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FEDERAL WATER RESOURCES RESEARCH: A Review of the Proposed Five-Year Program Plan

A Report Prepared by the
Water Resources Research Review Committee
Commission on Natural Resources
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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DEFINITIONS

The following definitions were used by the Committee in preparing this report.

Research. The process of formulating and evaluating a hypothesis that might explain or lead to knowledge, understanding, or solution of hitherto unresolved questions or problems.

Basic Research. Research for the purpose of increasing knowledge or understanding of a subject without any specified use that might be made of the results.

Applied Research. Research for the purpose of increasing knowledge or understanding of a subject in ways that will have practical applications to specific problems.

Water-related or water resources research. Basic or applied research dealing with the quality and quantity of water and its occurrence, movement, and storage; the relationships between water and ecology; water and waste-water treatment processes; water resources management; and the political, legal, behavioral, economic, and other institutional aspects of the use of water resources.

Development. The bringing together, testing, modifying, and synthesizing of the results of research into a system or prototype for use.

Demonstration. Actual construction and operation of a system of water management or use for the purpose of showing that a process or technology can be put to practical use.

Technology Transfer. Facilitation of the widespread use of the results of research, development, and demonstration.

Programming. The process of establishing priorities and allocating funds among broad areas of research activities through evaluation of

probable benefits and costs associated with each. Proper programming should permit selection of that combination of research activities which, whatever the constraints on funds and research personnel, promises the largest possible return from the research program. Application of programming concepts to research activities is difficult because (a) benefits and costs of research cannot always be readily evaluated, and (b) in most cases there is a long time lag between the start of the research and its application to problem solving.

Institutional Analysis. Refers comprehensively to social, political, legal, economic, organizational, and administrative analyses.

SUMMARY

The Director of the Office of Water Research and Technology in the U.S. Department of the Interior asked the National Academy of Sciences for assistance in the preparation of the five-year water resources research plan called for in the Water Research and Development Act of 1978. The Academy was asked to review a draft of the proposed plan and comment as to the adequacy of the government-wide program, the allocation of effort among the federal agencies, the technical manpower base for the program, and management policies to improve the quality of the government's water research effort. The Water Resources Research Review Committee was created by the Commission on Natural Resources of the National Research Council to perform the study.

In preparation for its review of the five-year program report, the Committee studied the 1975 assessment of the nation's water resources by the U.S. Water Resources Council and other recent reports that highlight pressing water problems. The Committee then developed criteria by which to determine the research areas of highest priority. Using these criteria, the Committee identified thirty-one research areas where, in its judgement, emphasis should be placed in programming water resources research over the next five years in the continuing effort to see that the nation's water resources are used effectively to provide essential services. The thirty-one research areas are described in Chapter 3 in relation to the professional disciplines. An alternative listing related to problem areas is contained in Appendix B.

The draft of the five-year program report was furnished to the Committee for review in mid-December of 1980. It has many shortcomings. It does not describe an integrated, coordinated five-year research program; rather, it is a compendium of individual agency programs. There is very little discussion of priorities or of the relation of proposed research to national water problems or to the legislation underlying the federal programs. To develop an acceptable plan, these deficiencies need to be corrected; a consistent method of reporting the research program needs to be developed; and information needs to be assembled on certain programs that were not included in the draft.

The draft does not include information on the technical manpower base for the research program. The Committee believes that the necessary manpower will be available to conduct the research contemplated in the five-year program. In the light of recent declines in enrollment for graduate engineering education, however, there is some question as to whether the necessary manpower will be available over the long term. The Committee believes that the research grant programs of the Office of Water Research and Technology can serve an important role in training researchers for the future.

The draft of the five-year program report proposes surprisingly little research in institutional (social, behavioral, economic, legal, and political) areas; only about 2 percent of the federal agency programs are in this area. The Committee believes that the institutional areas should be the subject of significantly greater research effort in the future.

A very substantial portion, perhaps half, of the $380 million program described in the draft report appears to be aimed at providing services for or assessments of conditions or problems in specific localities. Funding for actual research is thus only about 2 percent of the funding for all activities related to water resources by the federal government. The Committee believes this is a modest level of funding, considering the importance of water resources to the national well-being.

The poor quality of the draft of the federal water research program is convincing proof that an improved management system is required for water resources research if the objectives of the Water Research and Development Act are to be achieved. The elements of such a system are described in Chapter 5, against the background of previous attempts at management of water research activities.

No one federal agency or interagency group is charged by law or executive order with responsibility for defining overall goals, determining priorities or coordinating the work of the various agencies. A comprehensive information transfer system has been developed, but there is little evidence that it is used effectively to transfer research results to state and local entities that could use the information. From 1963 to 1977 efforts were made to accomplish all of these functions through the Committee on Water Resources Research operating under the Federal Council for Science and Technology and its successors. While COWRR had some success in the areas of information exchange and coordination, it was not able to exert substantial influence in research programming and funding. In the light of the past experience, the Water Resources Research Review Committee now suggests three types of water management arrangements that might be considered: a managed multiagency research program; a policy committee based in the Office of Science and Technology Policy in the Executive Office of the President; or a committee based in a reconstituted Water Resources Council.

Because of the many outside forces and contingencies that affect the choices among these options, the Committee finds it difficult to recommend one management system over another. As the work of the Water Resources Research Review Committee was nearing completion, the President recommended elimination of the Office of Water Research and Technology and the Water Resources Council and a substantial reduction in the budget of the Office of Science and Technology Policy. If the President's recommendations are implemented, it may be necessary to find a new mechanism for the preparation of the coordinated five-year research plan called for in the Water Research and Development Act of 1978.

1. INTRODUCTION

The Water Research and Development Act of 1978 directs the Secretary of the Interior to develop a five-year water resources research program in cooperation with the state water resources research institutes and other appropriate entities, indicating goals, objectives, priorities, and funding requirements. The act calls for the secretary to cooperate fully with and to obtain continuing advice and cooperation from all agencies of the federal government concerned with water problems, from state and local governments, and from private institutions and individuals, to ensure that the water resources research programs conducted under the act will supplement and not duplicate other water research and technology programs, will stimulate research and development in neglected areas, and will provide a comprehensive, nationwide program of water resources research and development. The act also calls for the President, using such means as he deems appropriate, to clarify agency responsibilities for federal water resources research and development and to provide for interagency coordination of such research.

The Director of the Office of Water Research and Technology in the Department of the Interior asked the National Academy of Sciences to review and comment on a draft of the five-year water resources research program that was being prepared under the leadership of his agency. On May 30, 1980, following several months of negotiation, the National Academy of Sciences entered into a contract to undertake this work. The contract also called for an interim report, to be prepared by September 30, 1980, to assist the Office of Science and Technology Policy in establishing priorities to be used in preparation of the President's FY 1982 budget for water resources research. The interim report, Water Resources Research Priorities for the FY 1982 Budget, was completed on September 15, 1980.

On December 18, 1980, copies of a proposed report, U.S. National Water Resources Research Development, Demonstration, and Technology Transfer Program 1982-1987 (hereinafter referred to as the five-year program report), were furnished to the Water Resources Research Review

Committee (WRRRC, or "the Committee"), established by the National Academy of Sciences to undertake the work specified under the contract. The contract provided that the Academy would "(1) review the adequacy of the Government-wide program in water resources research and development and identification of technical needs in various water research programs, (2) make recommendations with respect to allocation of technical effort among the Federal Agencies, (3) review the technical manpower needs and findings concerning the technical manpower base of the program, [and] (4) make recommendations concerning management policies to improve the quality of Government-wide research effort. . . ." This report documents the Committee's analysis and review of the draft of the five-year program report. It sets forth the Committee's conclusions concerning management policies to improve the allocation and coordination of technical research efforts among the various agencies of the government. Because the five-year program report contains no information about the technical-manpower base of the program, the Committee could not reach any definitive conclusions in this area. The Committee believes that adequate manpower will be available to conduct the research program contemplated in the five-year program report, but in light of recent declines in enrollment for graduate engineering education, there is some question whether the necessary researchers will be available over the long term. The Committee believes that the research grant programs of the Office of Water Research and Technology play an important role in training manpower for future research programs.

The draft of the five-year program report does not cover any research programs of the Department of State or other internationally oriented agencies of the U.S. government, and the Committee's work is therefore confined to review of research performed in this country to solve U.S. water problems. It is clear, however, that basic research on water and much applied research and development are applicable outside the United States. Conversely, research and development performed abroad advance our knowledge and contribute to the solution of U.S. problems. A more thorough effort at programming research should take cognizance of worldwide research under way.

This report falls logically into two parts. The first part (Chapters 2, 3, and 4) deals with the water problems that need research, a classification plan, and research priorities and substantive aspects of the five-year program report. The second part (Chapter 5) deals with management and coordination of research programs and possible alternative management arrangements for the future.

2. THE NATION'S WATER PROBLEMS

The nation's water is a vital, finite resource that is used by everyone but cannot be exclusively owned by anyone. By custom, legislation, and court decree, the states and the federal government provide an institutional framework for the allocation of water among often competing uses, for the regulation of the wastes that may be discharged into surface- and ground-water systems, and for the public and private management of water resources. As demands on and problems involving water resources change with increased activities in various sectors of the economy, extensive information is needed about water use in each sector and about the trade-offs involved in any reallocation of water use, to ensure that water is used in ways that promote overall public welfare.

Ever since the nation was founded, public and private entities have grappled with water problems. The federal government has enacted legislation and appropriated funds to try to solve a variety of water problems, beginning with the provision of works for improvement of inland waterways for commercial navigation early in the last century. Most water problems are local or confined to one state; others are interstate, regional, or national in scope. Some have international aspects. The jurisdictions of federal, regional, state, and local agencies change and sometimes conflict. Seldom can a complicated water problem be solved by one jurisdiction alone. In recognition of the national importance of water resources, Congress, in the Water Research and Development Act of 1978, declared that the nation's capabilities for technological assessment and planning, and for policy formulation for water resources, must be strengthened at both federal and state levels, and that there should be a continuing national investment in water-related research and technology commensurate with growing national needs.

Analysis of recent studies (WRC 1978) suggests that regional and national water resources problems can all be related to four general areas. These areas are discussed in the following paragraphs and are used as the background for review of the five-year program report.

Offstream Uses of Water

The United States as a whole has an abundance of both surface- and underground-water supplies, yet in specific regions and at specific times water demands may exceed available supplies. Localized problems of inadequate surface-water supply have been identified in almost all areas of the country, and it has been estimated that by the year 2000 over 20 percent of the country will have serious supply shortages (WRC 1978). In several economically important areas of the country, including the Great Plains, the Southwest, the Gulf Coast of Texas, and Long Island, the local economies depend on ground-water reserves, which, if used in the future as they have been used in the recent past, will be exhausted. The time it will take to exhaust ground-water reserves ranges from a few years in some of these areas to several decades in others.

There are few, if any, remaining substantial technological problems associated with moving, storing, and delivering water from surface or underground sources for agriculture, industrial, and municipal purposes. But while no major technological supply problems are in urgent need of research, many problems amenable to research efforts remain in the areas of environmental quality, health effects, economic efficiency, financing, systems reliability, water rights, and institutions. Needed efforts include the prevention of deterioration in quality of both surface- and ground-water supplies; the reallocation of water from lesser- to higher-priority uses; the planning and development of more energy-efficient distribution systems; sound financing and cost allocation methods for water projects; procedures for effectively renovating and replacing major antiquated systems in urban areas; the development of systems that will be reliable in areas subject to major natural disasters; an equitable definition of water rights; and the appropriate structuring and coordination of institutions at federal, state, and local levels.

Ground-water contamination by saltwater encroachment in coastal areas, infiltration of wastes from livestock feedlots, solid-waste landfills, fecal coliform bacteria from septic tank drainfields, and discharges of toxic and hazardous material pose significant health problems in many areas and potential problems for the substantial portion of the population that depends on water from underground sources. Areas of ground-water pollution have been identified in every state in the country.

Measures that should be considered to reduce the frequency and extent of problems caused by inadequate water quantity and/or quality at specific locations include water reuse and recycling, reallocations to more productive uses, demand reduction, increased irrigation efficiencies, improved water distribution and treatment systems, reservoir storage, interbasin transfers, weather modification, control of point and nonpoint sources of pollution, prevention of ground-water contamination, improved coordinated ground- and surface-water

management, and coordinated water- and land-use planning. Research problems stem from an imperfect understanding of many of these measures, and research priorities for solution of these problems are discussed in the following chapters.

Instream Uses of Water

Water resources can be inadequate for instream uses because of their poor quality or because of hydrologic, economic, and environmental constraints. Surface-water pollution occurs throughout most of the United States. Municipal, industrial, and agricultural wastes, acid mine drainage, and accelerated runoff from urban areas are the significant sources of pollutants. Significant surface-water pollution from point sources occurs in about 80 percent of the streams of the eastern United States and in isolated areas elsewhere. Significant pollution from nonpoint sources is also widespread.

Quantities and qualities of water are often inadequate to maintain desirable habitats in lakes, rivers, wetlands, and estuaries. Federal and state laws have set water-quality standards for most water bodies, but in many cases these standards have not been met. Ensuring compliance is often difficult because of problems in measurement, monitoring, and control; because the technology required is at present inadequate or too costly; because the standards are sometimes inappropriate to the water body in question; and because necessary institutional changes are difficult to achieve. All too often water-quality standards have been set without sufficient knowledge of the natural assimilative capacity of water bodies and their associated aquatic ecosystems. Likewise, requirements for instream flow quantities have been set, irrespective of the naturally or artificially-induced intermittent flow of streams. The effectiveness of alternative means of dealing with those problems requires further research.

Flooding, Erosion, and Sedimentation

Even after almost half a century of intense federal, state, and local efforts to mitigate damages from flooding, erosion, and sedimentation, major problems continue to exist. Throughout many areas in the United States, damage from floods is increasing in spite of continued investment for structural and nonstructural damage-reduction measures. Major flooding problems have been identified for more than a third of the rivers within the continental United States.

Often overlooked are the loss of productive land caused by erosion, the loss of nutrients that adhere to the eroded soil particles, and the adverse effects of sediment deposits downstream. These effects include increased frequency of flooding and damage and the destruction or degradation of wildlife, fish, and associated aquatic ecosystems.

Accelerated erosion from agricultural land, surface mines, construction sites, and channel banks during periods of high runoff is one of the most pervasive water-quality problems in the country. Sediment carried into streams is deposited in the channels, causing reduction of water-carrying capacity of channels, spread of water beyond stream banks, and reduction of storage capacity in reservoirs.

Both structural and nonstructural programs for flood damage mitigation should be based on the probability of floods of various magnitudes. The sizes of reservoirs, the capacities of stream channels, the requirements for levees and other control structures, the extent of floodplains, the effects of flood-proofing, and the requirements for flood-insurance coverage will all be incorrectly estimated if the assumed probability of floods lacks validity.

In many cases the institutional and legal problems of land-use restrictions, zoning, and other incentives for the best management of the land to prevent flood damage and to control erosion are far more difficult to solve than the technical problems. The technology is reasonably well understood, but without adequate institutional capabilities, the best or most appropriate technology may be impossible to apply.

Investments in Water Management

Some ill-advised investments have apparently been made in water management because of incorrect assessments of the cause and magnitude of water problems; because of institutional limitations that unduly restrict the choice of solutions; because of incorrect projections of future economic, environmental, and social factors influencing these problems; or simply because of research not having been undertaken early enough to obtain sufficient information about how to solve the problems. Excessive focus of research on past problems, or on problems of immediate interest but of short duration, may divert funds from innovative research that might help in identifying and solving significant future problems.

