EARTH SCIENCE IN THE PUBLIC SERVICE

A symposium presented during dedication ceremonies,
U.S. Geological Survey National Center, Reston, Virginia, July 10–13, 1974

GEOLOGICAL SURVEY PROFESSIONAL PAPER 921

Contributions from:

Canada Department of Energy, Mines and Resources
Council on Environmental Quality, Executive Office of the President
Dartmouth College, Department of Earth Sciences
Environmental Research Institute of Michigan
Illinois State Geological Survey
Johns Hopkins University, Department of Geography and Environmental Engineering
Massachusetts Institute of Technology, Department of Earth and Planetary Sciences
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Resources for the Future, Inc.
Syracuse University, Department of Geology
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UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

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WELCOMING REMARKS

By V. E. McKelvey
Director, U.S. Geological Survey

Welcome to our symposium on "Earth Science in the Public Service" and to the dedication of the John Wesley Powell Federal Building.

I appreciate your coming—especially our distinguished speakers who have given so generously of their valuable time to come and share their views on the important topics to be discussed here today and tomorrow.

The dedication of this building is a fitting occasion for the symposium we are now beginning, for earth science in the public service is, of course, what the U.S. Geological Survey is all about. Had there been no such occasion, however, it would have been desirable to create one, for we are at a stage in this country's, and indeed the world's, development where we face critical problems whose solution requires the application and further development of earth science. Problems of energy, minerals, and water-resource adequacy, of land use and preservation of environmental quality, of the management of the resources of the public lands, and of the reduction of natural hazards are examples of problems in the domain of the earth sciences that are of critical importance to the Nation's future.

It is not only appropriate, therefore, to focus on this topic of earth science in the public service, but urgent that we do so with the greatest perception and imagination at our command. We in the U.S. Geological Survey are applying ourselves as vigorously as we can to the problems I mentioned, but in planning this program, we expressed our need and desire to have the benefit of other viewpoints. The response to our invitations to speak on these topics has been heartwarming, for our speakers are distinguished leaders in their respective fields, and they have paid us a great compliment in coming to share their views with us.

We plan to publish the papers that will be given here today, and I am sure that the result will be a valuable guide not only to us in the U.S. Geological Survey but to all who are concerned with public problems in the earth-science domain.

Again, welcome, and thank you for coming.

GEOLOGICAL SURVEYS IN THE PUBLIC SERVICE

By CHARLES H. SMITH
Assistant Deputy Minister, Canada Department of Energy, Mines and Resources

I am honored to have been invited to join and speak with you on the occasion of the dedication of the John Wesley Powell Federal Building—this remarkable building which is named after an outstanding geologist and explorer, which represents your National Center for earth studies, and which stands for both the historical past and the future challenges facing the United States Geological Survey. The reputation of the U.S.G.S. extends to all parts of the world, and it is obvious that Major Powell and the other scientists and politicians who were responsible for establishing the Survey in 1879 "planned better than they knew."

The phrase "geological survey" means different things to different people. To some it is the systematic recording of rock types along a picket line in the bush or a steep mountainside, and it excludes geophysical, geochemical, topographic, and other related surveys of the Earth. To some, the phrase refers to routine work and not to research, which is called instead "geological science" or "earth science." Modern specialization has led to a multiplicity of professions, societies, and allegiances, which feel more comfortable under such collective phrases as "earth sciences," "earth resources," and "earth surveys." We increasingly use these latter phrases to the point where people may rightly ask, "What is this institution—the Geological Survey? Either it is misnamed for the scope of its legitimate activities, or, alternatively, it is doing things beyond its mandate. By all the sacred principles of program planning and budgeting the Geological Survey should cease and desist, cut out these other activities and use the money for geological work in the narrow sense, or, alternatively, why not rename the institution—perhaps the National Earth Surveys and Research Institution?" It is unfortunately necessary to remind the uninitiated continually that geology means "the study of the Earth"; it is a respected name with a long and honorable history and is not a specialized subdivision of the term "earth sciences." Geology is an integrating science, created directly from man's observation of natural phenomena and his effort to understand them and make use of them, and it is based upon many basic sciences and common sense.

I submit to you that the *concept* of a geological survey in government today is the same as originally conceived by your Powell, and by our Logan, the founder of the Geological Survey of Canada. It encompasses the full spectrum of scientific and technical activities to provide data, information, and advice on the national landmass and its resources, thus ensuring proper husbandry of the land and proper government of the nation. The original geological surveys included not only the full range of earth resource, survey, and science activities of their day, but, in addition, studies of the flora, fauna, and native peoples; the geologists of the day were indeed broad in interests and practice. Today, in many countries, these earth-oriented activities have become increasingly dispersed through a number of organizations, federal, state, or provincial, in universities and industry. Earth-science expertise has developed in various parts of government to serve such policy areas as defense, transport, agriculture, environment, and energy, to name a few. The institution originally named the national geological survey is now a lesser component of the total earth survey-science-resource function of government than it was when originally formed. Nevertheless, the need of governments for accurate and timely information on their landmass and its resource base has not diminished, and one of the questions of the day is the role of responsibility of the national geological survey in providing that information and advice. My thesis is that governments, and the public, need, more than ever, to know in an integrated way about the landmass and its contained resources, and the conceptual model of the original geological surveys offers the best means of acquiring such knowledge as against recent trends of institutionally dispersing the inventory task.

To appreciate a central government's interests and responsibilities in earth studies, it is beneficial to look back to the early evolution of earth surveys, earth sciences, and interest in earth resources, which resulted in positive action by both our governments to formally establish geological surveys in the last century. Then we might consider briefly the changing policies and thrusts of these organizations over the years, the scope of their involvement in human affairs, and the changing needs of the future.

Earth surveys, earth sciences, and earth resources have been inextricably entwined in the support of mankind's occupation and use of our planet. One can look far back to the first use of *earth resources*—flint, chert and other hard stones—for weapons by primitive man. Economic geology may have had its inception with the desire for gem stones and metals by the Egyptians and Greeks. This led to mining activities by the Egyptians as early as 2000 B.C. The early history of *earth surveys*, or maps, is not easy to trace, but it is difficult to imagine a time when there were no maps. The ancient Babylonians certainly practiced surveying, having made a cadastral survey of their kingdom in 2800 B.C. *Earth sciences* followed in historical sequence, as mankind developed both the need and the capability to study and understand the mysteries of the Earth, for both intellectual and practical benefit. The great sea voyages of the 16th to 18th centuries sparked research in mapmaking, geodesy, and magnetism. This was the period of Mercator's maps, Copernicus' solar system, and Newton's theory of gravitation. If one were to draw a conclusion from the early historical record, it would be that the conduct of earth surveys, interest in the earth sciences, and the development and use of earth resources grew steadily in response to man's occupation of the Earth. In critical periods, earth surveys and sciences were of significant importance.

In the last century, at the period of the Industrial Revolution, man's interest increased remarkably in the search for greater quantities of earth resources. The development of new lands in the Americas not only depended upon the availability of mineral resources but also on surveys of and information on the land surface and its potential use. Geology was turning more and more into an exact science based upon a body of clear principles. Geologists accepted the concepts that rocks had formed by processes similar to those in action today; that in undisturbed strata the upper layers are younger; that fossils change from older to younger beds and can be used for regional or even worldwide correlation. There were strong debates over the sedimentary versus igneous origin of rocks, and considerable progress was being made in establishing a uniform system of stratigraphic nomenclature. It was this fortunate confluence of intellectual ferment, industrialization, and settlement that formed the environment for the earth sciences, through geology, to assume a major role in governmental endeavors.

Governments have traditionally funded earth surveys in order to effectively administer the affairs of a land. Most of the earlier applications had centered around military activities and land settlement. In the early years of the 19th century, many States in your country sponsored geological surveys to evaluate the mineral resources and to help with the disposal of State lands. Some, such as the New York Survey, were quite successful, but others were of short duration. It is a mark of the wisdom and foresight of a generation, or governments, when major governmental structures are established and maintained *well in advance* of a need or crisis. Such events occurred when national geological surveys such as the U.S. Geological Survey and the Geological Survey of Canada were formally established in the last century. I do not suggest that these organizations were not needed at the time of their formation—rather, that the needs are greater, far greater, today than when Powell and Logan attended to the creation and development of our broadly conceived Geological Surveys.

The directions given by governments to the first directors of these Surveys, many years ago, are as meaningful today as when they were first stated. Clarence King, your first Director, was required to "examine the geological structure, mineral resources, and products of the national domain, and to classify public lands." William Logan was called upon to "make an accurate and complete geological survey and furnish a full and scientific description of its rocks, soils and minerals which shall be accompanied with proper maps, diagrams, and drawings, together with a collection of specimens to illustrate the same." Of course, in neither case did the governments of the day adequately estimate the cost or time span of such a task. Nevertheless, they pointed in the right direction and laid the foundation for the earth-resource knowledge base of our Nations today. The Surveys they created have become major instruments of economic and scientific development, with far-reaching effects that have gone beyond our national boundaries. The systematic examination of our national domains over the years has had the dual characteristic of establishing an inventory of mineral resources and the facts of nature, through repeated observations.

Governments have grown in size and complexity since the early founding years of their geological surveys. They have passed through years of abundance and shortages, wars, and depressions. In each case the geological surveys have responded to the challenges placed upon them—to provide the nation with information and advice on its landmass and resources. In their formative years, work evolved around the exploration and settlement of the land. The members of the survey became the foremost authorities on the unsettled regions. Their reports, maps, displays, and lectures drew the attention of governments, industry, and the public to the resources and opportunities of the land. Along with their surveys came many scientific discoveries which attracted the attention of the international scientific community. The surveys established a close relationship with the mining industry, providing information and ideas that guided prospectors to the most promising areas, contributing to the opening of major mining regions and to the development of important mines. At times they were criticized for being too closely involved in the search for, as opposed to research on, ore deposits. At other times they were criticized for being too academic, or working in geographic areas too remote and inaccessible for short-term economic development. However, through this complementary relationship, industry and government have been successful in reaching a high level of mineral development in our lands. The geological surveys have also developed their supporting role to governments through the provision of sound information and advice for agriculture, for the military, for space programs, nuclear programs, foreign aid programs, earthquake and hazards prediction, engineering work, energy development, and many more. During both World Wars, the survey staffs were engaged in major strategic mineral programs and resource appraisals.

Geological surveys today are being put under increasingly severe pressure, probably greater than have existed in any peacetime period since the time of Powell and Logan. Human occupation over the surface of the Earth has grown to such an extent that man is recognized as a significant geological agent. He has touched all parts of the Earth's surface, penetrated the depths of the oceans, and ventured into space. What he does not touch, he senses remotely. His erosion of nature's bounty is putting into question the adequacy of resources to maintain, for the future, established standards of life, and his alteration of the environment has created concerns about his ability to survive under conditions made almost suddenly different from those under which he has evolved. In the last 150 years, man's development has not been in the wise light of integrated knowledge but rather along compartmentalized thrusts. A developing technology and population have dictated at each moment or period of time the measure to which the Earth's resources are used. A systematic measure of the Earth's capabilities has not been the standard of man's discipline towards nature. Such a measure of the Earth's capacity to stand modifications in its materials and in the regimen of processes should derive from the type of concerted action for which our geological surveys were created. Unfortunately, man's use of the Earth has outstripped the rate at which the knowledge of our lands and their resource base has been generected, communicated, and understood by policy-makers and the public. The aim of Powell to "educate the nation" has not yet been achieved in any country.

The public is now becoming increasing interested and concerned with the results of their geological surveys—and let us remember again the direction to Powell and Logan "to survey the mineral resources." Now the public and governments are concerned over increased warnings of resource depletion. The Secretary of your Department, Mr. Morton, stated recently that "the United States, and the world as a whole, face a crisis of exhausted natural resources within 25 years unless they act soon to develop the long range planning to prevent it." There have been equally startling statements about man's effect on his environment. Who will provide the public with the basic information respecting resource depletion or degradation of the physical environment? I submit that this is the responsibility of the national geological surveys.

It might be asked, "Could not this responsibility be undertaken by industry?" The task of gathering information on the mineral endowment and landmass has been pursued in the United States and Canada, since Powell and Logan, by industry, State (or

Provincial), and Federal institutions, supported to a lesser extent by university groups. The success of industry, in particular, has resulted from its ability to develop and exploit resource data in a competitive and confidential manner. A great many data have thus been collected by many groups, but they are not well coordinated or synthesized in a national sense. Although industry has synthesized national data for fuels, there have been no comparable national estimates by industry for the other mineral resources. The separate roles of industry and governments in the process of resource inventory over the past hundred years is reminiscent of the situation in the 1870's, when rivalry between the military and civilian surveys brought disorder to government science, reduced public confidence in it, and resulted in the formation of the U.S. Geological Survey to reduce duplication and increase efficiency! Without belittling the tremendous knowledge and expertise developed by industry, I believe that the public is now seeking its own independent source of advice on the resources and environment of the nations. In our universities and nonprofit research organizations, there are admittedly experienced and interested scientists with interests and viewpoints on the resource base and its adequacy. Their role is extremely important in developing new methodologies and new concepts and in assisting with the major role of educating the public. They lack, however, access to a sizeable data base which permits factual and timely statements on the national and international resource situation today.

Can a geological survey produce the timely and meaningful analyses required for the resource and environmental policies of the next decade? For geological surveys to rise to this increasing responsibility will require the focusing of talents and efforts in a manner not unlike that of wartime, but the possibilities of disaster warrant such a reaction, even if only to prove the predictions to be unfounded or premature. However, this advisory activity is fraught with many problems. The time is short. The existing data base is inadequate. A pooling of industrial and government data will be required for immediate effectiveness, along with new programs to obtain data from as-yet-unexplored regions. It is essential to an informed debate that the basic observations of industry and other groups become increasingly accessible in the public realm, and new legislation may be required to bear on this problem.

That is not all. We know that a single drill hole can still turn a "barren region" into a "Prudhoe Bay." We must recognize that the methodology for manipulating resource data and forecasting concentrations in unexplored areas is also inadequate. Much depends upon intuition—or qualitative interpretations. We must look to those experiences in the vagaries of geology to extrapolate, now with the aid of the computer, the possible abundances of metals or fuels in unexplored areas. But how will the quality of their work be tested? It may not be subjected to the test used by industry—drilling—for many years. It may not be subjected to the normal tests of science—the reproducibility of results. Under such circumstances, the whims or judgments of a few specialists can have a major influence on the policies of a nation. In this area of judgment where the facts are not crystal clear, the special interests of scientists can easily influence their interpretations. Hence, a new system of checks and balances will have to be developed within the scientific community to test the work and conclusions of their colleagues. It will be a test of our geological surveys whether they succeed in mobilizing our limited national expertise from all sectors for this work, and thus show true national leadership, or become merely one of a rising babel on the world scene. What additional problems will this create for the geological survey? There will be problems of credibility, as the forecasts change when new information is added. There will be problems of communication in explaining the meaning and variations of resource estimates. There will be problems in confronting professional experts from other sectors, and in debating the technical terminology, data, and interpretations in a public forum. However, such debates will have to occur with increasing frequency in the technical community, if the people or their elected representatives are to make their own decisions. There will be problems to ensure that the pressures of this work do not cut excessively into the scientific excellence and quality of other essential survey programs. Vigilance will be required to ensure a continuing buildup of the basic geological data and derived information that provide a survey with a springboard for any new thrust, in any direction, arising from the events or concerns of the day.

Before closing, I would like to add a word concerning the importance of international activities. Study and understanding of the earth is not limited by national boundaries. It is essential that governments, through their survey organizations, work closely together to set the standards and methods for resource estimation. Although there is a trend to consider such information as semiconfidential, it is extremely important, in my view, that such knowledge be increasingly exchanged to provide a better basis for discussions on the resource problems and opportunities of the world.

The earth sciences and earth surveys are entering a new era of public service. It is up to the earth scientists and our earth-science institutions to rise to this challenge and to show that the dreams and aspirations of Powell and Logan were not in vain. It is up to the national geological surveys to lead the way by coordinating the many centers of information now existing across the land and, by building upon their established reputations for excellence and objectivity, to ensure that the public receives the information and sound policies required to meet the new way of life that lies ahead.

NEW DIRECTIONS FOR ENERGY POLICY AND ANALYSIS

By JOSEPH L. FISHER
Director, Resources for the Future, Inc.

The dedication of the John Wesley Powell Federal Building as the U.S. Geological Survey National Center is an auspicious occasion for the Nation. The U.S.G.S. has played a major role in the unfolding history of our country: In the development of the earth sciences; in the establishment of standards of excellence in geologic, topographic, and hydrographic data gathering, mapping, and analysis; in the opening up of the West and Alaska and now the offshore seas; and in the underpinning of economic and social progress itself. In these times of widespread disillusion with government and established institutions of all kinds, Americans can take heart that their Geological Survey holds firmly to its mission of providing objective nonpolitical information of high quality about the land and water resources on which we all depend for both life and livelihood. This is what I mean when I say that this is an auspicious national occasion.

I want to deal with some important problems facing this country in energy and to suggest some new directions for policy and analysis. Now that last winter's energy crisis, problem, or whatever, has eased, we in this country must take care not to revert to old attitudes and habits about energy. We must take advantage of the respite to change our consumption patterns, to try much harder to conserve energy, and to find new reliable sources of supply. None of this will be easy.

The energy future of the United States is vulnerable. Renewed embargoes, higher costs of oil, difficulties in preventing environmental problems, excessive profits for energy companies, and unrestrained growth in demand can threaten that future. We must do better through national policy and individual action to limit consumption and increase supply. The objectives of low-cost energy, new and diversified supply sources, environmental protection, competition among companies, fair taxes, national security, and good sustainable relations with other countries must all be served.

The energy problems ahead are many and can be a serious threat to the welfare of this and other nations and to the peace of the world. If within the next year the United States has not vastly improved its energy policies for both the immediate future and the longer range, an opportunity will have been lost and much trouble will lie ahead.

At this point a short quotation from Art Buchwald is appropriate:

Three moving men walked into the office of the Energy Crisis and started taking down the pictures and the graphs.

"What are you guys doing?" the Energy Crisis asked.

"We have orders to move all your stuff out. They're moving another crisis into this office."

"But I just got here," the Energy Crisis protested.

"Don't talk to us. We just do what they tell us."

"Why am I being moved out of my office?" the Energy Crisis demanded.

"You want it straight? We don't need you anymore. You're washed up. Get lost."

Although the oil crisis in the immediate sense has passed, the longer range outlook is full of "ifs," "ands," and "buts." *If* the embargo is not reinstituted, *if* the American people will intensify their efforts to conserve, *if* research and development for coal liquefaction or breeder reactors pays off, *if* offshore drilling reveals lots of low-cost oil . . . *and* environmental damages can be contained, *and* peace can be maintained in the Middle East, *and* more refineries can be built . . . *but* will oil prices hold at politically tolerable levels, *but* will companies accept a reduction of their special tax advantages and still proceed vigorously to expand supply, *but* will consumers—industries, individuals, families—sustain the discipline necessary to reduce their consumption of energy, *but* will technology continue to provide new practical means for converting energy raw materials into usable heat and power? These are only a few of the "ifs," "ands," and "buts" in the American energy future.

Many observers believe that this country and the world are passing over a major divide and entering a new watershed in which energy will never again be plentiful and low in cost. They believe that the large boost in crude-oil price forced on the world in late 1973, principally by the Arab contingent in the Organization of Petroleum Exporting Countries (OPEC), marked the end of the era of easy oil, that from here on, 50- to 60-cent gasoline will be the unpleasant fact of life, and that there will be a continual scramble for new sources of oil and gas. Others surveying the same scene are more optimistic. They see higher prices weeding out unnecessary consumption, stimulating new supply, and providing the incentive for conservation.

Whatever one's outlook may be, some fairly basic decisions regarding the direction of future energy policy and analysis seem to be at hand. Here are some of them:

1. Market pricing—or controls. Should the U.S. Government stand aside and let oil and other other energy commodity prices rise to whatever level proves necessary to equate the forces of demand and supply? Such a hands-off approach has advantages: Consumer and producer choices would be allowed to work their way without restriction, price and rationing administration would be avoided, high prices would stimulate the flow of investment funds to expand supply. Politically, however, this approach would not be easy to live with, as many members of Congress will testify, and it would be hard on the low-income group. Also, at least in the short run, higher prices would exacerbate inflation.
2. Drastic alteration of the structure and functioning of the oil industry—or business more or less as usual. Large numbers of people are convinced that industry, especially big oil, is mainly responsible for the recent energy crunch and has perpetrated a conspiracy to raise prices by withholding supply. Others do not agree with this but nevertheless think that the oil-depletion allowance, foreign tax credit, and other tax advantages should be eliminated or at least reduced. Now is the time to do it, they argue, because prices are very high and the companies would not be hurt. In addition, the case for breaking up the large vertically integrated oil companies through tougher application of antitrust laws is now being made more vigorously than for some time. This is urgent, so the case goes on, because oil companies have been extending their activities far into coal, uranium, and other parts of the energy industry. Finally, support is mounting for direct Government development and operation of commercial-scale yardstick plants to produce shale oil, liquid or gaseous fuel from coal, offshore oil, and nuclear power. The structure and functioning of the oil industry may indeed be in for drastic change.
3. Extension or relaxation of environmental controls. The direction of change regarding protection of the environment has been set in the clean air and water legislation of the past few years in response to the so-called environmental revolution which amounted to a sudden perception of increasing pollution, congestion, and landscape degradation. The energy-supply crisis came in on the heels of the environmental crisis, causing a reexamination of the air, water, and other quality standards which had been set, and especially the dates by which the standards were to be reached. The National Commission on Water Quality is a part of this process of reexamination, as are other studies of air-quality standards now progressing in various places. The battle lines have been drawn, and the outcome will hinge largely on what happens in hundreds of specific cases for locating powerplants, relaxing sulfur or other discharge standards, leasing oil lands onshore and offshore, raising electric rates, taxing industrial effluents, and enforcing regulations.
4. National self-sufficiency—or a world system. The President has announced a goal of U.S. self-sufficiency in energy by 1980. Prior to the Yom Kippur War, this country was importing nearly 30 percent of its crude oil, 10 percent or so from the Middle East and North Africa. Many regard the achievement of total self-sufficiency by 1980 as impossible and undesirable as well. Large increases in domestic supply

of oil, they state, will take more time and will be costly. The leadtimes for breeder reactors, coal-conversion plants, oil-shale mining and processing, and significant offshore oil development are quite long, ranging from 3 or 4 years to 10 or 12 for single installations, let alone whole new industries. Furthermore, national self-sufficiency, pursued rapidly and relentlessly, might upset entirely the applecart of international relations and leave the United States with troubles compounded in all directions. On the other hand, a countercase can be made that Western European countries and Japan would be better off to the degree that the United States is self-sufficient in oil. There would be less pressure on world oil prices, more Arab oil for them, and larger U.S. domestic production for them, as friends, to draw on should the Persian Gulf source be shut off. The principal opposition to U.S. self-sufficiency, however, comes from internally oriented persons and agencies whose profound belief is that problems like oil and energy are world problems and have to be met on that scale. Self-sufficiency is a flirtation with disaster, they maintain, because it tears the fabric of international cooperation and peace.

5. Stability and manageableness in the international balance of payments—or chaos. Oil selling in the international market at $10, $12, or $15 a barrel, when production costs range from 10 cents to $1 a barrel, when transportation costs to almost any refinery in the world are less than $1 a barrel, and when refining costs are about the same, means huge monetary gains for the exporting countries. Next year, the Middle East and North African oil countries could realize more than $50 billion—perhaps as much as $80 billion—in profits, taxes, rents, or whatever these gains might be called. Already, very large sums in the hands of these countries have piled up in volatile short-term deposits and investments in U.S. and European banks from which they have been loaned on a longer term basis. The problem of sustaining this kind of international monetary transfer will be severe in the extreme and will call for both national and international policies for long-term investment of these oil funds in the more developed oil-importing countries and in less developed oil-poor countries. Also the situation will call for technical aid and industrial capital to be furnished by the more developed to the less developed countries. Recently I have been advocating an ongoing World Conference on Energy and Minerals Policy to cope with these and related problems, perhaps under United Nations' auspices.

6. Open information regarding energy—or privilege and secrecy. The energy situation is of such critical importance for the national welfare, and the state of public confidence in the energy industries is such that the proprietary aspect of energy information should now be largely eliminated. Information from the energy industry on reserves, production, shipments, processing, sales, prices, costs, and profits from now on should be reported to the Government and made public. The only exception should be in instances clearly and directly affecting military security. The major change being suggested is for revealing information on reserves; most of the other information is already made public. This, of course, would raise the hackles in the industry and would constitute a sharp change from past practice. However, because all major and substantial companies would be treated alike, no one of them could easily claim that it would suffer any serious disadvantage because the information reported is made public. The retention of some, perhaps much, information in a confidential or secret status inevitably will lead to doubts and apprehensions on the part of many people and would mean that many companies will continue to be in the unenviable position in which the truthfulness of what they say will be doubted.

Several reasons for this position are important. First, the country remains in a serious energy bind which will take some years to loosen. The hard job of increasing supplies, especially of oil and gas, will take a number of years to complete, as will the job of establishing habits of greater conservation. In this situation and with this outlook, Government leadership is imperative and cannot be exercized effectively except on the basis of the most complete, systematic, and prompt information that can be obtained. Second, the information should be kept open and available for public inspection. There is no other way of convincing people that games are not being played with the vital public interest. Without full disclosure of information, the widely held belief that some kind of rip-off is going on will not be dispelled. Third, it is unrealistic to expect public support for spending more than $2 billion a year on oil exploration, development, and research generally, much of it for new sources and technologies, if knowledge of known sources and existing technologies is kept locked up in company files.

7. Sustained, long-term, and large research and development programs—or sporadic hit-or-miss efforts. There can be only one answer to this choice, of course. The problems are how to organize for it, at what scale to carry it on, and how to define priorities and sequences. At present, energy research and development in the Federal Government is widely scattered among many agencies—the Atomic Energy Commission, the Office of Coal Research, and many others. Each has its own mission, legislative authority, funding, style, and constituency. Nowhere is the whole set of research and development activities brought together, ordered, coordinated, and made to serve deliberately chosen national objectives in an economically and sustainable way. Two billion dollars or more a year for energy research and development is too much to spend in a relatively unorganized way. The heavy emphasis of recent years on conventional and breeder nuclear energy now needs to be reexamined and placed in a larger context of research and development on conversion of coal to liquid and gaseous fuel, development of oil shale and tar sand, offshore exploration, solar energy, geothermal energy, and nuclear fusion. Technology for some of these processes has already been proved; other processes are nowhere near ready for commercial use. All of them must be brought together in a long-range program designed to meet anticipated needs. Research on environmental protection is equally urgent, as is research on conservation of energy materials and improvements in the efficiency of mining, conversion, use, and reclamation. All logic points toward a special, probably new, agency for energy research and development.

