres in thousands)	89,315	65,247	112,401	74,616	80,529	85,000
Percentage of tracts sold	91.7	70.1	84.8	74.2	65.9	94.9
Bonus (dollars in thousands)	$2,203	$2,296	$8,203	$4,934	$7,821	$14,000
Regulatory and supervisory operations [3]:						
Status of oil and gas leases:						
Total number of leases supervised	115,761	123,652	125,720	125,817	127,006	129,800
Total area (acres in thousands)	79,116	89,829	93,717	93,682	97,036	101,000
Number of producing leases	11,953	12,386	12,961	13,541	14,219	15,000
Area (acres in thousands)	5,902	6,349	6,564	6,794	7,208	8,700
Percentage	10.3	10.0	10.3	10.8	11.1	11.5
Number of nonproducing leases	103,808	111,266	112,759	112,276	112,847	114,800
Area (acres in thousands)	73,214	83,480	84,153	86,888	89,828	93,000
Percentage	89.7	90.0	89.7	89.2	88.9	92.0
Oil and gas lease operations:						
Number of new well starts	1,848	2,312	2,277	2,032	2,619	3,425
Number of new wells completed	1,132	1,280	1,569	1,525	1,763	1,880
Number of new zones completed	1,172	1,341	1,646	1,391	1,817	1,910
Oil zones	507	701	923	789	900	980
Gas zones	601	579	606	542	833	839
Service zones	64	61	117	60	84	91
Total number of completed wells	38,199	38,372	38,218	37,835	39,050	40,200
Total number of completed zones	39,991	40,251	40,292	39,470	40,760	42,663
Oil zones	23,139	22,791	21,868	21,101	21,481	22,461
Gas zones	11,083	11,487	12,272	12,211	12,963	13,802
Service zones	5,769	5,973	6,152	6,158	6,316	6,400
Oil and gas production:						
Oil and condensate (barrels in millions)	208	208	200	195	190	186
Percentage of domestic production	6.2	6.4	6.6	6.7	6.4	6.4
Gas (cubic feet in billions)	1,153	1,234	1,111	1,209	1,166	1,191
Percentage of domestic production	5.1	5.6	5.3	6.1	5.9	6.0
Gasoline and LPG [4] (gallons in millions)	669	567	521	461	300	240
Percentage of domestic production	2.5	2.2	2.1	1.9	1.2	1.0
Status of geothermal leases:						
Total number of leases in effect	----	----	552	915	1,064	1,140
Total area (acres in thousands)	----	----	1,270	1,760	2,017	2,017

[1] Estimated in part.
[2] On Federal lands only.
[3] On Federal and Indian lands.
[4] Liquified petroleum gas.

TABLE 40.—*Royalties from oil and gas leases on Federal and Indian lands for calendar years 1973 to 1978*

[In thousands of dollars]

Commodity	1973	1974	1975	1976	1977	1978 [1]
Total royalties	**$ 34,568**	**$ 219,630**	**$ 243,345**	**$ 279,066**	**$ 315,607**	**$ 348,715**
Total production value	(1,074,758)	(1,728,536)	(1,915,768)	(2,156,497)	(2,459,120)	(2,697,550)
Oil and condensate:						
Royalties	100,963	176,566	193,608	200,864	199,602	211,000
Production value	(783,149)	(1,349,656)	(1,459,088)	(1,499,835)	(1,496,983)	(1,585,000)
Gas:						
Royalties	31,263	39,798	47,508	74,616	111,519	132,000
Production value	(248,768)	(315,490)	(374,785)	(593,659)	(880,367)	(1,019,000)
Gasoline and LPG [2]:						
Royalties	2,323	3,238	3,789	3,132	3,888	5,000
Production value	(42,398)	(62,758)	(76,632)	(60,636)	(76,309)	(83,800)
All others:						
Royalties	19	28	440	454	598	715
Production value	(443)	(632)	(5,263)	(2,367)	(5,461)	(9,750)

[1] Estimated in part.
[2] Liquified petroleum gas.