Water problems are not static. Changes in many factors not directly related to water--for example, the rapid development of new agricultural chemicals--can create problems for which no ready solution exists. The sudden increase in the cost of energy raises questions about many energy-intensive water projects and poses the challenge of designing energy-efficient water projects. There clearly needs to be more economic and institutional research devoted to identifying future trends and alternative policies that might reduce unwise investments in water-management.

The Need for Research

For many of the foregoing problems the basic and applied research has already been accomplished in substantial part, if not entirely. What is often lacking, however, is adequate technology transfer--that is, federal, state, and local governmental and private efforts to convey the merits of new ideas to practitioners. In some cases, publicly funded demonstration is necessary to promote widespread use.

Solution of many other problems requires research and development to advance the state of knowledge. Many federal agencies have been authorized by the Congress to undertake in-house research or to fund universities and other research institutions to meet their research needs. The priority research areas described in the next chapter have been selected on the basis of both the seriousness of the problems and the likelihood that research will contribute to their solution. The Committee believes that adequate authorization already exists for undertaking the research by, or under the sponsorship of, the several agencies involved in water research.

3. RESEARCH PRIORITIES

The control and utilization of water involve a great number of scientific disciplines. Not only do technological problems require a diverse array of research efforts, but the institutional implications of water use also need attention. The wide range of the research problems means that some way must be found to classify them.

Classification Systems

Over the past two decades a number of attempts have been made to program federal water research so as to ensure that research in the most important areas will receive the highest priority and that unnecessary duplication of effort will be eliminated. The more important reports on these efforts are described briefly in Appendix A. Almost without exception these reports have resorted to disciplinary classification systems to systematize data on the several federal water-related research programs and to permit ready retrieval of information on what is being done and what is proposed.

In the preparation of its report on water research priorities for the FY 1982 budget, the Committee reviewed previous efforts to establish classification systems for water research problems and defined five major categories for use in its report. The categories used are a simplified version of those recommended in the last report of the interagency Committee on Water Resources Research (OSTP 1977). With appropriate subcategories, this classification system can be used to provide a framework for analysis of agency programs with a view to determining priorities. The categories in this system were used by the federal agencies in preparing the five-year program report that is under review.

To be most helpful, a classification system should relate to the problems with which past, on-going, and proposed activities are concerned and should be compatible with the budgetary system used by the federal government as well as with the customary scientific

disciplines. The Committee's classification system attempts to group research according to the professional disciplines. The Committee recognizes, of course, that its categories are arbitrary, as real-life problems do not fully respect classification systems and are likely to involve many activities that could be placed in more than one category. Moreover, research projects and programs normally can focus on only part of a problem, and results from many research efforts must be synthesized into planning and management solutions. Another way to classify research priorities is to relate them more closely to actual water-use problems, such as drought and water conservation, flood hazard mitigation, waste disposal, water resources planning and policy implementation, and food and fiber production. Several members of the Committee would prefer such a system of classification of research priorities, and Appendix B contains a grouping of the research priorities by problem area. The Committee has agreed to continue to use the system that is discussed in the following paragraphs, however, because it is the system that was used by the federal agencies in the preparation of the five-year program report.

The Committee's five categories are:

- Category I. Atmospheric, Hydrologic, and Hydraulic Processes
- Category II. Ecological and Environmental Relationships in Water Resources
- Category III. Water-Quality Protection and Control
- Category IV. Water Resources Management
- Category V. Institutional Analysis

In using the classification system, the federal agencies found that some of their research, development, or technology-transfer activities did not fit under any of the five categories. These programs are tabulated in the five-year program report under Category VI (Other). They are not discussed here because they do not appear to include any work the Committee considers to have high priority.

Criteria for Establishing Research Priorities

The Committee used a number of criteria in recommending priorities for water research in the five categories:

A. The importance or severity of a water problem as indicated by its

   1. effects on human health and life;
   2. effects on the environment, quality of life, and sociocultural values;
   3. effects on local, regional, and national economies; or
   4. irreversibility of damage to the resource.

B. The probability that research (within the limits of time, talent, and money available) will improve knowledge and lead to solution of problems by

   1. expanding the understanding of basic principles, or
   2. identifying technological or institutional factors that might foster or hinder solutions.

C. Judgment as to the cost of the proposed research in relation to possible benefits as compared with benefits that might be derived from other water research.

The Committee's interim report on research priorities for the FY 1982 budget presented conclusions and recommendations as to the priority areas of research for the near term, based on a report prepared by the federal agencies showing what they proposed to do in FY 1981. This final report presents the results of the Committee's review and analysis of the five-year program report, which indicates what each federal agency believed was needed and justified without considering other uses of federal funds as expressed in the President's budgetary policies.

The Committee has reviewed its previous listing of research priority areas in light of comments and suggestions received on the interim report and believes some clarification is desirable. Over the longer term of the five-year program, the terms "critical," "urgent," and "important" lose their significance, and the Committee has not used them in its statement of research priorities for the five-year program. The Committee is aware that different weights or values can be placed on goals, objectives, or solutions to problems, and the priority given an activity can well be different at local, state, regional, and national levels.

Priorities will also shift over time as perceptions and conditions change. The priorities discussed herein thus represent only the Committee's considered judgment as to where the emphasis should be placed in programming water resources research over the next five years. Provision should, of course, be made in any research program for innovative and unprogrammed research that might be proposed by researchers or by water users who perceive that they have a problem. The Committee recognizes, too, that solution of many of the water resources problems requires research cutting across several of the disciplinary categories. Interdisciplinary research is discussed in Chapter 5 of this report.

Research Priorities

The priority research areas are presented here by category, then, not necessarily in the order of importance.

Category I: Atmospheric, Hydrologic, and Hydraulic Processes

In this category the Committee places research on the physical processes involved in the movement of water in lakes, streams, and underground aquifers, including atmospheric and meteorological processes affecting precipitation, water availability, and water quality, and the physical processes involved as water travels through various conveyance systems and reservoirs to points of use. The category includes research leading to basic understanding of the use of water by plants and of erosion and sedimentation processes. Interactions of ground water and surface water are covered, as are the forces and hydraulic processes that ultimately influence floods, droughts, water supplies, and instream and offstream uses.

Hydrologic characteristics of the vadose zone. Researchers have devoted relatively little effort to improving knowledge of the movement of water and its pollutants in the vadose zone, the unsaturated zone below the root zone and above the permanent ground-water table. In many cases pollution from waste dumps, sanitary landfills, agricultural chemicals, and other sources has reached the ground water, precluding the use of well water for human (and sometimes other) purposes. Knowledge of the transport processes for solutes (dissolved substances) from the land surface to ground water is needed so that hazards can be evaluated and controlled before serious problems develop. This research will provide an important underpinning for other priority research areas.

Atmospheric transport and precipitation of contaminants. Atmospheric pollution leading to deposition of particulates and solutes, including "acid rain," is widely believed to be causing serious problems in lakes and streams. Some ecosystem damage has occurred, and agricultural problems may develop. Another committee of the National Research Council is currently assessing these problems (NRC, forthcoming). If water pollution increases with increasing air pollution, other uses of water may suffer.

Research should be aimed at increasing scientific knowledge of how pollutants of all kinds are transported in the atmosphere and eventually returned to the land. This research would permit anticipation of future problems and provide a basis for planning a program to control emission of critical pollutants to the atmosphere. A plan for a national assessment of acid precipitation and its effects has been proposed (CEQ 1980). Research in this area is related to priority research areas in Category II.

Flood frequency determination. Improved methods are needed for evaluating the uncertainties involved in estimating flood probability. Better knowledge of the statistical characteristics of floods and the physical processes associated with excessive runoff is prerequisite to development of effective systems for mitigating damage from floods. By the year 2000, potential flood damage is expected to rise above $4

billion annually in 1975 dollars (WRC 1978), unless the nation finds a better way to cope with floods. Many techniques have been developed for estimating flood frequencies at ungaged sites, but these often give different answers. Research in this area can aid the evolution of improved institutional responses to flood hazards, listed as a priority area under Category V. Some lines of approach to this problem may also suggest improved approaches to predicting probability of drought.

Hydrologic factors in water quality. Pollution abatement programs, especially for nonpoint sources, require monitoring to verify their effectiveness. Monitoring has often failed to give timely and definitive information about degree of success or failure, because time trends in concentration and flux of pollutants are obscured by fluctuations in streamflow. Better techniques for monitoring pollution and relating hydrologic and water-quality data are needed to provide a basis for planning pollution control measures and evaluating the success of measures adopted.

Pollution from nonpoint sources is usually related directly to precipitation and runoff. Such pollution is thus responsive to the dynamics of the hydrologic process and requires different analytical techniques from those appropriate for analysis of pollutants from urban and industrial point sources.

Climate variability and trends. Climate changes, whether induced naturally or technologically (as by carbon dioxide emission) may have profound effects on agriculture and industry and hence on the nation's socioeconomic structure. Intensified research on climate is urgently needed, and greater emphasis should be given to the interrelationship between climate and water resources. Precipitation is obviously the most important element, but temperature and other elements of climate also affect water resources. Research interests range from desertification and changes in the frequency of droughts to changes in the frequency of floods.

As national and global populations continue to increase, the nation is becoming more vulnerable to the effects of variability and extremes of climate on water-related activities of society. If such changes could be predicted, research could be focused on the expected problems, and government policies could be developed to minimize undesirable consequences of expected climatic changes. The national climate program (DOC 1980) is also concerned with research on this topic.

Erosion, sedimentation, and nutrient transport. Research on methods of erosion control has been under way for nearly 50 years, and many useful techniques have been established. Future work should concentrate on new agricultural techniques, such as minimum tillage, which show promise of reducing erosion and conserving energy. Acceptable erosion rates in relation to rates of soil formation need to be established to provide a basis for measures that will prevent the loss of productivity of land resources. The products of erosion

deposited in streams, lakes, and harbors create additional problems with associated costs. Adsorbed and/or associated nutrients, pesticides, and heavy metals are responsible for much nonpoint-source pollution. Research on such transport is closely related to priority research areas described under Categories II and III. Further research should also be directed at finding institutional arrangements needed to put to use techniques that are known to be effective (Category V).

Weather and hydrologic forecasting. Any improvement in the ability to predict weather and hydrologic events on a scale of hours to months would be beneficial to water resources management. Short-term hydrologic forecasting has been practiced for more than 100 years, with success limited largely by the ability to forecast weather. For example, a forecast for a specified amount of rain over a specified time interval provides a basis for making estimates of the probable flood flows that will result. In the very short range, flash flood forecasts are almost entirely dependent on short-term weather forecasts before the rain has fallen. The national climate program (DOC 1980) includes some research that may yield promising results in this area.

Category II: Ecological-Environmental Relationships in Water Resources

Research on the effects of human use, modification, and management of water resources on environmental quality and biological resources constitutes this category, which forms a bridge between the basic ecological sciences and water management. It is a particularly difficult area in which to program research, because the natural functions of water in affected ecosystems and functions of these ecosystems within productive biomes are not well understood. The category includes basic research on aquatic ecosystems as well as research on short- and long-term effects of contaminants on ecosystems as these influence water quality or human health.

Effects of waterborne pollutants on aquatic ecosystems. Contaminants enter surface waters from precipitation and from point and nonpoint sources of pollution. Many contaminants have deleterious effects on plant and animal species (including endangered species) and on the productivity of aquatic ecosystems. The extent of these effects is not yet fully understood, particularly for persistent alterations of water quality. Areas in which research is especially needed include the effects of acid precipitation on water quality and ecosystems, the effects of organic and inorganic pollutants from nonpoint sources in watersheds, and the effects of pollutants associated with sediments and released to aquatic systems over a period of years. Aquatic resource degradation due to eutrophication and biological magnification of certain persistent organic chemicals is a serious and growing problem. Normal functioning of freshwater, estuarine, and coastal ecosystems is vital to nutrient cycling and food chain stability, both of which can be altered by materials and chemicals whose effects in aquatic ecosystems are poorly understood.

Consequences of waste disposal in marshes, estuaries, and oceans. Marshes, estuaries, and coastal waters are more and more heavily used by municipal and other water disposal systems. The natural assimilative capacity of these resource systems may provide more effective waste disposal than alternatives such as incineration or landfill disposal, but knowledge of long-term consequences for the aquatic resources is meager. Sound decisions about use of wetland or marine environments for waste disposal require significantly greater understanding of the hydrology (or circulation) of the systems and of the alteration of nutrient cycles in a wider variety of climatic and biological conditions. For protection of estuarine, coastal, and ocean areas having environmental as well as recreational and economic values, response relationships must be understood well enough to allow benefit-cost evaluations to be made.

Physical alteration of wetlands and estuaries. Wetland resources have come to be recognized as among the most threatened and most poorly understood aquatic systems undergoing alteration as a result of human activities. They are subject to dredging, extensive drainage for agriculture, use as waterways, filling through waste and dredge disposal, and filling for construction sites, all of which affect the productivity of wildlife, reduce diversity of landscapes, and interfere with hydrological processes and nutrient availability. Documentation of the costs and benefits associated with the maintenance and/or development of wetlands is essential if present regulations authorizing habitat protection are to be implemented. The fact that some of these wetland values remain unmeasured, at least in parts of the United States, places potentially important future benefits at risk.

Environmental degradation from water projects. Means need to be developed for mitigating the adverse side effects of water projects. Management of streamflow for hydroelectric power or water supply can greatly alter temperature and nutrient content of downstream waters, often diminishing stream productivity and damaging riparian habitats. Likewise, use of water for once-through power plant cooling can have adverse thermal effects on aquatic ecosystems in some localities. Fluctuation of water levels in reservoirs may promote growth of undesirable aquatic plants and reduce the spawning success of resident fish. Irrigation projects can encourage the growth of a variety of disease vectors or undesirable higher forms of aquatic plants. Conversion of river systems to lakes can block fish and game migration routes, threaten already endangered species, and affect recreational activities. Most of these negative effects can be mitigated, but knowledge is insufficient to anticipate new problems.

Category III: Water-Quality Protection and Control

The quality of water is a major consideration because it often determines the potential uses of water resources. For public water supply, those factors that affect human health are paramount. Other

uses, such as industrial and agricultural, can proceed with different kinds of quality. This category is not concerned directly with the quality of water in its natural setting as it affects the ecosystem (see Category II); it is concerned with the quality of water as it affects offstream uses. Development and use of particular water resources change the availability of the water for reclamation, or reuse. To plan for reuse, it is necessary to understand the movement and alteration of contaminants that are released to the water.

Significance of trace contaminants to human health. The need to develop an understanding of the significance to public health of trace contaminants in water is becoming even more critical despite considerable investment in this area over the past 10 years. A problem of major concern is the potential for chronic disease produced over the long term by exposure to chemicals carried by water. Included are chemicals of industrial and agricultural origin, naturally occuring trace metals, and the chlorinated hydrocarbons created by reactions between chlorine used in water treatment and organic constituents of water. Many cities have used drinking water containing trace amounts of chlorinated hydrocarbons and naturally occuring trace metals for generations without evidence of any widespread major chronic illness. But the uncertainty associated with this practice and with the appearance of newer synthetic organics in water supplies is unacceptable and needs to be alleviated.

Water reuse. The concept of reuse encompasses use of any waters that consist, even in small part, of waste-water effluents, including water taken from sources that have received discharges from upstream communities, industry, and agricultural irrigation, as well as waste-water effluents proposed for direct recycling. Research on reuse necessarily includes improvement of the methods for separating suspended, colloidal, and dissolved solids from water. More specifically, this research covers waste-water treatment and water purification.