8. Major changes in life styles—or not. Many important and sensitive groups in this country—many young people, for example—argue and in various ways demonstrate for a more simple style of living and less consumption of energy and energy-using vehicles and products. Whether this devotion will be sustained into middle age against the lure of creature comforts and the easy mobility of the auto remains to be seen, but the challenge is serious and the option may well be viable. High energy prices make it attractive, as do its environmental advantages. The typical American uses 40 to 50 times as much energy as most Asians and Africans. People in Europe, Japan, and some other countries enjoy quite good standards of living, in many respects better standards than Americans do, on half as much energy per capita. Prudence points in the direction of a life style requiring less energy, certainly in the direction of conservation and more efficient use of energy; however, many still regard it as sensible not to reduce consumption or to save on things unless one absolutely has to.

9. New policy-making agencies and processes—or muddle along with what we have. Debate on how to instrument changes in energy policy and programs is hot at this time, in Congress and elsewhere. Most would agree that the Federal Government, and the States and local governments also, need to pull their boots up, reorganize some, and do a better job in energy. At the Federal level, a statutory energy administration has recently been established. A separate agency for research and development, a new Department of Energy and Natural Resources, better coordinating arrangements, and, on the Congressional side, a Joint Energy Committee have been proposed and have merit. Doing nothing, or not much, to improve policies and programs would seem to be a failure of political leadership, which in the face of new and severe problems, the country should not tolerate. The traditional dispersal of energy responsibilities and the resulting poor performance has got to go, as almost everyone would agree. The question is exactly what changes should be made and how the tasks and responsibilities should be assigned so that decisions on new policy directions can be translated promptly, smoothly, and fairly into action.

These are some of the major issues in energy that will have to be worked out if the needs of people in this country are to be met in the coming years. The answers are not easy because the problems are complex. My own preferences for policy may have been revealed somewhat in my presentation of the main issues. They are for a readiness to guide, and if necessary to control selectively and temporarily, the operation of the market in establishing energy prices in these times of rapid inflation; for reduction in certain tax advantages of oil companies; for stout adherence to improving environmental conditions with a minimum of compromises and delays; for a decisive though limited movement in self-sufficiency to lessen the insecurity of too great dependence on uncertain overseas sources of oil; for retaining an international trading and investing system in oil and other energy commodities; for some fairly major changes in life style; and for organizational changes in government to promote an integration of energy policies and programs.

My preferences for policy, or those of anyone, will be no better than the facts, the research, and the analysis that underlie them. The Geological Survey is forever extending the facts and improving the research and analysis. Increasing attention in recent years has been given to offshore geology, to environmental aspects of mining and water development, and to satellite and other remote-sensing devices. Economic analysis has been strengthened; as an economist myself, I would hope that this could be enlarged still more. The Survey might well aim to develop as much expertise in appraising needs and requirements for energy and other materials as it has long had in appraising reserves. It could to advantage probe deeply into the changing structure of demand for the various energy sources as these are utilized in industry, transportation, space heating and cooling, and electric-power production. The role of prices should also be considered, and various international factors should be taken into account. A systematic and comprehensive framework of demand and supply estimates, looking ahead to both the short range and the long range, should be the goal. Such a framework, reworked periodically, will reveal many clues as to the priorities of research and analysis on new sources of supply and new technology. Other agencies of government can help in this work, but I am urging the U.S. Geological Survey to take the lead. It would be a new and exciting enterprise.

The other decisions about energy outlined earlier also call for more study than has been given to them thus far. Much more needs to be known about the structure and behavior of the energy industries, the response of both industries and people to environmental controls, the world implications of greater self-sufficiency in energy on the part of the United States, the ramifications of the balance of payments problems arising out of the much higher price of oil, and the likely effects of higher prices on consumption, new technology, and exploration for new sources of supply. The agenda of future research on energy is a long one, full of interest and excitement.

The Government's role in energy, which involves not only the Geological Survey but all agencies concerned with energy, is likely to become more important and, I believe, should become so. It will have to establish the broad objectives—low cost and dependable supply, environmental protection, national security, employment—and some degree of consensus as to trade-offs among these objectives. It will have to provide incentives for appropriate private initiatives and itself perform certain functions. It will have to furnish much more basic information about energy resources, likely future requirements, costs, new technology, environmental impacts, and ways to conserve supplies and increase efficiency in extraction, processing, and use. And here again is where the Geological Survey comes in.

Even though an Energy Research and Development Agency may soon be established to pull together the more applied programs, the U.S.G.S. will still have to be relied on for much of the basic information and appraisals within which subsequent research and development will take place. The higher the structure, the more necessary that the foundation be deep and firm. The American people have come to expect excellence from the Geological Survey. This new building, this National Center, especially the people here who will do the work, can be trusted to continue this tradition and to improve on it.

MINERAL-RESOURCE APPRAISAL AND ANALYSIS

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"... There are only a limited number of places left to search for most minerals. Geologists disagree about the prospects for finding large, new rich ore deposits. Reliance on such discoveries would seem unwise in the long term" (The Limits to Growth, the Club of Rome Report, 1972, p. 55).

This less-than-optimistic attitude of the authors of the Club of Rome report indicates, if nothing else, that mineral raw materials are so important to the continued industrial life of this Nation that we must obtain the best possible understanding of the quantities of such materials in our subsoil. Although the United States almost certainly can never again become essentially self-sufficient in metallic raw materials, we would be foolhardy not to try to find all deposits of them that exist within our borders.

Most present exploration for mineral raw materials is carried out by examining what the prospecting organization considers to be the geologically most favorable areas available to it. Such areas are either (1) districts in which workable ore deposits have been found previously, the most favorable sites being those whose geology is decidedly similar to those in which ore bodies have occurred; or (2) districts that do not contain known ore bodies, but that have geology much like that of areas that do. Examples of (2) are provided by the recent finding of the zinc deposits of central Tennessee or those of the new lead belt in Missouri. Examples of (1) are furnished by the discovery of the Kalamazoo ore body at San Manuel or by the several deposits found around the rim of the Sudbury basin since the end of World War II.

In an area in which ore deposits have previously been found, some considerable information is known on the surface geology. In addition, data are available on the subsurface geology because both drilling and mining, as well as surface work, have been carried out. This subsurface geology will not, of course, be as well known to a company that does not own one of the ore bodies already being exploited in the district as to one that does. The first company will, however, have acquired, in one way or another, more knowledge of the character of the rocks in the subsurface than it would of any area that has not been drilled and mined. Such an undrilled and unmined area may, however, have been mapped and perhaps examined by surface geochemical and geophysical studies. To some extent, the surface mapping and the geophysical work will have provided some insights into the character of the subsurface geology, but, at best, the inferences drawn from this work are not applicable more than a few hundred feet beneath the surface. What can be assumed from surface geochemical work provides even less penetration beneath the surface.

In any area in which the information derived from the surface is encouraging, the mining company examining the area will lay out a drilling program to provide knowledge of the subsurface. The drilling will be continued for as long as the results suggest that ore has been found or may be found. As soon as the balance of (usually subjective) probabilities ceases to favor the discovery of ore, drilling will be stopped, and exploration will be started in the next (potentially) most favorable area. This method provides a continuously increasing amount of geologic information, but if this information is not deposited in a single repository, it is not readily available to any but the company that acquired it. Thus, as a means of providing a broad survey of what ore might be available in the United States, exploration by individual companies or groups of companies leaves much to be desired.

If a broad survey is to be achieved, several things must be done. The first of these is to continue, accelerate, and refine the surface mapping done by the U.S. Geological Survey, so that much more of the Nation is covered by geologically mapped quadrangles than is now the case. The second is for the Survey to continue and expand surface geochemical and geophysical work. The third is for the Federal Government to require that the results of geological, geochemical, and geophysical work done by private firms on Federal lands must be deposited with the Survey and that the Survey integrate this work with their own results. The fourth, and most important step, however, is that we obtain systematically a much greater knowledge of what lies beneath the surface than can be provided by the first three methods of geological information gathering that have just been mentioned. Such knowledge of the rocks at depth can be produced best by drilling on a large scale, the holes being taken down at least 3 miles beneath the surface.

This drilling can be done in two ways. The first is to drill areas thought (again mainly subjectively) to be geologically favorable, starting with what are considered to be the most promising, and working outward into surrounding ones that show less favorable surface indications of ore beneath. This approach has the advantage of making maximum use of what is known of surface geology, but it confines the prospector to rocks and rock relations he already knows to be associated with ore bodies. It provides no basis for bold strides into the unknown. The second approach is based on the premise that much ore lies below the 1,000-foot outer skin of the crust that we know something about by surface mapping, geochemistry, and geophysics. To check the value of this premise, it is necessary to prospect by drilling a regularly spaced series of holes throughout the United States. The only areas not to be drilled would be those now used in such a way that they cannot possibly be profitably subjected to mining operations even if they were to overlie large ore deposits.[1] If a second Rand were found beneath Manhattan Island, it would not be good economics to convert that island into a mining camp. Much of the area of the United States, however, is so used at present that a large mine would be more profitable than whatever is being done on that part of the surface today.

We will never know what underlies the entire surface of the United States unless we look, and regularly spaced drilling provides the only systematic method today for such explorations. It can be convincingly argued that so much recoverable mineral and fuel material would be found by such drilling (Griffiths, 1967) that the cost would be repaid many times over. Griffiths (1967; Griffiths and Singer, 1970) has suggested that such drilling be carried out on a grid pattern, the holes being spaced at 20-mile intervals and each hole carried to a depth of 3 miles. This program would require some 7,500 holes and would cost about $3 billion.

Griffiths has pointed out that if five circular or elliptical targets, 28 miles across (the approximate size of major oil fields in the United States), remain undiscovered in this country, they would be found with certainty by this drilling method. Smaller but still large targets, such as major porphyry copper deposits, would be less probably discovered directly, but enough indications would appear in the holes to justify further exploration by a more closely spaced grid. Griffiths has assumed that the mineral raw materials found in this country to date constitute a random sample of the outer 3 miles of the crust of the contiguous 48 States. This justifies the conclusion that, if the entire 3 million square miles of the 48 States were tested, the area would be large enough and mineral-rich enough for a commercial success to be assured for the drilling program under a wide variety of boundary conditions.

Using 1966 data, Griffiths estimated the average value of mineral raw materials recovered from the surface and subsurface mineral deposits in the conterminous United States. Allowing for the recovery of mineral materials since that date, this average value is now about $250,000 per square mile. The frequency distribution of dollar value per square mile for the 48 States is lognormal, having a mean value of about $150,000. The variation from the average is considerable; the value per square mile in Oregon is less than $16,000 and that in Pennsylvania is more than $1,800,000. These data do not mean, of course, that each area of 400 square miles in which each drill hole is centered will contain $100 million of recoverable raw materials, but Griffiths' calculations show that each 400 square miles would, on the average, contain that dollar value of raw materials. Thus, the entire 3 million square miles of the United States, to a depth of 3 miles, should hold $750 billion of recoverable raw materials. The best approach to making sure that all such materials are found seems to be grid drilling.

[1] It should be obvious that such a program of exploration cannot be carried out for minerals alone. It must be designed to look for anything of value within the crust of the Earth. Thus, to attempt to make separate appraisals for oil and gas and for solid minerals is economically and geologically unsound.

The usefulness of the drilling program would be apparent long before it had been finished, because the information available from any sizable drilled area could be analyzed immediately and made the basis for secondary exploration efforts.

It probably would be advisable to fit the primary 20-mile grid to the area of the United States so that, although the drilling would still be done on regularly spaced centers, the holes would miss as many of the known major areas of mineral raw material concentration (solid, liquid, or gaseous) as possible. This modification of Griffiths' concept may be somewhat less than mathematically sound and must be thoroughly tested to make certain that it does not introduce an unacceptable bias into the drilling scheme. In favor of such a nonrandom fitting of the grid is the fact that probably less new data would come from a hole through the rocks of the Butte copper district or those of the East Texas oil field than through those of areas less well known geologically.

Probably only by some version of Griffiths' scheme will it be possible really to understand the ore geology of the United States and to be certain that all deposits of mineral and fuel materials in the outer 3 miles of the crust of this country would be found. Such an approach would be a radical departure from the system of exploration now practiced, but it should discover the ore potential of the entire country much more rapidly than do present exploration methods.

Another mathematically based approach has been developed by Harris and his coworkers (1966, 1969, 1973; unpub. data). His methods, described briefly below, are designed to aid in the determination of areas favorable to ore occurrence through quantifying objective and subjective geologic and economic variables and analyzing these mathematically. He deals, however, with areas in which ore already has been found or with areas whose geology is similar to that in which major ore deposits have been discovered.

In the first study in this series, Harris (1966) has suggested how to construct an objective model that will associate probability of occurrence of some measure of mineral wealth with the reconnaissance geology of each subdivision (cell) of the area in question. The model he developed has determined that geologic variables can be related mathematically to the probability of the occurrence of mineral wealth. His quantification of the geologic variables of a geologically known ore-containing area in Arizona and New Mexico in counts, percentages, and lengths produced the values necessary to test his model. He found that multiple discriminant analysis and classification analysis by Bayesian statistics and multivariate probability constitute a two-phase probability model that associates probabilities with geologic data and mineral wealth. On the basis of the successful test of the model in the area studied, Harris concluded that geologic data on a known ore-bearing area can be used to guide exploration in an unknown area of generally similar geologic characteristics.

In his paper with Euresty (1969), Harris refined his model to go beyond the assessing, through the quantification of geologic variables of expected gross value of resources to the adjustment of gross value through the consideration of economic factors. The approach means that the geologically determined gross value of a given cell is modified in terms of its location relative to existing markets and transportation networks at a given time. This method, therefore, may indicate that a geologically less favorable area may have advantages of place at a given time that make it a better area for exploration than one with more encouraging geologic characteristics.

Still further studies by Harris, in collaboration with Brock, Donald, and Euresty (Harris, 1973; unpub. data), have advanced models that also include subjectively determined variables. The subjective material is obtained from estimates by geologists knowledgeable in the area under study as to the probabilities of the occurrence of ore in regularly or randomly arranged cells.

These methods are designed to work from known to less well known but geologically similar areas and are confined in their scope by this approach. They provide, nevertheless, excellent supplements to the study of areas in which only the surface geology is known. Further, they can be adapted to the integration of the geology determined by Griffiths' grid drilling with what surface geology is known in each drill-hole area.

It is, of course, apparent that such a huge number of holes to such considerable depths (as Griffiths' method would require) would not be within the financial resources of any one mining or petroleum company or even of a consortium of them. Thus, it seems obvious that, as the program here outlined must be planned and executed as a unit, it must be carried out by the Federal Government, through the agency of the U.S. Geological Survey. The results must be made public property as soon as a sufficient number of holes to give significant geologic results have been drilled in any one major part of the continental area of the United States. Once any major segment of the drilling has been completed, the data from that and all other sources should be analyzed, probably by the Survey's Computer Resources Information Bank (CRIB), supplemented by models of the Harris type. Then, appropriate areas should be offered for lease to mining companies for further and more detailed exploration in somewhat the same manner that areas are offered for lease in the potentially oil- and gas-bearing regions of the Continental Shelf. For such a program to operate efficiently, the areas offered for lease would have to be large enough to contain possible worthwhile targets and yet not so large that they would be too expensive for any one company to explore in the time allowed before all interest in the leased area would have to be given up. Areas already being actively prospected by companies or consortia would not be offered for lease to other mining organizations, but safeguards would have to be established to make certain that areas claimed to be under an active program of prospecting actually were being so studied. For this program to function properly, it probably would be necessary for the U.S. Government to take over all mineral rights to all land in the Nation (except areas being actively mined or prospected) under its power of eminent domain. At the same time, the Government would have to guarantee to the owner of the surface rights, adequate compensation for any damages done to the surface, and to the owner of the mineral rights, royalties for any material that might be removed from the ground in any manner. Legal arrangements would have to be made to insure that surface damage and environmental impact were held to a minimum and that the surface of the land ultimately would be restored to usable conditions, whether or not the exact contours of the original surface were actually duplicated. Drilling would be a waste of time and money if it were done in centers of considerable population or industrial activity, but with such advances in technology as solution mining, much more of the subsurface could probably be mined than would at first seem possible. The amount of surface and environmental damage caused by the recovery of oil is less great than that caused by mining, but whatever the exploiting process, all surface areas would have to be restored.

For any tract leased, a time limit would have to be placed on exploration, with provisos that part of each tract be relinquished by the private exploration organization at regular time intervals so that, at the end of a period of perhaps 6 to 8 years, the exploring group would be left with one-quarter of the original tract, which it must either exploit or drop after a further period, perhaps 2 or 3 years. The prospector-discoverer would have the right, against all other persons, to obtain the mining rights to the final remaining fraction of his exploratory lease, but he would not be obligated in any way to establish a mine in the area unless he wished to do so. If the prospector-discoverer and the owner of the mineral rights, whether a private person or the Federal or a State Government, were unable to reach agreement on the payments to be made for the mining rights, either party could appeal to a specifically created Government judicial or quasi-judicial body to decide what recompense the owner of these rights should receive.

Although the granting of rights to mine and to prospect would limit the rights of the individual property owner, the owner would not lose his property permanently, as he does when the Federal Government expropriates property for such uses as roads and public buildings. Therefore, under the right of eminent domain, the Government would probably find it constitutionally possible to enact such legislation as I have outlined to encourage exploration and the exploitation of the Nation's natural resources.

All geological, geophysical, and geochemical information obtained in the course of exploration and mining of leased tracts would have to be made available to the appropriate agency of the Federal Government (the U.S. Geological Survey). Further, the Federal Government would be able, after a stipulated lapse of time, to make public this information in connection with other requests for bids for exploration rights to parts of the original lease not retained by the original leasee.

It should be emphasized that the information derived from the grid drilling is to be integrated with known surface geology and that the mapping and geophysical and geochemical work of the Survey should build on and expand the data provided by drilling. Thus, the Survey's surface programs probably would be concentrated around those holes that gave the greatest indications of valuable mineral raw materials at depth (solid, liquid, or gaseous), thereby helping to add more rapidly to the workable mineral reserves of the Nation.

It might be argued that the assignments of rights to prospect would be on sounder legal grounds if they were granted under the auspices of the several States. The confusion that would result from 50 different controlling sets of laws and governing bodies might be obviated by the preparation of a model statute for such control and its adoption by the 50 States. However, areas geologically suitable for exploration may well overlap State boundaries, and, even if the same laws were applicable in the two or more States involved, the obtaining of a geologically viable concession would be complicated by the need to consult, negotiate with, and report to, at least two administrative bodies and to comply with the requirements of no less than two sets of inspectors. Nor would the information obtained by work in more than one State be as easily collated and distributed as it would be if a single Federal agency (the U.S. Geological Survey) were to control the granting and operation of prospecting concessions.

Tax laws would have to be altered to permit exploration costs to be deducted as current expenses by the exploring organization. Further, these laws should allow any actual exploitation, perhaps by a reduced depletion allowance, to be carried out a fraction more profitably than if the sums spent in exploration and exploitation had been invested in any average type of economic activity within this country. No company, consortium, or individual, is going to invest money in petroleum or mineral extraction for fun. Such work is done in the hope of making a profit. There are sound arguments for considering mining or petroleum recovery as a more hazardous way of investing funds than in, say, the making of shoes or the manufacture of flour. Therefore, a somewhat higher rate of return must be allowed the exploiting organization either through tax concessions or higher prices. This remains true despite the current agitation against "windfall" profits. If the first method is adopted, the cost of supplying minerals or fuels from our subsoil would be borne by the general public. In the second, the actual consumers of the materials so produced would bear the cost. Because of the widespread use of minerals and fuels or of the products made from them, either method would bear about equally on the average consumer.

Much of the mineral-bearing rock found by, or with the help of, grid drilling might not at present be exploitable competitively with ore bodies now being mined, here or abroad. As world requirements grow and technology advances, however, more and more of the mineral material so discovered will come to be profitably mineable. Thus, returns will be achieved from the information developed by the grid drilling program far into the future.

The program here suggested is not designed to be a gigantic boondoggle but to be an economically sound method of achieving complete knowledge and recovery of the mineral and fuel resources that are available within the continental limits of the United States. Such a system could also be applied to Alaska, or to any major area of the world for that matter, with equal opportunities for success.

It is readily apparent that the scheme just outlined to promote prospecting and exploitation of mineral resources in the United States would have to be developed in much greater detail than I have presented here. If this program is to be implemented effectively, it must consider not only exploration and exploitation but also the protection of society in general against the ill effects of such activities. Careful and sound planning of these discovery and recovery operations, however, should reasonably balance the good and ill effects of the finding and the removing of mineral raw materials concentrated beneath the surface.

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CRISIS AND CATASTROPHE IN WATER-RESOURCES POLICY

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"A good rain is the only quick solution to the problem of drought . . . Unfortunately a good rain washes away more than the drought; it washes away much of man's interest in providing for the next one, and it washes the supports from under those who know that another dry cycle is coming and who urge their fellows to make ready for it." In these words, Walter Prescott Webb (1954, p. v), the Texas historian, enumerated one principle of the politics of water. So stated, the principle relates to natural phenomena. It is, in fact, a corollary of the political scientist's observation that issues in politics are accidental and evanescent, not planned and long lived.

In contrast to these views, many a scientist and engineer hopes for a more orderly approach to policy. Thus, an engineer discussing Federal water policies in the 1930's expressed the hope ". . . that the politicians and planners eventually will be guided more and more by fact-finding and hydrologic research than by politics and social philosophy . . . national water policy, in regard to both practice and planning, should be based upon economic and engineering facts . . ." (Guy, 1943, p. 312). Although perhaps few today would publicly propound sentiments that assume such a neutral, or value-free, role of science and technology in society, Don K. Price (1954, p. v), in his book on government and science, ". . . was struck by the way in which a professional consensus, based on the findings of research of a scientific or semi-scientific nature, often brought about the adoption of a new public policy and determined the methods of its administration."

At the dedication of a building bearing the name of John Wesley Powell, a brief historical review of some approaches to the problems of water resources in the United States, which keeps these conflicting models of chance and planned action in mind, may be useful. These two models are not, of course, the only ones that have been used to explain government expenditures for public works or research. This review emphasizes trends in water quality and quantity and some broad social and economic trends; it neglects an analysis of bureaucratic behavior, which some analysts have suggested is the major determinant of budgetary decisions (Wildavsky, 1964). Such a bureaucracy hypothesis is drawn upon in relating the historical findings to possible orientations of future programs in water quantity and quality.

SOME GENERAL TRENDS

Since 1860, trends in population, gross national product, expenditures for public works for water supply, sewerage, and flood control, and for water-resources investigations and stream-gaging stations have been roughly parallel in the United States. Even the value of damages from floods has risen consistently, along with expenditures for flood control. As the country has grown, so too has interest and activity in water resources. Growth has generally been continuous, although each activity shows momentary periods of acceleration or deceleration such as the reduction in economic and population growth in the 1930's, a time when expenditures for water-resources investigations increased threefold. Since World War II, the rate of increase in expenditures has followed the growth of the economy, except during the decade 1955–65, the post-Sputnik era, when total expenditures for water-resources investigations rose sharply from about \$30 per million dollars of gross national product to the current rate of about \$60 per million.

This graphical view of history suggests that continuity, if not planning, characterizes the development of society and the concomitant development of planning and execution of water-resources programs. A broad brush and moving averages do demonstrate continuity, but they also mask or belie other facets of the record. Upon closer inspection, as many observers have noted, one can discern distinctive eras and cycles, as well as isolated moments when public interest in water quantity and quality was stimulated by natural events and political or social crises.

MAJOR INFLUENCES IN WATER-RESOURCES HISTORY IN THE UNITED STATES

Only some highlights in a well-known history, including legislation, engineering structures, influential literary works, and scientific studies, will be touched upon here. Beginning with the Powell era, a chronology of significant events in water-resources history would start with the passage of the Homestead Act in 1862. That act did not represent the start of public interest in the development of the West, but it did initiate a boom in westward migration and land settlement, one of several in the period from the Civil War to the closure of the public domain. This western orientation can be characterized not only by the Homestead Act but by a variety of familiar milestones such as the Timber Culture Act (1873), the Desert Land Act (1877), the establishment of the Reclamation Service (1902), and the diversion of water from the Colorado River to the Imperial Valley in 1901. Of special interest here was the publication in 1878 of Powell's "Report on the Lands of the Arid Region of the United States."

A second period overlapping the first and continuing a strong western flavor includes the conservation era of Teddy Roosevelt, characterized by the 1908 Conservation Conference or the earlier White House Conference. Although the act establishing Yellowstone Park in 1872 represented a milestone in the concept of preservation, in general, the turn of the century conservation movement spearheaded by civil servants such as Pinchot, McGee, Leith, and Newell, emphasized "wise use" or the "gospel of efficiency," as the historian Hays (1959) referred to it, and not preservation.

Depression and the initiation of public works and planning characterized the 1930's, a period reviewed by W. G. Hoyt (1943), a principal engineer-hydrologist of the U.S. Geological Survey. Hoyt noted that during the 1930's, natural catastrophies, floods and droughts, occurred during a period of major economic upheaval and changing political philosophy. The combination produced the greatest surge in interest in environment and in expenditures for water-resources planning and development that the country has experienced. Although the economy as a whole dipped, water science and development, along with land management, burgeoned.

The period of rapid economic and population growth since the end of World War II has seen both a resurgence of development after the wartime hiatus, and the recent environmental movement. Much of this recent interest has emphasized, at least vocally, the "Spaceship Earth," or the finite nature of the world's resources, and hence conservation with greater emphasis upon preservation as opposed to development. However, expenditures for major water programs and for investigations have risen roughly with the economy during the same period.