TABLE 41.—*Mining operations on Federal and Indian lands for fiscal years 1973 to 1978, by activity and by commodity*

[Acres and tons in thousands]

Activity and commodity	1973	1974	1975	1976	Transition quarter	1977	1978 [1]
Total number of leases supervised	**2,579**	**2,488**	**2,479**	**2,557**	**2,575**	**2,425**	**2,143**
Total area in acres	**7,566**	**7,830**	**7,977**	**9,096**	**9,167**	**8,891**	**8,533**
Total number of producible mines	**338**	**377**	**435**	**450**	**450**	**460**	**470**
Total production in tons	**42,028**	**54,978**	**76,113**	**81,554**	**21,000**	**89,276**	**95,400**
Coal:							
Number of leases supervised	561	563	565	570	573	562	565
Area (in acres)	1,038	977	1,023	1,057	1,060	1,054	1,056
Production (in tons)	24,247	32,139	43,590	52,491	14,000	74,439	78,300
Percentage of domestic production	4.1	5.4	7.2	7.9	8.5	10.8	11.0
Oil shale:							
Number of leases supervised	------	4	4	4	4	4	4
Area (in acres)	------	20.4	20.4	20.4	20.4	20.4	20.4
Production (in tons)	------	------	------	------	------	------	------
Phosphate:							
Number of leases supervised	219	194	194	279	280	279	278
Area (in acres)	131	100	100	114	114	114	114
Production (in tons)	3,156	6,258	5,772	6,937	1,500	4,432	4,640
Percentage of domestic production	7.4	14.0	11.8	13.9	12.0	9.0	9.5
Potash:							
Number of leases supervised	163	158	161	163	163	160	163
Area (in acres)	246	238	237	237	237	231	233
Production (in tons) [2]	3,442	3,551	3,302	3,576	1,000	3,677	3,296
Percentage of domestic production	75.5	79.2	87.8	81.3	83.0	90.3	84.5
Sodium:							
Number of leases supervised	84	84	84	89	90	90	91
Area (in acres)	132	132	132	136	138	133	133
Production (in tons)	2,336	2,092	2,826	3,311	950	2,629	3,955
Percentage of domestic production	50.5	45.4	58.9	69.2	79.4	38.8	54.9
Other commodities:							
Number of leases supervised	1,552	1,485	1,471	1,452	1,465	1,330	1,042
Area (in acres)	6,019	6,363	6,465	7,532	7,598	7,339	6,977
Production (in tons)	8,847	10,938	20,623	15,239	3,550	4,099	5,209

[1] Estimated in part.

[2] Converted to refined tons, estimated in part.

TABLE 42.—*Revenues from mining leases on Federal and Indian lands for fiscal years 1973 to 1978, by commodity*

[In thousands of dollars]

Commodity	1973	1974	1975	1976	Transition quarter	1977	1978
Total revenue	**$16,484**	**$470,464**	**$31,596**	**$36,479**	**$11,012**	**$54,758**	**$59,434**
Bonuses	34	[1]449,192	4	50	12	----	----
Total royalties	16,450	21,272	31,560	36,429	11,000	54,758	59,434
Total production value	(335,282)	(463,811)	(681,281)	(813,221)	(240,000)	(1,138,046)	(1,332,863)
Coal:							
Royalties	4,044	5,535	8,335	10,949	3,000	16,667	18,791
Production value	(93,307)	(140,307)	(224,947)	(337,312)	(97,000)	(560,334)	(684,322)
Copper:							
Royalties	158	563	1,331	1,328	328	3,121	1,611
Production value	(2,691)	(6,087)	(7,140)	(7,347)	(1,750)	(39,046)	(17,715)
Fluorspar:							
Royalties	86	31	----	11	5	1	33
Production value	(865)	(322)	----	(180)	(100)	(9)	(734)
Lead:							
Royalties	2,192	3,241	5,109	3,677	950	5,751	5,781
Production value	(54,640)	(75,319)	(11,340)	(81,564)	(22,000)	(127,433)	(125,281)
Limestone:							
Royalties	4	6	10	----	----	----	13
Production value	(54)	(86)	(83)	----	----	----	(265)
Phosphate:							
Royalties	842	1,618	1,538	1,868	500	2,038	3,011
Production value	(11,314)	(31,158)	(28,383)	(25,769)	(6,000)	(28,697)	(46,849)

See footnotes at end of table.