Research into water reuse is urgent, since every year higher proportions of potable water supplies are derived from sources containing effluents from upstream users. Because raw water sources of poorer quality may have to be used for public water supply to a greater extent in the future, quality criteria and standards need to be reevaluated. For example, no standard for viruses is now included in the drinking water regulations, and standards for only a few organic chemicals are currently included. Suitable analytical methods must be developed for the detection and enumeration of viruses and other infectious agents such as helminths and protozoa and for the monitoring of chemical contaminants. Reliable surrogates are needed to provide for dealing with contaminants that cannot be directly analyzed.

Reuse of water for purposes that do not require potability does not pose the same degree of health risk as does reuse of water for human consumption. Hundreds of projects involving reuse for industrial and

power plant cooling, irrigation, recreation, and ground-water recharge are already in operation, and more are being planned at an increasing rate. Criteria for many types of reuse systems for nonpotable water have been in effect in California for many years, but an urgent need remains for standardization of such protocols in other locations. Use of reclaimed waste waters where potable water is not required will permit conservation of high-quality water for use where potability is necessary.

Control of contaminants resulting from energy development. Wastes from projected energy industries including coal gasification, coal liquifaction, coal slurry transport, shale oil conversion, uranium ore processing and refining, and geothermal systems will create new, difficult problems in water-quality control. These problems will be especially significant because substantial quantities of such waste waters will be produced in arid areas where water is normally in short supply, and where, therefore, pollution of the water resource may be very damaging to other uses of water. Where water is scarce, energy industries may have to be frugal in their use of water. The result, in all likelihood, will be waste water with high concentrations of pollutants. Research into reliable characterization of the waste waters and waste-water treatment and recycling is thus imperative to reduce costs of cleaning the return flows.

Land disposal of wastes. Land disposal of chemical concentrates, sludges, municipal solid wastes, and other waste materials will probably continue to expand. Various contaminants may affect the quality of both surface and ground water as well as the land itself. Basic information is needed on the short- and long-term transformation, movement, and fate of a whole range of waste materials and their associated contaminants. Research must take into account soil types and moisture regimes, as well as other variables. The establishment of acceptable application rates for waste material on land depends on information of this nature. Control systems for the protection and rehabilitation of ground water must be developed.

Monitoring for pollution control. Substantial investment in pollution control facilities has been made in recent years, but there is no reliable way to gauge success in improving water quality because ambient water quality cannot be monitored effectively. Thus it is frequently difficult to determine which streams are improving significantly over time. The problem stems from a variety of causes, all important. In many streams--particularly wide, shallow, slowly moving rivers--mixing is complex, and the concentration of contaminants within stream cross sections therefore varies. Estimates of contaminant flux are crude compared with those of concentration values, because knowledge of streamflows at water-quality monitoring stations is uncertain (see Category I, Hydrologic factors in water quality). And frequently, contributions to pollutant levels from bottom deposits are ignored. The need for improved monitoring systems is acute in view of the continuing large expenditures for waste-water treatment systems.

There is special need for dependable, cost-effective systems of monitoring that will provide warning of the occurrence of spills or accidental discharges of hazardous chemicals and oils. Such spills are among the most perplexing problems in water-quality management: the special threat they represent to public health and ecosystems is large; the threat to social and economic values is substantial.

Category IV: Water Resource Management

This category comprises research on the physical and engineering principles, methods, and techniques involved in managing the use of water resources. For example, floods and droughts can be managed to a degree by techniques that divert, store, or conserve water if the natural processes are sufficiently understood. Conservation (the beneficial reduction of water use and/or losses) may decrease the need for construction of new facilities and reduce energy demand. Research on the management of water for multiple purposes falls within this category, as does research on the effects on water of developing other resources, such as energy.

Water problems of food and fiber production in stressed environments. The production of food and fiber in environments stressed by water shortage or by contaminants in the water is a vital issue. In the arid, semiarid, and subhumid areas of the western states, food and fiber production is highly dependent on water for irrigation. In many areas, particularly in the lower Colorado Basin, salinity of irrigation supplies is an important problem. Downstream irrigators are forced to use return flows with increased salinity. This has led to international conflicts, because some of these downstream irrigators are in Mexico. In the humid East, irrigation in coastal areas such as Florida causes local depletions of ground water and lowers the water table below mean sea level, permitting saltwater encroachment or saltwater upwelling.

Alternative inputs and improved cultural practices--e.g., scheduled irrigation for crop production--need to be identified, both for subhumid environments and for stress periods in humid environments. More knowledge is needed about both terrestrial and aquatic food sources and alternatives to them and about ways to develop species with greater tolerance to drought or salinity stresses. Information is needed on minimum irrigation requirements, efficiency of timing of irrigation, and alternative dryland crops or crop adaptability in the face of declining ground-water levels.

Conjunctive management of ground and surface water. In many regions of the United States the optimal management of water resources requires the conjunctive use and blending of surface and ground waters. Adequate management of water withdrawals from either ground- or surface-water bodies requires better knowledge of their interactions. Physical or chemical changes in ground-water systems often affect surface-water systems, and vice versa. Often these sources

have markedly different sets of impurities and therefore significant problems can occur once the waters are blended. Supply interactions can also result in a decline in ground-water levels and a subsequent decline in surface streamflow.

Conjunctive management of ground- and surface-water resources has been shown to be an effective tool for coping with shortages caused by drought, but research is needed to develop reliable monitoring and mathematical models for predicting water quantity and quality in supply systems, optimum rates of withdrawal from and recharge of underground aquifers, and other physical data. Resulting data and models should be matched to the information needs of management institutions to provide a better basis for decision making.

Water conservation in municipal, industrial, energy, and agricultural uses. Water conservation, defined as beneficial reduction in water use and/or losses, has become increasingly prominent in the planning and management of water resources and is likely to continue in the future for numerous reasons. First, in some areas of the country, supplies of ground and surface water are inadequate: new reservoir sites have become increasingly scarce, and ground-water depletion is occurring. Second, the concern for environmental quality has constrained the development of new supplies. Third, political, economic, and institutional problems impede the interbasin transfer of water. Fourth, water-development costs have risen enormously during the last decade as a result of increased costs of land, labor, equipment, and construction materials; higher interest rates; rising prices of energy; and stricter water-quality standards mandated by federal legislation. Finally, the demand for water is expected to increase, particularly in the Southwest, where population growth and urbanization are more rapid than in most other portions of the country.

The effect of water conservation measures is to reduce the scale of, or to delay the need for construction of water resource development projects, or to do both. It is essential, therefore, to ensure that the appropriate combination of water supply and water conservation measures is chosen. Research is needed to identify and measure the full range and magnitude of effects of the reduction in water use and losses. Little is known concerning the possible environmental effects of water conservation. For example, what are the environmental effects when there is a reduction in return flows from various offstream uses?

Control of pollution from nonpoint sources. Although the beneficial effects of treating waste water from municipal and industrial point sources have significantly improved the quality of the streams that receive effluents, the results fall short of what is desired or expected because pollution carried to streams in the runoff from rural, urban, and industrial lands remains largely uncontrolled. Research is needed to identify innovative methods for effectively reducing pollution from nonpoint sources, such as residential and agricultural land use, mining, and forestry.

Planning groups operating under Section 208 of the Federal Water Pollution Control Act recommend best management practices in an attempt to reduce pollution from a variety of nonpoint sources. Often the effectiveness of these practices is not verified. Research is needed on the transformation and transport processes involved in nonpoint-source pollution and on reliable monitoring and verifying techniques. Improved chemical transport models are needed to systematize information so that effects of development or changes in land use can be accurately predicted. Research in this area is related to priority research areas in Categories I and III.

Management systems for water resources. Water management typically has multiple, complex effects on economic efficiency, environmental quality, distribution of income, health and safety, and other social objectives. Many aspects of these effects are not well understood, and better methods are needed to identify economic and environmental impacts of and trade-offs among alternative courses of action. This information must then be communicated to both professionals and citizens; the information-transfer problem is closely related to some of the research needs identified in Category V.

Management of resources under flood and drought hazards. Annual losses from floods in the United States are increasing, even when expressed in terms of constant dollars. Droughts are well-recognized natural phenomena in rural areas but are relatively little recognized as hazards to urban communities.

Needed research includes studies directed toward improving the delineation of flood hazard areas; discovery of methods for mitigating future flood loss in the process of recovery from a flood; development of a precise definition of "drought" for purposes of urban planning and emergency management (e.g., number of months with below-average rainfall, reservoir storage, or soil moisture levels); development of means to monitor and enforce water conservation restrictions, and finding opportunities for dual systems to permit substitution of lower-quality water (e.g., treated sewage effluent) for nonpotable water uses, such as air conditioning; and development of systems for conjunctive use of ground and surface water during periods of drought. This research is closely related to the hydrologic research mentioned under Category I and the socioeconomic and behavioral research included under Category V.

Category V: Institutional Analysis

The various social, behavioral, economic, legal, political, and other institutional factors underlying management of water resources are the subjects of the research included here. Especially important is research on the institutions designed to ensure effective and socially desirable use of water resources. Other topics of research in this category include methods of estimating emerging and future demands

on the water resource, systems of analyzing the beneficial and adverse effects of various uses of water, and methods for using this knowledge in the decision-making process.

Institutional arrangements for reallocation of water. State and federal laws and the nation's water institutions, in the main, have been established to develop and distribute water in response to demand rather than to manage the reallocation of use among competing demands. Now that costs and effects of developing new water sources are increasing and are often unacceptable to large segments of the public, reallocation of water from one purpose to another becomes a necessary alternative to developing new supplies.

Institutional arrangements for facilitating reallocation of water use through market-transfer mechanisms or other means should be studied with regard to socioeconomic and environmental impacts and trade-offs and with regard to institutional impediments to such reallocations. A related research topic is the institutional obstacles to interbasin transfers.

Institutional arrangements for ground-water management. The physical problems of ground-water management are listed as a priority research topic in Category IV. Adequate institutional arrangements for management and protection of ground water are also crucial to the future of this resource. Increased competition for the use of ground water, the need for safe drinking water, the need for control of toxic substances, and the land disposal of wastes make this problem increasingly difficult. Management of ground-water resources is primarily the responsibility of the states, and some state laws may not be adequate to the task. Furthermore, many ground-water basins extend under two or more states, creating complex management problems. Analyses are needed of the relative efficiency of alternative institutional arrangements for managing the use of ground water, avoiding depletion, and protecting its quality.

Assignment of responsibility for water and related resource management among federal, state, and local levels of government. Some recent proposals to reassign institutional responsibility for planning, financing, constructing, and operating water-management systems among federal, state, and local levels of government create awareness of the fact that allocation of such responsibilities is a major institutional problem. Greater state participation in financing federal water resource projects has been proposed, and an indirect charge has already been placed on users of inland waterways through imposition of a fuel tax. Many other proposals have been made for shifting responsibilities from federal to nonfederal entities. On the other hand, in the case of pollution control, federal authority and responsibility have been increased. Likewise, there are proposals for increasing responsibilities of the federal government for urban water supply, an area where responsibility has traditionally lodged with local communities.

Presumptions that underlie existing allocations of authority and responsibility should be identified, and the validity of those presumptions should be analyzed. The experience of the various levels of government in planning, financing, constructing, and operating water-management systems should be analyzed and compared in relation to political, social, economic, environmental, and other objectives.

Institutional arrangements for water conservation. The future importance of water conservation is discussed under Category IV, but not enough is known about the economic benefits and costs of implementing specific conservation measures. Research is also needed on the social, economic, and other institutional incentives for and obstacles to implementing water conservation. The capacities of existing institutions and possible alternatives for implementing water conservation programs should be evaluated.

There is a paucity of information about the factors that affect consumer adoption of water conservation measures except in crisis situations. In a drought crisis, the public has been willing to reduce water use; under nondrought conditions, however, the obstacles to and incentives for the implementation of water conservation measures are different. Research is needed to evaluate the effect of such measures as changes in price--that is, rate-structure changes--on water use. Empirical studies should examine rate structures that provide incentives for water conservation.

Estimates of the effectiveness of conservation measures and their effects may include substantial errors when inadequate water-demand forecasts are used. Water-use forecasts must be developed, by user sector, season, and other factors affecting water use. Research on how to do this is needed.

The effect of public information programs concerning water conservation is poorly understood. Research is needed to evaluate the cost-effectiveness of programs disseminating information on water conservation. In addition, it is important to learn to estimate how socially acceptable potential conservation measures would be. Without such estimates, it is difficult to predict the reduction of water use from given conservation measures.

Flood and drought hazard mitigation. Needed research on management systems and technologies for reducing risk from floods and droughts was discussed under Category IV, and research on flood frequency determination was discussed under Category I, but research on the institutional aspects of the same problems is also needed. Management systems and technologies for avoiding and alleviating risk from flood and drought through structural and nonstructural measures are known, but often poorly implemented. Better methods are needed for evaluating the effectiveness and analyzing the economic and social benefits and costs of alternative flood and drought management programs. Improved legal, financial, and other institutional arrangements could reduce

exposure to loss and reallocate costs. Research is needed on how to improve communication of hazard forecasts to potential victims so that suitable responses are elicited; how to manage disaster relief programs so that future exposure to flood or drought is reduced; how to manage hazard insurance programs so that new development in areas of high risk is discouraged; how to achieve better coordination among public authorities both vertically (federal/state/local) and horizontally (between adjoining jurisdictions); and how to assess the liability of public authorities, lenders, realtors, and sellers of real estate for failure to disclose known or probable flood hazards to land purchasers.

Resolution of conflicts over alternative courses of action. The complexity of differences in public and private values associated with water resource use has led to the preparation of plans for alternative courses of action. For each alternative plan, account must be taken of beneficial and adverse effects on a number of objectives. Different interest groups often place different values on the same objectives, however, and resulting conflicts can block selection of any course of action.

Research is needed to determine the effects of various public participation techniques and programs in water resource planning. Answers to questions such as the following are needed. How effective is public participation in water resources planning? What are the obstacles and incentives in effective public participation programs? What are the costs of various programs? To what extent has public participation affected water resources planning? What factors help or hinder the achievement of a broadly supported plan?

Institutional arrangements for achieving erosion and sediment control. Decades of research, education, and technical and financial assistance have not yet resulted in agreement on acceptable levels of erosion control and on the relationship among soil erosion control, soil losses, and soil formation. In addition to research on the physical processes involved and on control techniques discussed under Category I, further research is needed on the institutional problems. The institutional arrangements that have been used to control erosion on privately owned land should be analyzed and their deficiences identified. Alternative institutional arrangements should be formulated and tested for incentives and sanctions that might achieve acceptable erosion and sediment control.

Impacts of water-management policies and programs. Over the past two decades, Congress has established more than 15 new federal programs involving water resources management. The benefits and costs of these programs should be analyzed to determine whether they are working well, need improvement, or should be abandoned.

Institutional arrangements for water resources research. Like water management itself, water research has become a highly complex institutional system involving many organizations and professional and

scientific disciplines. In the conduct of its assignment, the Committee has become convinced that the institutional arrangements for water research should themselves be the subject of research to identify the most productive and efficient alternative arrangements for conducting water resources research.

4. ASSESSMENT OF THE FIVE-YEAR PROGRAM

This chapter contains the Committee's comments on the substantive aspects of the water resources research program described in the draft of the five-year program report and also includes suggestions for improving the draft and for preparing future five-year programs.