This simple sequential history is known by, or at least taught to, every American schoolchild. Its recurring themes or near-cyclical character are currently played down by some, perhaps in the misguided view that such a recounting will tend to confirm the notion that "history repeats itself," or that such a view of our history leads to cynicism. For better or for worse, still closer inspection begins to reveal singular episodes superimposed on these broad eras and continuing growth.

WATER QUANTITY

In 1888, Powell was directed by the Congress to establish the Irrigation Survey. This reflected a growing recognition that development of the more arid parts of the West would depend heavily upon the availability of water. Powell, as his 1878 report described, felt strongly that settlers should not be encouraged to settle on lands that could not be provided with adequate quantities of water. He believed further that land should be parceled out in larger units and in such a fashion that settlements could be clustered and water made available to assure each settler a sufficient share. Powell's approach allied science directly with public policy. The hydrographic survey was to develop the facts for proper distribution of water and planning of land settlement, and to do so rapidly and accurately to the satisfaction of Congress and the engineers. Neither, in fact, was satisfied.

Congress became increasingly disturbed that settlement would have to be delayed or prohibited in areas that the hydrographic studies showed were too dry or for which information was not forthcoming. Engineers considered the accompanying topographic survey misdirected and too general. The Irrigation Survey itself was abolished 2 years after its inception. The setback represented the demise of Powell's dominance in Federal science and in his relationship with the Congress (Manning, 1967). Although many today disagree with some of his specific suggestions for land settlement, virtually no one denies the prophetic insights in his report on the arid lands. Vision and public interest coincided for only a brief moment. Yet, although Powell's policy views and the specific agency program may have been eclipsed, the Reclamation Service was established 12 years later, and the work was continued by the same individuals involved in the hydrographic measurements of the earlier Irrigation Survey.

Subsequent history is replete with examples of social action precipitated (no pun intended) by the vagaries of nature. The Johnstown Flood (1889) initiated the first legislation on the safety of dams. The flood of 1913 on the Miami River in Ohio not only sparked the creation of the Miami Conservancy District in 1914 but initiated the classic technical studies of hydrology and hydraulics embodied in its reports. Creation of the Conservancy District and advances in science and engineering represented a rare instance when a man and a moment combined to advance a prophetic future. Arthur E. Morgan (1951), a man of vision, guiding genius behind the Miami Conservancy District (and later a leader in the development of the Tennessee Valley Authority), capitalized on peaks of public interest stimulated by natural and manmade calamity.

The flood of 1927 on the Mississippi River stimulated initiation of the "308 Reports" of the U.S. Army Corps of Engineers. The Ohio and Mississippi River floods of 1936 and 1937 and the floods of 1936 and 1938 on the Connecticut and other rivers in New England led directly to the flood control acts of 1936 and 1938 and to the initiation of construction of dams and reservoirs. Floods and drought in the 1930's provided the ideal stimulus for the maintenance of public and political interest in land and water. As Hoyt noted, expansion of the work of the Corps of Engineers, creation of the TVA, the Soil Conservation Service, the Fish and Wildlife Service, and the National Resources Board (1934) (later the National Resources Planning Board) and its Water Resources Committee were derived from the combination of depression, political upheaval, and natural catastrophe. This combination promoted huge expenditures, not only for land and water management but also for the science and technology needed to support these efforts. Once again, however, as in Powell's day, Congress decided that too much planning might be a bad thing, and in 1943, the National Resources Planning Board was abolished with the provision that no other agency pursue the work.

The recent coming-of-age of flood insurance and alternatives other than structural measures to reduce flood damages suggests an interesting effect of catastrophe falling upon the "prepared mind." In 1942, Gilbert White observed that many alternatives to structural measures might be useful in mitigating flood damage. In the intervening years, White and others amassed information on the effects of flooding and on the experience in using these alternatives. More than a decade later, a flood insurance act was passed, and this year, three decades later, congressional appropriations specifically recognize additional alternatives.

To the best of our knowledge, no change has taken place in the long-term mean runoff or rainfall in various regions of the United States over the past 100 years. Although geologic evidence indicates that the floods in 1936 on the Connecticut and Ohio Rivers were the greatest in a geologic record representing some thousands of years, there is no evidence that floods today or during historical times are greater than those of the past, or that droughts are deeper and longer (Hoyt and Langbein, 1955). Further, we have learned that wet years follow wet, and dry follow dry, and that climatic change is the rule, not the exception. This unexplained paradox of both a constant mean flow and evidence of climatic change in historic and geologic records may reflect both the relatively short period of time over which measurements have been made and the subtle nature of changes in combinations of different climatic parameters which lead to significant variations in effects. Even without major changes in climate, "extremes" of either drought or flood beyond those we have experienced are likely to occur in many areas. This is so not only because we can readily envision combinations of meteorologic events which have not yet chanced to occur, but in addition because the longer the record, the greater the likelihood that a still larger flood or longer drought will be experienced.

The country has, of course, derived little comfort from the evidence that the mean rainfall or climate is much as it always was, or that the magnitudes of oscillations about the mean are also much as they always were. Generally we have responded to both low and high flow by building reservoirs. This is true both East and West. Not only Los Angeles, but New York and other eastern cities have gone long distances to provide water for growing cities. Reservoir storage in some arid and semiarid regions has reduced streamflow to a point at which loss by evaporation from additional reservoirs has exceeded gains from increased storage (Langbein, 1959). For the country as a whole, the added quantity of water made available by storage equals roughly 15 percent of total riverflow; only the Colorado, Pecos, and Upper Missouri basins are near maximum levels of regulation (Wollman and Bonem, 1971). Despite the fact that large reductions in floodflows have been achieved on many rivers, or perhaps because of the fact, the public is probably unaware that a finite risk of exceeding the storage capacity continues to exist in even the most heavily regulated basins.

If variability characterizes riverflow in the United States, it is not surprising that catastrophic extremes have captured public attention. At the same time, in the Eastern United States, where variability is least, economic growth has produced the earliest investments in reservoirs and aqueducts and has stimulated the most intensive observations of streamflow. The longest record and most intensive coverage are needed where the variability is both temporally and spatially the greatest. Because of the course of our history, however, for some time, the availability of money coincided with the availability of water to provide a surfeit of information in the Northeast and a deficit in the drier parts of the country.

Attempts to grapple with the captious behavior of natural streams have clearly influenced public policy. Floods and droughts have stimulated investment in observation, analysis, and control. At the same time, the absence of catastrophe, although it may have lulled the public consciousness, has not put it to sleep. Thoughtful approaches to public policy, such as the institutions propounded by Morgan for the Miami River and the Tennessee Valley or the alternatives to flood control suggested by White, have achieved acceptance, sometimes riding a wave of catastrophe. Perhaps even more important, the public has continued to support fact finding and analysis as the population and the economy have grown. This is illustrated perhaps by the coincidence of gaging stations and economic activity in the humid Eastern United States. That a Federal agency believes this relationship between economy and science is important is indicated by the following quotation from the Geological Survey's Long Range Plan (U.S. Geol. Survey, 1964, p. 45).

> The rate of development and use of water in the United States, and consequently the need for water information, has expanded faster than the water-resources program of the Geological Survey. This discrepancy is shown in [a comparison of] professional and technical scientific manpower in the water-resources program [and] industrial water use. During the period 1952–62, water intake by six principal water-using industries increased more than 60 per cent, whereas the scientific manpower of the Survey water-resources program increased only 40 per cent.

From 1960 to 1965, appropriations for water resources rose from $48 to $59 per million dollars of GNP. The Survey did not rest its case upon a flood or a drought.

WATER QUALITY

With regard to water quality, the record is different. With rare exceptions, environmental degradation, or loss in water quality, has had few moments comparable with the Mississippi River flood of 1927, the Susquehanna flood of 1972, or the New York City drought of 1965. For the most part, the chronology is characterized by the undramatic increase in sewage generated by more people, or by the periodic introduction and distribution of the products and wastes of society, such as DDT, detergents, or radionuclides. What is episodic, virtually random, and unpredictable, is the introduction itself of innumerable and wholly new materials, many of them foreign to nature.

Thus it is more difficult to isolate specific reasons for the resurgence of an interest in environmental quality in the 1960's. Some relate the true awakening of public consciousness to the reports of the astronauts and to the magnificent photographs of the lonely Earth in space that appeared on television and on the cover of "Life." Others have suggested that the barrage of studies of population growth and the ubiquitous character of air and water pollution struck the consciousness of an affluent leisure population able to enjoy the world of nature. True, there have been fish kills, Torrey Canyon and Santa Barbara oil spills, and the publication of "Silent Spring." Most of these incidents were not unique and represent some likely probability of error in a growing society of immense complexity. The number of such events in a given time period is increasing, but their frequency with respect to the magnitudes of the activities involved may well be decreasing. Acts of nature have great impacts on water quality, but for the most part they are ignored. The principal impact acknowledged comes from the scale of human activity, and the effect is primarily cumulative, and not episodic.

An equally important distinction between the place of catastrophe in water-quality policy and that in water-quantity policy is that, with few exceptions, degradation in water quality in this country has been less immediately and directly related to massive human suffering. Although water-quality-related disasters continue to occur, happily one must go back in history for good examples such as typhoid fever epidemics in Lowell and Lawrence, Mass., in 1890. These epidemics were river borne, and they were not unique. Again, however, politics, science, and catastrophe were joined. In 1885, the Commonwealth of Massachusetts had passed "an act to protect the purity of inland waters of the state." This act led to the establishment of the Lawrence Laboratory and, under the leadership of Sedgewick (1911), to the culmination of the movement for sanitation based upon an emerging science and technology. The remarkable results of this movement to improve the environment as a means of protecting human health are seen in the striking decrease in typhoid fever in the United States between 1900 and 1930, a decrease which parallels the introduction of public water supplies and treatment facilities and the growth of systems of sewerage and sewage treatment (Wolman and Bosch, 1963).

Because the history and timing of response to water-quality problems appear to differ markedly from the response to problems of water quantity (save in the penchant for building things), it is useful to look more closely at the history of the quality of the Nation's waters. Unfortunately, as the Director of the Geological Survey, the Environmental Protection Agency, the Council on Environmental Quality, and the authors of studies reconstructing this history have observed, the record available for the purpose is exceedingly weak. Some examples must suffice —and it is well to keep in mind in a review of water quality that before Columbus, the Saline River was saline, and the Missouri muddy.

Early history

Records indicate that dissolved solids in the Illinois River have increased roughly 30 percent and chlorides on the Ohio about 50 percent since the turn of the century. Apparently these constituents began to increase in Lakes Erie and Ontario at about the same time. In the same period, however, salinity on the Colorado rose 100 percent (see Wolman, 1971, for these and other general changes in river quality). Most changes in dissolved solids resulting from industrialization or from agriculture, as well as changes in sediment content, appear to have been progressive rather than abrupt. Meade and Trimble (1974) have shown, for example, that the sediment content of rivers in the Southeastern United States continues to reflect loads supplied from the watersheds during the height of cultivation in the last century, despite the presence of reservoirs upstream and recent changes in land use which have reduced the supply of sediment. In contrast, on the Colorado River, construction of major dams and reservoirs abruptly reduced or eliminated the movement of sediment downstream.

Fish populations in lakes and rivers apparently fluctuated significantly even before the 20th century. On the Delaware River, fish catches declined as a result of intensive fishing and the use of weirs and nets. Elimination of weirs and other obstacles about 1885 apparently permitted a resurgence of the shad population. The shad catch rose to a peak in 1900 and declined sharply by 1910 (Kiry, 1974). In the Great Lakes, marked changes have occurred in the composition of species of fish. Perch, for example, have completely replaced pike and herring in the Lake Erie harvest; total production continues to be about 50 million pounds of fish per year (Beeton, 1969, p. 175).

Dissolved-oxygen levels in the Hudson River in the vicinity of New York fell rapidly from about 1900 to 1915 as the result of the large quantities of untreated sewage delivered to the river. On the Potomac, as early as 1804, merchants in Georgetown (now part of the District of Columbia) were petitioning Congress to dredge sediment from the river. By 1883, Major Hains reported a stench from sewage sludge and sediment which he thought "inappropriate to the official residence of the first magistrate of the land" (Geyer and others, 1965, p. 30). In general, fear of typhoid fever, foul smells, and the unsightly condition of the rivers in the Eastern United States stimulated the initiation of measures to control pollution. Recent surveys of citizen's definitions of pollution continue to emphasize sights and smells and not the esoteric surrogates experts measure. Efforts at control of sewage effluents in many eastern rivers from the early part of this century until the 1930's were at best able to maintain relatively low levels of dissolved oxygen because of the growth of population and industry. By 1930 or 1940, anaerobic conditions prevailed in many rivers adjacent to metropolitan centers.

The last forty years

Large investments in sewage-treatment works, beginning in the 1930's, began to raise dissolved-oxygen levels and river quality, for example, on the Potomac at Washington, D.C., and on the Mississippi at St. Paul, Minn. In seeking models for public response to water problems, it must be noted that although the conservation ethic of the day contributed, investments made during the New Deal for sewage-treatment plants were viewed primarily as a vehicle to improve the economy and to provide employment. Ironically, in all likelihood they did little to improve the economy, but they did improve the rivers.

Some rivers, including the Delaware and the Ohio, may have reached their lowest quality by the mid-1940's during World War II. A section of the Delaware 12 miles long in the vicinity of Philadelphia was without oxygen, and sulfides blackened ships in the harbor (Kiry, 1974). Expenditures for sewage-treatment plants rose after the war. By about 1952, minimum levels of several parts per million dissolved oxygen prevailed in the Delaware as they do today. The Ohio River Water Sanitation Commission, created by Compact in 1948, had generated more than $1 billion of State and local funds for pollution control by 1965 (Cleary, 1967, p. 126). The river and many of its tributaries began gradually to improve in quality. These expenditures for pollution control after World War II seem to have been inspired by prosperity, not depression, and they moved forward without benefit of either natural catastrophe, political fanfare, or popular slogans; however, they were not without local popular support and competent technicians, who occasionally had the brilliant persuasiveness of an Ed Cleary (1967) of ORSANCO armed with a toothless compact.

A succession of Federal water pollution control acts marked the late 1950's and 1960's. The most recent peak of interest in the environment sparked the passage of "clean water" legislation in the 1970's. The most recent act, the Water Pollution Control Act Amendments of 1972, was predicated on the assumption: that waterways should not be used for the dumping of wastes; that effluents, not ambient water quality, would be a better basis for regulation; that technology could be depended upon to treat or control the wastes that a technological society had generated; and that point sources should be given priority for control.

Currently, New York City, in the middle of a $4 billion program, is spending at the rate about $1 million per day in the construction of sewers and treatment plants. According to "Engineering News-Record" (May 30, 1974, p. 14), this amounts to $143 per person annually, nearly five times more than Seattle, the second largest spender. As a result, dissolved-oxygen levels in the harbor have risen to 50 percent of saturation, the highest level since the early 1900's. Although New York had expended large sums on treatment plants from 1950 to 1965, the city's present heroic effort began in 1966 after the passage of State and Federal pollution control legislation.

The past 5 years has also seen a rapid rise in private expenditures for pollution control. Curiously, however, the interest that peaked in 1970 has not been accompanied by a comparable commitment of public money since that time. Expenditures for public sewerage facilities for the country as a whole have risen continuously since 1856, but in the past year these have begun to level off. This year's expenditures for public treatment works are likely to be less than those of last year (U.S. Environmental Protection Agency, 1973b). A variety of reasons have been given for this recent decline, including insufficient funds for public works, bureaucratic wrangling, and the state of the economy. Whatever the reasons, total discharge of pollutants from both point and nonpoint sources may well be continuing to rise.

Studies of the recent past have suggested, as yet, no clear patterns of response in the water environment to the new pollution control efforts. A U.S. Council on Environmental Quality (1972, p. 14) study suggests that from 1957 to 1970 dissolved oxygen may have risen at 50 percent of the sites sampled in the study and declined at 23 percent. The U.S. Environmental Protection Agency (1973a) reported roughly similar figures, comparing the 5-year period 1963–68 with the following 5 years to 1972. From the council study, improvement seems greatest where point sources of pollutants dominate, and no trend is evident in agricultural basins. Levels of phosphates and nitrates in streams continue to increase in many reaches, apparently as a result of inflow of detergents and industrial effluents in some places and of fertilizers in others.

Water quality has declined, or on occasion improved, as a result of the activities of man. Until recently, the greatest changes may be described as coincidental and not directly related to a concern for the quality of the water resource itself. Thus, development of farming in the forested East produced vast quantities of sediment which drastically altered the waterways. Abandonment of farming in turn reduced this yield, and lake and river quality improved. Similarly, in the drive to eliminate typhoid fever, the rivers benefited. Only in the 1930's did the effort turn principally to the waterways themselves, and, even then, a primary stimulus to action was the concern for unemployment and the state of the economy. Interest in water quality accelerated after World War II and may have peaked in 1970 or 1971.

Sequential changes in water quality and attention to them are not a response to natural catastrophe and are only occasionally a response to dramatic political or economic events. Indeed, political enthusiasm and expenditures for engineering works have run well ahead of the rate of acquisition of adequate knowledge about the quality of the water. Proposed expenditures for water pollution control currently run as high as $4 billion to $6 billion per year. This may or may not be an appropriate amount. Unfortunately, although major efforts are clearly needed, information about the quality of the water itself is too poor to permit sound evaluation of the efficiency of these large expenditures, or of alternative strategies for efficient use of increasingly scarce monies. Similarly unfortunate is the absence of measures of the social costs of polluted water. Lack of knowledge about water quality and about social costs clouds public debate over the appropriate level of effort to be expended in water pollution control.

LESSONS FROM THE HISTORICAL RECORD

STIMULANTS TO INTEREST IN WATER: THE MODELS

Historically, catastrophe, whether natural flood or manmade depression, episodically stimulated investment in water management. However, changes in water quantity, and particularly changes in water quality, although they may have influenced public policy (a policy about floods without floods is unlikely) have not been the dominant influence on expenditures for public works or for scientific investigations of water resources. As the Geological Survey has recognized, the budget is most closely tied to the broad social and economic march of the country.

Dominant social concerns have broadly determined historical behavior, and more often than not, legislation and action have preceded or even contravened scientific understanding; the Desert Land Act based on the hope that trees would induce rainfall to aid settlement, and the expectation that forests would control major floods are cases in point. Yet the results of these actions, often inefficient and sometimes ineffective, can be salutary and are not all bad. Then too, the very passions, sometimes spurred by catastrophe, that provoked action stimulate scientific effort, which may serve to redirect public policy at a later time. Progress in sanitation suggests that even between the peaks of political passion, gains can be made. One cannot, and apparently need not, wait for that rare combination of remarkable man, prepared science, and natural or manmade catastrophe. At the same time, one can be prepared to strike when the iron of public interest is hot.

The record suggests that a combination of continuous investment in science, the ponderous momentum of society, and preparedness to make quantum steps when opportunity affords may not be a poor strategy for a scientific agency. Some may lament that such a strategy too closely parallels the political scientists' model of a typical bureaucracy protecting its flanks while inching slowly forward (Tullock, 1965), an image of caution not boldness, of dullness not creativity. The image is not warranted. Continuity is desirable in scientific inquiry and particularly so in the observation of hydrologic phenomena. The relatively smooth growth curve that characterizes the history of water-resources investigations may be rational both in terms of the agency's needs and those of the society. At the same time that the country seeks guidance over the long term, it demands creative response to the problems of the day as it perceives them.

TRENDS TOWARD NATIONAL RESPONSIBILITY

In addition to a modest test of some hypotheses about the causes and stimuli of interest in water resources, even this brief historical review provides evidence of the continuing trend toward national and away from State and local responsibility for water management. Approaches to both water quantity and quality reflect this trend. The visitation of catastrophe in the form of floods and droughts on any one section of the country has, since the 1930's, for example, led to the increasing assumption of responsibility at the national level. The Flood Control Act of 1938 liberalized cost-sharing provisions for the Federal flood control projects and relieved the direct beneficiaries of major responsibility for reimbursement. More recently, the devastating floods associated with Tropical Storm Agnes in 1972 produced modifications of the flood insurance act of 1968. Requirements for land-use planning in flood-prone lands were strengthened, and the level of premium payments required of the beneficiaries was significantly reduced.

In the field of water quality, the tendency toward the assumption of national responsibility is also apparent in the passage of the Central Arizona Project by the Congress in 1970. Recognizing that the water available in the Colorado River was already overcommitted in this country, and further, that the United States had recently accepted a commitment to supply Mexico with a specified quantity of "unsalty" water each year, Congress provided that the Nation, not the region, bear the costs of meeting the added burdens of the recent agreement with Mexico on water quality.

Similarly, it may be ironic, but perhaps understandable, that Arthur Morgan's pioneering effort to "internalize the externalities," that is, to approach water management on a regional basis under local authority, is currently in danger of being dismantled as Federal and State powers over pollution abatement grow. Such conflict between local, State, and Federal government is, of course, a logical consequence of further expansion of the Federal and State interest reflected in the Water Pollution Control Act Amendments of 1972.

MODEST PROPOSALS

The fundamental work of an agency such as the Geological Survey consists of programs of observation and analysis which customarily grow incrementally as the needs of society expand. Over time, responsibility is assumed for a long list of activities. Many of these cannot be summarily abandoned. As custodian of the knowledge of long-term trends in the hydrologic cycle, for example, the Geological Survey cannot simply halt all observational programs directed toward this objective. Similarly, society would be ill served by wholesale abandonment of interest in specific facets of the hydrologic cycle. This does not mean that nothing is ever abandoned, or that programs never change, or that the emphases do not change. Rather, it means that additions and new emphases must be selected from a current array of public interests and demands. Some of these may require radical departures in attitude or approach, even if not in apparent content. The present scene abounds in issues, concerns, and catastrophes. These issues and the demand for continuity provide some basis for selection of priorities.

The issues are familiar. First, the evidence is good that although the fervor may have died in the breasts of some environmentalists, much of the American public is convinced that they want a better environment. Second, population will continue to grow, even at a reduced rate, for several decades, and continuing numbers of people will want to share in the fruits of growth. Third, energy has recently become a part of American consciousness. Fourth, in the world as a whole, drought, hunger, and starvation are daily realities. From the standpoint of an interest in water, these issues all involve two points of view, first the long view of what may be happening to the resource as a whole, and second, a detailed knowledge of how water is used and affected by specific human activities.

WATER-QUALITY APPRAISAL: A UNIFIED APPROACH

The ecological truism that "one man's garbage is another man's meat" or that things are connected, provides a starting point for the first approach. Legal fiat cannot disconnect the parts of the hydrologic cycle or the cycles of materials between land, air, and water. Given the major interest in environment and the large sums to be expended in behalf of its improvement, a major effort to structure a comprehensive program of evaluation of water quality covering the continental and coastal waters is needed. Like the Survey's emerging studies of regulated water systems (Benson and Carter, 1973), such a program must involve a knowledge of sources, transport, storage, and sinks of residuals to the water environment. Acid rain in New England and the linkage of ground water and land disposal illustrate the interactions of land, air, and water.

Today's map of areas of major pollution potential is virtually identical with one made in 1936; the areas of urbanization have simply grown larger, and more pristine areas have been invaded. Unfortunately, for most areas, we know neither the sources nor the sinks of materials entering the lakes, rivers, and estuaries. The relative contributions of point and nonpoint sources vary from 10 to 90 percent. Trace metals and other minor constituents are sometimes found in high concentrations in the water and bottom sediments. Not only is their distribution poorly known, but we cannot compute with satisfactory accuracy the rate of removal of such materials should new sources be completely controlled. The prospects for permanent burial or for mobilization of both nutrients and toxic materials are poorly known (Symons, 1969). In the long run, the estuaries and continental shelves are the probable sinks for pollutants if river regulation is not too extensive. Only very recently, however, has a true compilation of the transport of dissolved and suspended materials to the continental margins been published (Curtis and others, 1973; Leifeste, 1974). This is based on limited information, and data on other materials are even more meager.

The purpose of a comprehensive program of appraisal is to assist in the prediction of the impact of policy decisions. Because this requires a knowledge of process, observation must be accompanied by continuing analysis. Parameters chosen for study will include meaningful biological characteristics as well as significant physical features and inorganic substances. In depth and scope, the inquiry may complement the needs of law enforcement, but the two purposes are not synonymous. For example, a pollution index may be a useful monitoring tool, but such an index may mask the interrelationships needed to define effective policy instruments. Similarly, although regulators need access to facts and competent scientific assistance, the historic record has shown that mission-oriented agencies may become addicted to demonstration rather than evaluation (Schiff, 1962).

The pieces of such a program have, of course, received attention. Current efforts, however, appear both too limited and too fragmented relative to our presumed commitment to environmental quality. Perhaps the Water Resources Council can be made responsible for spelling out a truly broad mission for the agencies involved, not as a treaty but as a comprehensive plan. As the observer of water and the possessor of the sense of time, the Survey has a major role to play.

WATER AND CLIMATIC CHANGE

Famine in Africa and elsewhere calls attention to another facet of water resources that requires a long view but that has consequences directly related to problems of current public policy. What are the characteristics of climatic and hydrologic variations, and what is the level of uncertainty appropriate to the planning of human activities? As the history of Colorado River development illustrates, human experience, and particularly local experience, can only include patches of the record. Even the best of planning using stochastic concepts is unlikely to encompass some unexpected long-term trends; hence, shortage and surfeit may be mitigated but are not likely to be eliminated. The consequences of certain assumptions about hydrologic variability are becoming even more painfully evident today, as shown by the relation of the destruction of grassland and the recent dependence on wells in sub-Saharan Africa.

The problem of climatic variability is perhaps of even more significance in a broader context. Much current thinking is based upon too simple a concept of equilibrium or balance in nature. The record reveals that the entire landscape and the natural biota associated with it may undergo significant alterations from what we presume today to be a condition of equilibrium or stability, when such alterations are triggered by a succession of years of climatic and hydrologic change. Such changes in the past, for example, may have produced rates of erosion in the Midwest which exceeded those produced by farming, and they have resulted in the filling and excavation of the valleys of the Southwest a number of times. Public policies based on the assumption that men are responsible, as some policies were in the 1930's, may be both costly and doomed to failure.