TABLE 42.—*Revenues from mining leases on Federal and Indian lands for fiscal years 1973 to 1978, by commodity*—Continued

Commodity	1973	1974	1975	1976	Transition quarter	1977	1978
Potash:							
Royalties	3,270	3,962	5,565	6,321	1,800	5,960	5,862
Production value	(75,872)	(96,897)	(132,518)	(144,693)	(40,000)	(142,116)	(149,631)
Sand and gravel:							
Royalties	623	633	842	505	125	336	399
Production value	(6,846)	(7,430)	(18,774)	(12,431)	(3,200)	(3,211)	(5,100)
Silica—pumice:							
Royalties	1	----	----	----	----	----	----
Production value	(14)	----	----	----	----	----	----
Sodium:							
Royalties	2,547	2,439	5,046	7,364	2,600	7,412	10,970
Production value	(58,179)	(56,240)	(109,590)	(155,612)	(51,000)	(150,851)	(222,464)
Uranium:							
Royalties	2,303	2,224	2,664	3,191	800	11,961	12,282
Production value	(18,822)	(22,014)	(16,938)	(23,912)	(6,000)	(52,589)	(66,022)
Zinc:							
Royalties	336	936	1,006	1,001	350	1,439	550
Production value	(8,207)	(22,806)	(24,413)	(22,240)	(8,000)	(31,550)	(12,121)
Other commodities:							
Royalties	42	84	56	214	542	72	131
Production value	(4,490)	(5,146)	(3,155)	(2,161)	(4,950)	(2,210)	(2,359)

[1] Includes bonuses of $448,797,000 from four competitive oil shale lease sales.

TABLE 43.—*Information products ordered from the EROS Data Center for fiscal years 1975 to 1978*

[In thousands of dollars]

Product	1975		1976		Transition quarter		1977		1978	
	Images	Value	Images	Value	Images	Value	Images	Value	Images	Value
Totals	**414,084**	**$1,610**	**407,395**	**$2,589**	**104,414**	**$718**	**325,992**	**$2,515**	**313,347**	**$3,219**
Aerial photographs	190,031	567	148,993	735	51,195	221	190,471	789	196,875	974
Apollo, Gemini, and Skylab images and photographs	28,049	113	9,664	86	1,405	15	3,534	52	2,896	50
Landsat computer-compatible data tapes	879	169	2,289	404	1,010	178	1,887	371	2,853	535
Landsat images	195,125	760	246,449	1,238	50,804	274	130,100	1,083	110,723	1,441
Miscellaneous Landsat special products	----	----	----	125	----	30	----	220	----	219

TABLE 44.—*U.S. Geological Survey Library operating statistics for fiscal years 1973 to 1978* [1]

[N.A., not applicable]