Preparation of the Five-Year Program Report

The 350-page draft of the five-year program report was prepared by an ad hoc water research work group consisting of representatives from the federal departments and agencies having programs related to water resources. This group, reporting to the Office of Water Research and Technology and the Office of Science and Technology Policy, had previously compiled program information that was used in the preparation of an interim report to the President on priorities in federal water resources research in October 1979. Early in June of 1980, OWRT and OSTP issued instructions for preparation of the five-year program report. They called for (1) a brief statement describing each research program, (2) a citation of the statutory authority for the program, (3) a brief description of the primary objectives of the program, (4) estimated total levels of effort for FY 1982 through FY 1987, (5) brief descriptions of the research to be conducted--with dollar amounts per year--identified with the five program categories suggested by the Water Resources Research Review Committee, and (6) a brief program summary stating why the research is being conducted and what benefits are to be derived if the research is successful.

The ad hoc water research work group met several times to exchange information, establish deadlines, and coordinate activities. A member of the OWRT staff was assigned to prepare a summary chapter and to incorporate material from the reports on state and regional water resources research programs, which the directors of the state water resources research institutes had been asked to prepare. There is no indication that the working group itself made an overall assessment of

the five-year program. As a result, the report is merely a compendium of statements of what each agency believes it should do in the water resources research field, with a summary chapter containing brief descriptive material and a tabular summary of the funding requirements.

Content of the FY 1981 Program

The ad hoc working group produced the draft of the five-year program report during the six-month period from June to December of 1980. During that time the FY 1981 budget was undergoing review in the Congress and the FY 1982 budget was being prepared. By the time the report was completed in early December, the content of the 1981 program was well established but the FY 1982 budget had not yet been approved. The five-year program report therefore contains reasonably accurate figures for the FY 1981 program, but the figures for FY 1982 and the five-year period 1983-1987, inclusive, are obviously subject to revision in the light of the national fiscal policies and program changes that will be adopted over the next several years.

The Committee recognizes that the program shown in the five-year program report for the years beyond FY 1981 serves only as an indication of what each federal agency believed should be done, expressed in 1980 dollars, under a continuation of policies in effect at the time the draft report was prepared. Major changes are anticipated through the budget review that is under way at the time this report is being completed, and future inflation will undoubtedly lead to changes in funding figures. As the FY 1981 program is more realistic, the Committee prepared Table 1 to show the current program in some detail by category, by agency, and, where the information was available, by major program area. While the details with which program areas are shown is not consistent among the several agencies, the table does indicate the large number of administrative units that are concerned with water research, development, and technology transfer and manifests a need for coordination within and among major departments.

While the table indicates a total national effort of $380.7 million for water resources research, development, demonstration, and technology transfer, the Committee believes that only a portion of this total consists of activities the Committee would classify as research. In addition to the development, demonstration, and technology-transfer programs, substantial programs that provide service and assessments of conditions or problems in specific localities seem to be included. The exact magnitude of these nonresearch programs is difficult to determine from the generalized narrative in the draft report, but the Committee believes that the research program is about half of the total.

The table shows clearly that more than half, about $200 million, of the reported 1981 program represents activities concerned with aspects of pollution abatement and control and the quality of the environment.

TABLE 1. National funding of water resources research, development, demonstration, and technology transfer, classifed by WRRRC research categories, FY 1981 (in millions of dollars[a]).

Departments (agencies and programs where available)	WRRRC Categories						
	I	II	III	IV	V	VI	Total
Agriculture							
Economics and Statistics	—	—	—	—	1.1	—	1.1
Forest Service	0.5	0.5	0.3	7.0	—	0.5	8.8
SEA Agricultural Research	3.4	1.0	5.8	26.6	—	—	36.8
SEA Cooperative Research	—	1.5	2.3	0.7	0.1	0.1	4.7
SEA Extension	—	0.3	1.7	0.4	—	—	2.4
Total	3.9	3.3	10.1	34.7	1.2	0.6	53.8
Commerce-NOAA							
NWS Hydrologic Programs	1.5	—	—	0.4	—	—	1.9
NWS Precipitation Forecasting	0.8	—	—	0.2	—	—	1.0
NWS Systems Development	—	—	—	0.4	—	—	0.4
ERL Meterological	0.2	—	—	—	—	—	0.2
ERL Weather Modification	0.2	—	—	0.1	—	—	0.3
RD Weather Modification	1.1	—	—	1.1	—	—	2.2
ERL Marine Environment	0.2	1.0	—	—	—	—	1.2
ERL Wave Propagation	2.1	—	—	0.1	—	—	2.2
ERL Air Resources	0.2	—	—	—	—	—	0.2
ERL Fluid Dynamics	0.3	—	—	—	—	—	0.3
RD Great Lakes Environmental Laboratory	1.1	2.5	—	—	—	—	3.6
RD Sea Grant Program	—	4.6	0.9	0.5	0.8	—	6.8
CZ Coastal Zone Management	—	0.1	1.6	1.6	0.2	—	3.5
F Fisheries/Habitat	—	6.4	1.6	—	—	—	8.0
EDIS Environmental Assessment	0.1	—	—	0.1	—	—	0.2
EDIS Geo-Solar Data	—	—	—	0.6	—	—	0.6
NESS Office of Research	0.2	—	—	—	—	—	0.2
NOAA Remote Sensing	1.6	1.5	—	—	—	—	3.1
Total	9.6	16.1	4.1	5.1	1.0	—	35.9
Energy							
Energy Sciences	1.7	—	—	—	—	—	1.7
Power Marketing	—	—	—	—	—	—	—
Geothermal	8.1	—	—	—	—	8.4	16.5
Nuclear	1.3	0.1	0.1	4.7	—	0.1	6.3
Health/Environment	—	0.9	1.0	—	—	—	1.9
Small Hydroelectric	—	0.4	—	0.4	—	—	0.8
Environmental Compliance	—	—	1.3	1.6	—	1.8	4.7
Environmental Analysis	—	—	0.2	0.3	0.3	0.7	1.5
Conservation and Solar	—	—	—	—	—	1.0	1.0
Energy Regulatory Commission	—	—	—	0.2	—	0.3	0.5
Other	—	2.1	1.4	—	—	—	3.5
Total	11.1	3.5	4.0	7.2	0.3	12.3	38.4
Health and Human Services							
Food and Drug Administration	—	—	0.4	—	—	—	0.4
Cancer Institute	—	—	2.8	—	—	—	2.8
Eye Institute	—	—	1.2	—	—	—	1.2
Allergy and Infectious Disease	—	—	3.2	—	—	—	3.2
Environmental Health	—	—	1.6	—	—	—	1.6
Toxicology	—	—	2.5	—	—	—	2.5
Total			11.7				11.7

Departments (agencies and programs where available)	WRRRC Categories I	II	III	IV	V	VI	Total
Interior							
Land Management	–	–	–	0.8	–	–	0.8
Mines	–	2.0	–	–	–	–	2.0
Surface Mining	0.3	0.3	–	0.2	–	–	0.8
Research and Technology	1.8	1.7	5.2	13.8	2.9	8.3	33.7
Fish and Wildlife	–	2.5	4.7	10.3	–	–	17.5
Geological Survey	11.3	17.1	–	–	0.5	–	28.9
Water and Power	7.9	0.3	0.3	0.4	0.3	3.7	12.9
Total	21.3	23.9	10.2	25.5	3.7	12.0	96.6
Transportation							
Coast Guard	0.1	0.4	3.2	–	–	–	3.7
Highway Administration	0.7	0.5	–	–	–	–	1.2
St. Lawrence Seaway	0.1	–	–	0.4	–	–	0.5
Total	0.9	0.9	3.2	0.4			5.4
Environmental Protection							
Municipal Waste Water	–	–	21.4	–	–	–	21.4
Industrial Waste Water	–	–	16.3	–	–	–	16.3
Water Quality	–	–	26.0	–	–	–	26.0
Drinking Water	–	–	28.7	–	–	–	28.7
Total			92.4				92.4
NASA	1.7	0.2	1.0	1.7	–	–	4.6
NSF	2.1	1.4	1.1	–	–	–	4.6
TVA	0.3	1.2	2.2	1.5	0.2	–	5.4
U.S. Army Corps of Engineers							
Materials	–	–	–	3.3	–	–	3.3
Coastal Engineering	2.9	–	–	4.8	–	–	7.7
Floods and Navigation	0.2	–	–	4.8	–	–	5.0
Environmental Quality	–	3.5	0.3	–	–	–	3.8
Planning	1.0	–	–	1.4	0.8	–	3.2
Satellite Application	–	–	–	0.9	–	–	0.9
Aquatic Plant Control	–	–	–	1.4	–	–	1.4
Fisheries Protection	–	1.5	–	–	–	–	1.5
Environmental Studies	–	4.8	–	0.1	–	–	4.9
Stream Bank Erosion	–	–	–	0.2	–	–	0.2
Total	4.1	9.8	0.3	16.9	0.8		31.9
Total for all programs	55.0	60.3	140.3	93.0	7.2	24.9	380.7

[a]Data have been rounded to nearest 100,000 with adjustment to conform to agency totals.

SOURCE: Compiled from the five-year program report.

Although institutional factors are generally recognized as being the critical or limiting factors in solving water problems, it appears that less than 2 percent of the 1981 research program falls into this category.

Content of the Five-Year Program

The draft of the five-year program report presents information about the broad research areas and associated budgets but does not contain any analysis or narrative that indicates what the federal agencies would consider research priorities. Some priorities are suggested, of course, by the program areas scheduled for funding in future years, but there is very little indication of why individual programs are to be increased or decreased. Table 2, a summary of the entire five-year program by category, is taken from the summary given in the first chapter in the report.

For activities in Category I--atmospheric, hydrologic, and hydraulic processes--$55 million is available in FY 1981, and funding in this area is projected to remain essentially level through FY 1987. This level appears to be inadequate in view of priority research needs in this area. The Departments of the Interior and of Commerce are the major departments programming research in this category.

TABLE 2. Funding in the proposed five-year programs of all agencies (in millions of dollars).

	Fiscal Year						
WRRRC Category	81	82	83	84	85	86	87
I	55.0	55.4	59.2	57.9	57.4	57.2	58.1
II	60.3	66.8	71.2	74.4	75.9	77.5	80.0
III	140.3	147.0	182.4	211.4	221.8	213.5	203.4
IV	93.0	117.5	109.6	113.5	119.1	125.7	133.6
V	7.2	9.4	11.4	11.9	10.2	10.7	14.3
VI	24.9	30.8	27.7	25.7	27.2	26.8	32.2
Total	380.7	426.9	461.5	494.8	511.6	511.4	521.6

Funding in Category II--dealing with ecological and environmental relationships--is projected to increase from $60.3 million in FY 1981 to $80.0 million in FY 1987. We believe this modest increase is also inadequate, in view of the major unknowns in the complex fields of ecology and human health. The major agencies shown to be funding research in this area are the Departments of the Interior and of Commerce. A more detailed analysis might well show, however, that some of the EPA programs in Category III should be classified in this category.

Category III--relating to water-quality protection and control--is the category with the greatest funding, and funding is projected to increase from $140.3 million in FY 1981 to $203.4 million in FY 1987. We believe this level of funding is out of balance with funding in other categories, even though research in this area is very important. By far the largest share of this research is funded by EPA.

Funding in Category IV--dealing with management of water resources--is projected to increase from $93 million in FY 1981 to $133.6 million in FY 1987. This increase appears fully justified in light of the importance of research in this area for finding solutions to emerging national water problems. Major programs in this field are in the Departments of Agriculture and of the Interior and in the Corps of Engineers.

Category V--dealing with institutional analysis--receives by far the lowest level of funding, but funding is projected to increase from $7.2 million in FY 1981 to $14.3 in FY 1987. We believe that major constraints to the solution of water resources problems fall within this category. The increase is therefore well justified, and an even larger increase might be warranted. The Department of the Interior has the largest program in the category; lesser amounts are spent in the Agriculture and Commerce departments. Many agencies do essentially no institutional research but might find it profitable to undertake such work.

The relative size of the existing projected water resources research program is indicated by the data in Table 3. As of FY 1981, the cost of water research and related activities reported in the five-year program report amounts to about 1 percent of the cost of the total federal research and development program and about 4 percent of the money expended by the federal government for water resources and pollution abatement. If, as the Committee believes, only about half of the funds in the program are for water-related research, the figures would be 0.5 percent and 2 percent, respectively. Given the far-reaching importance of water research, the Committee believes this level of funding is modest indeed.

The Committee attempted to determine the extent to which the five-year program report addresses the research topics that the Committee recommended should have the highest priority for the FY 1982

TABLE 3. Federal outlays for water-related research, total research and development, and water resources development and pollution abatement (in millions of dollars[a]).

Fiscal year	Water related-research	Total research and development	Water research as a percentage of total R&D	Total for water resources development and pollution abatement	Water-related research as a percentage of total water resources development and pollution abatement
1965	70[b]	14,889	0.5	–	–
1966	88[b]	16,018	0.5	–	–
1967	117[b]	16,842	0.7	–	–
1968	124[b]	17,030	0.7	–	–
1969	114[b]	16,208	0.7	–	–
1970	121[b]	15,098	0.8	–	–
1971	163[b]	15,005	1.1	3,319	4.9
1972	166[b]	16,103	1.0	3,634	4.6
1973	182[b]	16,784	1.1	3,987	4.6
1974	177[b]	17,500	1.0	4,572	3.9
1975	190[b]	18,700	1.0	5,796	3.3
1976	226[b]	20,200	1.1	6,667	3.4
T.Q.	–	5,400	–	2,072	–
1977	–	22,500	–	7,520	–
1978	–	24,500	–	7,432	–
1979	290[c]	26,600	1.1	8,927	3.2
1980	330[c]	30,389	1.1	8,829	3.7
1981	381[c]	34,002[d]	1.1	8,858[d]	4.3
1982	427[c]	39,648[d]	1.1	9,833[d]	4.3
1983	461[c]	–	–	11,573[d]	4.0
1984	495[c]	–	–	12,429[d]	4.0
1985	512[c]	–	–	–	–
1986	511[c]	–	–	–	–
1987	521[c]	–	–	–	–

[a]Figures are not adjusted for changes in the value of the dollar.
[b]Estimates from COWRR reports.
[c]Estimates from the five-year program report, which includes research, development, demonstration, and technology transfer.
[d]Estimates from the Carter budget.

SOURCES: Budget of the United States, Special Analysis of Research and Development, COWRR reports, and five-year program report.

budget. Such a determination could not be made with precision because the narrative descriptions of the agency programs were not sufficiently explicit in describing the nature of the research. Table 4 summarizes the apparent coverage of the Committee's 31 priority research topics by the programs of the federal agencies. An "X" in the matrix of the table means that descriptive information in the five-year program report suggests that some level of water resources research on or related to the priority research topic is planned. Lack of uniformity and detail in the report prevented our determining the relative coverage or overcoverage of a topic. Thus the presence of an "X" means not that the Committee has been able to determine that a priority topic is being directly, adequately, or efficiently addressed, or that ongoing programs have been changed to devote more effort to priority topics, but only that the agency was sufficiently impressed with the importance of the subject to include mention of it in its narrative. The attention to all but one of the topics (institutional arrangements for water resources research) confirms the importance of these priority areas, but it also suggests the need for interagency coordination and evaluation to avoid duplication and to maximize the benefits to be derived from the research.

Assessment of Agency Programs

The descriptions of the agency programs in the five-year program report are far from uniform in their content and detail. They are generally organized according to the five categories defined by the Committee, but most lack sufficient detail by which to judge the actual nature of the proposed work. There are virtually no explanations or justifications for projected funding trends. There is also essentially no indication of coordination among the agencies; nor is the discussion of research priorities convincing.