WATER USE: DEMAND, PRODUCTION FUNCTIONS, AND MASS BALANCES

The Geological Survey has long had responsibility for measuring or estimating the withdrawal and "use" of water in the United States. These estimates are classically viewed as measures to be matched against estimates of supply, as part of the process of developing public policies for resource allocation. As so-called needs, or requirements, on the use side have risen, however, it has become increasingly evident that evaluation of policy alternatives requires a deeper knowledge of the demand and supply relationship. Not only must the use of differing quantities of water of a given quality be measured, but inquiry is needed into the economic and social factors that lead to particular choices. We need to know not only how much water of what kind is used, but also why.

Obviously the study of water use in every kind of industrial, commercial, or household activity is unwarranted. Clearly, however, production functions providing explicit information on the role of water in major economic activities and on the way in which it is used and transformed are essential to future policy choices. The widespread interest in energy makes analyses of the amounts of water used and the changes in water quantity and quality in the energy industry imperative. Considering their importance, current estimates of quantities of water needed for various energy conversion processes seem unnecessarily conjectural. Work has been started by the Survey and by others (Delson and Frankel, in press) in some of these fields. Additional effort in the energy industry, in agriculture, and perhaps in several other major sectors of the economy may be warranted. The use of production functions (Minhas and others, 1974; Lof and Kneese, 1968) and mass balance frameworks for studies of specific activities (Bower and others, 1972) will provide additional tools for measuring the effects of various activities on the water resource, for estimating needs for specific data or research, and for evaluating the probable response of different activities to different policies affecting water resources.

The Government Accounting Office noted that the budget for true research in the understanding and techniques of improving water quality is quite small —a Montana rancher recently referred to a disease she called "lackadata." Cries for research and for data can, of course, be excuses for inaction. As complete knowledge is unattainable, action cannot wait. Because this is so, scientific inquiry and appraisal of the kind described above—in current environmental jargon, "evaluation"—must accompany action. The argument is sometimes sound that we must do something to find out what happens. Unfortunately, we usually do something but rarely find out what happens. There will be no excuse 20 years from now for "lackadata" disease where reclamation following mining for coal or for shale oil in the West is concerned. A proper study of the impact on water resources of such activities as energy conversion or mining, however, demands elaboration of a plan of study before activities begin and a scheme of financing to assure the necessary longevity.

OBJECTIVES AND HOPES

Studies of long-term trends and variability in water quality and water quantity, as noted earlier, do not consist simply of data collection. Similarly, evaluation of demands and uses of water by man are more than hydrologic budgets. Adequate understanding of each requires an inquiry into the dynamics of processes. Hopefully, the results of such inquiry will lead to better understanding of the way in which human and environmental systems work and an improved basis for prediction of probable interactions, if not of probable futures. New concerns for energy and for conservation in the United States may stimulate research in water resources in directions promising greater utility abroad, particularly in the less developed world. While we seek solutions to our own legal, social, and technological problems, a search for efficiency in water and energy use coupled with attempts to minimize environmental impacts may aid this process.

Most of the major issues of the day—environment, growth, food and famine, cities, and energy—involve water. All are crises in that people today are poor and starving. None of the questions that confront us in the field of water quantity and quality can be properly called a crisis, however, if that word implies a short time scale. As they have always been, the problems of water quantity and quality are perpetual. The ability to take advantage of the political moment, or the awakened public consciousness, by virtue of a disaster or an election may determine the extent to which these fleeting moments of interest are well used in the slow business of improving the ability of the public and its representatives to make wise decisions about the future.

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ENVIRONMENTAL ANALYSIS AND EARTH SCIENCES IN THE PUBLIC SERVICE

By BEATRICE E. WILLARD
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It is a special honor to be with you for the dedication of the John Wesley Powell Building of the U.S. Geological Survey. It is most fitting that this symposium be held to commemorate that great geologist-explorer whose vision led to the establishment of the U.S. Geological Survey, and to direct our thoughts ahead to the contributions earth sciences can make to the problems ahead.

As a Westerner, familiar from childhood with the landscape Powell brought to the attention of the Nation and the world by his courageous scientific explorations, I have long been an admirer of Powell's work. The understanding of the geologic processes that produced this landscape contributes essential insight to the work of the Council on Environmental Quality, just as it has long made a major contribution to my professional competence and has been a source of continuing personal fascination.

Our two sciences have much in common. They both look at landscape from the process systems viewpoint—mentally seeing hundreds, thousands, even millions of years into the past, and, using this perspective, determining what the future might hold. They both, as sciences, have discovered basic principles about the operation of Earth's landscapes that can assist man in adapting to—harmonizing with—Earth's processes, if the principles are accepted and used.

If John Wesley Powell were alive today, he obviously would be proud of the many laudable scientific accomplishments of the U.S. Geological Survey, and he would be pleased at the expansion of its work into the oceans and Arctic regions. However, he would be astounded at the huge desert lake that bears his name and mortified that man could allow the submergence of land of such rare beauty and scientific value so that an engineering technique might be used to solve a political problem. I mention this distasteful fact only because it sounded an alert to citizens and, together with many other signs of environmental deterioration in the 1950's and 1960's, led to awakening the Congress to the great need for a National Environmental Policy Act.

In preparing for this auspicious occasion, I kept asking myself, "How would Dr. Powell want the Nation to use earth sciences were he alive today?" As a great student of nature and in tune with the natural processes operating in our landscape, he would urge our acceptance of the basic principles of landscape into the fiber of our thinking and action. He would insist that we choose these principles as our guidelines for decisionmaking, rather than political expendiency, economics, and development for growth's sake alone. He would utilize these basic landscape principles, as most scientists today do, as the framework for all action. He would communicate them in meaningful ways to the Nation's citizenry, the Congress, agency personnel, and administrators, so that these principles might permeate thought and action as our Constitution and Bill of Rights do.

I find it continuingly beneficial to reexamine the basic principles of the earth sciences and how they can guide thinking and action about landscape.

The first principle is by far the most important, yet hardest to accept: Everything affects everything else. This principle demands that we question the many ramifications of human action and choose the path that has the most overall positive effects, after taking into account long-range values and short-term benefits. This demand became law as part of the National Environmental Policy Act of 1969, in the requirement to prepare environmental-impact statements—analyses of the ramifications of human actions.

The second principle is that landscape is a mosaic of dynamic systems (earth systems, ecosystems) comprising physical components (rocks, landscape features, soil, climate, water), biological components (plants, animals, humans), and the intricate dynamic processes that operate among these two types of components (erosion, deposition, tectonic movements, cycling, competition, symbiosis, evolution, succession, politics, and economics, to name a few). In these systems, all components have a role integrated with the whole and are inseparable from the whole.

This second principle amplifies the first and makes the systems approach to research and decisionmaking mandatory. The systems-analysis approach requires a truly interdisciplinary team approach, where each member is interacting with each other member of the team in the design, planning, and conduct of research and data analysis. This approach precludes the possibility of omitting from analysis those lesser known or more difficult parts of the systems, because, to research, those gaps in knowledge of the system show up as blanks in the diagrammatic models of the system that block further analysis. The Western coal-mining study of a set of interacting local, regional, national, and global systems, rather than "rock in the box," encompasses the systems approach to a degree. It is encouraging to see systems analysis being applied to solid-waste management, and the resulting much more efficient use of time, minerals, energy, and land.

The third principle is that components of landscape systems have limits to their functioning such as melting points, freezing points, denaturing points, dehydration limits, nutrient limits, stress and tension limits, and absorption limits. These various parameters, interacting, describe the operational perimeters of the biological and physical systems and therefore dictate the characteristics of ecosystems. Learning what these parameters are and how they operate enables man to make more precise analyses and to draw up wiser plans for resource management. Projects designed with the operational framework of the system in constant view can avoid or mitigate problems that arise from ignorance or oversight of these limits. For example, a long-range view of national materials policy from the perspective of this principle could recognize these points and limit use of materials now, so as to prolong the supply of resources for the benefit of future generations.

The fourth principle is that components of ecosystems, operating through complex interlocking biological and physical processes, define a feature of all systems, which ecologists call "carrying capacity." Physicists call it a "breaking point," "fatigue point," "stress point." Whatever the term, it is a highly useful concept in wise management of systems. Environmental analyses that include determination of this feature for various human activities will show the way to avoid many of the overload characteristics that we see in air, streams, lakes, forests, and ranges. Standards set with an understanding of carrying capacity, which encompasses the concept of tolerance limits of organisms and physical factors, will work to bring man's activities into balance with ecosystems. Carrying-capacity determination, although difficult and complex to calculate, has been successfully done in engineering, agriculture, and wildlife management for decades. It is beginning to be applied in recreation resource management and in regional planning, as in the Pacific Northwest.

The recent investigations on "limits to growth" are an effort to determine a global carrying capacity for basic resources essential to life. It stands to reason that as all material resources are finite, the sooner we tailor human use of these resources to carrying capacity worldwide, the sooner we can bring human activities into balance with the Earth's resource base. Not a simple goal, but a highly desirable one, and the U.S. Geological Survey work of resource assessment is fundamental to it.

Furthermore, the carrying-capacity principle is dynamic, adjusting with the advent of new technologies and new discoveries of resources, while maintaining a balance between users and resources. I envision great potential for the U.S. Geological Survey in its second century, putting the carrying-capacity principle to work for the benefit of man.

The fifth principle is that landscape systems are dynamic. They progress through various phases of development to a point of dynamic equilibrium, in which state they remain until a major change of conditions takes them back to an earlier stage of development—precipitiously, as by earthquake landslide, flood, volcanic eruption, or insect infestations, or gradually, as by erosion, climate change, or evolution. Use of this principle in environmental analyses frees us from believing that the land-use and resource planning and management must be static. Environmental analyses that include calculation of the rate of change provide a measure of ecosystem cost and benefits to compare with economic costs and benefits. It is even possible to analyze ecosystem costs and benefits in dollar terms, as Eugene Odum has done with the salt marshes of Georgia. He has found that salt marshes sold for landfill and urban construction go at $1,000 to $3,000 an acre; if the land is maintained as marsh, however, the composite value of the work of the ecosystem for man—in air and water cleansing, nutrient production, nursery grounds for shell and fin fish, hurricane buffering, and recreational and scenic values—is $85,000 an acre—a free contribution.

As Powell well knew, these principles must become integral to the thinking, decisions, and actions of all of us. Practicing this fact an engineer in Denver designed a tool for integrating ecology, including the earth sciences, into design, planning, construction, and operation of projects. He calls this tool the "3 E's Tripod." One leg stands for engineering, one for economics, and one for ecology, including earth sciences. As you well know, tripods, to be functional, must have the three legs united to a firm central core, and each leg must be in action and bearing its proportionate weight.

If the principles of landscape are applied, together with those of engineering and economics, from the outset, a synergism is set up in the ensuing analyses that take place in the conceptualization, reconnaissance, feasibility, and decision phases. Just as in engineering and economics, the types and amounts of data and complexities of environmental analysis increase as you move from phase to phase.

What do these natural guidelines suggest for the second century of the U.S. Geological Survey:

First, in NEPA (P.L. 91-190), carrying capacity and recycling have been codified in Section 101(b):

In order to carry out the policy set forth in this Act, it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may—

* * * * *

(5) *achieve a balance between population and resource use* which will permit high standards of living and a wide sharing of life's amenities; and

(6) *enhance the quality of renewable resources* and approach the maximum attainable recycling of depletable resources.

A double-edged challenge is provided in implementing these two provisions: to maintain the quality of life and environment while bringing human activity into balance—harmony—with the functioning of landscape systems.

Second, as the knowledge of Earth increases, the interrelatedness of geologic, biologic, and climatic forces becomes more and more evident. This knowledge can enable humans to predict future phenomena with ever-increasing accuracy. This capability can make it possible to bring human activities into greater and greater harmony with Earth's landscape systems. For example, the ability to map earthquake zones and to predict the frequency and occurrence of earthquakes with increasing accuracy will make it possible to plan uses compatible with high-risk areas that complement uses on adjacent low-risk areas.

Third, geologic and ecologic knowledge can encourage precise specific adaptation of human activities to the landscape processes. Some of this is now evident; more interaction with the public can lead to more rapid application of the knowledge to solving human problems. For example, the public is learning that flood plains are river rights-of-way that can be shared by rivers and humans for activities compatible with periodic flooding; that earthquake zones can have human uses compatible with their instability; that erosion and deposition processes can be understood and human activities can be located in ways compatible with the continued operation of the processes, rather than altering the processes locally and regionally, only to wonder afterward why erosion is removing beaches and cliffs below cherished resort hotels and homes.

In conclusion, I have drawn some broad-brush implications of how earth sciences might contribute to environmental analyses in the future, on the basis of natural principles so that we can stand back a moment from the work at hand and ask ourselves, "Where are we going and do we have the right quadrangle map to get there?"—as scientists, as administrators, as policymakers, as engineers. The quality of life in the future depends in part on how well we apply these principles of earth science in our daily activities. I rest assured that the U.S. Geological Survey will continue to expand on its meritorious tradition initiated by the man we honor today, by providing the Nation and the world essential components of better and better environmental analyses.

LEASE MANAGEMENT AND RESOURCE CONSERVATION

By Don E. Kash
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In practice, public policy and management in the American experience reflect a consistent pattern. That pattern is to define decisions wherever possible as involving questions that can best be answered with information. If one only listens to the rhetoric, policy debates in this country regularly sound as if there are no differences among the values being promoted. In truth, the gut political choices are among preferences and tastes and who gains the benefits or suffers the costs. Value preferences have nonrational and nonempirical roots and generally cannot be changed by facts or more information.

This appears to be the case in spades with regard to lease management and resource conservation. In the resource sector, three fundamental value issues appear and reappear. They are: First, the question of "fair value" for resources; second, the question of who gets to develop the resources or resource allocation; and, third, the question of what values are to be maximized in postlease regulation.

One pattern of disguising value questions is to paper them over by establishing mechanical choicemaking procedures. An example of this is the procedure for allocating leases on the basis of bonus bids. In a complex situation, we elevate a single variable—in this case dollars—to a dominant position and let it make the choice. That camouflages the fact that the elevation of the variable involved a major value choice.

A second pattern is to submerge the value choices in a mass of information. The debate is then over who has the best information and what the information says. In both cases, the parties-at-interest never have to lay out their selfish purposes. The value choices in the resource area are especially clouded by the information quagmire. This tendency to seek answers in information usually allows decisionmaking to be transferred to the professionals and experts.

The central problem in our period of change is that the mechanisms we have traditionally used to convert value choices into choices among facts are not working well because the substantive conditions in our society have been undergoing massive changes as a result of modern technology. These changes have spotlighted some of the inherent contradictions in our traditional assumptions and rules of operation. Three of these traditions appear relevant to the topic of this paper.

The first and most hallowed tradition is the constitutionally established principle that there should be "walls of separation" established between the various sectors, functions, and institutions of our society. The fundamental purpose of this tradition has been to protect against the abuse of power thought to be the result of decisionmakers who have conflicts of interest. This particular term "wall of separation" was used by the Supreme Court in a 1947 decision declaring that the Constitution requires a "wall of separation" between church and state.

For our purposes, the most important reflection of this tradition has been the conception that an adversary relationship is to be desired in the relations between Government and business, or more generally, the public sector and the private sector. That conception has been particularly important in guiding relations between the Department of the Interior and the resource industry. The fact that the wall has been breached with regularity in the resource sector and, in fact, that conflicts of interest are endemic in a complex society has been consistently overlooked until recently. In practice, the wall has nearly crumbled in the natural-resources sector.

The second tradition is that the private sector best serves the public interest when it is governed by the competitive rules of the marketplace. Stated succinctly, this tradition says that the private sector, in this case the resource industry, operates best with minimal encumbrance by government. Increased Government involvement leads to increased inefficiency. That conceptual construct of what the economists called "the market" is supposed to be relied upon to govern business behavior. This faith in the marketplace provides much of the conceptual underpinning for the desired adversary relationship between Government and business because Government interference is supposed to foul up the operation of the market.

The third tradition is that down at the nitty-gritty level, on a day-to-day basis, Government-industry relations will be carried out in both sectors by professionals who share a common expertise and whose real world activities are organized around common problems. In the resource sector, whether these professionals be geologists, engineers, economists, or lawyers, they share the common bond of a community that views resource management as an activity best carried out by full-time experts. No matter where they may be employed—in a Government agency or a corporation—they see that adversary process of "politics," which is central to the first tradition, as a cross they must bear.

CONTRADICTIONS IN THE MANAGEMENT SYSTEM

Clearly, there has been a fundamental contradiction between tradition one, the wall of separation, and tradition three, professional management. That contradiction, however, could be dealt with on an ad hoc basis so long as leasing and management took place in a condition of abundance. The philosophical debate over the role of the public sector versus the private sector might exercise the glands of liberals and conservatives, but except in the rare cases, such as Teapot Dome scandal, it had little impact on what actually happened. Even in cases of scandal, the corrective action was aimed at constraining the abuse of power by corrupt and avaricious men in a condition of abundance. The objective was to find sanitary procedures that would protect the public from such men. In practice, this meant letting a system of clean procedures make the value choices.

Guided by these conflicting traditions, the Congress and the executive branch responded in expected fashion. Within the Department of the Interior, a formal "wall of separation" was constructed between the organization responsible for allocating resources and determining revenue (Bureau of Land Management) and that responsible for conservation and follow-on management (U.S. Geological Survey). This was the case even though the effective exercise of these responsibilities required the agencies to be intimately intertwined.

For those resource allocation and revenue decisions assigned to the Bureau of Land Management, the traditions have further required the establishment of procedures that allow minimum discretion. Where competing companies were desirous of obtaining the right to develop resources, that right was given either by bonus bids or lottery, and where there were no competitors, it was given on a first-come basis.

Where procedures are used to disguise and therefore make value decisions, the only information necessary is that which is associated with the single decisionmaking variable, in this case, time of request, lottery number, or size of bonus bid. On the other hand, where facts are used to disguise and therefore to make the value choices, as in the case of follow-on regulation, responsibility is assigned to the professional, scientifically oriented U.S. Geological Survey. In general, the information disguise was possible because a maturing resource industry and the Government shared common goals with regard to conservation. Those goals were the orderly and timely resource development and maximum ultimate recovery of the resource. Although conservation management required sharing information and analysis between industry and Government, that did not pose a serious threat, given the shared goals of the postlease or heavily professional management phase.

CHANGING VALUES

As society's values have changed and as scarcity has replaced abundance, the elements of the public interested in resource management have expanded, and many of the new elements manifest different values. This has resulted in resource policies being subjected to a different kind of scrutiny and has led to widespread criticism. The criticism reflects a belief that existing resource management arrangements are not responsive to the threats of existing or potential scarcity, new kinds of multiple-use concerns, and heightened environmental sensitivities. These pressures have blurred the boundaries between the responsibilities of the professionals and the lay public. Similarly, the dividing line between the resource allocation and revenue questions and the follow-on management activities is no longer clear.

Stated differently, leasing and resource management must now be responsive to a much broader set of goals and criteria. Both leasing and resource conservation decisions must now reflect tradeoffs among revenue returns, accelerated resource availability, and environmental-multiple-use concerns. The dilemma is well illustrated by the proposal to lease 10 million acres of Outer Continental Shelf (OCS) lands a year.

It seems unlikely that leasing at that rate will generate a per-acre bonus-bid return equal to that produced under a program that leases 1 million acres a year, thus raising fair-value questions. Similarly, the need to lease according to some scheme of areas ranked for their environmental sensitivity, as proposed by the Council on Environmental Quality, will likely affect both revenue return and rate of development.

An equally complex condition is developing in the area of postlease management of resources, as environmentally responsive management appears to require substantial prelease planning. This requires early acquisition of a broad range of information and a substantial increase in the range and amount of management expertise.

These changing goals and the public attitudes they reflect spotlight two operational demands. First, there is a demand that at all times, Government must have information and interpretations on resources equal to those held by industry. The underlying assumption is that the complex and highly discriminating judgments Government must now make among conflicting values requires the best available information. If you cannot use a single variable and mechanical procedures, you try to substitute information and expertise.

Second, there is the demand for public participation in all resource decisions from prelease planning through postlease regulation. Laymen want a role. The professionals find this difficult because without professional competence, even with complete information, the layman does not understand the critical nuances of resource management.

Few things are more offensive to a professional than a layman questioning his professional decisions. The professional and lay perspectives differ as follows: Experts focus on cause-and-effect relationships. They are oriented toward understanding what causes events to take place, and they understand the complex and frequently difficult problems associated with modifying causal relationships. Laymen are oriented toward what the effects mean to their value preferences. They manifest little concern for professional values. Laymen may not be able to explain why, but they can tell what they like and do not like. When dissatisfaction is high, the lay public demands the right to participate so that they can register their likes and dislikes. The changes I see in resource management are all linked to this demand for expanded public involvement. When nonprofessionals assert the right to participate in resource management and when they further assert that nonprofessional values must carry equal weight, the system is politicized. That has happened to the resource management system. Successful political systems are those that find accommodations among conflicting values and conflicting facts. Resource management in the future must find such accommodations.

THE CHALLENGE

This is a major challenge for resource managers generally, but especially so for a professional organization such as the U.S. Geological Survey. The essence of the present demand for management change is that the contradictions be eliminated by assuring an adversary relationship between the Government's professionals and those in industry. This is a major reason behind the demand for better Government information and more public involvement.

The objective is to insure that Government professionals can and will perform as competent adversaries of the industry professionals. In this, as in every area of our technological society, the growing pressure is to create a system of "our professionals" and "their professionals." This seems to reflect a belief that the public has been snookered by communities of experts who deny access to the uninformed. The critical public wants its own experts—it wants the Government experts to demonstrate their loyalties by fighting with those in industry.

These demands are particularly threatening to the resource industry. From my vantage point, the resource industry reflects a distinctively conservative posture. By this, I mean that it inherently fears change. The reasons appear to be at least threefold: (1) The industry has a history of living with wide fluctuations—going from surpluses and low prices to scarcity and high prices—and its response has been to make stability a highly sought goal; (2) it has been an industry populated by no-nonsense professionals; (3) it has made a conservative free-enterprise ideology its rhetorical touchstone.

From the industry's point of view, the changes that are being demanded are seen as a threat to its profits, a threat of Government meddling in its day-to-day operations, and as a result, a threat to the American way. Change in the way the leasing and resource management system operates is therefore, to be resisted, as even small changes are viewed as having the potential for opening the floodgates.

In my view, the industry's approach to change must, in the end, fail. Existing or potential scarcity will probably not be effectively managed by institutions and arrangements set up to manage surplus. Nor will multiple use and environmental values be effectively responded to by a system established when they were of no concern.

INFORMATION

Central to the whole issue of industry-Government cooperation at present is the question of information—how much there is, how adequate it is, who has access to it, and how adequate various organizations are in an interpretive capacity. The great danger is that, given our traditions, the adversary process will involve a conflict over facts, when in reality the differences are over values.

The importance of information is therefore more symbolic than real, but it is no less important for that reason. Only when both industry and Government approach resource information as a public commodity, in fact only when vigorous and positive efforts are made to communicate it and make it understandable, will stable resource management be possible. The symbolic issue that must be addressed is the belief that actions are being taken that are not in the public interest and that such actions are possible because of selective use of information and expertise.

Having said that information is central to the whole debate, let me repeat that I believe it is something of a red herring. Perhaps it is best characterized as having a distorting effect. It leads to industry exaggerating what it does not know and its critics exaggerating what it does know. In substance, the availability of all of industry's information will provide few answers. My point is that any effort at addressing the more basic issues requires taking actions aimed at getting the information issue into perspective. I believe that that requires Government having access to all resource information, and that as far as is possible, resource information should be made public.

MAJOR ISSUES

What would the major issues look like if information were eliminated as an issue. The "fair value" question would have to be faced for what it is. That is, how much of the profit should flow to Government? In practice, this is a question concerning what the Government gets after the company has made a reasonable profit. I do not know what a reasonable profit is, but that is the basic value question. Given a decision on fair value, there are many straightforward ways of collecting the money. Either profit sharing or straight taxation arrangements could handle the mechanics, but to assume that a bonus bid-fixed royalty will result in "fair value" is to dodge the basic question.

The question of who gets to develop the resources would require defining criteria sensitive to a broad set of public interests. Presumably, the criteria would focus on who could bring the resources on line rapidly and provide adequate protection for multiple use and environmental concerns. The major concern revolves around big companies versus small operators. In the case of OCS oil and gas, my personal view is that we do not want small operators incapable of paying the costs of responding to a "Santa Barbara." Should the value choice be to insure access for small operators, however, the Government would need to make adjustments, such as developing the capability for responding to accidents.

The question of postlease regulation and conservation, like the other two, requires value choices. In this case, the issue is which of the conflicting values you bias the system toward. The Department of the Interior outlines its management objectives, in part, as follows: orderly and timely resource development, encouragement of development compatible with other land uses, maximum ultimate recovery, protection of the environment, rehabilitation of lands, protection of public safety, compliance with NEPA, and insuring fair market value return on the disposition of its resources. That list contains some fundamental conflicts if one gets enthusiastic about any one of those objectives. Regulation involves finding the "golden mean" among these objectives. It cannot be found with more information. Further, different interests have a different conception of what the "golden mean" is.

The central regulatory question is where you rest what the lawyers would call the burden of proof. Regulation varies, depending upon whether you require the developer to prove that there will be "minimal environmental damage" or the critic to prove "major environmental damage," or whether you require the use of "best available technology" as opposed to "best practicable control technology." In summary, regulation involves making continuous judgments in gray areas; vesting those judgments in a professional organization equipped with the best available information does not change that reality.

A PROPOSAL FOR COOPERATION

Basic to the needs of successful resource management in a complex society is the development of consensus among parties reflecting different values. This is the challenge to Government at present. Such an approach is juxtaposed to the call of many critics who want a more vigorous adversary process which comes to a head at major decision points.

Implicit in the preceding interpretation is the view that planning, resource allocation, and follow-on regulation are inseparable elements. They therefore require close cooperation at every stage among industry, other interests and Government, and between the Bureau of Land Management and the U.S. Geological Survey. Only such cooperation will provide the stability necessary to balance the multiple values. On this point, I would note that we may have lessons to learn from other industrialized countries which seem to do better at working in such a cooperative mode.

Achievement of cooperation requires a resource allocation-management system that makes cooperation beneficial to all parties-at-interest. Designing a system that would accomplish that goal requires craftsmanship of mind-boggling proportions. Under no circumstances would I claim to have accomplished the task. Nonetheless, let me suggest the outlines of a system to which I have given some thought.