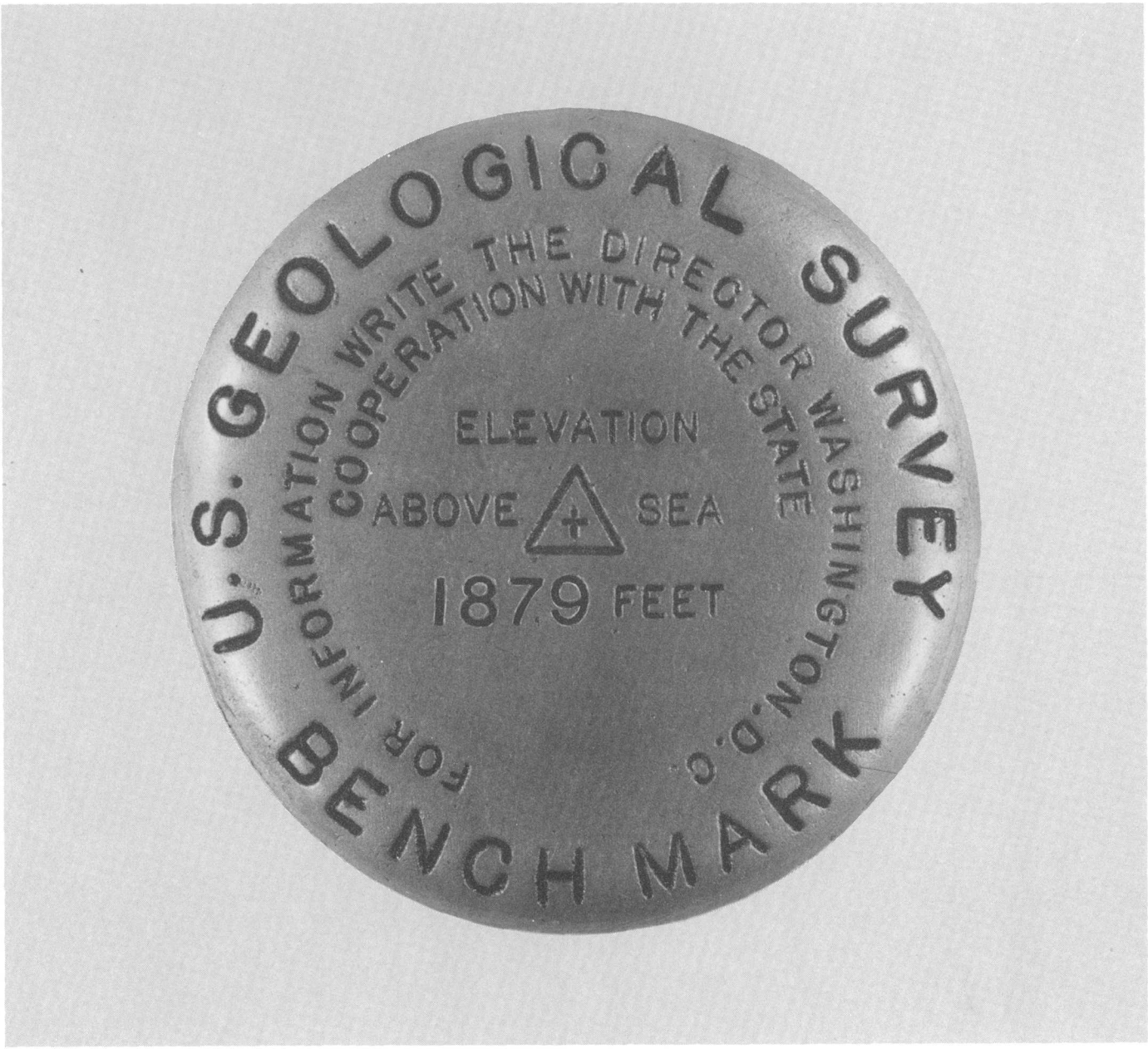
Activity	1973	1974	1975	1976	Transition quarter	1977	1978	Estimated total holdings
Library acquisitions:								
Total items	**84,208**	**91,047**	**136,106**	**116,927**	**25,077**	**170,960**	**115,839**	**2,362,803**
Books and monographs	7,183	11,600	12,891	11,796	1,666	11,731	12,208	352,401
Bound and unbound issues of periodicals and serials	45,499	48,095	49,775	58,360	14,890	60,122	61,815	780,187
Pamphlets and reprints	2,425	2,901	2,798	6,927	1,863	7,197	1,695	367,682
Single-sheet maps	20,653	19,439	21,777	20,873	3,102	14,045	14,298	402,318
Photographs, negatives, slides and transparencies	1,121	7,818	3,485	15,387	3,222	8,261	1,898	228,768
Aerial photographs	1,019	812	45,000	1,888	125	3,111	3,693	60,817
Field record notebooks and related materials	308	382	380	1,104	209	362	382	14,057
Microforms	------	------	------	592	------	66,131	19,850	156,573
New serial titles	650	434	657	631	204	358	384	N.A.

See footnotes at end of table.