The Committee devoted a great deal of effort to analyzing the agency programs but in the end decided that commenting in detail or drawing more than general conclusions from the draft would be unwise. Because of the deficiencies in the report, specific conclusions drawn from our analyses might well have been misleading and could have been damaging to important programs. It should be noted that in most agencies the great bulk of the research is directly related to the mission of the agency supporting it. This is to be expected, but caution should be exercised when conducting mission-oriented research to avoid too narrow a focus, repetition, and rejection of new ideas.

Department of Agriculture

Over half of the research of the U.S. Department of Agriculture--both in-house and through its cooperative programs with the land-grant universities and agricultural experiment stations--is in Category IV (Table 5). The overall program includes research on plant genetics,

TABLE 4. Reported coverage of priority water research topics by federal agency programs.

Priority research topics[a]	Federal agencies appearing to support some water research																					
	Agriculture								Interior													
	Economics and Statistics	Forest Service	Agricultural Research Service	Cooperative Research Service	Extension Service	Commerce (NOAA)	Energy	Health and Human Services	BLM	BOR	OSM	OWRT	Fish and Wildlife Service	USGS	Water and Power Research Service	Transportation	EPA	NASA	NSF	TVA	U.S. Army Corps of Engineers
Hydrologic characteristics of the vadose zone														X						X	X
Atmospheric transport and precipitation of contaminants		X				X												X			
Flood frequency determination						X						X		X	X	X		X	X		X
Hydrologic factors in water quality						X												X			
Climate variability and trends						X												X			
Erosion, sedimentation, and nutrient transport		X	X			X			X		X	X		X	X	X		X	X	X	
Weather and hydrologic forecasting						X	X					X						X			
Effects of waterborne pollutants on aquatic ecosystems		X	X	X		X	X	X					X	X	X		X			X	
Consequences of waste disposal in marshes, estuaries, and oceans						X							X	X	X		X				
Physical alteration of wetlands and estuaries						X										X	X				X
Environmental degradation from water projects							X								X					X	
Significance of trace contaminants to human health							X	X						X			X				
Water reuse						X	X					X					X				
Control of contaminants resulting from energy development							X			X		X		X			X			X	
Land disposal of wastes		X	X	X			X					X					X				X
Monitoring for pollution control				X								X					X				
Water problems of food and fiber production in stressed environments			X	X																	
Conjunctive management of ground and surface water												X									
Water conservation in municipal, industrial, energy, and agricultural uses			X	X								X			X						X
Control of pollution from nonpoint sources		X	X	X			X		X			X					X			X	
Management systems for water resources												X									X
Management of resources under flood and drought hazards		X	X			X															
Institutional arrangements for reallocation of water	X											X		X							
Institutional arrangements for ground-water management	X											X									
Assignment of responsibility for water and related resource management among federal, state, and local levels of government						X															
Institutional arrangements for water conservation	X			X		X						X		X	X						
Programs for flood and drought hazard mitigation												X									
Resolution of conflicts over alternative courses of action															X						
Institutional arrangements for achieving erosion and sediment control	X			X								X									
Impacts of water-management policies and programs	X			X		X						X		X	X						
Institutional arrangements for water resources research																					

[a]Order of listing does not connote order of priority.

TABLE 5. Funding in the proposed five-year program of the U.S. Department of Agriculture (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	3.9	4.3	4.7	5.1	5.6	6.1	6.6
II	3.3	3.8	4.1	4.4	4.8	5.3	5.8
III	10.1	11.1	12.0	13.1	14.3	15.5	16.8
IV	34.7	38.5	43.3	47.2	51.7	55.5	59.9
V	1.2	2.1	3.5	3.5	1.2	1.2	3.5
VI	0.6	0.7	0.7	0.8	0.9	0.9	0.9
Total	53.8	60.5	68.3	74.1	78.5	84.5	93.5

plant physiology, soil fertility, pest control, drainage, irrigation, and agricultural engineering problems. These are major factors in food and fiber production and are important to water resources management, although not all of the above research can be considered to be water resources research. Programs in soil conservation and land and water management are directly related to water resources management. The department's research is also closely related to the concern of the Environmental Protection Agency with control of pollution from nonpoint sources.

The proposed five-year program of the USDA appears to contain some priority work in the following areas: water conservation in agriculture; the effects of fertilizers, insecticides, and herbicides on water quality; the use of land for waste disposal; management of water resources under flood and drought conditions; and the institutional arrangements for water allocation and ground-water management. From the information given, it is not possible to determine the level of effort in each priority area, however, or the amount of overlap between USDA's research and that of other agencies. Emphasis should be placed upon research to improve the tolerance of crops to drought and salinity stresses, in order to improve efficiency of use of existing freshwater supplies and to permit the use of lower-quality water and thereby increase the effective supply of water in some areas of the nation.

Evaluation of USDA's water research program would be facilitated if the narrative description of the program contained better descriptions of the department's research, development, and technology-transfer programs, including examples of expected results or listings of types of questions to be answered. Here, however, are some general comments on research in sections of the department:

- The Forest Service, Agricultural Research, and Cooperative Research programs all contain research on erosion and sedimentation. Much of this research probably should be refocused on the topics discussed under priority research in Chapter 3 of this report.

- The research effort of the Economics and Statistics Service is of major importance because it represents the only substantial in-house capability within the federal government for institutional analysis (Category V). Its economic research and its modest legal and other social science research should be strengthened.

- The erosion and water-management research of the Science and Education Administration/Agricultural Research directed toward improved crop and animal production should be performed in such a way as to provide results that can be more easily related to research programs of other agencies.

- The work of the Science and Education Administration/Extension Service is largely technology transfer and is an important adjunct to the research program.

- Although the Soil Conservation Service does not perform research functions, its technology-transfer services on water management are utilized by individuals and local, state, and federal agencies, and these functions should be better documented.

Department of Commerce

The department's programs are concentrated in Categories I and II (Table 6). Priority research efforts are reported in the fields of weather modification, rainfall forecasting, climate dynamics, and acid rain. This work accounts for about 45 percent of the program. Over half of the programmed funds appear to be service-related in support of the missions of the National Oceanic and Atmospheric Administration. The Sea Grant Program is included in the five-year program, and although it is a very important national program, it is not really a water resources program per se. The work in oceanography and some parts of the weather forecasting research also appear to fall outside the area of water resources research. The funds for coastal zone management do not appear to be properly described as research, as they are used by the states for administering coastal zone study programs.

TABLE 6. Funding in the proposed five-year program of the U.S. Department of Commerce (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	9.6	12.8	18.2	17.4	17.6	18.1	18.3
II	16.1	17.4	19.0	19.5	20.2	20.6	21.1
III	4.1	5.8	5.9	5.9	6.0	6.1	6.2
IV	5.1	7.6	7.9	7.7	7.6	8.0	8.1
V	1.0	1.4	1.5	1.5	1.6	1.7	1.7
VI	–	–	–	–	–	–	–
Total	35.9	45.0	52.5	52.0	53.0	54.5	55.4

Department of Energy

The research program described by the Department of Energy focuses upon meeting needs for water for energy development and upon preventing environmental contamination from emerging and expanding energy industries, including those involving synthetic fuels and increased use of coal. Work falls in all categories (Table 7), but several programs reported in FY 1981 and FY 1982 are not included in the totals for succeeding years because the agency could not predict the future directions of the programs. Much of the research effort is directed toward development of fuel alternatives to petroleum. Part of the effort is related to protection, cleanup, and management of waters associated with utilization of geothermal steam, petroleum and gas, oil shale, and coal. A large effort is proposed for demonstrating the potential of salinity gradients in solar ponds for production of electricity.

The department's program includes some research on small-scale hydropower resource assessment; engineering for energy development; environmental effects and safety of energy development; and legal, institutional, and technology-transfer problems related to energy development. Some of the research proposed appears to fall in our priority water research areas, but a large portion of the program probably should not be considered water resources research or be included in the five-year program.

TABLE 7. Funding in the proposed five-year program of the U.S. Department of Energy (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	11.1	3.3	1.9	2.0	2.2	2.5	2.6
II	3.5	3.4	1.2	1.3	1.3	1.4	1.6
III	4.0	4.0	3.1	3.4	3.5	3.8	4.0
IV	7.2	18.9	3.1	2.8	2.8	3.1	3.1
V	0.3	0.3	0.3	0.3	0.3	0.3	0.3
VI	12.3	9.6	7.2	3.9	3.7	3.9	3.9
Total	38.4	39.5	16.8	13.7	13.8	15.0	15.5

Snowmelt forecasting, listed in DOE's research program, is already practiced by three other agencies, NOAA , USDA (Forest Service), and the Department of the Interior (Water and Power Resources Service); the need for a fourth agency performing research in this area should be carefully evaluated.

Department of Health and Human Services

The Department of Health and Human Services program is all reported under Category III (Table 8), but the Committee believes the portion dealing with shellfish might appropriately be included under Category II. Each DHHS agency listed in the five-year program report is conducting research on agents of disease that may have a relationship with water. For example, the Food and Drug Administration is concerned with the occurrence of toxic substances and biological agents in shellfish; the National Cancer Institute is concerned with identifying agents in water that may be carcinogenic; and the National Eye Institute is conducting research on the prevention of trachoma, a viral disease that may be transmitted through water. Such studies are important to society but can only remotely be considered as part of the water resources research program.

TABLE 8. Funding in the proposed five-year program of the U.S. Department of Health & Human Services (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	–	–	–	–	–	–	–
II	–	–	–	–	–	–	–
III	11.7	12.6	13.6	14.7	15.8	17.0	18.4
IV	–	–	–	–	–	–	–
V	–	–	–	–	–	–	–
VI	–	–	–	–	–	–	–
Total	11.7	12.6	13.6	14.7	15.8	17.0	18.4

Department of the Interior

The Department of the Interior is responsible for developing better ways to identify and foster wise use of a significant portion of the natural resources of the nation. The department has described a total FY 1983 budget of $126.1 million for water research, demonstration, and technology transfer, most of which is evenly distributed in Categories I, II, and IV, with lesser amounts in III and V (Table 9). With the exception of the programs of the Office of Water Research and Technology, the U.S. Geological Survey, and the Atmospheric Resources Program (Project Skywater), the department's program is largely mission-oriented. Priority water resources management research topics include management of ground and surface water, water conservation, control of pollution from nonpoint sources, and methodologies for water resources management.

It appears that a very substantial part of the program is not research, development, or technology transfer, but rather service activities and demonstration of desalting techniques, as directed by legislation. Desalting is energy-intensive and should probably be considered as a technology of last resort. The Committee believes that research and development to serve the existing market for desalting technology should be left to the private sector.

TABLE 9. Funding in the proposed five-year program of the U.S. Department of Interior (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	21.3	24.5	23.6	22.7	21.7	20.3	20.4
II	23.9	26.9	31.4	33.1	33.8	33.7	33.8
III	10.2	11.3	15.8	16.6	17.1	17.2	19.6
IV	25.5	28.2	30.6	33.3	33.9	36.5	39.5
V	3.7	4.4	4.9	5.2	5.7	6.1	6.6
VI	12.0	20.5	19.8	21.0	22.6	22.0	27.4
Total	96.6	115.8	126.1	131.9	134.8	135.8	147.3

The research program of OWRT, mostly carried out through state water resources research institutes, is one of the few major water programs supporting external research that considers unsolicited proposals. Funding of unsolicited proposals is an important segment of the total research program and can help to find solutions to problems unique to particular states or regions. In addition, these programs form a basis for training students in important water resources fields. OWRT would be the appropriate agency to undertake research on management and programming of water resources research, one of the areas the Committee believes to be of high priority that is not mentioned in any of the agency programs.

Work of the Water and Power Resources Service, Bureau of Land Management, Bureau of Mines, and Fish and Wildlife Service is largely mission-oriented, often demonstration or technology transfer, but includes a number of priority research topics. Programs and projects related to pollutants in rain and water-use efficiency in agriculture should be coordinated and performed in cooperation with other federal agencies to avoid duplication, along the lines successfully developed for coordination of the weather modification program of the Water and Power Resources Service with programs of other agencies.

TABLE 10. Funding in the proposed five-year program of the U.S. Department of Transportation (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	0.9	0.9	1.0	1.0	1.0	0.9	0.8
II	0.9	1.0	1.0	1.1	1.1	1.3	1.4
III	3.2	5.2	3.5	3.5	3.6	3.7	4.0
IV	0.4	0.7	0.8	—	—	—	—
V	—	—	—	—	—	—	—
VI	—	—	—	—	—	—	—
Total	5.4	7.8	6.3	5.6	5.7	5.9	6.2

Department of Transportation

The Department of Transportation reports a program of $5 million to $6 million, over half of which is in Category III (Table 10). Its research appears to be entirely mission-oriented, with no priority research component. The Coast Guard is concerned with marine environmental protection. Both the Coast Guard and the St. Lawrence Seaway Development Corporation are concerned with river and lake ice as it affects navigation.

The Federal Highway Administration program is aimed at the design of highway drainage structures and the control of erosion and pollution caused by highways. Research on several high-priority topics is included and should be coordinated with work of other departments.

Environmental Protection Agency

The Environmental Protection Agency is charged with the protection and enhancement of the quality of the environment. In support of this mission, EPA has a broad-based research program, all of which it classifies in Category III (Table 11). The Committee believes that a small portion of the water quality management research program might appropriately be included under Category II. The program includes intramural and extramural research on the effects of contaminants on

TABLE 11. Funding in the proposed five-year program of the Environmental Protection Agency (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	–	–	–	–	–	–	–
II	–	–	–	–	–	–	–
III	92.4	92.0	123.0	149.0	157.0	146.0	130.0
IV	–	–	–	–	–	–	–
V	–	–	–	–	–	–	–
VI	–	–	–	–	–	–	–
Total	92.4	92.0	123.0	149.0	157.0	146.0	130.0

human health and the environment and on the establishment of water-quality criteria and standards. In addition, EPA performs research toward better treatment of municipal and industrial waste water and purification of drinking water. The overall purpose of EPA's research is to provide information and the technical base required by its regulatory and federal grant programs for protecting the quality of the water environment.

From the description of EPA's five-year research plan, it would appear that EPA is addressing most of the Committee's priority topics associated with water quality. The existing technical and scientific knowledge in these areas needs to be expanded through both basic and applied research. Much of EPA's research program has been designed to get quick answers to regulatory problems, without due consideration of the need for basic information of broad utility. In answer to this criticism, EPA has recently initiated research centers at universities and nonprofit research organizations. Supported under EPA's Exploratory Research Program, these centers are supposed to pursue fundamental research on environmental problems. This program is a step toward providing a scientific and technological base for understanding and solving water quality problems.

The EPA research program includes research, development, demonstration, and technology transfer, but the narrative of the five-year research plan does not provide sufficient detail to indicate

the proportion of the budget devoted to each of these activities. Since EPA has the primary national responsibility in areas in water quality, related research in other agencies and departments should be coordinated with EPA's research programs.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration's water resources research program focuses on the development of remote-sensing techniques for use in monitoring the nation's water resources. Most of the research is distributed among Categories I, III, and IV (Table 12). While this work touches on several priority research areas, a large fraction of the budget appears to be for demonstration or technology transfer. Since some of the technology has not advanced to the stage of reliable operating tools, NASA needs to continue to coordinate its program with those of other agencies to improve the reliability and usefulness of remote-sensing information. The research might be characterized as high-risk--i.e., the possible payoff is high, but the probability of success in achieving significant improvement over existing capabilities in the water resources field is low.

TABLE 12. Funding in the proposed five-year program of the National Aeronautics and Space Administration (in millions of dollars).