Central to this scheme is the substitution of a system of licensing resources based on work programs for the present leasing arrangements.

Step 1 involves Government collection of early and expanded resource information. Such information would include all that collected by companies or individuals under exploration or prospecting permits, plus a substantially expanded Government exploration program.

Step 2 would call for long-term licensing schedules for each major resource. This would provide the necessarily long leadtime for planning resource development.

Step 3 would require preparation of regional programmatic impact statements, as areas in new regions are added to the long-term license schedule. These statements should be planning documents and should go considerably beyond present environmental impact statements. They should be prepared by interagency task forces and should be general development plans including resource, land-use, and environmental concerns. Their purpose should be to define the role and relationship of the resource development to the overall use of the region. The programmatic statements should also include an assessment of the Government management structure's capacity to meet its obligations as defined in the statement. A major purpose of the programmatic statements should be to provide early access to information and policymaking for all interested parties; the statements would therefore be the first step in the process of political accommodation and consensus-making necessary to resource development.

Step 4 would involve preparation of a shorter, perhaps 5-year, license schedule consisting of areas defined by coordinates. More specific designation of the areas to be licensed is necessary to guide the resource and environmental data collection necessary for the preparation of the license impact statement.

Step 5 would involve preparation of a license impact statement. It should be subsidiary to the programmatic statement and concentrate on local concerns. The license statement should not repeat material covered in the programmatic statement except where it is necessary to amend the plan described in the programmatic statement. It should, however, include an assessment of the agency capabilities for managing the involved resource development.

Step 6 would involve allocating licenses based on work programs that meet the requirements laid down in the impact statements. Where there are competing bidders, licenses should be allocated by choosing among the competitive work programs. The decisive variables should be (1) speed and completeness of exploration activity, (2) time schedule for initiation of production, and (3) responsiveness of exploration and production activities to land-use and environmental concerns. All proposed work plans should be made public when licenses are awarded.

Step 7 should involve regulation that requires application of "best available technology and procedures" for the protection of health and safety and the environment.

The scheme I have just sketched would involve a redesign of much of the existing management system. It would require both new legislation and major changes in the existing administrative arrangements. It is my view that nothing less is required to develop the cooperative system required to meet the new resource management circumstances we face.

RESOURCE AND ENVIRONMENTAL DATA ANALYSIS

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INTRODUCTION

All the predictions on the depletion of our national resources are pessimistic. We are exhausting our raw materials, and now it is only a question of when. It is of top importance, therefore, that optimum use be made of these resources as they are exploited, and it will be necessary to achieve a balance between use, conservation, and environmental considerations. As difficult as this may be, however, the real problem will be in finding new reserves to replace the depleted ones. Geologists will play a key role in the exploration for these new mineral resources.

I was impressed several years ago by the comments Bob Weimer (1970, p. 154) made in regard to future exploration for petroleum in the Rocky Mountains. Bob, among other things, advocated a team approach in the evaluation of scientific data, or, in his words a ". . . turn to sophisticated geology in the search for . . . [mineral resources] . . . ." In this day and age, when large volumes of data are automatically acquired, and techniques are readily available by which to massage them, this approach demands use of the computer.

Because significantly fewer prospects are being found by traditional methods and because the easy-to-find prospects are gone, the success ratio will obviously decline. This means an ever-increasing effort to find less and less. Thus, significant changes in philosophy, applied methods, and education are in the offing if explorationists are to meet the challenge of the future. In the words of Andre Hubaux (1973, p. 160), former research secretary of COGEODATA, "The very future of the geological profession may well depend on its capability to set a policy for the presentation to proper authorities of the basic geological data to estimate the reserves of commodities."

The new philosophy will reflect team inquiry. The geologist now will integrate his thinking with computer scientists, statisticians, engineers, hydrologists, geochemists, and geophysicists in outlining areas of interest and in monitoring their development. Methods will reflect the latest available techniques and perhaps simulated real-world models based on millions or even billions of items of data. New ideas wil be put forth by the younger better disciplined geologists who will have been trained to interpret and judge the interdisciplinary multibased data that have been treated in a complex manner. Therefore, it is extremely important to train young professional geologists to think in a multidisciplinary approach to problem solving, to introduce them to all the latest developments, and to give them a thorough background and understanding of computers and their use.

In the past when new concepts were introduced, it was not long until methods and technology were developed to implement the associated ideas. For example, the application of geophysics in mineral-resources exploration resulted in an entire new area of theory and an industry to provide the equipment. As each new exploration technique is introduced, the success ratio increases for a time and then declines slowly. This results in a series of surges followed by intervening low periods. Advent of the computer and application of it to exploration and exploitation problems will be no exception. Just now we are in the application phase of this concept and as the team approach is used and as computers are fully utilized, we should witness a surge, although short lived, in successful exploration for mineral resources. It should be emphasized here that even though the locations of resources are known, the resources may not be recoverable because of economic or technological reasons—a point well made by Pratt and Brobst (1974) in their recent U.S.G.S. Circular "Mineral Resources: Potentials and Problems." The computer also can help in problems of exploitation as well as in bookkeeping, as, for example, in the resource appraisal program of the U.S. Geological Survey, and in projecting short- and long-term supply and demand.

I would like to take, in turn, each of the areas—philosophy, applied methods, and education—and examine them in more detail. First, however, the data should be examined.

THE DATA

Data are accumulating at an almost alarming rate. If the geologist is to digest even part of them, he needs help, and that help must come from the computer.

There are many advantages in computer-processable data. These data are usualy collected under controlled or semicontrolled conditions, and thus they are, or should be: (1) objective (usually), (2) systematic (or in a form that easily can be made so), and (3) organized (thus ready for analysis by mathematical and statistical techniques). In the long run, computer-processable form is the most economical in which to store large masses of data.

Most data files are accumulated for special projects. In fact, objectives should be outlined clearly before initiation of such a file (Gilliland and Grove, 1973). In contrast, an archival file is one of basic data, diverse, but having widely accepted standards (Hubaux, 1969).

Several countries are working towards development of archival files, notably Canada, through the Canadian Centre for Geoscience Data (Burk, 1972). Romania also is making an effort on a national basis (Dimitriu and Dumitriu, 1973), as is Czechoslovakia (Hruska, 1971). I suggest that it would be proper for the U.S. Geological Survey to take the lead in this country and establish a national center based on the one in Canada. One of the charges of the U.S. Center for Geoscience Data would be the development and maintenance of data files for use by the geological community. Along with this function would be the responsibility of setting standards and exercising quality control of the files. Inasmuch as the Survey is deeply involved in data storage and retrieval already, this seems to be a logical next step.

One notable example of the Survey's ever-increasing commitment in this area is the recently established mineral-resources data bank, CRIB, a Computerized Resources Information Bank (Calkins and others, 1973). CRIB will provide a quick means for summarizing and displaying data on mineral resources. In just 5 months after the bank was implemented it contained about 10,000 records. Another important file is RASS, a Rock Analysis and Storage System. The main file has been in operation a little more than 5 years and contains about 250,000 records.

It is interesting to note that the national, state and provincial surveys have been in the forefront in developing data systems. This is undoubtedly because historically they have been repositories for these data. Museums also have been involved with data systems because of their special curatorial problems. Recently, two comprehensive summaries have been published on the status-of-the-art: "Computer-based Storage, Retrieval and Processing of Geological Information," which appeared as Section 16 of the 24th International Geological Congress in Montreal (Bergeron and others, 1972), and "Data Processing in Biology and Geology," which was edited by John Cutbill (1971) for Academic Press. The status of data processing in the earth sciences in Canada was reviewed by obinson (1970).

Robinson (1974) of the Canadian Survey has noted that data must be the original observations free from conclusions of the observer. Many geologic terms however have genetic implications and thus in fact have conclusions inherent in their use. This practice, of course, allows disagreements to arise because of the terminology. Semantic symbols as proposed by Colin Dixon (1970, 1971) and Pierre Laffitte (1968) are one possible solution to this dilemma.

Data are important, and their half-life has been estimated as nearly infinite in contrast to conclusions which have a half-life of only about 3.7 years. The preservation of data is of international concern, and COGEODATA, a committee sponsored by the International Union of Geological Sciences, presently is making plans for the future. "The aims of the committee are to facilitate access to available geological data and to promote compatibility between these data on an international scale" (Hubaux, 1973, p. 163). A common data base would allow easy communication on a worldwide basis, enhancing geological interpretations; effective use could be made of mathematical and statistical techniques where standard and comparable data were available; and many misunderstandings could be avoided.

In addition to public files, several commercial systems are in operation at present. The one best known to geologists is the Well History Control System (WHCS), which even 2 years ago had data from about 700,000 wells in computer-processable files (Forgotson and Stark, 1972). A list of representative special files is given in table 1. Hubaux (1972) has compiled a more exhaustive list.

TABLE 1.—*Tabulation of select special data files*

File	Organization	Content	Size	Remarks and references
		General		
GEODAT	Geological Survey of Canada.	Chemical analyses, C^{14} dates, sediment analyses, rock properties.	80,000 items as of 1972.	Started in 1964; directed by K. R. Dawson (Burk, 1972).
SIIRS	Smithsonian Institution.	Specimen records for rocks, marine crustaceans, and sea birds.	About 25,000 specimens processed in the first 18 months at a rate of about 430 records/week.	Started in 1967; retrieval programs written in COBOL (Squires, 1970).
	Department of Geology, University of Reading, England.	Many data sets, project oriented.	100,000 cards	Contains data back to 1964; utilizes ROKDOC (London, 1969).
		Geologic mapping		
GEOMAP	Geological Survey of Sweden and Boliden Co.	Geological field data; mainly for mapping igneous and metamorphic terranes		Introduced in 1970; retrieval programs in FORTRAN; also contains data-analysis programs such as DA (Discriminant analysis), PCA (Principal components analysis) and FA (Factor analysis) (Berner and others, 1972).
EDP System Agto	Geological Survey of Greenland.	Field and laboratory data for a high-grade metamorphic area.	To handle about 75,000 observation points, with 150,000 systemic registrations and approximately 15,000 samples.	Initiated in 1966; system programmed in Gier ALGOL 4 (Platou, 1971).
GRENVILLE	Quebec Department of Natural Resources.	Geological field mapping in the Grenville province.	Descriptions of about 10,000 outcrops.	Started in 1968; directed by A.-F. Laurin (Laurin and others, 1972).
		Mineral resources		
M-file	Geological Survey of Canada.	Detailed geological and mining data.	Data on about 4,000 deposits.	Contains information on Canadian deposits (Burk, 1972; Robinson, 1970).
CRIB	U.S. Geological Survey.	Mineral resources information bank.	10,000 records in the first 5 months.	Contains information on U.S. mineral resources; retrieval program, GIPSY (Calkins and others, 1973).
		Geochemistry		
RASS	U.S. Geological Survey.	Data on rock, soil, vegetation, or water samples.	About 88,000 records with as many as 300 items for each record in analytical laboratory file; as many as 620 items for each sample of 162,000 records in exploration research file.	Started in 1969; pre-1968 data stored in a card file. Utilizes STATPAC (Miesch, written commun., 1974).

TABLE 1.—*Tabulation of select special data files*—Continued

File	Organization	Content	Size	Remarks and references
		Paleontology		
UCMP	University of California, Museum of Paleontology.	Vertebrate, invertebrate, plant, and micropaleontological collections.	About 84,000 localities and 100,000 specimens.	Started in 1965 (Berry, 1972).
Western Interior Foraminiferal Data Project.	Colorado School of Mines.	Cretaceous foraminifers from the Western interior.	704 references; 6,000 species citations involving 3,000 different species from 4,000 localities.	Retrieval uses SAFRAS (Kent, 1972).
		Well information		
Borehole data from central Scotland.	Institute of Geological Sciences.	Lithologic data from cores of Carboniferous age.	Four borehole records into the detailed file and 15 into the general file as of 1971; 60 more records ready.	Retrieval programs in Atlas machine code—utilizes ROKDOC (Gover and others, 1971)
Well data from Libya.	Oasis Oil Co	Company records of boreholes; lithologic, stratigraphic, structural, and paleontologic data.		Data retrieved in raw or summary form (Conley and Hea, 1972)
Lithologic well data.	U.S. Geological Survey and Kansas Geological Survey.	Water-well records in Kansas; lithologic data.		Started in 1965 (Morgan and McNellis, 1971)
Saskatchewan Government well-data system.	Saskatchewan Government.	Subsurface geological and engineering data.	18,000 wells	Started in 1964; retrieval by TELLUS (COBOL based) (Buller, 1972)

RETRIEVING THE DATA

Putting data in machine-processable form for inclusion in data system is all well and good but of little value if such data cannot be retrieved. Many retrieval programs, some rather sophisticated, are being used at present include GEOMAP, TELLUS, GIPSY, and SAFRAS. Many of the retrieval programs are constructed for use with a particular file system, for example, GEOMAP programs with GEOMAP files, and the TELLUS program system with the Saskatchewan well-data file. GIPSY and SAFRAS, on the other hand, are designed for general use. GIPSY, for example, is being used to process the data in CRIB.

SAFRAS, an acronym for self-adaptive flexible retrieval and storage, was developed by Pete Sutterlin and associates at the University of Western Ontario with a grant from the Geological Survey of Canada. Here, I would like to encourage Federal support of research. The U.S. Geological Survey, through a system of direct grants, could commission special computer-oriented research at universities having special expertise. This system has been highly successful in Canada and could be equally successful in the United States. The SAFRAS system was designed for general application so that no prestructuring of the data is required; it is easy to use—files can be merged, sorted, and reorganized—and the retrieval is in plain language. A directory precedes the data, giving a complete description of the file; this feature allows the flexibility (Sutterlin and DePlancke, 1969).

G-EXEC, an acronym for the Geologist EXECutive, is a super system designed not only for storage and retrieval, but for analysis and display of data as well. The system was developed mainly by Keith Jeffery and Elizabeth Gill [1] in response to needs of the Institute of Geological Sciences in London. It consists of two parts: (1) the data files and (2) the process programs. The system is data independent because each data set is self-describing. The system is modular so that it can be implemented on small computers and can be modified or improved easily. The user commands are in near-English, facilitating use of the system.

Other systems undoubtedly will be developed in the future. There are pros and cons to big systems for archival data versus small specific systems for project-oriented data files. Small systems are cheap to develop and use, and search is quick because the data are limited. Large systems are expensive to develop, maintain, and use, and a search may be time consuming and thus expensive. However, the ultimate use is greater as the data base is larger.

In the future, big data storage and retrieval systems will be put into use and small specialized sys-

[1] Jeffrey, K. G., Gill, E. M., and Henley, S., 1974, G-EXEC system, user's manual: Inst. Geol. Sci, unpub. rept,, prelim. draft of issue no. 2, 136 p.

tems will proliferate. Standards and quality control will gradually be installed at all levels, and geologists will eventually record all their data on standard forms utilized worldwide. The U.S. Geological Survey, as already pointed out, can continue to be an effective leader in this area of electronic data processing where so much expertise is available from years of experience.

PHILOSOPHY OF SEARCH

Now, I would like to turn to the philosophy of search, or if you prefer, exploration. In the words of John Griffiths (Griffiths and Singer, 1973, p. 9),

> The search for non-renewable natural resources is usually conducted on the 19-century "cause and effect" philosophy. It is generally believed that if we could explain the origin of an ore body or petroleum deposit we could predict where to find additional resources. This philosophy is the main basis for much research devoted to the description and analysis of natural resources.

Unfortunately, this philosophy, as outlined by Griffiths, was good enough in the past but may not stand us in good stead much longer, at least without modification.

Recently, a new approach to the search problem is emerging; that is, combining statistical techniques and geology with the expectation of increasing the exploration success ratio. This approach is through simulation, in which a stochastic model can simultaneously consider many variables to determine the "best" solution to the problem. Since the work of Allais in 1957, in which the Algerian Sahara was used as a case study, the purely statistical approach has been modified to take into account geology and other factors.

One note of caution here, and that too sounded by John Griffiths (1968, p. 6): ". . . the importance of the philosophy of the scientific method is that it encourages an investigator to take a new look at his problem and not, as is quite commonly done, to attempt to use new tools—more or less as fads—as additions to old practices." The one big advantage of a new approach is that it allows the problem to be reexamined with a new outlook and to be appraised from a different point of view.

The first step in any search is to outline the areas of interest, that is, to determine the favorable areas for exploration. The selection of favorable areas will be based on many factors, including geology. Once the areas are defined, then the exploration and development of the deposits require additional data. These data may be collected according to a predefined plan, taking into account the size and shape of the suspected targets. Much has been written on the "best" methods to use, sampling schemes, and techniques to evaluate the data. Once a deposit is found and delineated, it needs to be evaluated. For each of these steps, computer techniques are available to assist the geologist.

Dee Harris (Harris and Euresty, 1969) of the University of Arizona has approached the problem by appraising the effect of economic factors which are evaluated prior to the allocation of exploration effort and concurrently with mineral occurrence. The techniques used to analyze simultaneously the probabilistic events between economic and geologic conditions are multivariate geostatistics and simulation. This regional, multiple-mineral evaluation approach has been applied in several areas including Alaska (Harris, 1969) and northwestern Canada (Harris and others, 1971).

Frits Agterberg and his associates at the Geological Survey of Canada also use a regional approach. Geological and geophysical parameters are assessed for cells of a predetermined size, and probabilities of mineral occurrence are extrapolated from known cells to unknown ones. The potential of any cell is the difference between the projected and the proven reserves for each cell. The Abitibi area on the Canadian Shield is the object of an ongoing study (Agterberg and others, 1972).

John Harbaugh (Harbaugh and Prelat, 1973) and geologists of the Kansas Survey are developing an historical model for parts of Kansas. Outcome probabilities for exploratory wells are estimated for each step through time, on the basis of the geology as perceived at that particular time increment. The probabilities are revised with each increment of time for each cell, as information becomes available.

Larry Drew (1974) of the U.S.G.S. developed a random-walk simulation model for exploration of petroleum deposits in the Powder River basin of Wyoming. The hindsight model was used to demonstrate the relationship between the intensity of drilling and the exploration outcome, as summarized by the quantity of petroleum and the number of deposits discovered, and the probability of gambler's ruin and different levels of success.

These are just a few of the possible models that offer insight into exploration philosophy; refinements of these models, or new ones, certainly will be used in the future. The U.S. Geological Survey can continue its work in determining strategies for exploration for natural resources. These models would be helpful in evaluating Federal lands available for lease and perhaps could be applied directly in areas where the private sector has no interest.

APPLIED METHODS

Techniques are available for analyzing three types of data: (1) sequential data, (2) map data, and (3) multivariate data. Most techniques have been adapted from other disciplines, including medicine, engineering, biology, statistics, and psychology. Individual programs are usually put together into systems to facilitate the analysis procedures, for example, G-EXEC, ROKDOC, and NTSYS. NTSYS is a large system of classification programs developed by the biometricians at the State University of New York (SUNY), Stony Brook. ROKDOC was developed by geologists at Reading University in England, and G-EXEC has already been described.

Few techniques have been specifically developed for solving geological problems. However, one such set of techniques, regionalized variables, was developed by the French school of geostatistics headed by George Matheron.

Many examples could be cited of the successful application of statistical techniques to exploration and exploitation problems. For the most part, these techniques are applied to problems within the 19th-century context of "cause and effect." That is, the techniques could have been applied years ago, if it had been practical to do the calculations by hand. Even so, their application now has not been without positive effect, and here are a few examples.

The first used and probably the most successful technique has been trend analysis. Trend surfaces are used to separate map data into two components—regional and local. In structural geology, trend surfaces can be used to simulate regional dip of beds; the resulting residuals correspond to local structural highs and lows. The anomalous areas thus are emphasized by removing the regional dip. The technique has been used especially in petroleum exploration in areas of low dip, where local highs, masked by regional effects, may serve as petroleum traps.

Harmonic analysis was used by Agterberg and Fabbri (1973) to determine that the pattern of clusters of copper and gold occurrences on the Canadian Shield are more or less equally spaced. The copper deposits were shown to coincide with geological structures of one age, and the gold mineralization was associated with features of another age. This technique was used also to demonstrate that algal limestone buildups were formed at approximately equal intervals in the Pennsylvanian seas of Kansas. These buildups occur in the subsurface and are of interest because they may serve as possible petroleum reservoirs (Merriam and Doria-Medina, 1968).

Effective use of cluster analysis of geological data of tungsten deposits of North America has been made (Collyer and Merriam, 1973). This particular study was traditional in the sense that the technique was used to evaluate a "cause and effect" relationship; that is, which deposits formed in a similar environment. Analysis of the clusters of deposits with similar attributes emphasized subtle or unrecognized relationships in the original data. Once these attributes were determined, they could be used in exploring for similar deposits. Because nonnumeric data can be used in this type of study, the technique offers promise in utilizing historic records. A similar analysis was made for 30 base-metal mining districts in the United States by Joe Botbol (1971) of the U.S.G.S.

Factor analysis is a technique which displays data in a simplified and condensed form. It is used to determine structure within a complex interrelationship of variables. Factor analysis has been used extensively with geochemical data (Miesch, 1969), and a factor-analysis exploration model was proposed by Ed Klovan (1968), a model in which factor scores would be mapped and favorable areas projected from the coincident patterns of known occurrences.

Discriminant analysis has been used by John Griffiths (1964) to identify petroleum-producing from nonproducing sandstones. The technique can be used to assign unknown samples to previously defined groups.

Many techniques are presently being tested to determine their range of applications and limits with geological data. The Geological Survey can do much to foster development of new techniques for analyzing geological data. Work along this line is proceeding, and the Survey is publishing results. These publications should be increased and made more readily available, as they constitute the only series of this type in the United States. I would like to suggest that the Survey take the responsibility in serving as a clearing house for computer programs, in the framework of GEOCOMP as proposed by John Harbaugh (1964), and as the Kansas Survey did so admirably during the mid- and late 1960s. This function could well come under the aegis of the U.S. Center for Geoscience Data. I would encourage the Survey to consider making their network of computers available to the geological public. Just imagine some of the results in teaching and research if such access could be arranged! This possibly could be the forerunner of a national hookup having many remote terminals distributed around the country and operated on a basis similar to the Dartmouth system.

EDUCATION

Universities are responding—albeit slowly—to the needs of the modern computer world. Computers are introduced at an early stage in education, sometimes in high school, and certainly in university—usually in the first year. Mathematics and statistics are taught and used in geology courses. Many textbooks on geomathematics and computer applications now are available. Most universities have at least one numerically oriented faculty member. Computers are readily accessible and economical (at least they are for users in the university where generally they are free), and of course they are easy to use! However, despite all the activity, only about 10 percent of the geology students in this country are exposed to computer-oriented courses in university. More and more the interdisciplinary approach to problem solving is being stressed.

Professional geologists can take advantage of the published literature, take night classes and short courses, or attend any of the many workshops, seminars, conferences, and chautauquas that are held throughout the country each year.

Communication and the handling of the published literature is an increasingly difficult problem. Some 2 million items have been published in geology, and that number is increasing at a rate of about 100,000 items per year. This means that the geological literature is doubling every 6 to 7 years (Lea, 1972). No geologist, no matter how fast he can read, can possibly keep up with more than a fraction of the total publications. In fact, it may be difficult to keep up in his own field. Greater dependence then is placed on the bibliographies, current-awareness journals, and such services as GEO • REF. GEOCOM Bulletin and GEOCOM programs for the computer-oriented geologists are available through Geosystems in London. The International Association for Mathematical Geology is an active organization, and membership is open to anyone interested in mathematical geology or computer applications. The Association publishes a quarterly journal (which in 1975 becomes a bimonthly) and a newsletter. In addition to all the other sources of information, a new journal, "Computers and Geology," starts in 1975.

The U.S. Geological Survey is making a contribution to the national reference scheme in supporting GEO • REF. In addition to support for indexing published material, I suggest that it would be in the national interest to establish a U.S. Index to Geoscience Data. The index, patterned after the Canadian index, would include all sources of geoscience data, including computer-based files, published literature, unpublished open-file reports held by government agencies, and relevant public documents. The index would identify original observations and measurements, but it would not abstract literature. The production of the index would be part of the U.S. Center for Geoscience Data.

SUMMARY

This summary of "Resource and Environmental Data Analysis" has been, of necessity, short and much abbreviated. Emphasis has been placed on the "resource," but many of the generalities and summaries could serve the "environmental" aspect of data analysis equally well. Although many problems lie ahead, I look for geologists to meet their responsibilities and commitments with foresight and ingenuity. The future looks bright for the Geological Survey as it continues to fulfill its role as the organizational leader in American geology.

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NEW DIRECTIONS IN TOPOGRAPHIC MAPPING

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We are asked to consider a product of engineering, the topographic map, that has become a fundamental, indeed an essential, tool in our society. It has won this important use in local, regional, state, and national levels from its unique ability to serve basic-planning and decisionmaking problems that confront all levels of society, from the individual to the most complex group within industry and government. This accurate and up-to-date graphic representation of natural and manmade features portrays location, shape, and elevation of plains, hills, mountains, valleys, rivers, and lakes, as well as roads, buildings, dams, mines, quarries, towns, and cities.

The primary goal of the National Topographic Mapping Program has been to complete the 1:24,000 quadrangle map series of the 48 conterminous States and Hawaii. This objective was accomplished for Virginia in 1972 through a 10-year cooperative effort between the U.S. Geological Survey and the Commonwealth of Virginia. Virginia now has an accurate and consistent base to which a variety of critical information can be related and combined for decisionmaking. Although the national goal is to have such coverage for all States, individual States may shorten the time period for such coverage by entering into a cooperative financial agreement with the U.S. Geological Survey.

The primary reason for a State geological survey to become interested in topographic maps is to obtain an accurate base on which to depict geological formations and mineral resources and to show physical features. Through expanded technology and a significant shift toward increased involvement by individuals in such activities as energy and resource exploration and development, land-use planning, environmental protection, urban development, reclamation projects, and outdoor recreation, new and somewhat specialized products have been derived from the topographic mapping process. The U.S. Geological Survey has recognized the importance of these new approaches and has developed new products that can complement topographic maps and that fill some of the needs of urban planners and other specialists. Urgent and demanding needs have brought about a product known as the orthophotoquad as a complement for line maps; used in combination with a standard quadrangle map, it will provide the detail of a photograph. These rectified photographs make possible direct measurements at the scale of 1:24,000, and provide information in photographic detail that is not portrayed on conventional quadrangle maps. Land use and the differentiation of coniferous from deciduous trees can be interpreted from them. Orthophotoquads are of such importance that the U.S. Geological Survey has proposed a 3-year plan to have all the country's unmapped areas, except Alaska, photographed and have orthophotoquads available for sale. In Virginia, 11 orthophotoquads of growth areas have been received recently, and 15 others are awaiting printing.