TABLE 44.—*U.S. Geological Survey Library operating statistics for fiscal years 1973 to 1978* [1]—Continued

Activity	1973	1974	1975	1976	Transition quarter	1977	1978	Estimated total holdings
Library circulation:								
Total items	**[2]66,327**	**[2]61,565**	**[2]80,991**	**[2]95,814**	**[2]24,575**	**112,766**	**104,654**	**N.A.**
Books and periodicals	63,980	59,402	76,658	87,611	23,058	80,855	79,712	N.A.
Maps	2,347	2,254	4,333	8,203	1,517	6,736	6,028	N.A.
Other (slides, aerial photos, well logs, microforms, and negatives)	------	------	------	------	------	25,175	18,914	N.A.
Interlibrary loans:								
Total items	**16,308**	**15,252**	**20,356**	**18,977**	**4,767**	**19,705**	**23,147**	**N.A.**
Items loaned	13,818	13,073	16,965	15,144	3,407	15,123	17,777	N.A.
Items borrowed	2,490	2,179	3,391	3,833	1,360	4,582	5,370	N.A.
Reference queries	**11,358**	**14,047**	**14,774**	**17,765**	**3,836**	**28,507**	**26,955**	**N.A.**

[1] Statistics include the operations of the Survey's main library in Reston, Va., and branch libraries in Denver, Colo., Menlo Park, Calif., and Flagstaff, Ariz.
[2] Does not include slides, aerial photos, microforms, negatives, or well logs.



Update for U.S. Geological Survey Offices

HEADQUARTERS OFFICES

OFFICE OF THE DIRECTOR

Official	Name	Telephone Number	Address
Associate Director	Joseph S. Cragwall, Jr., Acting	(703) 860–7412	National Center, STOP 102
Assistant Director—Mineral and Water Resources	George H. Davis, Acting	(703) 860–7481	National Center, STOP 171
Assistant Director—Eastern Region	[Vacant]	(703) 860–7414	National Center, STOP 109

GEOLOGIC DIVISION

Official	Name	Telephone Number	Address
Associate Chief Geologist	Gordon P. Eaton	(703) 860–6531	National Center, STOP 910
Deputy Chief Geologist, Program and Budget	David A. Seyler	(703) 860–6544	National Center, STOP 910

WATER RESOURCES DIVISION

Official	Name	Telephone Number	Address
Chief Hydrologist	O. Milton Hackett, Acting	(703) 860–6921	National Center, STOP 409
Associate Chief Hydrologist	[Vacant]	(703) 860–6921	National Center, STOP 408

LAND INFORMATION AND ANALYSIS

Official	Name	Telephone Number	Address
Associate Chief	Gene A. Thorley, Acting	(703) 860–7471	National Center, STOP 703
Earth Resources Observation System Program	Frederick J. Doyle, Acting	(703) 860–7881	National Center, STOP 730

PUBLICATIONS DIVISION

Official	Name	Telephone Number	Address
Chief	William B. Overstreet, Acting	(703) 860–7181	National Center, STOP 341

SELECTED FIELD OFFICES

TOPOGRAPHIC DIVISION

REGIONAL MAPPING CENTERS

Mapping Center	Chief	Telephone Number	Address
Special	Roy E. Fordham	(703) 860–7760	1925 Newton Square East, STOP 560, Reston, VA 22090

GEOLOGIC DIVISION

REGIONAL OFFICES

Region	Regional Geologist	Telephone Number	Address
Eastern	Avery Drake	(703) 860–6631	National Center, STOP 953

CONSERVATION DIVISION

REGIONAL OFFICES

Region	Conservation Manager	Telephone Number	Address
Central	[Vacant]	(303) 234–2855	Box 25046, STOP 609, Denver Federal Center, Denver, CO 80225
Western	John J. Dragonetti	(415) 323–8111, ext. 2093	345 Middlefield Rd., Menlo Park, CA 94025

PUBLICATIONS DIVISION

PUBLIC INQUIRIES OFFICES

Location	Official in charge	Telephone Number	Address
California:			
Menlo Park	Bruce S. Deam	(415) 323–2817	345 Middlefield Rd., Menlo Park, CA 94025

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest 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 interest 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.