WRRRC Category	Fiscal Year						
	81	82	83	84	85	86	87
I	1.7	3.2	3.5	3.4	2.9	2.7	2.7
II	0.2	0.2	0.1	0.1	0.1	0.1	0.1
III	1.0	1.0	1.0	1.0	1.0	1.0	1.0
IV	1.7	1.9	1.4	1.1	1.0	1.0	1.0
V	—	—	—	—	—	—	—
VI	—	—	—	—	—	—	—
Total	4.6	6.3	6.0	5.6	5.0	4.8	4.8

TABLE 13. Funding in the proposed five-year program of the National Science Foundation (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	2.1	2.1	2.1	2.1	2.1	2.1	2.1
II	1.4	1.5	1.5	1.5	1.5	1.5	1.5
III	1.1	1.1	1.2	1.2	1.2	1.2	1.2
IV	—	—	—	—	—	—	—
V	—	—	—	—	—	—	—
VI	—	—	—	—	—	—	—
Total	4.6	4.7	4.8	4.8	4.8	4.8	4.8

National Science Foundation

The National Science Foundation's water research activities described in the five-year program report are directed mainly toward providing a better fundamental understanding of the water-related sciences and engineering processes. Its program is primarily based upon the merit of unsolicited proposals from the academic community, and its support is concentrated in Categories I, II, and III (Table 13). Like OWRT, NSF provides important support for basic research and education. Without a detailed assessment of individual project grants, it is not possible to estimate the amount of priority work currently funded, but the nature of the program should make it possible to emphasize priority research.

Members of the Committee are aware of water-related research projects funded by the National Science Foundation in areas that are not covered in the agency's description of its research program. It would be helpful to a display of the entire program if these could be added.

Tennessee Valley Authority

The research program of the Tennessee Valley Authority is directed toward support of the mission of the agency. Activities in all five categories are reported (Table 14). Much of the support seems to be

TABLE 14. Funding in the proposed five-year program of the Tennessee Valley Authority (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	0.3	0.3	0.3	0.3	0.3	0.4	0.4
II	1.2	1.2	1.2	1.1	0.6	0.6	0.7
III	2.2	2.5	2.9	2.6	1.9	1.5	1.7
IV	1.5	2.8	2.9	1.5	1.4	0.3	0.3
V	0.2	0.2	0.2	0.3	0.3	0.3	0.3
VI	—	—	—	—	—	—	—
Total	5.4	7.0	7.5	5.8	4.5	3.1	3.4

for operations rather than research; only about 10 percent of the budget is in research areas. The program discussion includes reference to a number of priority research areas.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers reports activities in all categories, with about half in Category IV (Table 15). About 40 percent of the Corps's proposed program appears to be mission-oriented, with a considerable portion that is more correctly called demonstration, technology transfer, and service than research. Only a very small portion of the program seems to touch on priority research areas, although the Corps has classified its entire program as priority research. As much as 20 percent of the program directed to materials and methods of construction is related to water resources only insofar as it serves the mission of the Corps. A number of the Corps's research projects should be conducted in coordination with other agencies; these include aquatic weed control, water quality, water conservation, soils, rock, concrete, mechanical and structural engineering, estuary models, and hydrologic methodology.

TABLE 15. Funding in the proposed five-year program of the U.S. Army Corps of Engineers (in millions of dollars).

WRRRC Category	Fiscal Year 81	82	83	84	85	86	87
I	4.1	4.0	3.9	3.9	4.0	4.1	4.2
II	9.8	11.4	11.7	12.3	12.5	13.0	14.0
III	0.3	0.4	0.4	0.4	0.4	0.5	0.5
IV	16.9	18.9	19.6	19.9	20.7	21.3	21.7
V	0.8	1.0	1.0	1.1	1.1	1.1	1.9
VI	—	—	—	—	—	—	—
Total	31.9	35.7	36.6	37.6	38.7	40.0	42.3

Suggestions for Improvement of the Five-Year Program Report

The Committee has identified a number of deficiencies in the draft of the five-year program report that need to be corrected if the report is to be of value in guiding Congress and the Administration as the future course of water resources research is determined. Suggestions for improvement are discussed in the following paragraphs.

Priorities need to be treated. While President Carter singled out the setting of "research priorities aimed at meeting our future water needs" in his directive to the Secretary of the Interior and the Director of the Office of Science and Technology Policy, overall priorities are not treated in the report, and separate priorities are discussed superficially, if at all, in the reports of the departments and agencies. No recommendations are made for phasing out or reducing any types of research based on an examination of accomplishments. To be of maximum value, the report should indicate the relative importance of each major area of research and discuss the programs of the various agencies in relation to overall national priorities.

Water problems need to be linked to research problems. The summary of the five-year program report refers to The Nation's Water Resources, 1975-2000--the second national water assessment of the U.S. Water Resources Council--and to the water problems identified therein, but the problems are neither identified nor connected analytically to the mission of the agencies or their research programs.

Research needs to be linked to existing laws. The foreword refers to 18 laws enacted in the last 20 years, presumably to help solve water problems, but no connection is made between the provisions of these laws and continuing water problems; nor, in many instances, are these laws related to the mission statements of the federal departments and agencies. The report should indicate how the research in the five-year program relates to Congressional directives.

A basis is needed for five-year budget projections. The report projects that most agency and program budgets will increase--some substantially--over the five-year period, that some will stay constant, and that a few will decline. Not only is no rationale provided for the individual projections, but no rationale is provided for the size and future trend of federal funding for water research on the whole. The report should show how projected budget increases or decreases relate to research priorities.

Clear and accurate definitions are needed. The report by its title purports to cover more than than "water research"--namely, "development, demonstration, and technology transfer," although these terms are not defined. Rigorous attention is not given to distinguishing those separate activities in the program statements of the individual agencies, and no overall assessment of these activities is included in the program. The instructions to the agencies mentioned only research. Funds for some programs that do not appear to fall under any of the activities are included; examples are the administration grants to states by the Office of Coastal Zone Management, the environmental assessment program of the Department of Energy, the activities of TVA set forth under the institutional research category, and the research on trachoma (even though the disease is waterborne) of the National Eye Institute.

Because development, demonstration, and technology-transfer activities were not included in the draft in a consistent way, we have had no choice but to confine our review mainly to research activities. To be of maximum value, the five-year program report should include accurate definitions of the activities included, and agency program descriptions should be reviewed carefully to see that they are in accord with and cover all of the categories included.

All relevant federal water research needs to be identified. At least one mission-oriented water agency known to fund water research, the Federal Emergency Management Agency, is completely left out of the draft five-year program report. The role of the Water Resources Council is set forth, but no dollar amounts are shown for the research that it and its associated river basin commissions finance. Furthermore, some agencies submitting water research programs have not reported all their water research. Examples are the water research undertaken by the Office of Biological Services of the U.S. Fish and Wildlife Service, water research funded by the National Science Foundation other than on civil engineering, and the economic and other

institutional research funded by the Environmental Protection Agency. Agency programs should be reviewed to determine that all activities qualifying under the definitions are included in the five-year program.

The report should be more uniform in format, style, and depth of description and analysis. Its lack of consistency makes the report extremely difficult to review, and it appears that not even a rough attempt was made to overcome the most obvious disparities. Rewriting, additional analysis, and a rigorous editing of the report are required to correct the problems pointed out in the previous paragraphs.

State water research programs need to be more adequately covered. The description of the OWRT program contains brief regional summaries for the eight regions, and a partial listing of the state institute five-year programs is contained in an appendix to the five-year program report. The summaries do not contain sufficient information to permit a determination to be made of the value of the work done at the 54 water resources research institutes, nor do they cover or relate to the research efforts of other state agencies.

Summary. The Committee believes that the five-year program report can be made into an important guide for programming future research efforts but that inadequate attention has been given to the preparation of the draft furnished for review. Obviously, a considerably greater effort will be required to produce a useful program. Further suggestions as to how this effort should be managed are contained in the next chapter.

5. APPROACHES TO MANAGEMENT OF WATER RESEARCH

This chapter contains a discussion of what a good system for planning and managing water resources research would look like, a review of the history of coordination and management of water research funded by the federal government since the early 1960s, and an examination of three possible alternative arrangements for management of water resources research.

Considerations in the Design of a Water Research Management System

The declaration of policy and statement of purpose in the Water Research and Development Act of 1978 make very clear the Congressional expectations regarding water resources research and the need for clarification and definition of the responsibilities of the federal agency programs. At present, however, no federal agency or interagency group is charged by law or Executive order with responsibility for coordinating the work of the various agencies. The deficiencies of the draft five-year program report indicate the need for clear assignment of such responsibilities if the objectives stated in the 1978 act are to be achieved.

A research management system as a whole should provide the planning and maintain the record of implementation for a comprehensive, government-wide water research, development, demonstration, and technology-transfer program. Goals, problem areas, priorities, and funding requirements should be clearly identified. The program should provide for interagency coordination and elimination of duplication. It should consider the manpower needs of proposed programs in both the short and long run. Finally, it must address the policy issues implicit in many aspects of water research.

Defining Goals

Research management is most effective when it is guided by a clear statement of purposes and objectives. Problems in achieving previously stated objectives should be identified and new goals set. A determination must be made early as to the research, development, demonstration, and technology-transfer activities that are to be included in the program being managed. Guidelines are needed to indicate which activities are to be considered water-related. When priorities are translated into projected budgets, a decision must be made as to the expected sources of funding--federal, state, or private.

As stated earlier, solution of the nation's water problems can be aided by water-related research, but not all problems can be solved by research. Economic limitations, failures in political leadership, and other obstacles can prevent the alleviation of problems even when technical solutions are known and only remain to be implemented. Thus, problems must be examined closely to determine whether their solutions really require research or whether known solutions need to be implemented.

Priority Determinations

Because only limited funds can be made available for water research needs, it is not possible to do all of the work that an analysis of water problems may require. If higher-priority research is to be undertaken, some lower-priority work must be forgone. The criteria for considering research priorities (discussed in Chapter 3) are complex. Their application, in the final analysis, involves informed judgment. There is no technique of benefit-cost analysis by which priorities can be determined mechanically. A system for establishing water research priorities among both federal and state needs must be devised and implemented in a way that is acceptable to research managers.

In addition, the tendency for long-established agency research activities to persist because they are related to agency missions or because the agency has specific facilities and staff must be overcome by government-wide review of priorities. Priorities must change with time because research solves problems as it proceeds, new problems develop, and the relative importance of problems changes with time.

Interagency Coordination

An important component of program management is examination of the opportunities for agencies to conduct joint studies. Most water problem areas extend beyond the purview of any single federal agency. Where more than one agency is conducting research in an area of common or general concern, there is at present no systematic way of ensuring

that the research is not being duplicated. Similarly, there is no effective way of ensuring that important information is being properly exchanged, that no part of the needed effort is neglected, or that the aggregate of the activity is an efficient scientific program.

Experience with multiagency research-program coordination is still scanty. Despite some success in interagency cooperation on the basis of formal interagency agreements, most units of government seem generally to be unpersuaded of the benefits of cooperative studies. Criteria for effective coordination, and understanding of the many routes by which coordination may be accomplished, should be examined fully.

Leadership and Authority

Experience with several different types of programs has shown that leadership with appropriate authority is a major factor in the success of research-planning and -management initiatives, particularly in multiagency research programs. Leadership responsibility should be lodged in the Executive Office or in an office of government fully independent of the major agencies, in order to provide the necessary authority and independence. The leadership structure should be one that promotes direct communication among the research entities and in-depth understanding of the problems and programs of each agency.

Information Systems

The timely transfer of information on newly initiated research, on findings from research in progress, and on the accomplishment of research goals is a basic element of an effective research-management system. In recent years numerous computer-based reference services have been developed to help researchers keep up with the rapid expansion in the amount of literature. Over 60 such computer-based systems are currently available. In the water resources field, this function has been performed by the Department of the Interior's Water Resources Scientific Information Center (WRSIC), which at present contains approximately 150,000 citations. An effective, decentralized information retrieval procedure has been provided.

These systems also could be used to develop summary statistics on topics being investigated, accomplishments, and the amount of effort being planned for specific topics. Although some federal agencies have very effective systems of this type for their research management, such systems have not yet functioned in water resources research management. They could, however, facilitate coordination by showing what agency divisions were involved, where research was apparently being duplicated, and where there might be significant gaps in research. Regular updating and evaluation of such summaries should be a routine component of the water research management system.

Separation of Research and Operating Functions

Many federal agencies have both a water-related research program and an operations program, such as a construction or regulatory program. It is not inappropriate for a mission-oriented agency with an operations function to have a research program. The Environmental Protection Agency, for example, promulgates criteria and standards based on research largely sponsored by the agency. Support of its regulatory responsibilities requires EPA to be involved in research of many kinds. Attention should be given to including broad and basic research in addition to work related to regulatory functions.

Independent Review of Programs

Past experience with interagency programs and with the research-planning process indicates that an independent, outside review is highly desirable. A committee sponsored by a recognized scientific organization with members of national stature in the water resources field would be able to evaluate research priorities and influence the quality of the research conducted. Considering the rate at which new problems are recognized and the pace of research progress, committee review might be required at three- to five-year intervals. Although there are advantages of continuity with a standing committee, ad hoc committees might be more adjustable to changing problems.

Several important conditions should be satisfied if the independent review is to be productive: the proposed research program of the agency or agencies should describe problem areas in specific rather than general terms; the plan should present the major proposed research tasks in logical sequence and with unambiguous objectives; it should include realistic budget estimates; and it should provide reasonable time for the review.

Federal/State Relations

In response to the need for technology to solve local, state, and regional water problems, various federal/state arrangements for cooperative research and technology-transfer programs have evolved. Examples include the Department of Agriculture and the state land grant university programs, the federal cooperative state and county extension services, and the Office of Water Research and Technology and the state water resources research institutes. These nationwide institutional arrangements enable federal, state, and local entities to work together to identify problems, conduct research, and provide information to the public through demonstration and technology-transfer programs. Typical problems addressed by these programs include supplying water of adequate quantity and quality for municipal uses, efficiently using water in food and fiber production, conserving water and soil, and, to some extent, developing technology for industry, energy, business, and

recreational users of water. State and local programs are the key to the operation of this system and are particularly important to the transfer of results from federal research to water users.

Only a few states give significant financial support to water resources research at present. There is a growing need for states to increase their support of research directed at problems important to their own areas. The five-year program plan (discussed in the previous section) seems to make inadequate provisions for technology transfer at the state and local level. Increased effort here could pay significant dividends in the areas of water-use efficiency and water conservation, particularly in municipal and agricultural water consumption. State and local governments are the institutions best placed to disseminate research results, through public education and technical service programs such as those conducted by the county agricultural extension service and soil conservation districts. Increased participation by states and regional entities in research, development, and technology-transfer planning should direct attention to the need for such activities.

In-House vs. External Research

The amount of research and development conducted externally, as opposed to in-house, varies considerably among government departments and agencies, depending on such factors as the nature of the research, agency tradition, availability of expertise, agency budgets, and manpower ceilings. The Committee makes no specific recommendation for shifts in the balance of research between in-house staff and external grants or contractors but notes that such balance should be part of the programming process. It is clear that training another generation of scientists in the universities is related to the conduct of some of the important water-related research at those locations. Private and nonprofit research institutes outside of the government and universities can also play an important research role, particularly in basic research not related to governmental programs and in controversial policy research.

Research sponsored by the National Science Foundation and the Office of Water Research and Technology in the Interior Department has been conducted largely at universities. Other agencies, which may now conduct their research largely in-house, could profitably consider sponsoring research in universities and other nonprofit research laboratories.