Demand for orthophotoquads has been accelerating, and Robert Lyddan, Chief of the Topographic Division of the U.S. Geological Survey, has informed me that cooperative programs for their preparation are underway with Connecticut, Nevada, New York, North Carolina, and Virginia, that orthophotoquads are in preparation for the entire State of Arizona, and that the Bureau of Indian Affairs and the Soil Conservation Service are cost sharing with the U.S. Geological Survey for orthophotoquad preparation.

Orthophotomaps, another product, combine the features of orthophotoquads and topographic maps and show, by using color tones, wetlands and vegetation differences. The Dismal Swamp and Wachapreague areas in Virginia are being prepared in this form.

Of specific interest are two relatively new products, the slope map and the land-use classification map. The first of these is a valuable tool for land-use planning and portrays various slope zones of the terrain. Such maps are prepared by mechanical techniques from the contour plate of standard topographic maps. Classification of land into zones of slope may be elementary to users of topographic maps, but to individuals who have little or no training in engineering or geology, a slope-classification map is more readily understood and is a usable item. These maps may find great use by legislators as a quantitative aid in making land-use decisions.

Land-use classification maps have become a desirable product. Interpretation and delineation of land-use information in conjunction with the production and revision of standard topographic maps in Virginia has met with the acceptance of individuals interested in current use of the land and planning for future uses. Land-use inventory has been overprinted in four 7½-minute orthophotoquads in the Fredericksburg, Va., area. Certainly more such information will be required in the future. It is our opinion that such maps should be made for each 7½-minute quadrangle. In urban areas in Virginia where there is an update schedule for revision every 5 years, such maps would be of great value to local and regional planning groups.

Eight states have land-use-mapping programs utilizing ERTS data and high-altitude photography (Alabama, Colorado, Maryland, Mississippi, Nebraska, Rhode Island, South Carolina, and Tennessee).

To implement an efficient revision program to keep the topographic maps up to date, Virginia has been divided into five sectors of approximately equal size; one sector is flown each year to produce quad-centered mapping photographs. These are enlarged three times and compared with the existing printed quadrangle. This comparison is an efficient way to determine cultural changes and to schedule priorities for updating the topographic maps. A quad-centered photograph replaces a mosaic of perhaps nine or more mapping photographs formerly needed to depict the area of a 7½-minute quadrangle. These photographs are available for more than half the 805 Virginia quadrangles, and the remaining are scheduled within the updating program. Those maps selected to be photorevised depict growth features in purple; to date about 25 percent of the Virginia quadrangles has been revised. This aerial photography as a sales item from the U.S. Geological Survey is an important byproduct of the mapping program.

Intermediate-scale maps are in demand and Virginia is giving consideration to a county series at 1:50,000 scale. This scale is easily convertible to the metric system and will fill the present needs as well as lessen the future impact caused by this country's adoption of the metric system. Careful consideration should be given to converting all the present 7½-minute quadrangle series from 1:24,000 to 1:25,000 scale. Consideration should likewise be given to 1:50,000- and 1:100,000-scale intermediate or county- or regional-format maps. Such intermediate-scale maps need to be designed so that they would be suitable for enlarging or reducing for use by planners and engineers.

I would like to spend a few minutes considering several items that would make a good product even better. It is necessary to keep up-to-date State coverage at several scales, the graphics of which could take one-half reduction. A program should be expanded to make mapping expertise available perhaps on a consulting basis to public bodies for large-scale mapping and to assist public agencies in the selection of a common scale for mapping. Other improvements would be to locate all routes of access such as trails and former roadways; to annotate all benchmarks; to correctly identify all public-use boundaries, especially those of the United States forests; to differentiate pipeline commodities; to identify river miles for the plotting of hydrologic data; to keep information at the same date that is used for county maps or maps that have scales of 1:50,000 or 1:100,000; to better annotate restrictive land-use areas, such as hospitals, churches, cemeteries, military areas, actual forest boundaries, and airports; to identify all public recreation areas such as parks, forests, game management tracts, parkways, and so forth; and to develop physical and cultural map information in digital form.

If such improved maps were available, there would be more meaning in the present topographic mapping goals. Briefly speaking, these goals are: to keep up to date the 1:24,000- 1:250,000- and 1:500,000-scale map series; to have orthophotoquads, slope maps, orthophotomaps, and county maps made for areas of demand; to inform the public of map availability and uses by means of press releases, mail-outs, displays, and conferences, and to provide a communications link between the mapmaker and the user; to identify map needs; and to advertise byproducts such as aerial photographs, stable base copies, stable base copies of color separation plates, and geodetic control.

Who are the users of topographic maps? The early development of topographic mapping had a close link with the need for an adequate base on which the geology of an area could be depicted. New groups have found uses for the topographic map that exceed those of the geologist, even though his requirements have expanded to include detailed magnetic, gravity, and seismic data as well as stratigraphic, rock-type, mineral-resource, and surface- and ground-water data. Every individual is a potential user; at present his greatest use of the map is for recreation, including hunting, fishing, hiking, camping, and vacationing. State agency uses throughout the country have increased. In Virginia, the Division of Mineral Resources utilizes topographic maps as bases for geologic maps and mineral-resource maps, and for benchmark data. The Division of Mined Land Reclamation uses the maps in delineating areas to be strip mined and to be reclaimed, and the Division of Forestry uses them in fire-control access and in the control and determination of insect infestation. The Division of Industrial Development uses the maps as graphic aids for depicting potential industrial building sites, the Department of Taxation utilizes enlargements as an aid for delineating properties, and the Game and Inland Fisheries Commission uses the maps to prepare sportsman guide maps on which campsites, picnic areas, and boat ramps are annotated. The Department of Highways utilizes the maps in planning new roadways. The Office of Emergency Preparedness maintains a file of 7½-minute quadrangle maps to aid victims of natural hazards. The Outdoor Recreation Commission maintains up-to-date map files to locate and keep an inventory of recreational facilities, and the Historical Landmarks Commission makes an annotation of buildings that are on the National Register. Regional planning districts utilize the 7½-minute series for an inventory of natural and cultural features and for land-use plans. City and county planners and engineering departments use the maps as an aid in the development and expansion of public utilities as well as to portray various factors of environmental interest. Policemen, county sheriffs, firemen, and rescue squads utilize the maps to shorten the response time in answering emergencies. Public schools find the maps invaluable in courses on geography and land-use planning. Land surveyors, realtors, and transmission companies have asked our organization for assistance, including questions on the availability of aerial photographs and topographic maps.

One hesitates to mention quality control in such an overall excellent product, but inadequate depiction of public ownership of land has become a vexing and frustrating problem. In Virginia, our National Forests are not recorded properly, and the boundaries as shown are erroneous and misleading. Consider a standard 7½-minute quadrangle, half of which is designated as National Forest; however, within that 30-square-mile area, all the land is in private ownership. Not even 1 acre is owned by the National Forest. Further, consider the confusion of the poor hunter who is confronted with no-trespassing signs on land indicated on the map as National Forest. Also consider the frustration of the property owner who pleads with us to have correct boundary information on the map. The answer that the land lies within a proclamation boundary or a land acquisition boundary of the National Forest is of no help. These individuals become distrustful of an otherwise excellent product. If specifications do not allow accurate boundaries of forest lands and other public-use lands, the question will be raised over and over again—for whom are the maps being prepared?

Within the past few years a new and imaginative system has been developed to use various types of imagery in small-scale mapping. Such images have attracted serious investigators by offering the opportunity to monitor temporal changes through repetitive observations. Certainly users who are concerned with land-use analysis have welcomed the color composites derived from the spectral band of ERTS–1 imagery. The images now available have a fitted Universal Transverse Mercator grid and a 1:500,000 scale. The map of tomorrow may be a refinement of such images. Technical advances that would make possible even greater resolution than exists today will become tomorrow's commonplace method for making large-scale maps. Aerial photographs will be replaced by satellite and airborne imagery, just as alidades and plane tables were replaced by photographs and electronic measuring devices.

GEODYNAMICS

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INTRODUCTION

Almost 200 years ago, Benjamin Franklin (1782), after some geological observations, wrote to Abbé Soulavie in France

> Such changes in the superficial parts of the globe seemed to me unlikely to happen if the earth were solid to the centre. I therefore imagined that the internal parts might be a fluid more dense, and of greater specific gravity than any of the solids we are acquainted with; which therefore might swim in or upon that fluid. Thus the surface of the globe would be a shell, capable of being broken and disordered by the violent movements of the fluid on which it rested.

Franklin thus anticipated the Geodynamics Project and the plate-tectonics model that has caused a revolution in geological thought during the last decade.

Franklin continued,

> If (these thoughts) occasion any new inquiries and produce a better hypothesis, they will not be quite useless. You see I have given a loose to imagination; but I approve much more your method of philosophizing, which proceeds upon actual observation, makes a collection of facts, and concludes no farther than those facts will warrant.

Here I believe that Franklin is anticipating the existence of the U.S. Geological Survey and is putting his stamp of approval on the methodology that has been in its tradition since the days of John Wesley Powell. This tradition has served the country well, as have the many distinguished geologists of the Survey, past and present. Of special importance has been the interplay of ideas, the interchange of people, and the coordination of efforts between the Survey and the academic community, a part of this tradition that has been of mutual benefit to all parties and that should be continued and strengthened in the future.

THE GEODYNAMICS PROJECT

The roots of the Geodynamics Project are of some age, pregeological phylloxera, so to speak, and drew nourishment from the rich organic topsoil of geological speculation. Speculation on the origin of the surface features of the Earth, the causes of natural disasters, and the reasons behind economic emplacement of mineral deposits and hydrocarbons has a long and varied history. The ideas were many, but the data necessary to substantiate or repudiate these ideas were few.

Early ideas about the origin of the surface features of the Earth were many and often bizarre, but no more so than the model that we find most acceptable today. This model assumes that the Earth's outer shell consists of a small number of large lithospheric plates that, as suggested by Franklin, are decoupled from the underlying substratum and move relative to one another, colliding along the young mountain systems, separating along the midocean ridge system, and sliding relative to other plates in regions such as that of the San Andreas fault system in California. Development of this model was less a question of establishment of new ideas as it was one of collecting and analyzing data that would allow selection from among many ideas.

The basic data were in three areas. The first related to the concept of a rigid lithosphere overlying a more plastic asthenosphere. This concept had many adherents, Barrell (1914–15) and Daly (1914) especially, who concluded on the basis of geodetic and petrologic grounds that the asthenosphere was either liquid or glass. Beno Gutenburg (1926) in the 1920's, took full advantage of inadequate data from the propagation of body waves through the Earth and concluded that a low-velocity layer existed at depth, a conclusion that was subsequently substantiated by studies of surface-wave dispersion when modern electronic computers became available. Hugo Benioff (1949) added to the concept through his studies of the energy release from South American earthquakes during the first half of this century. He found a large change in the rate of energy release of intermediate- and deep-focus earthquakes during the 1920's that was not reflected by the shallow-focus earthquakes. This led to the conclusion that the outer shell of the Earth was decoupled from the interior. More recently, Joe Boyd of the Geophysical Laboratory, Carnegie Institution, and Peter Nixon of the Department of Mines, Lesotho (Boyd and Nixon, 1973), have come up with what they suggest is the first direct evidence of a less competent asthenosphere through studies of rocks blasted out of kimberlite pipes in southern Africa. From experimental petrology, geological thermometers and barometers have been devised that allow equilibrium samples of certain rock types to be related to depth and temperature. From studies of the rocks from the kimberlite pipes, Boyd and Nixon (1973) were able to sort out the deep stratigraphy of the lithosphere and the upper asthenosphere. Their results indicate a jump in the thermal gradient at depths of about 150 km beneath South Africa, a jump that may be related to mechanical heat sources. Further, the rocks from depths greater than this jump are sheared, whereas those from above are crystalline. It should be noted that objections to this relatively simple picture have been raised both by geochemists and geophysicists. Nevertheless, the body of data that exists to date supports the first idea espoused by Franklin that beneath a rigid outer shell is a layer that is dense and fluidlike on which the outer shell swims.

Franklin's second thought, that this outer shell was capable of being broken and disordered by the motions of the underlying liquid, was followed by the concept of continental drift. This has had a long and checkered history, beginning with Snider in 1858, and had an early culmination in Wegener's classic presentation in 1915. This culmination was premature, however, because many objections were raised to the concept, particularly with regard to the driving mechanism and the mechanics of the system, but also on emotional grounds because the concept was so fantastic. When paleomagnetic data in the 1940's and 1950's revealed consistent polar-wandering tracks for the individual continents and diverging tracks among the continents, the controversy was renewed. It remained a controversy until further magnetic work coupled with marine investigations and Deep Sea Drilling Project results led to the seafloor-spreading idea. This idea was based first on the time sequence of reversals of the magnetic field established by Cox, Dalrymple, and Doell (1967) of the U.S. Geological Survey in Menlo Park, and second on the correlation, by several investigators, of this reversal sequence with the linear magnetic anomalies that parallel the midocean ridges. This correlation suggested that new crust was being formed at the axes of the midocean ridges and was moving laterally away from the axes at rates of a few centimetres per year, a conclusion borne out by basement ages determined by the Deep Sea Drilling Project. These findings did not solve the mechanism problems; they bypassed it by demonstrating that movements similar to continental drift *had* taken place. Marshall Kay likes to cite Ayer's Law in cases like this, which states "Things that have happened, can happen."

Now Franklin did not, apparently, conceive of the Earth as expanding, but if we create new crust at the ridge axes, we either have to expand the Earth to fit it in, or we must somehow get rid of old crust. This problem was resolved by the seismologists. Most of the earthquakes of the world occur at shallow depths—less than 70 km. The exceptions are found in the areas where young mountain systems and island arcs are found—around the Pacific and in a belt extending from the East Indies to the Mediterranean. Deep-focus earthquakes were first noted by Turner in 1922, and Wadati in 1935 showed that in the Japanese region they dipped on a plane from the Nippon trench to beneath the continent in China. Benioff in 1954 demonstrated that this was the case in the entire circum-Pacific region. Isacks, Oliver, and Sykes (1968) studied the Tonga region in detail and found evidence that the outer shell of the Earth, the lithosphere, was being underthrust to depths of at least 700 km. Thus, old lithosphere—old oceanic crust—was being returned to the deep mantle and reassimilated and at rates comparable with the rates of generation of new crust at the oceanic ridges. This was true in most areas around the Pacific, a prime exception being California, where the two plates slide along each other, producing shallow earthquakes of often devastating character.

Thus Franklin's concept has grown into the plate-tectonics model, a model that evolved during the Upper Mantle Project, an international project designed to study the outer 1,000 km of the Earth's crust and upper mantle. The significance of the model was not lost on the scientific community, and it resulted in the establishment of the Geodynamics Project, sponsored by the International Council of Scientific Unions at the urging of the International Union of Geodesy and Geophysics and the International Union of Geological Sciences, to which more than 50 countries have subscribed. The program is strongly based upon the plate-tectonics model, because it is the most promising model to date, and its purpose is to study the dynamics and the dynamic history of the Earth. A program for United States participation by Government agencies, academic institutions, and industry was designed by a committee of the National Academy of Sciences (Natl. Acad. Sci., Geodynamics Comm., 1973), with the aid of some 200 correspondents and advisors; a committee, which includes the U.S. Geological Survey as a principal participant, has been established by the Federal Council on Science and Technology to coordinate the Federal program.

THE FUTURE

If we look to the future, we can see opportunities both in terms of basic science and in terms of practical consequences of a better understanding of the dynamics of the Earth. Let me give a few examples. We have managed to bypass temporarily the question of the driving mechanism for plate tectonics by demonstrating indirectly that large horizontal movements of the lithosphere have taken place. Many models have been proposed, but we are hampered by the lack of boundary conditions—good physical and chemical parameters for the materials deep within the Earth. This is an area in which there are many opportunities for pioneering work.

Our present model for the movement of the plates is essentially that proposed by Wegener in 1915. It is excellent on a large scale, but inconsistencies on smaller scales must be resolved if the model is to be useful geologically. For example, if the Atlantic is closed completely, we are faced with serious overlaps of ancient rocks in Central and South America that must somehow be accounted for. Resolution of this and similar problems will require careful analysis of the onshore and offshore data into a coherent picture.

The model also assumes that the plates are rigid; yet there is both geodetic and geological evidence for vertical movements at rates comparable with the horizontal movements, that is, centimetres/year, *within* the plates. The apparent rates decrease by orders of magnitude as the length of time over which they are measured increases, which suggests that the vertical movements are oscillatory. Both the Geological Survey and NOAA are involved in the study of these vertical movements, through geological and geodetic investigations, and I can think of no efforts that are likely to be more fruitful than efforts in this area. Not only is it important scientifically to see whether or how these vertical movements are related to the major horizontal movements, but most of the hydrocarbons of the world have accumulated in areas that have been affected by these vertical motions. The petroleum industry has taken a very strong interest in the model. The search for hydrocarbons is focused upon structures that might trap them rather than upon oil and gas directly; thus, the best knowledge of the dynamic history of the Earth, the rates of motion and the accelerations and decelerations of these motions, will yield the most accurate structural interpretation.

Recent studies of earthquakes by investigators from academic institutions and from the Geological Survey have led to plausible models for the initiation of major tremors. These models suggest that forerunners of such tremors may allow more accurate prediction of major events than has been the case in the past. As long as the lithospheric plates move relative to one another, earthquakes will take place, but it is not inconceivable to imagine that the stored energy might be released gradually rather than suddenly, thus mitigating the damage. A critical unknown is the cause of major earthquakes in plate interiors, such as the ones in New Madrid, Mo., Boston, Mass., and Charleston, S.C. These were very large earthquakes, but unlike those in the circum-Pacific region, they have no obvious relationship to the interplate reactions and perhaps are related to the recent vertical movements within the plates mentioned earlier.

In recent years, identifiable relationships have been indicated between the plate-tectonics model and the occurrence of major ore deposits. In the Red Sea and Salton Sea areas—regions of diverging plate boundaries—metal-rich brines and sediments have been found. High metal contents have also been found in other parts of the ocean ridge system. Again, it is not inconceivable that metal concentrations may accompany the formation of new crust at the ridge axes, that these move laterally with time, and that a distillation process in the underthrusting areas concentrates these metals into exhalative, vein, or porphyry deposits. As most of the metal deposits with readily identifiable surface manifestations have already been identified, it is not unreasonable to conclude that the future lies with those who have the best understanding of the dynamic history of the Earth. Dan Merriam pointed out at the dedication that new approaches are also needed, but these must be combined with the best genetic models.

New tools and approaches will play an important role in this project. The Deep Sea Drilling Project has been an exciting and scientifically productive program that has enormously increased our knowledge of the geology of the ocean basins. Much more remains to be learned from further detailed study of the cores in the archives. Similarly, deep drilling for scientific purposes on the continents, combined with very deep penetration reflection studies, promises to be equally revealing. A panel established at the instigation of the U.S. Geodynamics Committee and supported by the Carnegie Institute of Washington has studied this problem and has made far-reaching recommendations. Several sources have shown enthusiasm for a continental drilling program, and it is inconceivable that such a program could be implemented without major participation from the U.S. Geological Survey.

Of equal significance is the opportunity that exists for reevaluation and synthesis of existing geological data on the continents in light of the new model. Most of these data were collected and interpreted prior to the development of the new model, and the reevaluation will not only have beneficial scientific and practical consequences, but it will also identify critical areas that deserve additional study. This observation provides an opportunity to offer strong encouragement to basic field mapping. This mapping provides the basic elements of all our geological knowledge. Without it we have no boundary conditions. It is easy to lose sight of this when we have black boxes, computers, aircraft, spacecraft, ships, or other exciting things to work with.

The Geodynamics Project is not designed to find minerals or energy sources or to prevent natural disasters. It is a project whose aim is to learn about the dynamics and dynamic history of the Earth and to provide basic knowledge that will contribute to better utilization of the Earth's natural resources and to the mitigation of the effects of natural disasters. As such, it clearly falls into the area of responsibility of the Geological Survey. Many Survey scientists assisted in the design of the U.S. Program (Natl. Acad. Sci., Geodynamics Comm., 1973), and I look forward to continued Survey participation in its implementation.

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EARTH-RESOURCE SURVEYS

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INTRODUCTION

In the summer of 1974 the world stands on the threshold of a new, greatly increased ability to inventory and monitor the Earth's resources. It seems especially appropriate to examine a few of the implications of that ability on the occasion of this dedication symposium, for the U.S. Geological Survey has played a central role in bringing earth sciences to bear upon our need for earth-resource surveys.

The aspects which I wish to review briefly involve the development and application of remote-sensing technology to the attainment of the vitally needed resource data base. It is in this development and application that the U.S.G.S. has pioneered. Together with the National Aeronautics and Space Administration (NASA), and many other Federal agencies, the U.S.G.S. has created the knowledge needed to exploit the capabilities of space-based and aerial remote-sensing systems. Leading this activity within the Department of the Interior has been the Earth Resources Observation Systems Program. Many persons come to mind as we think back over the growth of this effort. Leading them all, I am certain, would be Dr. William T. Pecora, whose vigorous support and wise guidance of the program was an inspiration to all of us. Maintaining leadership in this field within the Department of the Interior has fallen upon the capable shoulders of Dr. John DeNoyer, and EROS still has the wisdom, insight, and counsel of Dr. William Fischer.

The developments of which I speak are well documented in the literature, particularly in a compilation of papers presented at the 13th Meeting of the Panel on Science and Technology, for the U.S. House Committee on Science and Astronautics (U.S. Congress, House, Comm. Sci. and Astronautics, 1972). Since then we have seen many of the results of the first Earth Resources Technology Satellite, and even some from the Skylab Earth Resources Experiments Package.

REMOTE-SENSING TECHNOLOGY

Remote sensing has now begun to appear in several academic curricula; it is identified as measurements remotely made by sensors not in direct contact with the object of interest. Since its explicit identification as a field of endeavor, about 12 years ago, it has constituted an extension of the already established and accepted practices in aerial photography and photogrammetry, including the following innovations:

1. Imaging from space platforms.
2. Imaging in the nonphotographic wavelength regions, particularly the infrared and microwave regions.
3. Attainment of quantitative nonimaging spectroradiometric measurements from space and aerial platforms.
4. Data recording and transmission in high-density electrical-signal form.
5. Establishment of signal- and data-processing methodologies, analog and digital, to assist human interpreters and to extract some information automatically.
6. Active (that is, illuminated) systems such as radar and laser systems.

Thus, this field has brought to bear the power of modern computer, space, and electronic technologies. Remote sensing has expanded our data-gathering *and* information-producing capabilities and now is engaged in enhancing translation from information to meaningful decisions. The chain we must follow can be visualized as:

DATA → INFORMATION → DECISION → BENEFITS

The changes introduced are so radical that remote-sensing technology can be viewed as a totally new attainment, one greater than the sum of the separate innovations.

Some general observations can be made on the nature of this new technology. As it is heavily involved with the use of information-gathering tools, it can be deemed a passive technology, one whose output is without value in itself. Thus, if our progress through the chain stops when information has been produced, we will find no "demand" in the economic sense. As a field, remote sensing is interdisciplinary in an integrating sense. It is nearing large-scale practical utilization. Although essentially benevolent, remote-sensing technology can be misused. This is dependent upon the decisions made.

Much of what we have just said could also be said of "bugging" or so-called electronic surveillance. Such use of implanted sensors for spying purposes, whether industrial, political, or military, has had strong and widely discussed repercussions. Illegal phone tapping can be seen as a clear example of the misuse of a passive technology. Concern has been voiced internationally about the possible misuse of remote sensing from satellites for earth-resources surveys. Perhaps the most cogent treatment of this topic was given by the NASA Deputy Associate Administrator for Applications, Leonard Jaffee (1974), at the February 25–March 5, 1974, meeting of the U.S. Outer Space Committee's Working Group on Remote Sensing.

The political aspects of earth-resources surveys are thus as real as the technological ones and may well be the pacing elements in the future of this field.

APPLICATIONS

The remarkably successful operation of ERTS–1 has allowed many investigators to demonstrate a wide range of uses of this particular configuration. Applications which seem to be at hand, range from mapping in the cartographic sense at scales on the order of 1:500,000 or 1:250,000 to many areas of broad thematic information extraction. One immediate factor is the speed with which large areas are covered. In almost an instant, the data for mapping a 185- by 185-kilometre area can be obtained. In a relatively short time, a State can be covered. The resulting product is a map of things as they were at one definite time, whereas a conventionally made map may contain old and new information and may represent things as they never were at any one moment.

Extraction of information on the renewable and nonrenewable resources has been treated in considerable detail in NASA's ERTS Symposium (U.S. Natl. Aeronautics and Space Admin., 1974). Scientists in the U.S.G.S. have made significant presentations at these conferences. Monitoring and inventorying of agricultural products have been shown, within some limitations, to be valid activities, although they require ancillary data such as crop calendars and so-called "ground truth." The use of ERTS data in disaster assessment and as an aid in directing efforts to alleviate the effects of floods and of drought have also been presented. Monitoring of World Bank projects is an example of a perhaps less known but practical use of ERTS imagery.

Time does not permit an adequate treatment of the results already obtained and published. For example, the activities in Canada and Brazil have been outstanding. Taken altogether, they represent an ever-growing truly global capability for use of space sensors for earth-resource surveys.

RESEARCH

Research in the field of remote sensing for earth-resource surveys is particularly attractive. This has seemed so obvious that we may have failed to articulate its merits properly. Recently, while in Indonesia, I had occasion to try to do just that. The attributes that came to mind were these. First, it is *applied* research having clearly understandable useful goals. Remote-sensing research attacks urgent world problems, among them those of finite resources of food and energy. Second, the work is scientifically challenging. The intellectual rewards are, accordingly, satisfying. Third, much of the research can produce good results reasonably quickly. This is an important attribute from the point of view of those seeking thesis opportunities. Fourth, much of the research work can be founded on and developed from a basis of earth sciences. Participation in such research inevitably brings the scientist into invigorating encounters with computer and space sciences. Fifth, and perhaps most important of all, this research brings the researcher and the operational user directly together. This necessary and mutually beneficial partnership is an uncommon extension in interdisciplinary interactions, beyond what is normally found in research. This attribute can be equally true for all those who engage in remote-sensing research —the earth scientist, the economist, the lawyer, the agriculturist, or the political scientist. Of course, not every program of study brings all disciplines together, but engagement in a series of such works comes surprisingly close. These five characteristics of remote-sensing research can be most relevant for work by teams in less developed countries, but they hold true for developed countries as well .