Privately Funded Research

Solutions to water problems are not found exclusively by government research, for many reasons. Given public budget constraints, more problems will have to be addressed by parts of the private sector

directly benefited or injured by water conditions and water-management decisions. Quite apart from government spending limitations, such factors as the political contraints surrounding controversial water policy issues, bureaucratic delays, and shortcomings in agency missions and priorities give rise to privately designed, conducted, and funded water research.

A possible analog for the water utilities can be found in the Electric Power Research Institute, which administers a large-scale research program on behalf of member utilities. Private foundations should be encouraged to increase their support, which is now minimal, for water research. In the past, the Ford Foundation and the Rockefeller Foundation, for example, have supported significant water research on topics that have been neglected in publicly funded research.

One of the challenges facing water resources research is how to foster independent research and policy analysis on politically controversial subjects. Water-management agencies serve particular public and private interest groups, and it is difficult for such agencies to encourage research that may be perceived as being adverse to the interests of their constituents. Institutions that have a stake in protecting or enhancing existing interests rarely initiate inquiries into new approaches, policies, and practices that may disturb the status quo. Nevertheless, it is clear that sound future water resources management will depend, in part, on answering hard, often unpopular, questions about prevailing water-use patterns and reallocation possibilities. In developing a national water research management plan, an effort should be made, and responsibility assigned, to foster unconventional or unpopular analysis through publicly funded research. Such analysis will, however, rely very heavily on private sources of funding and politically independent research institutions such as foundations.

Basic vs. Mission-Oriented Research

Review of the proposed five-year research program (see previous chapter) reveals that a preponderance of the research described is directly applicable to the proposing agency's mission. Little of the research appears to be theoretical or basic study undertaken to extend knowledge about national water problems. Since, in any programming effort, high priority will be assigned to problem-solving research, special consideration must be given to maintaining a core of basic research in those agencies best qualified to conduct it. In addition, an effort should be made in planning problem-oriented research to produce new understanding of the underlying scientific principles wherever possible. Even mission-oriented research can be conducted and reported in such a way as to make major contributions to scientific knowledge.

Disciplinary/Multidisciplinary Issues

Water problems, by nature, include many interdependent properties of our environment and our society. Research must be related effectively to the diverse natural and social science fields that bear on the problems, integrating the insights, approaches, and findings of many disciplines. Systems approaches and models, encompassing both quantitative and qualitative analyses, have been developed in water and related fields. They could be used more effectively as tools for research management and to establish links among the disciplines concerned with water research. For example, research on estuaries could be facilitated by integration of models depicting mixing of fresh and salt water, tidal flows, effects of pollution on ecosystems, and other physical processes with complex institutional factors that affect programs.

Institutional constraints tend to inhibit integrated multidisciplinary approaches to research problems. In universities, and in some research laboratories, present promotion and reward systems tend to discourage young scientists from working on multidisciplinary problems. Both university and government research enterprises are resistant to changes in their traditional disciplinary structure. But technologically complex modifications of the environment must be managed with knowledge from many disciplines. Some of the challenges for improving the water-related environment in a technological society will require, ultimately, controlling unwanted side effects resulting from the use of technology. Alleviation of the problem caused by these side effects will necessarily require multidisciplinary, as opposed to traditional disciplinary, approaches to knowledge.

To achieve successful multidisciplinary research requires more than simply bringing people of different backgrounds together and asking them to test hypotheses about complex aggregates of stresses and responses in ecosystems. The most successful results are likely to come from those who have spent time working together, learning the common language of their enterprise.

Previous Attempts at Management of Water Research Activities

The problem of managing federal water resources research has been of continuing concern for two decades. A review of the highlights of past efforts provides a helpful background for consideration of future possibilities.

In January 1961, the Senate Select Committee on National Water Resources recommended that the federal government undertake a coordinated scientific research program on water resources (U.S. Senate 1961). In February 1961, the President directed his Science Advisor and the Federal Council for Science and Technology to "review ongoing Federal research activities in the field of natural resources and to

determine ways to strengthen the total government research effort relating to natural resources" (President of the United States 1961).

As part of this effort, particular attention was given to water resources research. A federal task group issued a report, Federal Water Resources Research, in February 1963 (Federal Council for Science and Technology 1963). This report made the first comprehensive statement of the objectives and activities of all federal agencies engaged in water resources research. It represented an important step in the development of a coordinated program of water resources research as recommended by the Senate Select Committee. The report indicated the need for water resources research, inventoried ongoing programs, recommended improvements in programs, and suggested coordination and planning of research through a committee on water resources research under the Federal Council for Science and Technology.

Committee on Water Resources Research

The resulting Committee on Water Resources Research (COWRR) held its first meeting on September 18, 1963. COWRR adopted a statement of functions (COWRR 1964, p. 2):

- "to identify technical needs and priorities in various research and related data categories;
- "to review the adequacy of the overall program in water resources research in relation to needs;
- "to recommend programs and measures to meet these needs;
- "to advise on desirable allocations of effort among the agencies;
- "to recommend management policies and procedures to improve the quality and vigor of the research effort; and
- "generally to facilitate interagency communication and coordination at management levels."

Coordination under the Water Resources Research Act. During 1962, 1963, and 1964, extensive discussions and Congressional hearings were held on the subject of water resources research. They culminated in the Water Resources Research Act of 1964 (P.L. 88-379, approved July 17, 1964), which authorized grants to the states for conducting programs of water resources research. Two sections of the Water Resources Research Act were of particular importance to interagency coordination. The first was Section 304, which provided in part: "There shall be established in such agency and location as the President determines to be desirable a center for cataloging current projected scientific research in all fields of water resources."

By a memorandum dated October 24, 1964, the President designated the Smithsonian Science Information Exchange as the cataloging center in accordance with Section 304 of the Water Resources Research Act, with financial support from the Office of Water Resources Research--the agency responsible for administration of the Water Resources Research Act--and with the cooperation of COWRR. Information on about 10,000 current water research projects is now stored in the computer system. Although this information system is over 15 years old, the Committee is not aware that there has been any careful evaluation of how well the system serves the needs of the research community, of its possible use in coordinating efforts, or of other ways in which the system might be improved.

The second section of the 1964 Water Resources Research Act that was of importance to interagency coordination is Section 305:

> The President shall, by such means as he deems appropriate, clarify agency responsibilities for Federal water resources research and provide for interagency coordination of such research, including the research authorized by this Act. Such coordination shall include (a) continuing review of the adequacy of the government-wide program in water resources research, (b) identification and elimination of duplication and overlaps between two or more agency programs, (c) identification of technical needs in various water resources research categories, (d) recommendations with respect to allocation of technical effort among the Federal agencies, (e) review of technical manpower needs and findings concerning the technical manpower base for the program, (f) recommendations concerning management policies to improve the quality of the government-wide research effort, and (g) actions to facilitate agency communication at management levels.

The provisions for coordination of research as stated in Section 305 are very similar to the functions adopted earlier by COWRR, both statements stemming from the 1963 task group report (Federal Council for Science and Technology 1963, p. 204).

In his memorandum of October 24, 1964, in response to the research act, the President asked the Director of the Office of Science and Technology to take the lead in coordinating research activities. The President also made note of the fact that substantial progress toward coordination had been made through the Committee on Water Resources Research of the Federal Council for Science and Technology. Thus, COWRR was maintained and strengthened after passage of the Water Resources Research Act, and it provided advice and cooperation to OWRR in the early years of its administration of the act.

Information dissemination. Retrieval and dissemination of information on water resources research was of major interest to COWRR. Its studies led to the conclusion that a central information facility for water resources research would be more useful than

separate systems within each agency, which would necessarily overlap. Accordingly, the committee recommended that a central facility be established in OWRR in the Department of the Interior. OWRR established a computer-based Water Resources Scientific Information Center, which, in addition to cooperating with SSIE on the current research catalog, arranges for distribution of abstracts of published research and the semimonthly publication of Selected Water Resources Abstracts. About 150,000 abstracts are now stored in the system. Bibliographies on various topics related to water resources can be produced by computer.

Programming of water resources research. In 1966, COWRR, with the aid of an advisory committee of outside consultants, developed a long-term program for water resources research (COWRR 1966). The report recommended priority areas for the research and served as a guide to the federal agencies in the allocation of research funds. The recommendations of priorities had considerable influence on the allocation of grant and contract funds; the effect on in-house programs has been less obvious.

Subsequent annual reports by COWRR contained updates of the budget figures and restatements of the priorities. Through work groups and consulting panels, COWRR analyzed problem situations, evaluated ongoing research, and recommended priorities for future research, which to some extent were reflected in the programs of the various research agencies, because of their membership in COWRR.

Demise of COWRR. Under Reorganization Plan No. 1 of 1973, President Nixon transferred functions of the Office of Science and Technology, including those of the Federal Council for Science and Technology, to the National Science Foundation. The Department of the Interior agreed to take lead-agency responsibility for maintaining the COWRR under the council. Within the Department of the Interior, responsibility for COWRR was delegated to the OWRR, which from 1972 to 1977 provided the chairman and some administrative support. In mid-1976 COWRR came under the aegis of the Federal Coordinating Council for Science, Engineering, and Technology of the newly created Office of Science and Technology Policy in the Executive Office of the President.

In Reorganization Plan No. 1 of 1977, President Carter abolished the Federal Coordinating Council for Science, Engineering, and Technology. COWRR, which had survived many reviews and evaluations over the years, thus lost its interagency sponsorship and was also abolished.

While COWRR had many deficiencies, it also had some accomplishments. For example, the 10-year program plan of 1966 was the first attempt to formulate a comprehensive water research program. COWRR was at least partially successful in agreeing on priorities for future research. Another accomplishment was the establishment of government-wide information systems for research results and ongoing

research. Certainly, communication among agencies and with the states was improved. However, the status of the committee gradually deteriorated after the committee left OST.

COWRR was most effective in its early years, when Congressional concern with water resources research was at its height and when attention was devoted to the subject by Presidents Kennedy and Johnson and their Science Advisors, who also headed the Office of Science and Technology and the Federal Council for Science and Technology. The COWRR chairman was a member of the OST staff and from that position exercised considerable influence on the agencies and on the Bureau of the Budget. Even with this influential tie to the President's office, however, COWRR's major successes were in the areas of information exchange and coordination. COWRR was not able to exert substantial influence in research programming and funding.

Post-COWRR Management of Water Research Activities

The Water Research and Development Act of 1978 (P.L. 95-467) reflected the belief of Congress that water-related research requires a system of overall management. Specifically, the act again directed that the President shall "clarify agency responsibilities for Federal water resources research and development and provide for interagency coordination of such research" [406(b)].

The 1978 act also directs the Secretary of the Interior to "develop a five-year water resources research program in cooperation with the [state water research] institutes [authorized to receive funds for research and related matters under the act] and appropriate water entities, indicating goals, objectives, priorities, and funding requirements" [Sec. 103(b)]. Congress further directed the state institutes to cooperate in the development of the five-year program.

The President did not provide by executive order or by memorandum for any further delegation of this responsibility under the act. He only directed, as stated in the Science and Technology Message of the President, March 27, 1979, that the Secretary of the Interior and the Director of the Office of Science and Technology Policy "set research priorities aimed at meeting our future water needs."

As a consequence of the abolishment of COWRR, no interagency organization existed to undertake the coordination functions of the 1978 act. Thus, in response to the presidential directive and the statutory responsibilities of the secretary under the act, the Assistant Secretary of the Interior and the Associate Director of OSTP requested the federal water research agencies to form an ad hoc interagency work group. The group was asked to summarize the major water research under way in FY 1979 and FY 1980 and to describe the highest priority research needs for each agency as of May 1979.

In October 1979, a memorandum to the President from the Secretary of the Interior and the Director of the Office of Science and Technology Policy reported the initial efforts at establishing research priorities under the 1978 act. No attempt was made in the memorandum to translate the priority recommendations into projected budgets, but they were used in the review of the FY 1981 budget estimates.

In June of 1980, the ad hoc work group was again called together; several meetings were held during the summer and fall of 1980 to prepare material for the five-year water research program for FY 1983 through FY 1987 that the Water Resources Research Review Committee was asked to review.

Alternative Water Research Management Arrangements

The deficiencies noted in the draft of the five-year program report are convincing evidence that the ad hoc approach to management of the federal water research program will not yield the results expected by Congress when it enacted the Water Research and Development Act of 1978. The Committee has considered three major organizational strategies for carrying out the research-planning and -management functions described earlier. All three are similar in that they address the same needs, but they differ in the types of institutional mechanisms used to accomplish redirection of programs.

Managed Multiagency Research Program

The responsibility for leadership in the planning and management of water research might be placed in one office independent of the major water research agencies or in one federal agency with assistance and guidance of an interagency planning group. Examples of the latter organizational arrangement are the National Climate Program (DOC 1980) and the National Acid Precipitation Assessment Plan (CEQ 1980).

Under the National Climate Program Act, both research and the application of research are mandated in order to improve understanding of climate processes and to make useful climate information available to the federal and state governments, industry, and the public. These objectives require coordination among many agencies having substantial climate-related activities--the Departments of Agriculture, Commerce, Defense, Energy, and the Interior; the National Aeronautics and Space Administration; and the National Science Foundation. The program is administered by the National Climate Program Office in the Department of Commerce, with the assistance and guidance of several interagency bodies and the statutory Climate Program Advisory Committee.

The enabling legislation mandates that a five-year plan be produced to "establish the goals and priorities for the Programs" and define the agencies' roles, funding requirements, and expected achievements. Each

agency submits an annual budget request for its program. The Office of Management and Budget is directed to review the requests for appropriations as an integrated, coherent, multiagency request. The plan serves as an operational guide--for federal agencies, as they develop and manage their climate programs; for the research community, as the context for their studies; for private-sector meteorologists and climatologists; for Congress, as it exercises its oversight, authorizing, and appropriating functions; and for state and local governments, as they plan and implement their activities within the framework of the national program (DOC 1980, p. E-2).

The multiagency research management model is only now beginning to be tested in the Climate Program and in the National Acid Precipitation Assessment Program, so it is too early to reach any conclusions about their effectiveness. It appears, however, that a substantial degree of coordination among agencies has been accomplished during the planning process for both of these programs.

The Water Research and Development Act of 1978 contains part of the legislative authority to apply this concept to water research activities, but an Executive order or additional enabling legislation would be required to put a multiagency program fully into effect. Because water research activities are so diverse, strong leadership and a commitment from the Executive Office of the President would be required for such a program to work. Without strong leadership, the approach would probably be applicable only in closely integrated segments of water research activities. The diversity of Congressional oversight of water research in the various agencies appears to be a major problem in developing the multiagency approach to research planning for water.

An Office of Science and Technology Policy Committee

The responsibility for research-planning and -management functions might be placed in an interagency committee sponsored by the Office of Science and Technology Policy (OSTP). This alternative could be considered a restoration of COWRR and merits serious consideration. Earlier experience with this approach gives us some knowledge of the strengths to be encouraged and the weaknesses to be avoided in structuring a new group.

If COWRR is reestablished, the functions of water research management as outlined in the Water Research and Development Act of 1978 and the activities and responsibilities of the committee should be set forth by Executive order. The chairman of COWRR would have to be someone with a national reputation in water research. He or she would serve a two- or three-year term as a full-time staff member of OSTP. Membership should include two or three part-time public members in addition to representatives of the departments. Enough funds and staff should be supplied to provide efficient operations.