For example, one research area seeks to produce land-use maps by automatic processing of remotely sensed data. Our work at the Environmental Research Institute of Michigan, typical perhaps of that by several research workers in this field, has met with some success already. It involves participants from the users at State government level as well as our scientists. Such teamwork is both rewarding and challenging.

Two other examples come to mind. Our research in oil-slick detection began with laboratory spectroscopy and went through theoretical analyses and creation of models of predictive calculations, to the design of system concepts; we then worked with the ultimate operational user of the system on costs and reliability. The second example involves the creation of theoretical and empirical models to allow radiation-transfer calculations in real atmospheres and within vegetation canopies. One capability of these models is used for corrections to radiometric multispectral data, the other for prediction and analysis of such corrected data for forests and crops. Again, the involvement with many parties of interest is wide and, even today, growing. The quality of the work is reflected in the scientific publications that have resulted.

Much remains to be done, but this will always be true in such fields of research. One frontier lies in the attainment of resource-management models capable of efficient acceptance of remotely sensed data. Many gaps exist in our understanding of the connection between the remotely made measurements of, say, spectral radiance as a function of wavelength and the particular properties of the object being examined. Some applications remain just beyond our sensor configurations. Researcher eagerly await higher resolution multispectral systems having wider spectral coverage and having the observational advantages of geostationary platforms.

THE FUTURE

Dr. McKelvey's letter of invitation to present this paper stated that the purpose of this symposium was ". . . to survey the public problems to which earth science . . . should be addressed." No one today could resist such an invitation. One national issue is clearly evident in the field of earth-resource surveys. We stand, as I said before, *technically* on the threshold of attaining an ability to inventory and monitor the Earth's resources. Will there be a national decision to cross that threshold?

Let us be very clear what is at stake here. Simply having earth-resources surveys does not bestow social and economic benefits. Such surveys are merely a step toward the decisions that can bring about a wiser management of these resources. We cannot take as an article of faith that better information leads inevitably to better decisions. We *can* believe that the likelihood of better decisions is increased by having improved information. Indeed, the phrase "necessary but not sufficient" comes to mind.

The larger problem remains. It has been couched in many different terms. One that comes to mind is "distribution of wealth." If we consider that all the Earth's resources — human, natural, renewable, nonrenewable, energy, water, food—apply what modifiers you wish—all of these are the world's wealth, then we realize that the wealth is the world itself. How shall we divide the world? What share shall we leave for those to come? Will we consume the Earth, or husband and cherish it, sharing this wealth evenly with all humanity today and tomorrow?

Others have pointed to the need for stabilization—stabilized population levels, stabilized quality of environment, stabilized growth rates. If we are to achieve the global-management capability inherent in such concepts, we must develop far more powerful tools than mechanistic input-output management models, however complex these may become. Here the challenge is the creation of management tools that include and are responsive to human values. I suggest that this task is a social and political one.

The decision to cross the earth-resource surveys threshold is similarly a political one, involving or at least touching all countries. The international community of earth scientists cannot stand apart from active participation in the decisionmaking process. There is little time left—delay can mean the opportunity foregone. Not making a decision is as much of a decision as is any other action.

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FEDERAL INTERAGENCY COORDINATION OF NATURAL-RESOURCES STUDIES

By Robert M. White
Administrator, National Oceanic and Atmospheric Administration

It is a great honor for me to be invited to participate in this seminar on the earth sciences, commemorating the dedication of this magnificent new home of the United States Geological Survey. I bring you greetings and congratulations from your sister agency, the National Oceanic and Atmospheric Administration. I bring these congratulations with just a touch of envy. At long last, most of the Geological Survey in the Washington, D.C., area will be housed in one place, whereas we in NOAA live and work in some 20 different locations. How wonderful, I sometimes think it would be, if all in NOAA could get together as you are now doing in the Geological Survey.

I would have hoped that Vince McKelvey would have asked me to talk about something I enjoy, such as the weather or fishing, both of which we have something to do with in NOAA. However, it is my lot to talk about interagency coordination in natural-resources studies. My participation in interagency coordination activities is generally something I would like to forget rather than talk about.

Interagency coordination is about institutions and processes and is generally regarded as something apart from scientific and technical matters. When I first came to Washington a decade ago, the Assistant Secretary for Science and Technology of the Department of Commerce, Dr. Herbert Hollomon, in discussing my new duties as Chief of the U.S. Weather Bureau, told me that I would be spending most of my time on matters that would appear at first as irrelevant and far removed from the direction of the technical activities of the Weather Bureau. He did not tell me then that it would involve coordination of interagency activities. He was right. I spend more time on interagency coordination than any other single activity in which I am involved. After a few months, it was clear that interagency coordination may not be the stuff of scientific and technical substance, but it might very well be real substance in its own right.

I would like to advance that thesis. After a decade in Washington, I have become convinced that unless we learn how to direct and orchestrate the work of diverse groups, solutions to our problems can be seriously retarded. One of the major substantive problems we must solve is an institutional one. Our ability, or lack of it, to establish the necessary networks of specialized organizations to attack important tasks of society may very well determine success or failure.

I have lost count of the number of interagency boards, committees, and panels in which my organization, the National Oceanic and Atmospheric Administration, participates. You name it, and we have it. Interagency bodies are ubiquitous. There are interagency bodies for every level and echelon in the Federal Government, for the big wheels and the small wheels, for almost every subject and topic, for satellites and weather, geodesy, oceanography, geology. We have them in every form—bilateral agreements, multilateral agreements, informal arrangements, and formal arrangements. We have cabinet level coordination bodies, such as the Domestic Council Committee on Environmental Resources, and the Water Resources Council, both chaired by the Secretary of the Interior. We have the Federal Council for Science and Technology and its subcommittees and panels. We have Federal committees to deal with coordination of weather services and geodesy. We have bilateral arrangements with the Geological Survey, Federal Aviation Agency, National Aeronautics and Space Administration, the Coast Guard, the Fish and Wildlife Service. We have an incredible array.

"What do they all do?" This is the criticism heard so often. Sometimes that is a hard question to answer. Are they really as ineffective as some people feel? Do they really solve problems, or do they serve only to paper over unresolvable issues? As with most things in life, the truth is in between.

Interagency bodies reflect the existence of transorganizational problems. The real world develops in ways frustratingly different from the ones we have organized for. We continually make new stabs at changing organizational structures to meet new national problems, but we never really succeed in encompassing all aspects of a problem in a single organization. Interagency bodies reflect the complexity of modern problems. They reflect the wide spectrum of expertise that must be brought to bear on them. There is no way out, except to cajole, coerce, or direct various groups that have the expertise and resources needed to get together. We cannot reorganize for every problem, and we cannot afford the duplication of resources that such an organizational concept implies. What we are really about when we engage in Federal coordination, whether it applies to the field of natural resources or any other field, is establishing networks of expertise and resources. We do not have to cast about to understand what I mean by transorganizational problems.

Take the problem of greatest concern to us now—energy. Take one segment of that problem—development of oil and gas resources of the Continental Shelves. Literally, an army of organizations is immediately involved. The Geological Survey has wide responsibilities for the geology, geophysics, and the safety of oil and gas drilling on the shelf; the Bureau of Land Management has the leasing responsibility; the Environmental Protection Agency is concerned about pollution problems; the Coast Guard must monitor; and NOAA is concerned with the impact of oil development on fisheries. The solution requires coordination, but even more, it requires joint participation.

Another kind of resource problem is represented by the management of the coastal zones of the United States. Recent legislation, the Coastal Zone Management Act of 1972, sets up a system for State management of our coastal zones. It would be hard to find a problem involving more agencies. Sometimes I think every single agency in the Federal Government must have a stake.

The question is, how do you bring all Federal agencies together so that their interests are represented. What is more important, how can their talents be used in establishing the policies and guidelines?

It is not just that problems are more complex; other reasons underlie the formation of interagency mechanisms. Take multiple-application technology—the technology that applies to many problems. A good example is space technology. It can be used to study mineral resources, fisheries, oceanography, meteorology—and so on. Suddenly we are confronted with the question of how to deploy such a technology. We are fortunate enough to have had the wisdom to establish a space agency to develop the technology for all space vehicles. The more difficult institutional question is whose responsibility is it to operate the space systems and use the data. There is no way to deal with that problem except by bringing interested and affected groups together. Again, a need for interagency bodies.

When you get right down to it, we might very well ask why there are so few interagency coordinating bodies rather than so many. I am being only slightly facetious. Federal coordination, however, is only one corner of a very much larger problem—one that deals with a phenomenon that is affecting the way Government operates. It is not only Federal agencies that have interests. The people "out there"—the constituencies, interest groups, various State and local governments, the citizen himself—all are affected. They also want in. They want participation and they should have it. Coordination needs to be more than Federal.

I am caught up in an activity that has illustrated to me the widening circles of who must be involved. In NOAA we deal with resources of a different kind from those you deal with in the Geological Survey. Let us take the conservation of the world's whales as an example. I happen to be the United States Commissioner to the International Whaling Commission. We recently had our annual meeting in London. The issue we faced was how to establish conservation programs that would prevent endangerment of whale species and restore depleted stocks as rapidly as possible. The issue is emotional and symbolic. It is one on which environmental and conservation groups have strong positions. It is also one in which the structure of the International Whaling Commission favors those who seek weak conservation measures. It became absolutely vital to involve nongovernmental groups in every stage of our planning in order to arrive at difficult decisions as to how to proceed. The Coastal Zone Management Program is also a good example of the necessity of bringing in the views of many groups at the State and local levels.

Interagency coordination provides mechanisms for hearing all sides of a question within the Federal structure. These mechanisms can be good or bad. At their best, they can attack very difficult problems and yield excellent results. At their worst, they are bureaucratic fortresses of delay and procrastination and deterrents to innovation. Too often, they take the latter form. Why are they so often so frustrating? There are many reasons. Often, the agency representatives are given no real authority; often, they have no real standing in their own agencies and no freedom for compromise or decisions. Often, the budgetary discipline of the system causes a built-in reluctance to innovate. We could go on. We need to look at the set of causes that makes these coordinating bodies sometimes ineffective. Unless we can make interagency mechanisms work and unless we can get groups together, we are in deep trouble.

Too frequently we think in terms of developing new institutions because of dissatisfaction with the old. In many cases, new institutions are needed, but in many more cases, the problem is to use institutions that already exist. I keep plugging away at Federal interagency coordination because I do see instances of magnificent results through the establishment of networks of institutions. It all makes it worthwhile. Let me comment on a few of these, in areas with which I am familiar.

A good example was the execution of the Barbados Oceanographic and Meteorological Experiment (BOMEX). This was an experiment which took place in 1969, off the island of Barbados. The purpose was a field study of the interaction between the oceans and the atmosphere. Through the Federal Committee for Meteorological Services, it was possible to enlist the efforts of 10 Federal agencies along with academic and industrial institutions, working together on a program for 3 years, requiring extensive resources.

Another good example is in the field of hydrology. The International Field Year of the Great Lakes was a successful field program only because of the active participation of many different agencies of the Federal Government.

NOAA's working relationship with the Geological Survey is a model of bilateral agency cooperation. The deputy directors of the two organizations meet regularly to plan joint efforts and resolve issues. The relationship works because Vince McKelvey and I both insist that it work. We have similar arrangements with NASA, the FAA, and the Coast Guard, all of which work excellently.

I suppose we expect too much from interagency committees. Where they have directive authority as in many bilateral arrangements, they frequently work. Where there is a specific task to be done, they frequently work. Where they are of a standing variety, they frequently fail. Where interagency bodies do not have directive power, they can still be useful if we do not expect them to do more than their authority permits.

I see of no way to get our jobs done without them. Some say they cannot get their jobs done with them. It sounds like marriage—and maybe that is what this is all about—the marriage of agencies. It is, in fact, a phenomenon more enduring than a great many marriages. It will be with us until death us do part. There is no alternative but to make it work.

LAND RESOURCE–ITS USE AND ANALYSIS

By JOHN C. FRYE
Chief, Illinois State Geological Survey

Organized human society cannot exist without the basic resources of land to sustain and support it. Although we speak of food, shelter, and water as the essential commodities, all of these are derived from use of a land area. Furthermore, for several thousand years, mineral raw materials have been an essential item for human society, and they, also, are derived from the Earth. Therefore, their procurement is another form of land use. Indeed, the concept of use of the land resource is so all encompassing that it is difficult to consider any societal problem that does not in some way involve land use.

In spite of this universal dependence, the philosophical approach to the use of land has historically differed widely among the many human cultures. In some ancient and in some primitive societies, the land—that is, the Earth on which we live and its indigenous plant and animal population—was held in great reverence. An ancient Sanskrit prayer expressed the concept in the phrase "O, Mother Earth, ocean girded and mountain breasted, pardon me for trampling on you."

In America, the native Indians had a profound reverence for the land. Chief Joseph is quoted as saying, ". . . I never said the land was mine to do with as I chose." More than 100 years ago, at a treaty parley in the Northwest, an Indian leader said, "The Great Spirit, in placing men on the earth, desired them to take good care of the ground, and to do each other no harm."

In contrast, western culture has generally viewed the land as being for the exclusive use of man, to be modified or exploited as the individual owner or the local society wishes at the moment. The contrast in attitude was eloquently stated a half century ago by Willa Cather.

> When they left the rock or tree or sand dune that had sheltered them for the night, the Navajo was careful to obliterate all trace of their temporary occupation. He buried the embers of the fire and the remnants of food, unpiled any stones he had piled together, filled up the holes he had scooped in the sand. . . . Father Latour judged that, just as it was the white man's way to assert himself on any landscape, to change it, make it over a little (at least leave some mark or memorial of his sojourn), it was the Indian's way to pass through a country without disturbing anything; to pass and leave no trace, like fish through the water, or birds through the air.

Against this historical contrast, we must view present-day North America. The western practice of unrestricted land modification, if carried to an extreme, can result in modifications of one locality that seriously interfere with land use in an adjacent area. Land-use practice by a local group may prevent the larger society from making desired or necessary use of the land, including the production of food and raw materials. Such conflicts of land use have forced upon our collective consciousness the fact that, if our civilization is to survive, the use of land, particularly in the urbanizing areas, must be based on sound factual data and directed in such a way that it will not cause social deterioration. The numerical size of our population makes it abundantly clear that to support our citizens, even at a subsistence level, we are far past the point of return to the land ethic of the American Indian—even though there are those of us who wish that we could do so. The Honorable John D. Dingell underscored this fact when he said, "You are not going to sell aesthetics to a starving Hindu."

Because our modern society cannot return to the ancient and primitive ethic of preservation of the terrain in its pristine condition nor continue in the western ethic of "do as you please to any parcel of land you hold in fee simple title," we must move to a position between these two, but quite different from either. We must say in effect that the owner of a parcel of land may use it to his own benefit as long as that use does not conflict with the overriding needs of the populace and of the Nation, and that, preferably, the use should be compatible with the long-term needs and desires of the national culture.

Let me state clearly that I am not sufficiently presumptuous to contend that I can define the long-term needs and desires of our national culture, but I am convinced that those groups in our society that make such long-term decisions should base them on adequate scientific and technical data. Here enter geology, geochemistry, hydrology, geophysics, mineral-resource evaluation, and topographic mapping —all areas of knowledge, or activities, in which geological surveys have particular and extensive expertise.

We are here to take part in the dedication of the National Center of the United States Geological Survey, and particularly of the John Wesley Powell Building of that National Center. This is indeed an appropriate forum for the discussion of the application of scientific and technical data to the wise use of our land resources. Major Powell was a giant among pioneers, not only in scientific exploration but also in the development of governmental agencies that made possible the generation of data in a context in which it could be useful to public decision-makers.

Now, let us take a brief look at techniques available for attacking this broad basic problem and the directions that may be taken in the future.

The geological sciences, in all their applied branches, must be called upon to furnish the needed information for evaluation of our basic land resource. Many of the applications are obvious and have been described repeatedly and at length. Mapping of the topography and of the surficial geology clearly is part of the first step, because many of the essential features of the land are derived from these basic elements and can be understood only in the context of such background. The distribution and lithologic character of the earth materials at the surface, and to depths of as much as 50 feet, have a direct bearing on virtually any human use of the land. However, it is not enough merely to map the distribution of the formally described rock-stratigraphic or time-stratigraphic units. The mapped units must be characterized as to lithology, mineral composition, engineering properties, hydrologic characteristics, and lateral and vertical variability, and indication must be given of the rock type immediately underlying each unit mapped. The soils that have developed on the described deposits should be mapped from the standpoint of their physical properties as well as their agricultural utility. Each of the materials units mapped should be evaluated as to its suitability for the many specialized uses that can be made of a particular parcel of land—be it for residences, large buildings, highways, recreation, waste management, mineral-resource development, agriculture, or other use.

The type of map evaluation described is almost universally needed to determine what use of the land would be most beneficial to society. However, this basic evaluation is only the beginning of the application of the geological sciences. Essential in some areas, and for some uses, is a wide range of specialized data that may pertain to rocks hundreds or thousands of feet below the surface. Examples of these supplemental data are the presence or absence of aquifers containing ground-water supplies, and the quality and abundance of such potential water supplies; the presence and distribution of former or active underground mining that might at some time affect the use of the land surface; the character of deep rock units that are potentially useful for the safe disposal of liquid wastes; the seismic characteristics of the area, which can be used to evaluate earthquake hazard; and, of great future importance, the location and character of mineral resources that have potential for development so that their availability can be protected until they are needed. The last point is particularly relevant in the vast reaches of public land in the western half of our Nation, where we have been moving from an early policy of "free-for-all" for mineral claims and exploitation, toward a policy of preservation, but without accurate and detailed knowledge of the potential mineral resources that may be needed desperately at some future time.

The future availability of mineral resources is a problem that illustrates the importance of the concept of multiple-sequential use of land. If an area having an important mineral resource that has the potential to fill future needs is identified, the first phase of land use might be for recreation, for "open space," or for preservation. The first phase can then be followed by a second phase of mineral production, after which a possible third phase could be devoted to waste disposal, urban development, agricultural production, or recreation, as the needs of society at that time might dictate. The concept of multiple-sequential use of land is not new, and in fact it has on occasion been practiced by accident. In the future it should be practiced by deliberate intent, but it must be based on sound detailed information about the mineral resource involved and the suitability of the subseqently disturbed area for a third phase of use. This last phase clearly indicates the need for continuing research on the problems of reclamation or restoration of disturbed land areas.

As our social structure becomes more complex, and as we become increasingly more dependent upon the products of science and technology, we require increasingly sophisticated data on which to base decisions for the specialized uses of our land resource. This is well illustrated by the area of waste management. Solid waste is generally contained in sanitary landfills, which are a specialized form of land use. Landfills, which now occupy only a very small segment of the land area, have a potential side effect for the pollution of water resources that may move far beyond the site. Research on the leachates from landfills and the resultant potential for pollution is only starting at a few places, but it is an area of research that needs vigorous support in the near future from the earth-science agencies of the Federal Government. The effluent from landfills contains an amazing mix of potentially toxic trace elements and deleterious ions derived from the refuse in the landfill. Basic research is required to determine which and how many of the many potentially toxic constituents will be carried outward from the fill into the regional terrain to become potential pollutants of the regional water supply or will remain trapped in the surrounding sediments. Such research, although considered by some to be pure science, is essential to our social existence in the near future. The hydrologic system through the landfill is as important as the geologic parameters that influence the circulation of fluids. Hydrologic data are also essential in evaluating the potential effects of injection of liquid industrial wastes into deep rock layers.

Land use may be importantly influenced by a group of natural phenomena that have been loosely called "geologic hazards." They include ground movement associated with earthquake shocks, unstable ground and potential surface movement, episode flooding, accelerated shore erosion, and potential volcanic activity. At least some research is underway on all these problem phenomena. The best available information on these potential hazards must be part of the background data on which land-use decisions are based.

An aspect of the land-use resource that has been generally disregarded is the societal use of subsurface space. Although airspace above the land surface has been generally, and legally, regarded as being within the realm of public allocation, the use of volumes of space below the land surface has been considered subject to public control in only a few special circumstances. In our metropolitan areas, the use of subsurface space is becoming a societal problem. Subways, sewers, water mains, and service access for years have been normally situated underground in metropolitan areas. However, use of the subsurface for such purposes competes with groundwater supply, waste disposal, waste-water conveyance and storage tunnels, mineral-resource development, and underground storage of commodities and presents a problem that has been given neither legal nor public consideration. It is to be hoped that, before future decisions are made on the allocation of subsurface space that might permanently render it unusable for any other purpose, the earth sciences will be asked to provide the technical facts that should be background to any political decision on the subject.

In an analysis of land use, we must consider such problems as reclamation of strip-mined land; possible future subsidence of undermined land; regional effects of canalization, artificial impoundments, and levee construction along major rivers; and the conversion of vast acreages of agricultural land to urban use. The effects of such actions have long been predicted by earth scientists, but, unfortunately, the implications of future effects commonly have not been a component of the decisionmaking process. Furthermore, continuing research is clearly indicated. For example, we know more about effective procedures for reclaiming shallow strip-mined land with relatively gentle slopes and an original cover of unconsolidated Pleistocene deposits than we do about techniques of preventing surface subsidence in undermined areas.

Having considered the areas in which earth scientists should furnish needed data to guide the political decisionmakers in the use of our limited resource of land, we might briefly consider new techniques available to achieve their needed goals. Most of the approaches used by the geologist, geochemist, geophysicist, and hydrologist are well established, but new techniques of data gathering and predictive capability are constantly evolving. One of the major technologic changes is in our ability to analyze smaller and smaller quantities of potentially toxic substances. Publicly acceptable tolerances tend to follow our ability to detect. As the level of our chemical and mineralogical analytical capability increases—particularly our ability to detect trace quantities—we as a society tend to become conscious of possible hazards, and we consequently tighten our standards of acceptance until all tolerance disappears. In the wise use of our land and water resources, we must be aware of the fact that if we place our standards of acceptance beyond the level that existed before modern human societies occupied an area, we are being ridiculous. As a former Director of the United States Geological Survey has pointed out, nature's normal functioning is the world's greatest polluter. Clearly, therefore, an important area of basic research is the establishment of "background" data—that is, the determination of the levels at which the many constituents existed in the environment before the advent of western culture. Furthermore, the concept of zero tolerance —that is, zero discharge to the environment of the products of human activity—is totally unrealistic. We must determine instead what level we can tolerate.

New technologies have evolved that can aid the earth scientist in fulfilling his needed role of delineating and analyzing the factors involved in our land resource for the decisionmakers. Prominent among these are remote sensing, including sensors on satellites, and computer manipulation of data. Other new and exotic techniques will evolve through time, but it should be remembered that these are only new "tools of the trade," to aid in achieving the needed results. In themselves, they do not alter the problem or the basic data needed by the political decisionmakers.

In conclusion, let me return to the basic problem with which I started. The demands and needs of today's increasing population require that we depart from the philosophies of earlier cultures—be they ancient, primitive, or western—in their approach to the use of our land resources. Social decisions for land-use must, in the future, be based on the best and most reliable information that our public decisionmakers can obtain. We can no longer afford whimsical or emotional decisions, or decisions based on vicious self-interest. Earth scientists must use all the developing and advanced technology available to furnish our public administrators with the needed data. In turn, governmental bodies must support the acquisition of the needed data—at Federal, State, and local levels—by encouragement and funding, and they must heed the data available to them in their formulation of public polices.

EARTH SCIENCE IN THE PUBLIC SERVICE

TECHNOLOGY INFORMATION TRANSFER

By JOSEPH S. JENCKES
Administrative Assistant to Senator Paul J. Fannin

I find myself in a very unique and ambiguous situation, in that I don't know a great deal about geology. I *do* know a little something about politics, and maybe I might have something to say that will relate to some of the talks today. I first knew about this symposium a couple of days ago when Mr. Bettwy, who is the Land Commissioner of Arizona, called and said, "Joe, why don't you go out there; it's going to be very informal. Not too many people, no television—just talk for a little while about land use and other things in Arizona. No problem." And I said, "Well, what's the topic?" He said, "A very simple topic." I'll read it to you: 'Interfaces for a National Response to Resource Demands—A Need for Interagency Interdisciplinary Coordination,' subject of talk: 'Technology Information Transfer.'" I said, "What does that mean?" He said, "It's a snap. It means how we communicate information." I said, "Well that ought to be very simple, I'm an expert on that."

So, I got the information that he sent, including a paper that's so technical I don't understand it. That made me even more nervous. I thought, "I'm going to be speaking to all these technical people and experts, and I'm not going to know anything, and I'll make a fool of myself." And then I thought, "I ought to be able to just stand up there and talk a little bit about Arizona and tell some of the problems we have." Then I began to think of the title of my topic, "Technology Information Transfer." The title is so complicated, and it has to do with communicating ideas, communicating data. And I thought, "The very thing I'm suppose to talk about is so complicated that the man on the street doesn't understand it."

Then I began to wonder if the farmer, the city planner, and the water man in Arizona would understand these data when they get them. To illustrate that, I must tell you a little story that's true. It did not happen in Arizona. There's a farmer out west and the coyotes are eating his sheep. He says to himself, "My gosh, I can't control this thing. I have to go to the Government. They'll help me out." So he comes to Washington, and he meets a bureaucrat in one of the departments. The bureaucrat says, "There's no problem, Mr. Farmer. We'll handle this just like we handled the screwworm problem. We'll feed the coyotes the same stuff and that will sterilize them and you'll have no more problems." And the farmer said, "Sir, you don't seem to understand. The coyotes aren't making love to the sheep, they're eating them!"

So maybe that's part of our problem. Maybe the politicians and the bureaucrats and the technicians somehow are not getting the point across.

I come from Arizona. We're very conservative in Arizona. Let me tell you a little bit about Arizona's land. Arizona is a pretty big State: It covers an area of 114,000 square miles. Public land in the State, owned by the State, consists of about 1½ million acres or 13 percent of the total. That's just State land and it is scattered all through Arizona. The Federal land is 45 percent of the total. The Indian land is 27 percent. Private land is 13 percent. I don't want to get too political here, but we had a talk on land use, and if you go to Phoenix, Ariz., and you tell them there that somebody in Washington is going to tell them how to run their land, they're unhappy. They want to control what little land they have. They are concerned that perhaps the Federal Government—some of the people in the Federal Government—care more about the national interest than they do about the poor guy who lives in Arizona. Now that may be right, it may be wrong, but that's what they're concerned about.

Let me tell you a little about some of the problems that relate to this data business that we're all supposed to be talking about. How do you get the data out? How do you communicate it? How do you transfer it? I read through a technical paper about the ERTS satellite. As I was talking about what to speak on, I asked, "Well, is the farmer getting that information? Does the farmer know when half his grazing land is dead?" Remember it comes up white instead of red on one kind of image, because it's dead and doesn't have any heat anymore. I was told, "Well, we're trying to get it to them." I said, "Is the Geological Survey giving the Department of Agriculture this information?" "Well, we're starting to." And I said, "How about the miners?" One percent of the land in Arizona is used for mining, and we produce 50 percent of the Nation's copper. So, we have to be concerned about our things, and we're a little concerned about some of these data. I asked, "How is it working?" and was told, "The satellite is working great."

You can get ERTS data. A satellite *is* great. It doesn't have a vested interest, and they say it's working fine. In Arizona, they found out that they don't even have to make a field inspection anymore when they're looking for powerlines because they have all these photographs. There are problems, but good things are also happening. Arizona is getting a land-use plan that they want on a local level, and with the help of the Geological Survey, ERTS, and other data-gathering systems, they're getting a plan together.

Let me tell what else Arizona has done. They have a system called the Arizona Trade Off Model (ATOM). Here's what it does. They have a big computer, and they feed in a lot of demographic information—population, transportation, how the air is here, and how the water is there. They put it all in, and then a corporation will say, "We may want to move to Arizona. What can you tell us? Where should we move?" The computer is asked a question, and out comes the little card. It says, "Based upon your power need, your water needs, your electric needs, your real estate needs, the type of people, the skills that you have, and the people that you have, you should move to this point."

Maybe what I would like to see is this. A building, a square building. A person walks into the building and says, "I want to know X about this piece of land." And he would get a transparency—just pick it up and there the information is. Now they've got something like that, I know. At the Land Office you can find out a little bit about land management. At the Agricultural Office you can learn a little about that. You can go to Soil Conservation, and you can go to AEC. You've got to go all over the lot. Then I find out that nobody speaks the same langauge anymore! Remember this title—"Technology Information Transfer." I don't know what it means! So there's a problem; it has a technical name—"noncompatible data." This agency's got one mouthful and this one's got another. Example, I can only live by examples. You know what an *arroyo* is? It may be many things. It may be a dried creek. It may be an ear muff. It may be a Mexican freeway. It may be contraband. So we have to get our data right. How do you do that? Scientists speak in gobbledygook, farmers speak in gobbledy-gook, AEC people speak in gobbledy-gook, and nobody understands anybody. Maybe we have to do something about our terminology; maybe we'll have to go back to school and learn to use a simple language, like how do you communicate data or how do you communicate information? I don't even know what interagency-interdisciplinary coordination means! We ought to be simple. Hopefully, we can take politics out of data systems. What we do with our land is a political decision; it's a policymaking decision. But if data and systems get all confused and all wrapped up in the policy matter, you don't come out with a very good conclusion. I don't know what the answer is. I don't know whether it's one agency or not. I don't know whether we just have to call it a Government data agency, and no connection with any departments. But you've got to get back to "square one," you have to let people know, and you have to let the public know; we can't make proper decisions without proper data.

As a politician, I know we ought to make things as simple as we can make them. We need the Geological Survey. When I saw all of this equipment out here, I was impressed; you can do great things, and it will help. So, keep it simple, keep the data coming, and don't take all of Arizona's land away. Leave us that 13 percent, and if we get the information, I think the people of Arizona will work up a good land-use plan.

To get serious for a moment here, and I will end. The Governor of Arizona, Jack Williams, has written a letter to Mr. McKelvey. Mr. Radlinski, I think, is here to accept this letter and memento:

Dear Mr. McKelvey:

On this occasion of the dedication of the new John Wesley Powell Federal Building, it is my pleasure to present this plaque, representative of over 100 years of historical ties between John Wesley Powell's most significant accomplishment in the State of Arizona. John Wesley Powell explored this great land for over 40 years before Arizona ever became a State. He recognized the significance not only of the land and its resources, but he pioneered studies of the linguistics of the inhabitants of this land—the American Indians—who today occupy over ¼ of our State. It is highly significant that this new building be named after this great man. Arizona is proud of our long standing relationship with the U.S. Geological Survey and we are looking forward with high expectations to future accomplishments which will take place in this new structure.

Sincerely,

Jack Williams
Governor, State of Arizona

It's a tremendous structure; you've got tremendous people there. Just keep it simple.

INTERDISCIPLINARY APPROACH TO THE SOLUTION OF NATURAL-RESOURCES PROBLEMS

By NATHANIEL P. REED
Assistant Secretary of the Interior
for Fish and Wildlife and Parks

We must not, at the outset, consider the interdisciplinary approach to problem solving as itself new or in any way unique to this decade. Many of the so-called great individualists of the past in truth were great because they were adept at orchestrating a diverse collection of talents and resources into a focused effort to attain their objectives. Explorers before and after John Wesley Powell have enjoyed success substantially proportional to their ability to meld several disciplines in the pursuit of an overriding objective and to pursue that objective with determination. The same can be said of the captains of industry and the famous generals of military history.

More recently, we have been bemused with the mechanisms of operations research, systems analysis, and the like. Again, the emphasis was on the means of getting a mission accomplished, usually within a cost-effectiveness framework. Inputs and outputs were generally measured in dollars, or, varying non-dollar outputs were compared with alternative inputs of dollars. The variants were many and were fully capable of earning a niche in history for their perfector.

What we are talking about, then, is not a new concept but rather an expansion in the use of new planning tools, concepts, techniques, and disciplines, many of which were not available earlier or were not considered necessary. What we are considering, also, is the basic *decision* and its alternatives as well as the alternative *means* of implementing the decision once it is made. That is a basic change.

To be specific, the construction agencies have been making decisions for decades to build water projects on the basis of engineering and economic analyses. The time has come to add systematic environmental analysis to the considerations that lay the basis for a go, no-go decision—to proceed or to halt. The environmentalists must be a part of the basic decision-making appartus.

At issue in the 1970's is a belated recognition that factors heretofore ignored must be brought to bear in decisions that affect, particularly, the husbandry of scarce resources. Some resources are renewable, assuming that they are not irreversibly damaged by man's activities; others are so finite in supply as to be exhaustible in terms of economic recovery.

In short, we must look critically not only at the alternatives of *how* we do things, in the traditional sense of maximizing revenues, but also at whether there are more basic alternatives to the action that would maintain a measure of resource values for future generations; whether the decision should be made now, or whether the options should be held open; and whether to take no action, or whether to pull ahead, counting on the genius of our technicians to do something better later—buggies outclassed by autos, whale oil replaced by petroleum.

Will petroleum be replaced by fusion, solar power, or other sources of energy to power this great economy? Or must we settle for a more conservative level of growth? The full range of these decisions requires environmental knowledge and viewpoint. In short, both the depth and breadth of our considerations must be much greater. We now must consider not only whether to take oil and gas from the Gulf of Mexico off Louisiana but also whether energy alternatives are available to the Nation that would have improved prospects for sparing our national environment. This requires the advice, counsel, and, I submit, the consent of discipline not previously privy to decisionmaking of the more profound type.

The National Environmental Policy Act (NEPA) mirrors the public interest and concern in looking at national problems in a multidisciplinary context. It requires that all agencies of the Federal Government "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking which may have an impact on man's environment."

The courts have restated the essence of the NEPA requirement thus:

NEPA mandates a case-by-case balancing judgment . . . in each individual case, the particular economic and technical benefits of planned action must be assessed and then weighed against the environmental cost; alternatives must be considered which would affect the balance of values. The magnitude of possible benefits and possible costs may lie anywhere on a broad spectrum . . . in some cases the (economic and technical) benefits will be great enough to justify a certain quantum of environmental costs; in other cases they will not be so great and the proposed action may have to be abandoned or significantly altered so as to bring the benefits and costs into a proper balance.

To be redundant, the full meaning is that the modern concept of multidisciplinary planning requires that the planning team must include persons skilled in the environmental arts and sciences, and they must be included at the earliest stage of planning and at the critical decision points so that the basic decision is the right one, in terms of the long-term well-being of man.

This well-being of man is now the critical issue. There must be a clear recognition that, along with the Biblical authorization for domination by man of his environment goes a stewardship responsibility, which, if not discharged wisely, will eventually "do him in," or at least whittle down his numbers to some level more in keeping with a natural carrying capacity of his environment. You, as scientists, know that, and it is not necessary to belabor the point.

Man is in every sense a part of the Earth's ecoystem—a closed loop in which any disturbance to one sector reverberates through the whole web. The general public senses this relationship and, I fear, is more concerned with the implications than many scientists. Thank God for the public concern!

If the NEPA mandates the interdisciplinary approach, the principles and standards of the Water Resources Council provide the planning framework. They are, on first examination, so complex that they threaten to fall of their own weight. It is the challenge of the planning wizards to make them function. The standards do take into account multidisciplinary considerations. What they do *not* yet take into consideration is the need for multiagency interaction.

I can see little merit in adding environmental planners to the planning staffs of the water-development agencies, expecting thereby to have those agencies turned around from their traditional way of maximizing dollar benefits for a select clientele bent on a single objective—development. What is needed is the informed input of such agencies as the Fish and Wildlife Service, the Environmental Protection Agency, and the Geological Survey in the planning of Federal and federally assisted projects. There must be a planning team representative of advocate agencies—and of the general public—in a planning environment that invites interaction, opposing viewpoints, and outright friction at times. Alternatives representing the points of view must be formulated and compared. Tradeoffs must be evaluated and selections made. There must be recognition that some environments must be let alone and that nonstructural alternatives are the test. I believe that this interaction among agencies must take place and that, properly directed, it will produce enlightened results.

As an example of the institutional aspect, the question of what agency performs the fish and wildlife aspects of planning is covered in the Fish and Wildlife Coordination Act. This Act requires that the Service be consulted in such instances and that the Secretary of the Interior provide a report based on such findings. It also mandates certain considerations of fish and wildlife.

As environmentalists we are ill prepared for this kind of venture. The linkage between environmental excellence and human well-being is now only obscurely traced in many facets. There is a dearth of basic information on the exact characteristics of ecosystems and the reactions of those ecosystems to disturbances of various kinds. "What can we reason but from what we know?", to restate Alexander Pope's query. We must know more, and quickly.

Generally, Federal missions concerning the environment are pointed toward increasing our knowledge of the total environment, toward protection of the environment, and toward control and abatement of pollution. Understanding, describing, and predicting environmental phenomena require the investigation or study of weather, ocean-current patterns, earthquakes, and a host of other environmental disturbances and interactions. Basic inventories, which describe the extent, location, and quality of natural resources must be compiled; probably the most important are studies to understand the impact of man upon the environment.

This is no simple task. It means that we must learn something of the composition of the biological community being affected, including species, numbers, biomass, life history, and distribution in space of populations. It means that we must study the quantity and distribution of the nonliving materials such as nutrients, water, and soil types, and it means that we must examine the range or gradient of conditions in the community such as temperature, light, and other factors.

After learning these basics, we must ultimately relate them to man and to man's impact on those systems. Our environmental protection and enhancement activities must include preservation of unique natural areas and endangered species. These activities must include conservation and management of our fish and wildlife resources; recreation and historic preservation and conservation must also be included.

The greatest effort is in the area of pollution-control and abatement activities, including financial assistance to State and local governments for pollution-control programs, regulation of pollution and enforcement standards, research involving control and abatement of pollution, and the control of pollution from Federal installations.

Superimposed upon individual agency programs are national commitments that cross agency boundaries and shape the future of our natural resources. One program, as discussed in the President's Budget Message for fiscal year 1975. is a comprehensive energy program to deal with current shortages and to reestablish our ability to be self-sufficient. This national energy program includes

> . . . reorganization of Federal administrative machinery to deal more effectively with short- and long-term energy needs; stringent energy conservation measures . . . and allocation of petroleum products . . . reporting of oil production, inventories, reserves and costs; modernization of regulations for railroads in order to permit energy savings; policies to accelerate development of domestic oil and gas reserves . . . and development by private industry of western oil shale and offshore oil and gas deposits; measures to permit increased use of our vast coal reserves, including environmental safeguards for surface mining, conversion of oil-fired electric power plants to coal, improvement of mining techniques and accelerated efforts to develop technology for coal gasification, coal liquefaction, advanced combustion systems, and pollution control; development of fast breeder nuclear reactors which it is hoped will greatly increase the amount of energy recoverable from our nuclear fuel resources; more timely approval of sites for energy facilities and accelerated construction of nuclear power plants; and increased research on advanced energy sources including fusion power, and geothermal and solar energy.

I believe that several environmental problems related to this energy program need special attention because of their massive size and the industrial and urban changes associated with them. I would like to mention one or two of these which I consider particularly important, but this list is not all inclusive by any means.

Western coal and oil-shale resources.—The proposed development of the largest coal deposit in the world in Colorado, Wyoming, and the Dakotas, as well as increased production in other sections of the Nation, and the development of extensive oil-shale deposits have the potential for enormous damage to fish and wildlife resources. Proper attention must be applied to these resources and to their associated values during development of both coal and oil-shale resources to prevent destruction and degradation of land and water resources. The Appalachian syndrome—the wrecking of land and man—must not be transmitted to the American West.

Power plants.—Power-plant development is accelerating at a rapid pace. By December 1972, the Atomic Energy Commission had issued operating licenses for 29 nuclear power plants. Another 84 nuclear power plants are either under construction or under operating permit review. Nuclear and other forms of power development have the potential for effecting irretrievable and irreversible environmental losses. The impact of nuclear power plants on our national fisheries must be evaluated. Impingement, entrainment, loss of juvenile fish, and improperly designed screens must be minimized.

Coastal ecosystems.—The Nation's coastal areas, including tidal wetlands, estuaries, contiguous oceans, and the Great Lakes, are being altered by man through dredging, filling, channelization, pollution, and related actions. These fragile environments provide basic habitat requirements and food sources for more than 60 percent of the Nation's fishery resources. Coastal areas further serve as an important nesting, resting, and/or feeding habitat for a variety of animal life forms, including migratory birds, fur animals, and sea mammals, as well as endangered wildlife. Without proper planning and remedial management efforts, renewable natural resources and their environments will continue to be degraded significantly or may be virtually lost in the near future. We may not need the protein base of our coastal fisheries now, but our grandchildren may. We would be a foolish people if we continue to allow the desecration of our estuarine system.

Stream alteration.—This problem, I believe, is particularly appropriate for discussion, because the Geological Survey has a long history of involvement in water-resource problems through its collection of basic information and its basic and applied research programs. Stream alterations, including channelization, clearing, snagging, dams, and diversions, are common water-control and storage methods. The long-term ecological significance of such alterations has been largely ignored. These alterations affect the total ecosystem, which includes the channel proper and the flood plain. Flood-plain ecosystems generally are recognized as the most productive inland habitat in North America.

As Federal, State, and local construction agencies have broadened their environmental perspectives in water use, demands for answers to fish, wildlife, recreation, and ecological questions have increased. Our capacity to respond has not kept pace with the need. Our ability to evaluate biological and socio-economic aspects of water-project development accurately is inadequate. It is necessary for various local, State, and Federal agencies to work together to prevent further degradation of our streams and rivers.

This country is currently in a position where massive programs are going forward with inadequate knowledge or consideration of environmental consequences. We can no longer afford the luxury of compartmentalizing each segment of a resource problem so that it may fall neatly into the technical, scientific, or legal jurisdiction by law or expertise of a specific agency. It is time to look at the entire system, the interactions of that system's parts, and the required basic information for effective and efficient management of these systems.

We are living in an age of real or supposed crises. The real crises of overpopulation and overconsumption of finite materials, of food, and of declining energy reserves will be with us from now on. If light is to penetrate the darkness, if change is going to occur speedily to keep us on an even keel, then some old dogs must learn new tricks.

Paul Ehrlich brilliantly pointed out that it is not the starving have-not nations that are creating such a terrible strain on the world's ecosystems. It is we—the inhabitants of the highly industrialized nations—who generate the spiraling never-ceasing demands that overload our systems and resources. He stated in a recent speech:

> We have got to end the insane growth of consumption in the overdeveloped countries, and this can be done with a great increase in the quality of life. We can reduce our energy consumption and live better.
>
> We have got to stop population growth in the *over*-developed countries because it is the most serious population growth in the world, and it is starting to climb. We have got to convince under-developed countries that imitating the kind of development that we have done, say in the United States, would be a lethal mistake, and hope that they will choose different development goals, and that in particular as they choose their options, they will try and take ones which will lead among other things to lower birth rates as rapidly as possible. We will never convince them to do that unless we change our own ways . . . and if people cannot change their behavior rapidly enough, then we just will not get the job done, and like many other species that have overshot the carrying capacity of their environment, we will pay the price."

The American people cannot continue their accelerating growth binge. Sooner or later, even without our intervention, limiting factors will halt the growth. The major question is whether or not control of the growth syndrome will be the result of rational carefully planned human action or of chaos.

The scientists of the Geological Survey will be part of the great decisions which we as the world leader must make. The verdict on our success in this mission has not yet been rendered. The decision is in the hands of you, the educated. You must prepare a constituency to face up to the realities of the hard choices we collectively face.

NATURAL-HAZARDS REDUCTION

By FRANK PRESS
Chairman, Department of Earth and Planetary Sciences,
Massachusetts Institute of Technology

Up to this point in the symposium we have heard about energy and mineral resources and their development in the context of the need to conserve the environment. The same forces that created the hospitable and rich environment that enabled life to develop and civilization to progress beyond the Stone Age also trigger earthquakes, volcanic eruptions, tsunamis, and landslides and contribute to climatic change and destructive weather.

The human need to understand nature in order to discover her material wealth and to gain protection from her vagaries survives to this day as the major motivation of earth scientists. It is fitting therefore to take up the question of the Nation's response to natural hazards at the dedication of the new capital of earth sciences here in Reston, Va.

I should like to review for you some of the scientific progress of recent years and to say something of the response required by our public agencies to match the technical advances.

To begin with, let me first document the need for a national program dealing with natural-hazards reduction. Some years ago, when I presented a proposal for research in earthquake prediction and earthquake engineering to the President's Science Advisory Committee, one member questioned the need for a major investment in research, pointing out that in the history of our country only a few hundred lives were ever lost to earthquakes and that the apparent loss from earthquakes in this century could not have averaged more than about $20 million per year. What was overlooked in this critique was the future loss potential from a reoccurrence of a great earthquake such as those in San Francisco in 1906, Los Angeles in 1857, and New Madrid, Mo., in 1811. Tens of billions of dollars and tens of thousands of casualties are the kinds of numbers that have been appearing in sudden-loss estimates. Catastrophic earthquakes have occurred in the past and will occur in the future, as any geologist would vouch. The new ingredient is the astronomic growth in population and investment in the earthquake-prone regions of our country. Some 30 million people now live in the 20 States that are in seismic-risk zone 3—the most dangerous category in the seismic-risk map of the United States. An additional 40 million live in seismic-risk zone 2. The San Fernando earthquake of 1971 was a sobering experience to geologists and engineers. This relatively small tremor (much less than 1 percent of the energy released in the San Francisco quake) occurred in a densely populated region. The damage bill came to $500 million. Too few people know that one dam was stressed to near the failure point and that a slightly larger shock on another day would have resulted in casualty figures in the tens of thousands.

When one considers tsunamis, volcanism, hurricanes, storm surges, tornadoes, and landslides, no communities in our country are immune to loss from natural hazards.

On the bright side is the remarkable progress that man has made in understanding the natural systems that constitute his environment. In the limited time available to me I will highlight our new insights concerning the Earth's internal forces, although an equally impressive report could be made about our new understanding of the atmosphere and oceans.

The past decade has been a period of great discovery and excitement in geology. For the first time an all-encompassing theory—that of plate tectonics—ties together the large-scale geological phenomena of our planet. Most earthquakes and volcanoes, for example—their location and the forces that cause them—can be explained in terms of the relative motions of about a dozen plates that make up the outer shell of the Earth. In the laboratory, rocks have been stressed under the conditions of high pressure and temperature that exist in the Earth's interior, and physical changes that precede rupture have been found and explained. In research pioneered in the U.S.S.R. and extended here, these same changes have been shown to exist in the Earth's crust prior to an earthquake. Volcanoes have been instrumented, and the progress of magma from the deep interior to the place of eruption has been charted. To draw an analogy with medical research, it is as if the etiology of 90 percent of cancers was understood for the first time. We have reached a point where prediction of earthquakes and volcanic eruptions and accurate forecasting of tsunamis and landslides are achievable goals.

Rapid progress has been made in another aspect of hazard mitigation—the physical description of the hazard, mapping its geographic extent, and allowing for the response of structures to the forces involved. For example, more data have been accumulated on ground motion and soil response due to earthquakes in the past few years than in all preceding time. A whole new approach to risk analysis is being developed involving a physical description of the hazard, its probability of occurrence, and hazard-resistant design alternatives, all of which raise decisionmaking from the level of guesswork to a highly professional act. In citing these few examples, I want to make the point that science and technology are opening the possibility of significantly reducing man's vulnerability to natural hazards. As exciting as this progress has been, the effort has been supported at below the critical level needed to achieve these goals, in an operational sense, in this century.

Regardless of progress on the technical front, significant hazard mitigation cannot be achieved without a Federal policy and an organized program. For example, a policy decision to augment support in earthquake-prediction research can bring this goal to fruition in years rather than decades. The Government, through the many ways it influences construction—disaster insurance, impact statements, U.S. Army Corps of Engineers approvals, Government construction, subsidies, disaster relief—can mandate land-use and construction-engineering practice on the basis of the new technology. Information transfer from the research centers to the communities can be expedited in this way. It is an interesting yet sad commentary that in hazard-risk analysis both in this country and in the U.S.S.R., specialists have developed powerful techniques to rationalize decision-making in land use and construction, yet these specialists have difficulty is finding customers for their new technology.

Just as natural hazards know no geographic boundaries and affect man and his culture in many ways, so does the Government responsibility cut across departmental lines. The Departments of Housing and Urban Development, Health, Education, and Welfare, Defense, Interior, and Transportation and the Atomic Energy Commission, Veterans Administration, and the Food and Drug Administration have legitimate roles to play, as do State and county governmental units. There are not many precedents for policymaking involving so many agencies, some of which are potential users of new technology, some developers of new technology, and some serving in both capacities. Then there is the matter of relative urgency. If a major catastrophe were to strike tomorrow, the following day would almost certainly see a government-wide policy in natural-hazards mitigation. How does one sell preventive medicine for a future affliction to agencies beleaguered with current illnesses?

I believe that scientists and engineers must assume a role of advocate and even special pleader when they perceive a sluggishness in the Government's response to some new opportunity or to some future danger. It is not outside of the scientific tradition for scientists to make a case before the Executive Office or to brief Congress on an important issue. Einstein did it in his famous letter to President Roosevelt on the possibility of an atom bomb. The possible stress to the environment from a fleet of SST's, the nongovernmental expert testimony on ABM's, the design of a national cancer-research program, the campaign against cigarette smoking—these are famous examples where experts have reached and influenced branches of government.

Earth scientists anticipated the energy and mineral-resource crises. They knew years ago that these critical shortages would trouble us, beginning with the last decades of the 20th century, yet they are liable to the criticism that they did not speak out loudly enough or did not reach the right pressure points to influence Government policy.

Earth scientists have a case to make. They can point to housing tracts placed in fault zones or on unstable hillside slopes. They can cite newly built hospitals that collapsed when shaken by a moderate earthquake. They can question the policy of a department of the Government that spends billions in construction yet is unable to support research that would safeguard its investment. They can question the wisdom of budgeting less than 0.1 percent of the total construction investment for hazard-mitigation research. They can show how a research dollar invested today can yield an enormous return in lives saved and property preserved tomorrow. At a time when basic research budgets have not kept pace with the growth in the GNP, earth scientists can point up the practical value to society of their new comprehension of the forces that have shaped our planet.

What kind of Government policy is needed to encourage and then to exploit progress in the technology of hazard mitigation? After we list the ingredients of such a policy, it will become clear where in government the responsibility should lie for organizing and implementing a program.

I list some of the ingredients of a national policy:

1. Goals for hazard prediction, with adequate research support to implement these goals; for example, earthquake prediction in California in 10 years.
2. Goals for hazard control; for example, hurricane modification in 20 years.
3. Regionalization of the country according to disaster potential.
4. Land-use policy according to disaster potential, including regulations and incentives.
5. Research and development in antihazard engineering and risk analysis.
6. Development of construction codes in accordance with latest research and development results.
7. Use of new approaches to risk analysis in siting, selection of alternatives, and investment decisions.
8. Insurance, disaster relief, and reconstruction policies consistent with the preceding.
9. Information-transfer and public education program.

This list covers several disciplines and cuts across the responsibilities of various departments of the Government. Indeed, the budget for such a program would appear as a crosswalk table involving many agencies and many technologies.

It seems clear that a disaster-mitigation program must receive a charter and guidelines from the highest levels of the Government. Management, coordination, and interdepartmental budgeting are essential elements, as are the involvements of state-of-the-art science and technology. I believe that a task force, chaired by the President's science advisor, which should include senior representatives of the Office of Management and Budget (OMB) and the cognizant government departments, is called for. The coordinator must have authority, and he must enjoy the confidence of OMB, both of which go with proximity to the Executive Office. I believe a strong Government-wide program would receive the support of Congress. Does any one doubt that we would have a program similar to the one that I have described after the next magnitude 8 earthquake in a western State? Why not reduce the severity of future catastrophe by organizing a national program now. Earth scientists should take the lead in selling this concept and then getting on with this challenge.

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