Any such research-management committee should be located in the Executive Office of the President to enhance its authority. The active leadership of both the Office of Science and Technology Policy and the Office of Management and Budget, as well as the participation of member agencies, would be required.

Water Resources Council Committee

The responsibility for management functions might be placed in a strengthened Water Resources Council as recommended by the National Water Commission in 1973 (NWC 1973, p. 537). The commission recommended that "the Water Resources Council should, through the exercise of authority granted to it under the Water Resources Planning Act:

"a. Direct that water resources planning studies include an assessment of research needed to support planning objectives and a recommended research program to develop the scientific and technological base necessary to cope with future problems.

"b. Review planning reports for needed research as part of the customary WRC review to aid the Council in preparing annually an assessment of needed research with specific priority recommendations to support the objectives of the Water Resources Planning Act."

The commission further recommended that "the Committee on Water Resources Research, which has functioned as an arm of the Federal Council for Science and Technology, should be reconstituted as a committee of the Water Resources Council." As indicated by the National Water Commission, this option has the advantage of relating proposed water research to the problems identified in water-planning activities and the Water Resources Council's periodic assessment of water supply and demand.

Legislation was proposed in 1980 that would have established the council in the Executive Office of the President, with a full-time chairman appointed by the President and with advisory state representation. If Congress and the Administration were to agree on such an approach, the council would be a feasible and desirable management body for water research activities. However, the new Administration in early 1981 indicated that it intends to abolish the Water Resources Council and assign its functions, along with those of the Office of Water Research and Technology, to a water policy office in the Department of the Interior. Management of a multiagency water research program could be developed in such an office, but its location within one of the active research agencies creates problems which make it less desirable than a location in an independent office.

Concluding Remarks

So many outside forces and contingencies affect the choice among these options that it is difficult to form a clear preference among them. As pointed out above, the managed multiagency program option probably offers a solution for water research only if both the Executive Office and Congressional leadership support the process. However, similar leadership is needed for either the OSTP or WRC options. The Committee has not chosen between these two. In fact, the Committee believes that aspects of two or more approaches could be combined to create an optimal strategy. In any case, the approach must be assured credibility as well as continuity, which the earlier approaches lost in the reorganization of the Executive Office of the President.

President Reagan's recent proposal to merge the functions of the Office of Water Research and Technology and the Water Resources Council into an office of water policy in the Department of the Interior introduces complications that the Committee has not had time to consider. If this step is taken along with the proposed reduction in funding for the Office of Science and Technology Policy, it will be necessary to find a different mechanism for the preparation of the coordinated five-year water research plan contemplated by the Water Research and Development Act of 1978.

APPENDIX A

PREVIOUS REPORTS ON WATER RESOURCES RESEARCH PROGRAMS

During the past two decades, a number of efforts have been made to coordinate and improve federal and state water resources research programs. A number of the salient reports produced during this period were used as background for the work of the Water Resources Research Review Committee. Arranged chronologically by date of publication, these are described in the paragraphs which follow.

Water Resources Research Needs (Committee Print No. 28, in the series of reports on Water Resources Activities in the United States produced for the U.S. Senate Select Committee on National Water Resources, 86th Congress, 2nd Session, February 1960)

> This report was prepared by the U.S. Department of Agriculture in response to a request made by Senator Robert S. Kerr, Chairman of the Select Committee on National Water Resources, who was seeking information on needs for research in the various fields of agriculture dealt with by agencies of the Department of Agriculture and on the value of research in helping to ensure that the nation's water needs could be met in the future. The report suggested research objectives under four general headings: (1) basic research; (2) water supply; (3) water use, control, and conservation; and (4) multiple-purpose water management.

Report of the Select Committee on National Water Resources (Senate Report No. 29, 87th Congress, 1st Session, January 30, 1961)

> The committee's background studies and the testimony received at a series of hearings led the committee to recommend that the federal government undertake a coordinated scientific research program on water. This recommendation, made by Professor Raleigh Barlowe, head of the Department of Resource Development at Michigan State University, at the committee's hearing at Detroit, Michigan, in 1959, eventually led to enactment of the Water Resources Research Act of 1964 and the establishment of the state water resources research institutes.

Water Resources (A report to the Committee on Natural Resources of the National Academy of Sciences/National Research Council, by Abel Wolman, Chairman of the Water Resources study, Publication 1000-B, Washington, D.C. 1962)

This is one of seven reports supporting a research study of natural resources conducted by the Academy at the request of the President of the United States. Stressing the vital role of water in supporting the continued growth and progress of the nation, the report discussed the need for research and the important research areas that should be covered, concluding the recommendations by priority research topics.

Federal Water Resources Research Activities (Memorandum of the Chairman to the Committee on Interior and Insular Affairs, United States Senate, transmitting the Report to the President on Water Resources Research prepared by the Federal Council for Science and Technology, Committee Print, U.S. Senate Committee on Interior and Insular Affairs, 88th Congress, 1st Session, March 25, 1963)

This report of a task group on coordinated water resources research was prepared as part of a comprehensive review of federal research activities in natural resources initiated by President John F. Kennedy. The report was transmitted to the Congress to support the Administration's request for increased support of water resources research in FY 1964. It was the first comprehensive statement of the objectives and activities of all federal agencies engaged in water resources research and was a step in the development of a coordinated program of water research recommended by the Senate Select Committee on National Water Resources (Senate Report 87-29). The task group recommended the establishment of a committee on water resources research in the Office of Science and Technology as part of the activities of the Federal Council for Science and Technology.

A Ten-Year Program of Federal Water Resources Research, the "Brown Book" (Committee on Water Resources Research, Federal Council for Science and Technology, Executive Office of the President, 1966)

COWRR, with advice from a panel of consultants, recommended doubling water research efforts from $91.9 million in FY 1966 to $199.3 million by FY 1971. The increase was not proposed uniformly for all areas of research in the water resource field. COWRR suggested expenditures and time schedules consistent with the nature of the problems and the expected results. Research on the following problem areas was given high priority:

1. methodology and criteria for water resources planning;
2. water pollution control;
3. water conservation;
4. ecologic impact of water development;

5. effects of man's activities, such as urbanization, highway construction, and strip mining, on water resources;
6. improved water resource development technology and reduction in costs;
7. innovative or "far-out" ideas; and
8. evaluation of climatic changes and the significance of fluctuations from flood to drought.

COWRR recommended that an assessment of the extent and character of various water resource problems precede specific research undertakings.

Research and Development in Water Resources (A report prepared by John S. Gladwell as a member of the staff of the U.S. National Water Commission, National Technical Information Service, PB 210 823, January 1972)

The report contains a review of national goals and objectives in water resources research and development, describes the then existing programs, and discusses options in financing, organizing, and managing the programs in the future. The report supported a revitalization of the federal efforts in water resources research through the reconstitution of the then existing Office of Water Resources Research into a National Institute of Water Resources Research, which could be affiliated with a strengthened Water Resources Council housed in the Executive Office of the President. An advisory panel, consisting of members of COWRR, nonfederal members, and members of Congress would be created to provide guidance to the program.

National Water Research Opportunities (A report to the Office of Water Resources Research, U.S. Department of the Interior, from the Water Resources Research Institute, University of Nebraska, Lincoln, Nebraska, 1972)

In 1971, the Office of Water Resources Research funded a study to provide university assistance to COWRR in establishing water research objectives and priorities and in developing a sequel to the "Brown Book." The Universities Council on Water Resources cooperated in the study, and information was obtained from state planning agencies. The report highlighted ecology, social considerations, and public awareness as areas requiring greater emphasis. It recommended that two new research categories--ecological responses to water development, and human behavior and institutions--be added to the ten categories that COWRR used in the "Brown Book." In establishing priorities the report used four degrees of emphasis: (a) critical, (b) urgent, (c) important, and (d) significant. The subcategories of the 12 major categories of research were classified by degree of emphasis, and a program budget was projected for 1974-1978 by

showing the recommended percentage of the total research effort for each category. It was recommended that the total water research effort be increased to 220 percent in 1978 from a base of 100 percent in 1972. The categories of water quality, ecological responses, and human behavior and institutions were recommended for an increased proportion of the total, while the other categories were to remain the same or decline.

Reorientation of Urban Water Resources Research (Water Resources Institute, Rutgers, State University of New Jersey, New Brunswick, New Jersey, 1976)

The Universities Council on Water Resources and the Urban Water Resources Research Council of the American Society of Civil Engineers sponsored a workshop in 1976, which resulted in this report. Although the workshop did not deal with research budgets, the participants concluded that the federal research program on urban-related water problems was inadequate to meet future needs and should be redirected, particularly as concerns water quality, floodplain management, land-water interfaces, and governmental arrangements.

Water Resource Problems and Research Needs, FY 1978, Summary of State and Regional Water Resources Research Needs (Office of Water Research and Technology in collaboration with the water resources research institutes, 1976)

This is one of a series of reports produced annually by the state water resources research institute directors summarizing research needs for eight separate regions, with a national summary. The report is based on a recommended annual federal allotment of $250,100 and matching grants of $150,000 for each state water resources research institute. The proposed funds would be distributed for research as follows: water quantity problems, 25 percent; water quality problems, 41 percent; environmental impacts, 16 percent; and water planning and management, 18 percent. The report describes the regional distribution of these problems.

Final Report on Research Goals and Objectives (Office of Water Research and Technology, U.S. Department of the Interior, Washington, D.C., 1976)

An appendix to this report presents a list of water problems and research needs prepared at a Department of the Interior conference on water research goals and objectives held in February 1976. The report also examines the research program of the Office of Water Research and Technology in relation to the Department of the Interior's long-range objective of "Total Water Management." Research activities are ranked in relation to this objective, and priorities are expressed in terms of a hypothetical research

budget for the department and OWRT. Six problems deserving major effort in the next decade are outlined: (1) the community as the focal point for planning and managing water and land resources, (2) floodplain management, (3) water rights, (4) instream water uses, (5) evaluation of alternative management systems, and (6) drought management.

Directions in U.S. Water Research 1978-1982 (Committee on Water Resources Research, Federal Coordinating Council for Science, Engineering and Technology Policy, Executive Office of the President, Washington, D.C., October 1977)

This report, the last one prepared by COWRR before it was discontinued, analyzes the effectiveness of the 10-year program of water resources research (1965-1975), examines the role water resources must play in the United States, and identifies broad national issues in which water is a vital consideration. The committee outlined six important research areas: (1) hydrological and hydraulic processes, (2) water quality, (3) planning and institutions, (4) atmospheric and precipitation processes, (5) hydrological-ecological relationships; and (6) development and management of water supplies.

While the report contains federal expenditures by COWRR categories for 1965-1975, no attempt was made to project budget estimates for the five-year program as in the original "Brown Book."

Report of the Water Resources Research Task Force (National Water Policy Study, November 1977)

The task force was concerned with the management of a comprehensive national water research program, which would include those functions needed to strengthen the leadership, achieve coordination, allocate and deploy resources, and identify problems and needs, setting priorities at all levels of public and private endeavor. Management functions were examined in some detail, and eight options for stengthening water resources research were analyzed.

Scientific and Technological Aspects of Water Resources Policy (Office of Science and Technology Policy, Executive Office of the President, Washington, D.C., January 19, 1978)

This report was prepared by OSTP with the assistance of a panel of consultants to assist in the President's Water Resources Policy Study. The report identified nine major issues and presented summaries of technical and scientific findings, policy recommendations, and research directions for each. The issues were: (1) climate and water supply, (2) floods and drought, (3) ground water and its conjunctive use with surface water, (4) water

conservation in irrigation, (5) water quality, (6) erosion and sedimentation, (7) water for energy, (8) new methods to increase water supply, and (9) future demands for water. Two other issues were listed: (1) urban water programs, and (2) a systems approach for water. No specific policy or research recommendations were made for them, however.

Summaries of Major Federal Water Resources Research and Development Programs and Priorities (National Water Research and Technology Conference, April 24-26, 1979, revised May 1, 1979)

This report was prepared by an ad hoc, interagency work group on federal water resources research to summarize the major water research under way in the federal agencies in FY 1979 and FY 1980 and to describe the highest priority research needs for each agency. The statements and estimates were revised for the Water Resources Research Review Committee as of June 1980 to take account of action on the FY 1980 budget and any changes the agencies might wish to make in light of the Priorities report discussed below. Total federal expenditures for research, development, and technology transfer listed in the original report for FY 1980 were about $300 million, but in the revision the total was $394 million. The increase was due largely to addition of the programs of the Department of Energy on geothermal energy development. It should be noted that these estimates of federal water resources research expenditures are not comparable to earlier estimates by COWRR, because they included many programs not previously included as water resources research.

Interim Report: Priorities in Federal Water Resources Research (Memorandum to the President from the Secretary of the Interior and the Director of the Office of Science and Technology Policy, October 1979)

This memorandum represents the initial efforts at establishing research priorities in what is viewed as a continuing multiyear effort. Ten priority areas of research were identified and specific items were listed under each. The ten areas were (1) conservation, (2) socioeconomic-institutional impacts, (3) basic research, (4) ground-water/surface-water interface, (5) insteam flow, (6) health effects and water quality, (7) energy/water interface, (8) food-fiber/water interface, (9) natural disasters prediction and response, and (10) wetlands and estuaries.

No attempt was made to translate these priority recommendations into projected budgets. The memorandum states that the list of priorities is not intended to set internal priorities for individual departments or agencies in support of their specific missions. Rather, the list of priorities is

supposed to assist agency officials in making internal planning and budget decisions and to aid the Office of Management and Budget in its review of the FY 1981 budget.

APPENDIX B

AN ALTERNATIVE APPROACH TO WATER RESEARCH PRIORITIES

Several members of the Water Resources Research Review Committee have suggested that it would be more logical to group priorities around water problems for which the solutions require research. Such a grouping might combine the listing of research priorities described in Chapter 3 in the following manner:

Problem Area	WRRRC Category	Priority Research Area
Hydrology and climate	I	Climate variability and trends
	I	Weather and hydrologic forecasting
	I	Atmospheric transport and precipitation of contaminants
	I	Hydrologic characterictics of the vadose zone
Water-quality monitoring	I	Hydrologic factors in water quality
	III	Monitoring for pollution control
Waste disposal	III	Land disposal of wastes
	II	Consequences of waste disposal in marshes, estuaries, and oceans
Trace contaminants and water reuse	III	Water reuse
	III	Significance of trace contaminants to human health

Ground-water quantity and quality	IV	Conjunctive management of ground and surface water
	V	Institutional arrangements for ground and surface water
Wetland, estuarine, and ocean resource protection	II	Effects of waterborne pollutants on aquatic ecosystems
	II	Physical alteration of wetlands and estuaries
Downstream resource degradation	II	Environmental degradation from water projects
	III	Control of contaminants resulting from energy development
	IV	Control of pollution from nonpoint sources
Erosion and sedimentation	I	Erosion, sedimentation, and nutrient transport
	V	Institutional arrangements for achieving erosion and sediment control
Food and fiber production	IV	Water problems of food and fiber production in stressed environments
Water conservation	IV	Water conservation in municipal, industrial, energy, and agricultural uses
	V	Institutional arrangements for water conservation

Flood and drought hazard mitigation	I	Flood frequency determination
	IV	Management of resources under flood and drought hazard
	V	Programs for flood and drought hazard mitigation
Reallocation of authority over water	V	Institutional arrangements for allocation of wastes
	V	Assignment of responsibility for wastes and related resource management among federal, state, and local levels of government
Water resources planning and policy implementation	IV	Management systems for water resources
	V	Resolution of conflicts over alternative courses of action
	V	Impacts of water management policies programs
Conduct of water resources research	V	Institutional arrangements for water resources research

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